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

Phase I: Operationalisation of GIS Tools and Map Production in UK Test Sites

Final Report

G.M. Smith, N.J. Brown & A.G. Thomson
Centre for Ecology and Hydrology
Monks Wood
Abbots Ripton
Huntingdon
Cambs PE17 2LS

Corresponding author:
G.M. Smith
Section for Earth Observation
Centre for Ecology and Hydrology
Monks Wood
Abbots Ripton
Huntingdon
Cambs PE28 2LS

Telephone: 01487 772400
(Direct dial) 01487 772479
Fax: 01487 773467
Email: gesm@ceh.ac.uk

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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, using different methodologies. CLC2000 will be produced for the UK and Ireland, within national boundaries, but again using different methodologies.

The EEA / JRC standard method for CLC1990 production was based on a hardcopy inventory from the manual interpretation of satellite image printouts. In the UK a semi-automated generalization approach was applied to the more detailed 1990 Land Cover Map of Great Britain.

The standard method for CL2000 production is based on a change only update of the corrected CLC1990 via computer assisted on-screen photo-interpretation of satellite images. The correction of CLC1990 in the UK will be undertaken in two ways due to the origin of the CLC1990. The UK approach to CLC2000 production will combine semi-automated generalisation of the Land Cover Map 2000 (LCM2000) and a change only update similar to the one proposed in the standard methodology. Two test sites were selected for the operationalisation phase in the UK.

The first test site was on the border between Ireland and Northern Ireland and was selected to offer the opportunity to test the production of CLC2000 by the standard approach against that proposed by the UK.

A second site in Great Britain allows the UK approach to be tested in a different landscape context and where CLC1990 was produced by semi-automated generalisation of a 1990 national product.

The work during the operationalisation phase at the test sites was been extremely successful and identified a number of issues which needed to be addressed before the CLC2000 for the UK could go into full production. A Training Meeting with the CLC Technical Team was held in mid-December 2002 at which the UK approach was evaluated and the issues identified were discussed.

This phase has been an important exercise for normalising the UK approach to the CLC update as closely as possible to the standard approach that is being applied over most of Europe. This study has formed a sound basis for the production of CLC2000 products in the UK that are consistent with the rest of Europe. This work may also include the only study to consider the CLC2000 data produced by different national groups in such detail.

1. Introduction

This report follows on from the Interim Report (Smith *et al.*, 2002) and incorporates the results from two test sites and a review of the meeting in the UK with the CLC Technical Team. It represents the final report of the UK CLC2000 production, phase 1, operationalisation of GIS tools and map production in UK test sites.

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.

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 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).

Operationalisation of UK approach

The approach adopted 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 it's 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 in CLC1990 and the standard and UK approaches to updating.

Two test sites were selected for the operationalisation phase of the CLC2000 production in the UK. The choice was initially controlled by the need to use CLC1990 data derived by two different methods.

2. Manual update of CLC1990

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.

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.

3. UK semi-automated update of CLC1990

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.

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.

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.

UK CLC update methodology

To produce CLC2000 in the UK, it was again decided to start with the national land cover product, LCM2000, and 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. Firstly, CLC1990 was checked and corrected as per the recommended method to produce the revised CLC1990. The LCM2000 was then generalised to create a 'pseudo CLC2000' product. The pseudo CLC2000 was then compared with the revised CLC1990 to identify areas of change.

The CLC1990 data to be used for CLC2000 UK came from two different source; CLC1990 Ireland produced in the standard fashion and CLC1990 GB produced by semi-automated generalisation of LCMGB. Two approaches were therefore adopted to correcting CLC1990, but both approaches addressed the same issues.

Correction of CLC1990 – Great Britain

The conversion of LCMGB to CLC1990 was performed digitally, or in soft copy, with no hard copy intermediate products involved therefore the amount of error checking is dramatically reduced. Few, if any, errors can be associated with data transformation.

Paper maps were use as a reference source for geometric correction, but any resulting errors should be minimal as each map sheet was calibrated individually on the digitising tablet. The CLC technical guide states an accuracy requirement of 3 pixels for Landsat TM data, which represents approximately 90 m on the surface. The geometric accuracy of the CLC1990 can be traced back directly through LCMGB and the original images which are reported as having an accuracy of approximately 20 m on average. Further checks will be made between CLC1990, I2000 and OS mapping to determine the amount of residual geometric error present.

The main ancillary boundary information used for CLC1990 was associated with 'land use' areas such as golf courses, country parks and airfields were viewed as a backdrop with the LCMGB derived boundaries superimposed. This process therefore did not introduce any further geometric errors. Any new land use outlines were added using the CORINE interpretation guidelines for these items.

The majority of the image interpretation was linked directly to the LCMGB land cover information via look up tables and mosaic rules. CLC1990 GB does not contain uncoded land parcels and any erroneously coded land parcels will most likely be related to errors in the LCMGB. The land use parcels may contain human errors, but these can be checked, either in total or through a sample procedure.

Therefore, as part of the operationalisation phase CEH will perform the following checking for errors in the CLC1990 data for GB.

- Random check of geometric accuracy against British National Grid and I2000.
- Checks for consistency with the CLC 25 ha minimum mappable unit and 100 m minimum width specification.
- Check and correct 'land use' parcels, orchards, inland marsh, and smaller urban areas (small towns).
- Locate all differences between 1990 and 2000 that are at the significant level and modify 1990 if it can be stated that there is an error.

Correction of CLC1990 – Northern Ireland

The procedure for the correction of CLC1990 Ireland in Northern Ireland followed closely the methods recommended in the CLC Technical Guide (Perdigao and Annoni, 1997), and the Addendum (Bossard *et al.,* 2000) because of the origin of the data. In broad terms this required:

- Checks for shifts against Ordnance Survey Northern Ireland (OSNI) maps and I2000 data, geo-correcting if necessary.
- Checks for parcels < 25 ha, editing using 1990 ancillary data and imagery.
- Checks for linear features < 100 m wide, editing as above.
- Checks for illegal class codes, correcting if necessary.

- Checks for mis-labelled parcels using 'pseudo CLC2000' (see later in this section) to identify areas of change.

Generalising LCM2000

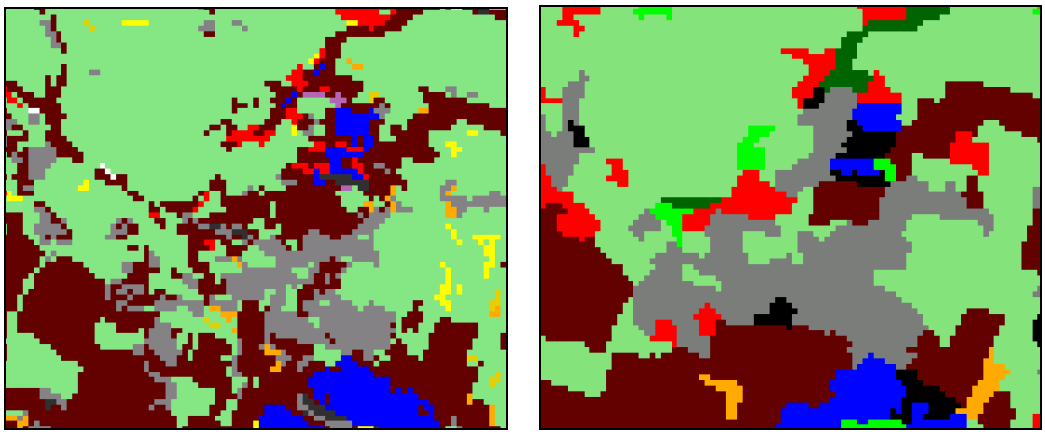
To produce the 'pseudo CLC2000', the first stage is create a set of land use parcels which are not specifically mapped in LCM2000. The land use parcels are extracted from the corrected CLC1990 and stored as a new dataset. With the help of the I2000 images and ancillary data (scanned raster maps, feature (e.g. golf course) catalogues), the land use parcel data set is checked and updated with changes greater than 5 ha and new parcels greater than 25 ha added.

The LCM2000 land parcels are then recoded to CLC class equivalents. The type of recoding and the issues involved fall into three groups depending on equivalence (Table 1). Firstly, those classes with direct equivalence (E.g. deciduous woodland) are recoded easily. Secondly, those classes with partial equivalence (E.g. some grasslands) use a rule base. Finally, those classes with no real equivalence, (E.g. 'montane habitats') require complex rules or manual intervention.

The recoded LCM2000 is then used to create the land cover parcels. Firstly, small parcels, generally less than about 2 ha, are removed and those with areas greater than 25 ha are extracted and stored separately.

In the conversion of LCMGB to CLC1990, CEH used a growing and shrinking process to deal with small isolated clusters of pixels. When converting LCM2000 to CLC2000 it has become apparent that this procedure is no longer required due to the fundamentally different spatial structure of LCM2000 compared to that of LCMGB (Figure 1). LCM2000 is a parcel based product with a MMU of 0.5 ha and thus no small isolated clusters, whereas LCMGB was raster based with a MMU of only 0.125 ha.

Figure 1. A comparison of the spatial structure of LCM1990 (left) and LCM2000 (right).



The land parcels which are less than 25 ha are then merged into mosaic classes using the CLC mosaic rules (Figure 2). These rules are based on selected combinations of classes or the use of the dominant class within the mosaic. An example is shown in

Figure 3. The UK approach is tending to move to a more interactive analysis of mosaic areas, as a result of our experiences in producing data for the two test sites. This aligns us more closely to the standard CLC updating methodology.

The datasets resulting from the above stages (land use parcels, land cover parcels great than 25 ha etc.) are merged into a single dataset (Figure 4). Any remnant areas that do not appear in any other data set are dissolved into their adjacent parcels.

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

Note: National groups may produce CLC classifications which go to level-4 or beyond. Such classes may be more aligned to the LCM2000 classes, for instance grasslands, but there is no common set defined and agreed for Europe.

Figure 2. Classifying mosaic land use parcels.

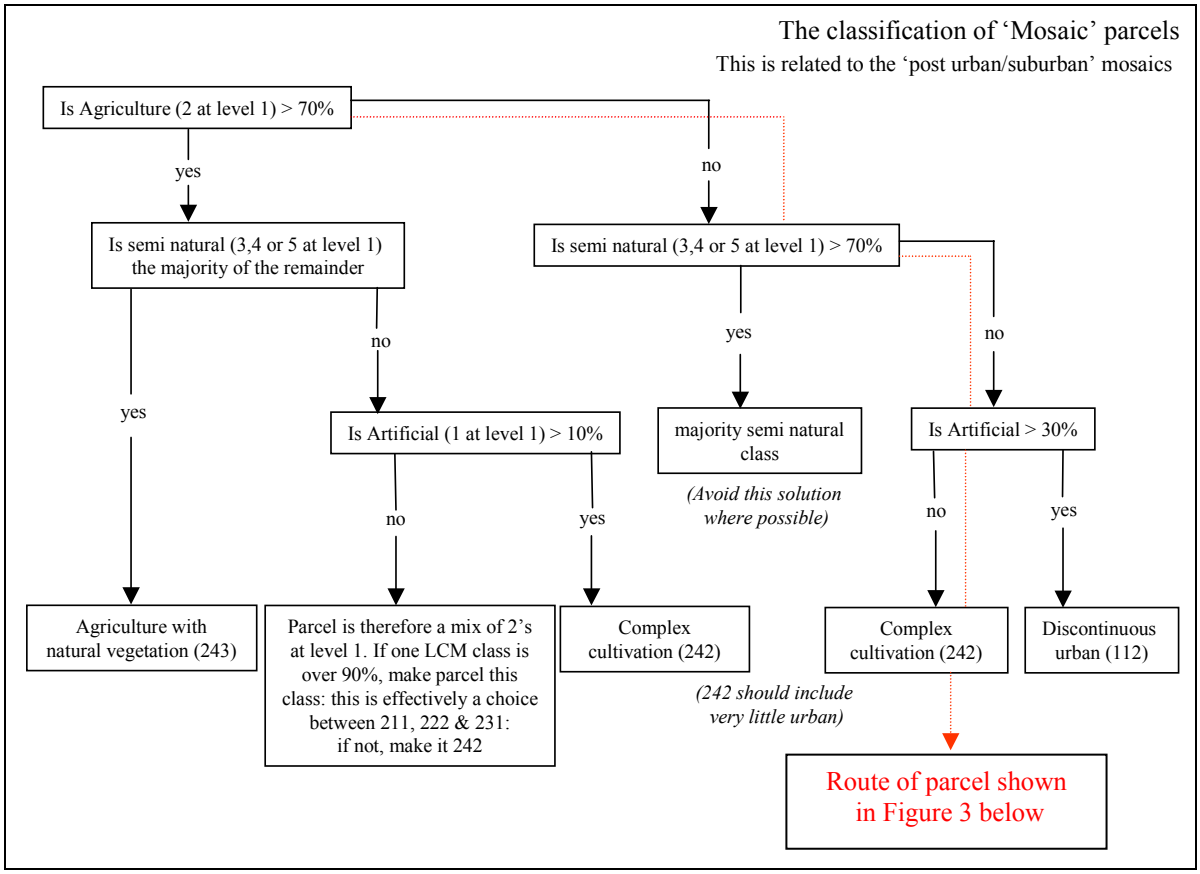


Figure 3. An example of the application the CLC mosaic rules.

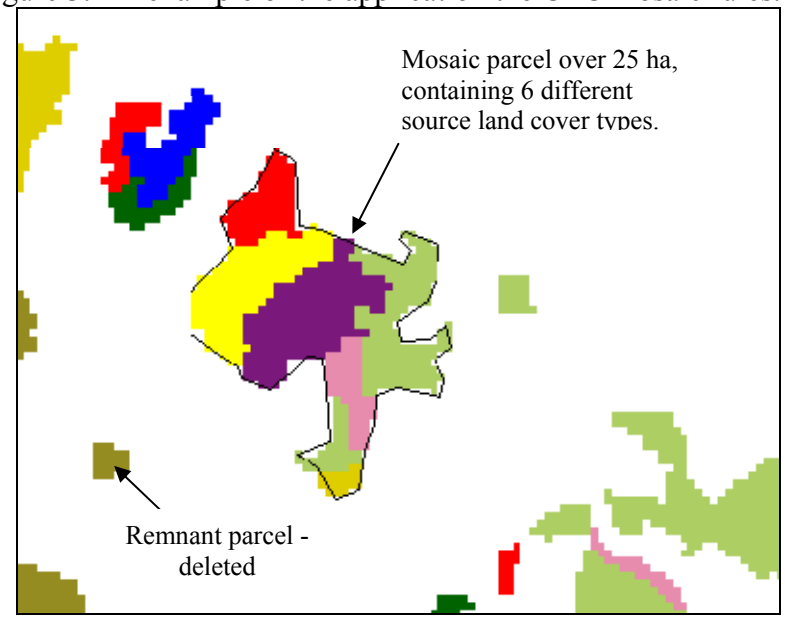
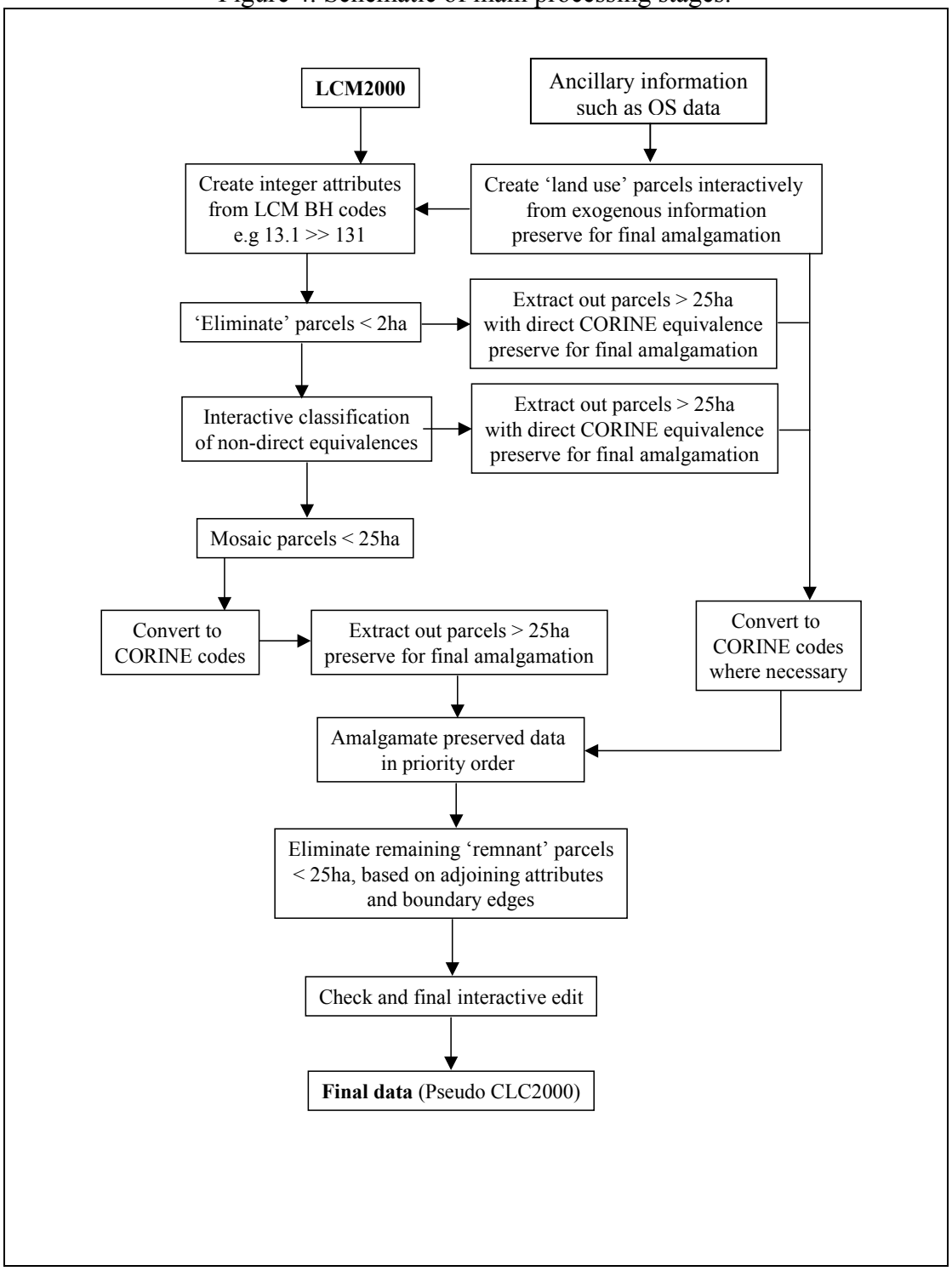


Figure 4. Schematic of main processing stages.



Updating CLC1990 to CLC2000 and recording change

For the updating process the 'corrected CLC1990' map and the 'pseudo CLC2000' map are combined to identify differences which could be caused by real change or error. The CLC Technical Guide offers guidance on how to deal with differences between the CLC1990 and CLC2000 maps, in relation to the standard updating procedures, such as acceptable differences (often called errors) and how, if necessary, they should be corrected in the CLC1990 map. This guidance was adapted as far as possible for use in the UK update methodology.

A map recording the 'areas of difference' was produced to include only those locations which were not excluded by the various CLC rules, such as the 100 m buffer exclusion along boundaries, and the 5 ha 'acceptable minimum limit' for change. All parcels where the classes were the same in both CLC1990 and CLC2000 were removed and parcels less than 5 ha were removed. A buffer around all land parcel boundaries was created for each map. The two 'buffered maps' were then combined to produce a single buffer map, which could be used as an 'exclusion zone' during the process of locating difference. Differences within this buffer exclusion zone were removed. This process created an interim map layer containing many sub land parcels which were differences.

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 whether it was a possible change. Then, whether it could be associated with a problem in the CLC1990 data. 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. If the class difference was a possible change then there was not necessarily a need to change either the CLC1990 map or the CLC2000 map, as this could be an example of real change in the landscape.

Once the differences had been checked they were built into the 'corrected CLC1990' to form the CLC2000 map. During this process the final map adopts the CLC1990 boundaries where no change is detected and the 'pseudo CLC2000' boundaries are used where changes have been detected.

The differences between the corrected CLC1990 and the CLC2000 were recorded separately as the change product.

4. Test site 1 : Cross border area in Ireland

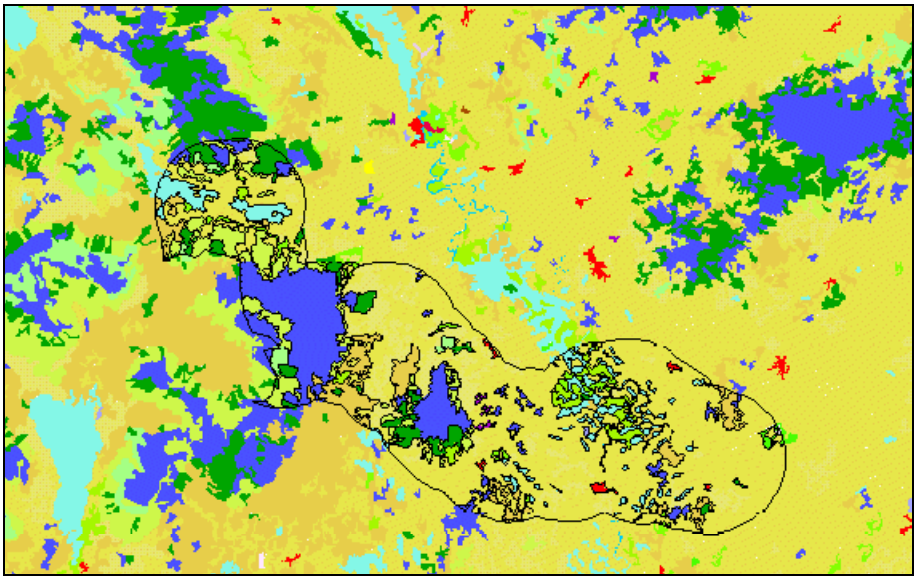
Test site description

An area along the border between Ireland and Northern Ireland was selected to test use of CLC1990 data which had been derived by the EEA / JRC standard methods. During the production of LCM2000 for Northern Ireland, it was requested that the river catchments which extended into the Republic also be included. In the event, not all of the requested areas outside Northern Ireland could be mapped due to lack of cloud free imagery. The production of CLC2000 in Ireland by ERA Maptec using the EEA / JRC standard methods allowed an opportunity for comparison with the UK methods.

The test site for Ireland was therefore chosen to lie on the border between Ireland and Northern Ireland, include a broad range of land cover types and be part of the area of Ireland also covered by LCM2000.

This cross-border area (Figure 5) was chosen originally, to contain about the same area of land surface either side of the border. At a subsequent stage it was noted that a portion in the extreme south west of the test site was not covered by LCM2000 data due to cloud cover, but was decided to press on using the slightly reduced test site limits.

Figure 5. The CLC1990 data for the area around Slieve Rushen with the outline of the cross-border test site.



The cross-border test site follows the border from just east of Clones, west across Slieve Rushen and Cuilcagh to around the middle of Lough Macnean Upper and covers an area of approximately 58 000 ha.

Correcting CLC1990

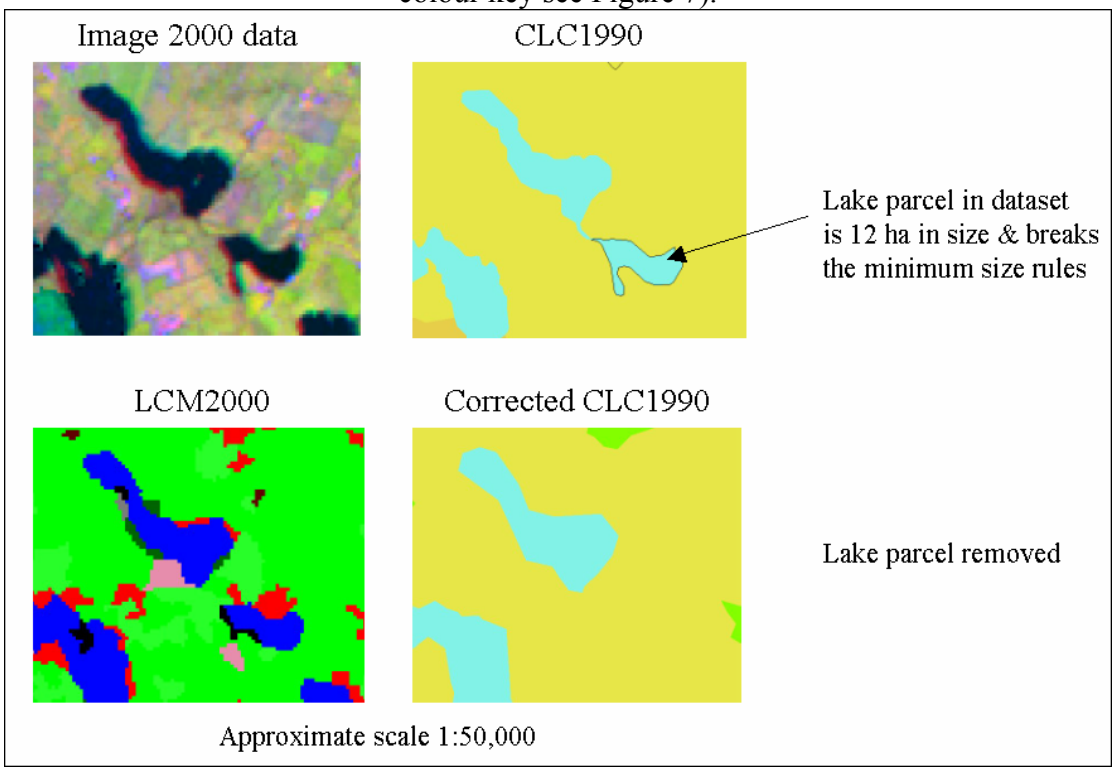
The cross border test site contained 471 parcels in the original CLC1990 used by CEH. Over 70 of these parcels were either beneath the CLC MMU of 25 ha or

beneath the linear feature width limit of 100 m. The parcels breaking the rules were 'dissolved' into the surrounding classes, using methods that included the examination of the most appropriate neighbouring parcels and longest adjoining boundaries (Figure 6).

There were also significant numbers of parcels that had 'Level-4' CLC codes; 'low productivity grasslands' (2312), 'mix productivity grasslands' (2313) and 'Exploited peat bogs' (4122) (O'Sullivan, 1994). These parcels were combined spatially and recoded based on their Level-3 CLC class to 'pastures' (231) and 'peat bog' (412).

The spatially and thematically corrected CLC1990 data could not be compared against 1990 images, as these were not available to CEH at the time. Comparisons were made against images used to create LCM2000, but no differences could be identified that could be attributed solely to error in the CLC1990 and not change.

Figure 6. An example of the removal of a lake below the CLC MMU of 25 ha (for colour key see Figure 7).



Area statistics

The most straightforward comparison of the data sets was to compare the total areas of each class mapped (Table 2). When comparing within a class some of the absolute differences appear quite large, but this must be seen in the context of the size of the whole cross-border test site. The differences are often explained by confusion between different classes, adherence or otherwise to the CLC specification and the different interpretations of the classes.

For instance, 'discontinuous urban' (112) has twice the area in the ERA data set compared to CEH, but as a percentage of the site the difference is very small. In this

case certain small urban areas had grown in size, but not sufficiently to be classed as a change by CEH within the CLC update specification. CEH maps less 'coniferous forest' (312), but the confusion with ERA is generally associated with other woodland / forest classes. ERA mapped large amounts of the CEH 'moors and heaths' (322) as natural grass or peat bog, which can be explained by how each group dealt with peat bogs. The CEH generalisations to adhere to CLC specifications in both the CLC1990 and CLC2000 products have caused differences due to particular land cover associations. In a landscape of deciduous woodland and small lakes, the removal of the lakes would increase the amount of deciduous woodland mapped. ERA mapped a number of linear water features less than 100 m wide which were removed from the CEH map. Much of the CEH 'broad leafed forest' (311) was derived from analysis of mosaic landscapes, in particular in the complex region in the east of the test site. The tree cover here is significant, but much water is lost because it is linear or in small parcels. CEH has mapped many parcels as 'broad leafed forest' (311) where the tree component, although the biggest, is not the majority. In contrast, ERA has mapped lots of 'transitional wood/scrub' (324) in this area, where CEH has selected 'broad leafed forest' (311). ERA has frequently chosen 'pastures' (231) as the most frequent component in these mosaic areas of semi-natural classes. It can be seen that the combined totals for all woodland classes are very similar. Certain land cover classes are only found in small isolated pockets, such as 'arable' (211) in this region, therefore it would not survive the generalisation procedures. Some classes can not be mapped without ancillary data, which was the case with the single parcel of 'sport and leisure' (142) mapped by ERA, but missed by CEH before the appropriate data was available.

Table 2. Area statistics from the CEH and ERA versions of the CLC2000 map.

CLC CLASS	CEH (ha)	ERA (ha)	Difference as a percentage of area
112 Discontinuous urban	181	420	0.4
131 Mineral extraction	104	150	0.1
142 Sport and leisure		98	0.2
211 Arable	25	271	0.4
231 Pastures	38961	32970	10.3
243 Arable and semi-natural		3061	
311 Broad-leaved forest	2937	892	3.5
312 Coniferous forest	2428	3153	1.2
313 Mixed forest	64	260	0.3
321 Natural grass	2293	3649	2.3
322 Moors and heaths	1077	636	0.8
324 Transitional wood/shrub	81	1664	2.7
332 Bare rock	71		
411 Inland marsh	393	36	0.6
412 Peat bog	6324	7603	2.2
511 Water courses		112	
512 Water bodies	3087	3261	1.0
TOTAL	58026	58236	

Direct correspondence

Pixel by pixel correspondence compares directly the land cover type reported at the same location in two different data sets and can be tabulated in the form of correspondence matrix. This approach takes no account of the structure of the

landscape and locations where boundaries have slightly different alignments will be reported as differences. Therefore if a boundary passes through the middle of a pixel it may be equally valid to include the pixel in either of the adjacent classes. If the data sets being compared treat the boundary slightly differently, then the pixel by pixel comparison could record an apparent, but false, mis-match.

Land parcels in both the CEH and ERA data sets frequently exhibited partial overlapping which is expected and acceptable. Both the CEH and ERA vector data sets were resampled onto a 25 m grid for the pixel by pixel comparisons. The re-sampling of the data sets to a 25m spatial resolution is too detailed at the CLC mapping scale of 1: 100 000, where such a pixel will be 0.25 mm across, and not individually discernable. Where spatial differences were beneath the CLC 'change' rules, they were counted here as a 'mis-match' or 'difference' when analysed on a pixel by pixel basis. Thus pixels within the CLC recommended tolerance of 100 m have not been excluded from the correspondence analysis shown in Table 3.

Table 3 represents the direct correspondence derived from the CLC data produced by CEH and ERA in terms of the percentage of the total areas of the cross border test site for the CLC Level-3 classes. Values that lie on the diagonal report the area with the same class in both datasets. Values off the diagonal represent differences between the two data sets.

About 70% of the two maps are an exact match (see red cells on Table 3). This may not sound particular encouraging, but considering the structural and thematic differences that are present in this test data and the lessons leant from this exercise, it will be shown to be more than satisfactory.

Table 3 Correspondence matrix of the CEH and ERA CLC2000 data sets by per pixel comparison (for class names see Appendix A).

	ERA																
CEH	112	131	142	211	231	243	311	312	313	321	322	324	332	411	412	511	512
112	**0.23**				0.08												
131		**0.14**			0.04												
142			**0.00**														
211				**0.00**						0.04							
231	0.45	0.10	0.16	0.43	**50.67**	4.71	0.80	1.03	0.28	3.22	0.42	1.45			2.23	0.11	0.97
243						**0.00**											
311					2.79	0.17	**0.47**	0.19	0.07	0.02	0.02	0.82		0.01	0.02	0.08	0.44
312				0.01	0.38	0.04	0.10	**3.25**		0.17	0.01	0.12		0.01	0.12		
313					0.01				**0.10**								
321	0.01			0.03	1.45		0.06	0.19		**1.33**	0.14	0.10			0.64		
322		0.01			0.21	0.22		0.11		0.53	**0.16**	0.06			0.58		
324					0.01			0.13				**0.00**					
332					0.01			0.08		0.04			**0.00**				
411					0.04		0.05							**0.05**	0.52		
412	0.03				0.11	0.05		0.30		0.91	0.34	0.14			**9.01**		
511																**0.00**	
512				0.01	0.79	0.09	0.02	0.06		0.02		0.19				0.01	**4.16**

The differences identified by the correspondence matrix have a number of causes and in some cases can be accounted for by assuming that values that lie off the diagonal may be valid. CEH identified a source of confusion in the recoding of LCM2000 grassland classes to those in the CLC specification (bright green cells). This would account for around 9 % points of the 30 % that is different between the two maps. ERA's approach to dealing with bogs and purple moor grass (*Molinia spp.*) differed from that of CEH thus causing confusion between peat bogs and natural grassland / moors and heathlands (blue cells). This would account for a further 2.5 % points of the difference between the two maps. Other minor issues, such as, mixed forest being included in deciduous forest in LCM2000 (orange cells), the separation of different upland and water classes (light green cells) and the availability of ancillary data on land use to CEH would account for a further 2 % points of the difference. When taken together, these thematic confusions would raise the correspondence between the two data sets to around 82 %.

Possibly more importantly, there are some structural and systematic differences between the two data sets related to CLC specifications and spatial offsets which could account for a lot of the differences. It is very difficult to quantify the impact of the presence of parcels that do not match the CLC specifications in the ERA data set. Tests have shown that an offset of 1 pixel (25 m) in easting and northing (effectively 35 m) could produce up to 4 % difference when comparing identical data sets with a pixel by pixel comparison. An 85 m offset was identified between the CEH and ERA datasets, which is likely to produce a difference of at least 8 %.

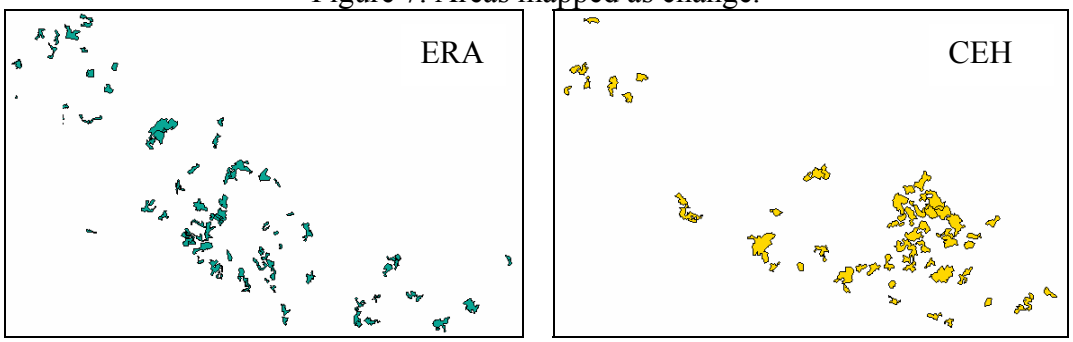
The direct correspondence, when combined with the thematic uncertainty and the structural differences would suggest an actual correspondence in excess of 90 %, an acceptable value when comparing data sets created with such different methodologies. When analysing the differences between two 'map products', the differences detected are the product of multiplying the accuracies of each individual classification (Petit and Lambin, 2001).

Resulting change parcels

Both CEH and ERA, identified change between their own versions of CLC1990 and CLC2000. Overall, similar amounts and types of change have been identified, although the distributions of these changes are somewhat different (Figure 7). ERA identified 93 instances of change; 7 are in the part of border test site not covered by LCM2000 data and 15 associated with land use classes where ancillary information was not available to CEH. Of the remaining 71 land parcels; 48 involve a grassland class in the 1990 map, 8 changed to arable and 5 were 'arable with semi-natural' (243) in 1990. A number of 1990 peatbogs from the 1990 ERA map now match the CEH 2000 class (often 'pasture' (231)). Few changes in either product are extensions or reductions along the edge of 1990 parcels.

The CEH change map identifies 44 instances of change; most of which are due to class 'pasture' (231), which was affected by grassland recode issues from LCM2000. Also a large number of changes are concentrated in the area south east of Loch Erne, where CEH performed a lot of generalisation on their CLC1990 data.

Figure 7. Areas mapped as change.



Visual comparisons

The CLC is designed as a European-scale land cover product at 1:100 000, therefore local comparisons can be mis-leading or undervalue the correspondence at the landscape level. By visually comparing the CEH and ERA CLC2000 maps (Figure 8a and 8b) a better appreciation of the differences and similarities of the two data sets can be obtained. Overall, the two maps appear to be describing the cross border test site in a very similar way, but three main differences appear. A large amount of 'arable with semi-natural' (243) is mapped by ERA to the southwest of Swanlinbar, where the LCM2000 reported little arable land and thus the CEH CLC2000 recorded the area as 'pasture' (231). Around Slieve Rushen, ERA mapped large homogeneous areas of coniferous forest, whereas CEH mapped a more complex mosaic of forest and woodland with patches of upland and bare classes, which may be clear felling or replanting. Finally, the complex of lakes, woodland and grassland around the south eastern end of Loch Erne has been treated differently by CEH and ERA due to the adherence or otherwise to the CLC generalisation rules.

A useful way of visualising the differences and similarities of the two data sets is to merge the maps at the border in the same way as they will appear in the final European level CLC2000 product or all island map. Figure 8c shows the combined data set with the CEH data to the north of the border and the ERA data to the south. There is no perceptible change in the CLC classification at the border and it would be impossible to identify the border due to different land cover classes in such a product.

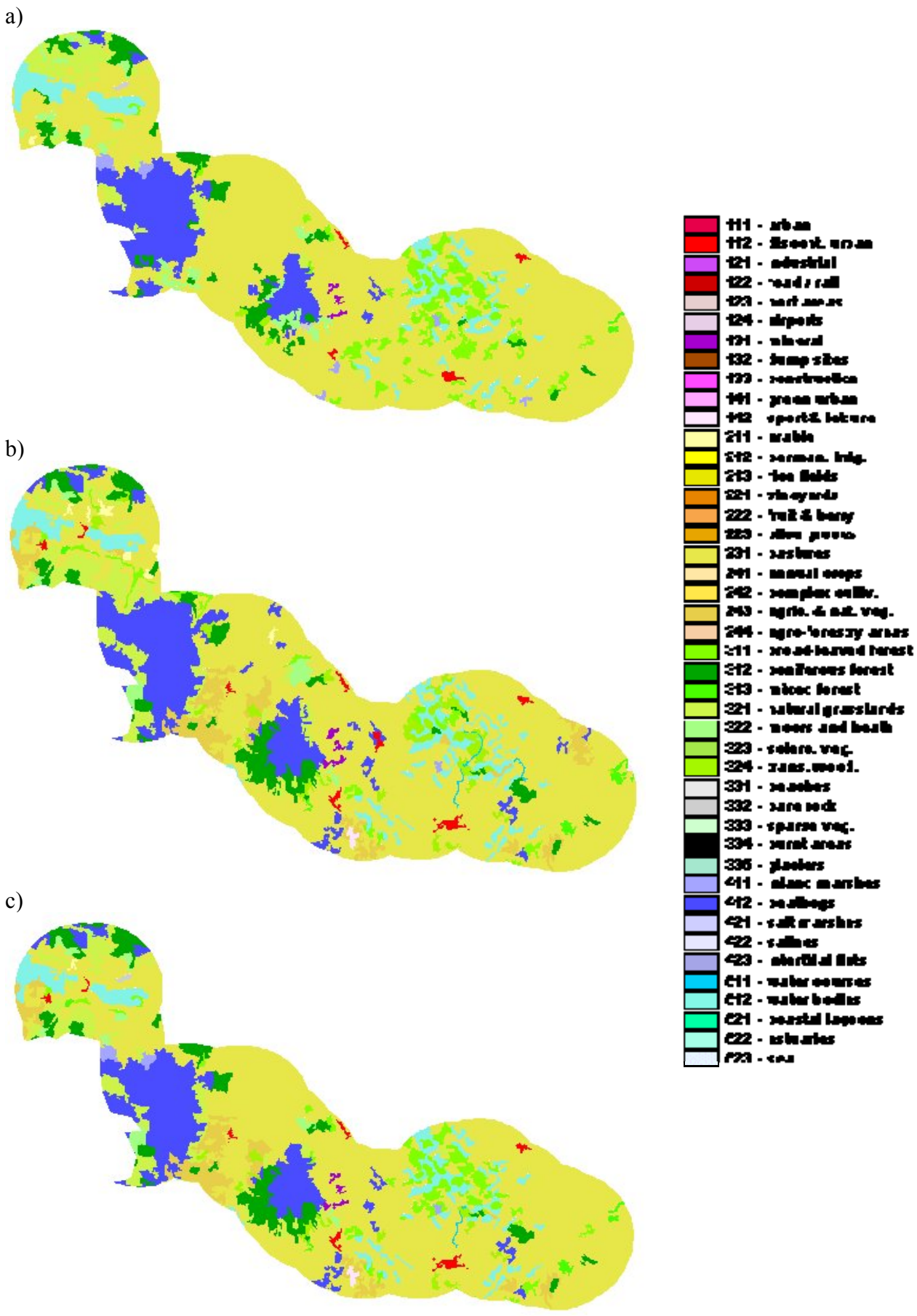


Figure 8. Comparison of the a) CEH, b) ERA and c) combined CLC2000 data.

Discussion and explanation of differences and similarities

This section outlines the issues identified by comparing the source data, methodologies and results produced by CEH and ERA in the course of the study. The impacts and solutions will be outlined with respect to future all island work and the UK semi-automated update methodology.

Different CLC1990 inputs

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 Crawford Jordan of 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. We 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 is a sensible approach to use this revised data set as it will reduce the amount of work which must be done to fix any errors in the CLC1990 data. In terms of this comparative study it has caused problems as CEH is not aware of the changes that have been made to ERA's CLC1990 data and these may not always be obvious during the correction of CLC1990 undertaken by CEH.

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. As both CEH and ERA will attempt to correct the CLC1990 to the same level of quality, this should not have a major impact on the compatibility of the CLC2000 products.

Correcting CLC1990

The approaches to correcting CLC1990 adopted by CEH and ERA are very similar for the island of Ireland due to the format of the original data and the guidance provided by the 'CLC Updating – Technical and Methodological Guide and Addendum 2000'. CEH will obviously adopt a different approach when dealing with the CLC1990 data for Great Britain which was derived by semi-automated generalisation of the LCMGB.

If excluding the issues surrounding the different versions of the CLC1990 for the island of Ireland described above, the differences found between the corrected CLC1990 products from CEH and ERA will be down to operator subjectivity, experience and the availability of ancillary data. These differences, within the limits of quality assurance, would be expected in any case where multiple operators were working on the same data set.

A shift of about 85 m was identified when comparing the map boundaries of the original CLC1990, held by CEH, and CLC2000 produced by ERA. The majority of

the land parcels are affected and the ERA CLC2000 land parcels fit correctly the I2000 data.

This shift was applied by ERA to correct an offset against the I2000 data, but the same shift was not applied by CEH as the estimated shift was within the acceptable tolerances (100 m) set by the CLC technical guide. From discussions with ERA this shift was not applied to CLC2000 data for Ireland, only the cross-border test site. Therefore the policy adopted by CEH to ignore the shift will maintain consistency with the CLC specification and across the border region.

The semi-automated approaches adopted by CEH to the generation of the 'pseudo CLC2000', and the resulting updated product, mean that the CLC update specification are fixed in the system. These tolerances and rules specify the exclusion of linear features narrower than 100 m and areas of less than 25 ha. As the fixing of the CLC1990 for Ireland is a manual process for both CEH and ERA, it is possible to break these rules.

CEH decided to adhere as closely as possible to the CLC updating specification, even when significant features of ecological or environmental importance were lost. ERA were less strict in their application of the CLC updating specification and this has lead to some apparently dramatic differences between the two maps.

For example, in the area to the south east of Loch Erne, there are cartographic issues of how to represent a complex landscape containing linear water features, mosaics of many small semi-natural and woodland parcels, and many lakes beneath the 25 ha limit. CEH has adhered to the specified rules and has generalised out a number of features. On the other hand, ERA has included a number of features (most noticeably a long linear water feature) that are not wholly within the rules. This different approach also accounts for the presence of class 'water courses' (511) in the ERA map and its absence from the CEH map (Table 2).

From a cartographic point of view, the detailed CLC specifications for dealing with complex landscapes of this type are not adequate. The specification does not accommodate the standard type of cartographic generalisation that takes place when moving from a large to a smaller scale maps. The CLC technical guides do permit some subjective interpretation by operators, but this will lead to differences of interpretation. These problems are probably caused by the need to deal with the wide range of landscape types found across Europe and the problem of producing a single set of mapping rules to deal with them. For instance, in this part of Ireland there occurs a landscape of many small patches of semi-natural classes with no arable, but this landscape does not fit into the standard CLC nomenclature. What is needed in this case is a class similar to 'heterogeneous agricultural areas' (2.4), but called 'heterogeneous semi-natural areas'.

Treatment of land cover classes

The CLC and LCM2000 nomenclatures will cause a number of issues which have been described in Section 4 and can be seen Table 1. The presence of many-to-one and one-to-many relationships will 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.

The CEH CLC2000 for the cross-border test site was produced with only very limited access to ancillary data. Initially, CLC1990 data was used to identify the possible location of land use parcels. As a result, several parcels, such a new golf course and some new mineral extraction areas were omitted from the analysis. For the production phase of CLC2000 in the Northern Ireland, OSNI, through EHS, have made available scanned raster maps at 1:50 000 scale which should provide some additional land use information. CEH continues to compile it's ancillary datasets for CLC2000 on a UK basis.

Comparison of the CLC1990 and 'pseudo-CLC2000' highlighted significant 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 the cross-border test site 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 by EHS and was associated with a deficiency in the KBC rules for 'bog' / 'fen, marsh and swamp' that were applied in Northern Ireland. EHS intends to investigate the solution of this problem in the near future. For the purposes of the CLC2000 production, interactive checking will be performed on the 'inland marshes' (411) and 'peat bogs' (412) classes. 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. CLC1990 for Ireland further subdivided 'pastures' (231) into 3 level-4 classes based on high, low and mixed productivity. 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 the test site had 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 4).

Table 4. 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 4 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 this region which are changing managed grassland to a more semi-natural character. Further work would need to be done to recreate the level-4 'pasture' (231) classes of ClC1990. This process will need to be considered further, especially when processing other grass areas of the UK. It may be necessary, time permitting, to do some significant interactive re-assignment of the grassland land parcels.

The area south west of Swanlinbar contains the class 'agriculture with semi-natural' (243) in the ERA version of CLC2000. The original LCM2000 data shows very little agriculture in the cross-border test site as whole and therefore this class was not 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.

Areas mapped as change

The results of identifying the areas of change were at first quite disappointing, but must be seen in the context of CLC as a European level product, the comments made above and the actual changes that were mapped. Many of the changes are between similar classes or the results of issues particular to this study. When recording change, the differences in the original CLC1990 data and the corrections applied become crucially important. This study is not a simple comparison, but involves effectively four methodologies and two different sets of input data. Also the level of change, around 5 %, is probably below the level of error present in each of the data sets. The LCM2000 data when compared with CS2000 field survey data was found to contain

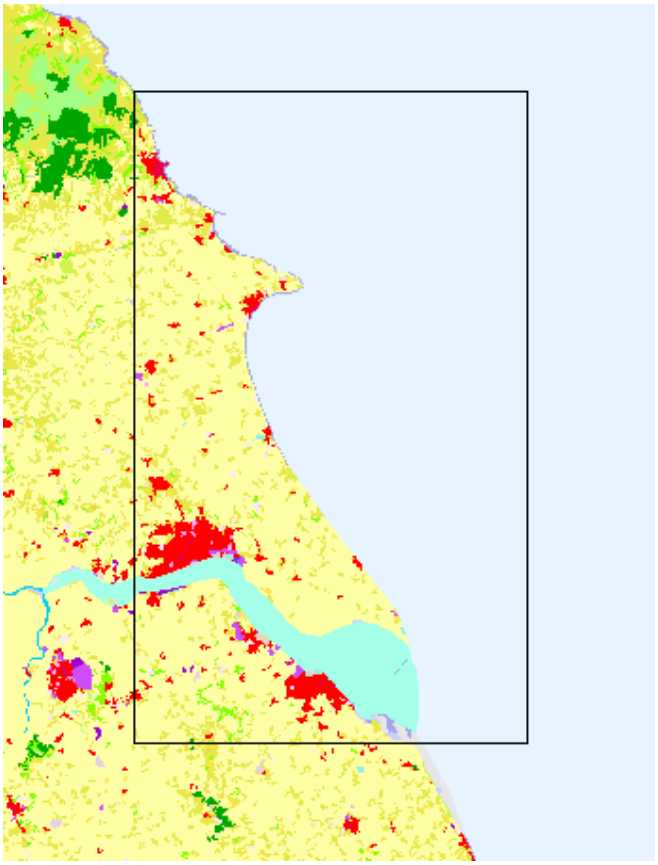
around 10 % error at the target class level. It is therefore not unusual for the two results to identify different areas of change, or in fact error.

5. Test site 2 : Coastal / agricultural area in Great Britain

Test site description

The LCM2000 was built as 100 km tiles due to the large data volumes created by a land cover map with a MMU of 0.5 ha. The test site selected in GB was a 100 km tile which contained a large amount of sea, thus providing enough information for testing methods, but not so much that large amounts of time were wasted waiting for completion. The area in Figure 9 contrasts with the area in Ireland by having large areas of agricultural land, a number of large urban areas and coastal habitats.

Figure 9. The CLC1990 data for the area around Humber Estuary with the outline of the OSGB 100 km tile TA selected for testing in GB.



The area covers the Holderness Coast region of Yorkshire and the Humber Estuary. The urban areas of Grimsby and Hull are to the south and north of the Humber respectively. Just outside the 100 km tile to the northwest is the upland area of the North Yorkshire Moors. This test site covers an area of approximately 215 000 ha.

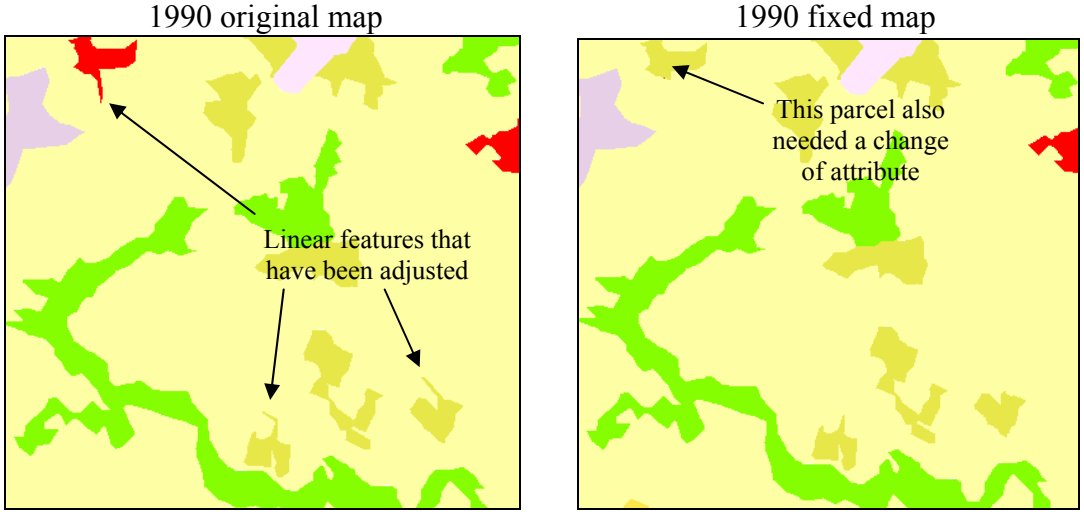
Correcting CLC1990

Due to the nature of the CLC1990 production in GB, it was only necessary to check the geometric accuracy of the CLC1990 product against national mapping. Four areas were selected across the UK and the locations of 38 sample points within these areas were checked (Annex 1). The results were very encouraging, producing an average error of around 30 m (ranging from 20 m to 39 m for the four areas and comparisons

with OSGB mapping and I2000 imagery). Only at two points did the errors approach the specified acceptable error of 100 m. The geometric correction of the CLC1990 data for GB was not required.

In the original CLC1990 data for the TA test site there were no erroneously coded parcels. There were also no parcels that broke the CLC minimum mappable area limit of 25 ha. Some changes were made to a small number of 'linear shapes' that did not meet the CLC rules for minimum width of linear parcels. Approximately 15 parcels of this nature were changed, some examples are shown in Figure 10 below.

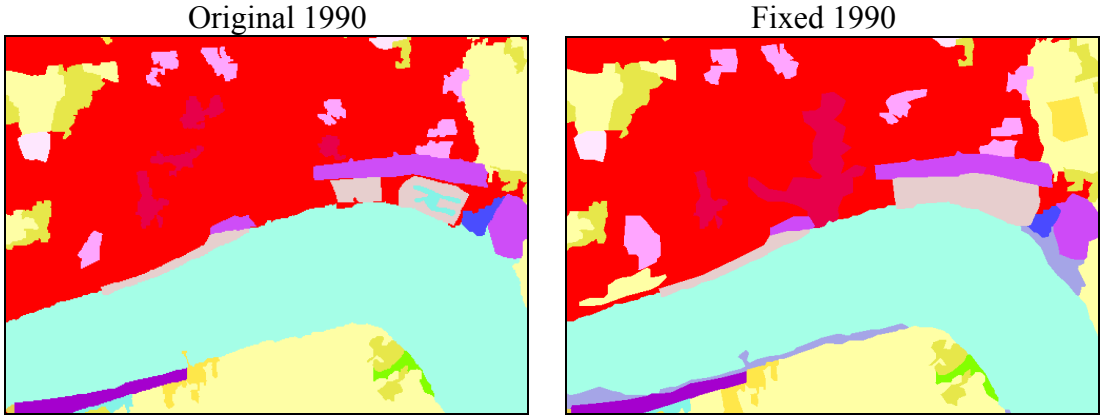
Figure 10. Some linear features that were removed during fixing of the 1990 map.



The main activity for correcting CLC1990 for the TA test site was therefore the adjustments required to the thematic labels attached to the polygons. These changes were assessed, both within CEH, and in conjunction with the CLC Technical Team. In the TA test site the changes were as follows:

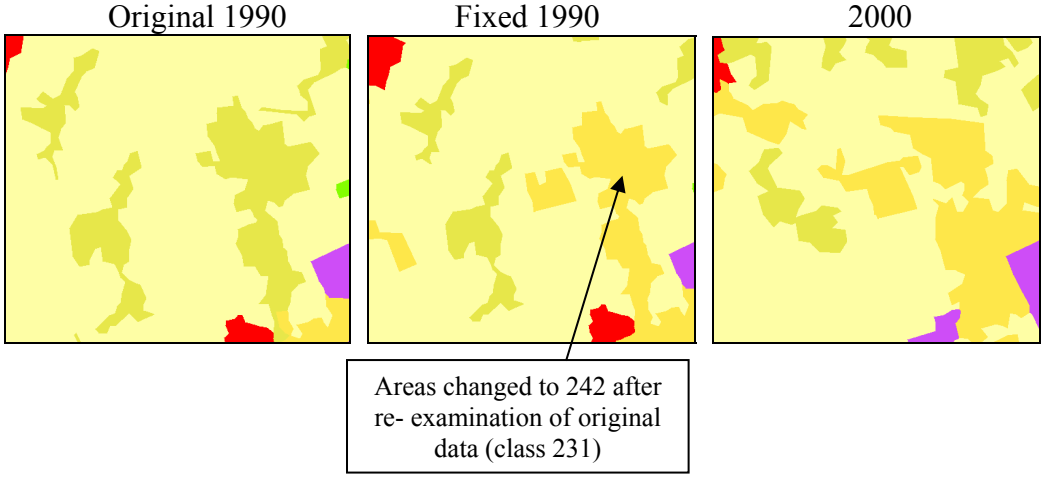
- The 1990 map was revised in the centre of Kingston upon Hull to reflect the correct balance of 'continuous urban fabric' (111) and 'discontinuous urban fabric' (112) (Figure 11). This issue was also addressed in the other urban areas within this area.
- There was a significant difference in tidal states in the imagery used for 1990 and 2000 resulting in less exposed intertidal surfaces in 1990. These coastal areas were edited to reflect similar tidal situations. In this case, the exposed surfaces coded as 'intertidal flats' (423) and 'beaches, dunes, sands' (331) on the 2000 map were edited into the 1990 map.
- Many of the steeper, rocky coastal areas were given a code of 'bare rocks' (333) or 'sparsely vegetated areas' (332).
- Where possible, some 'cultivated areas' in the 1990 map were given a revised code of 'complex cultivation patterns' (242). Similar changes were made to the 2000 version to increase the frequency of this class.
- Some 'isolated' areas of 'discontinuous urban fabric' (112) in the 1990 map were removed, after close examination of the source 1990 imagery (Figure 10). These had been erroneously classified in the LCM1990 source data.
- Some areas of 'natural grassland' (321) within arable regions were recoded to 'pastures' (231).

Figure 11. Reclassification to ‘continuous urban fabric’ (111) and ‘discontinuous urban fabric’ (112) in centre of Kingston-upon-Hull.



Much of the TA test site is cultivated land. Large areas of ‘non-irrigated arable land’ (211) interspersed with significant patches of ‘pasture’ (231) and occasional other classes. As mentioned above, we have revisited these areas in an attempt to increase the frequency of classes ‘complex cultivation patterns’ (242) and ‘land principally occupied by agriculture with significant areas of natural vegetation’ (243) (Figure 12).

Figure 12. Some parcel changes to increase areas of ‘complex cultivation patterns’ (242).



Update of CLC2000

The initial final version of square TA for 2000 was demonstrated to the visiting CLC Technical Team, who made the following recommendations.

- As was the case for the 1990 map, edits were required in the centre of Kingston upon Hull, from ‘continuous urban fabric’ (111) to ‘discontinuous urban fabric’ (112).
- As was also the case for the 1990 map, more areas have been changed to ‘complex cultivation patterns’ (242), generally from groups of ‘non-irrigated arable land’ (211) and ‘pastures’ (231).
- The coastal area has been more closely aligned with 1990 pattern. This has included an increase in ‘bare rocks’ (332) and ‘sparsely vegetated areas’ (333) to reflect steep rocky coasts.

There is a significant amount of coast within this test site. Classes 'salt marshes' (421), 'beaches' (331), 'bare rocks' (332) and 'sparsely vegetated areas' (333) occupy about 1500 ha (14 parcels) in the 1990 map, but 1544 ha in 2000. This small increase is largely due to a single salt marsh at the edge of the Humber estuary, which has increased in extent since 1990. Classes 'intertidal flats' (423) and 'estuaries' (522) occupy over 30000 ha, and are similar in pattern and extent in both maps.

In general, the 'land use' classes within the TA test site have not undergone much change, for instance, class 'sport and leisure facilities' (142) has increased from 28 to 32 parcels with an increase in area of about 21% to 2280 ha. These changes are mainly due to a new golf course and a new country park designation since 1990.

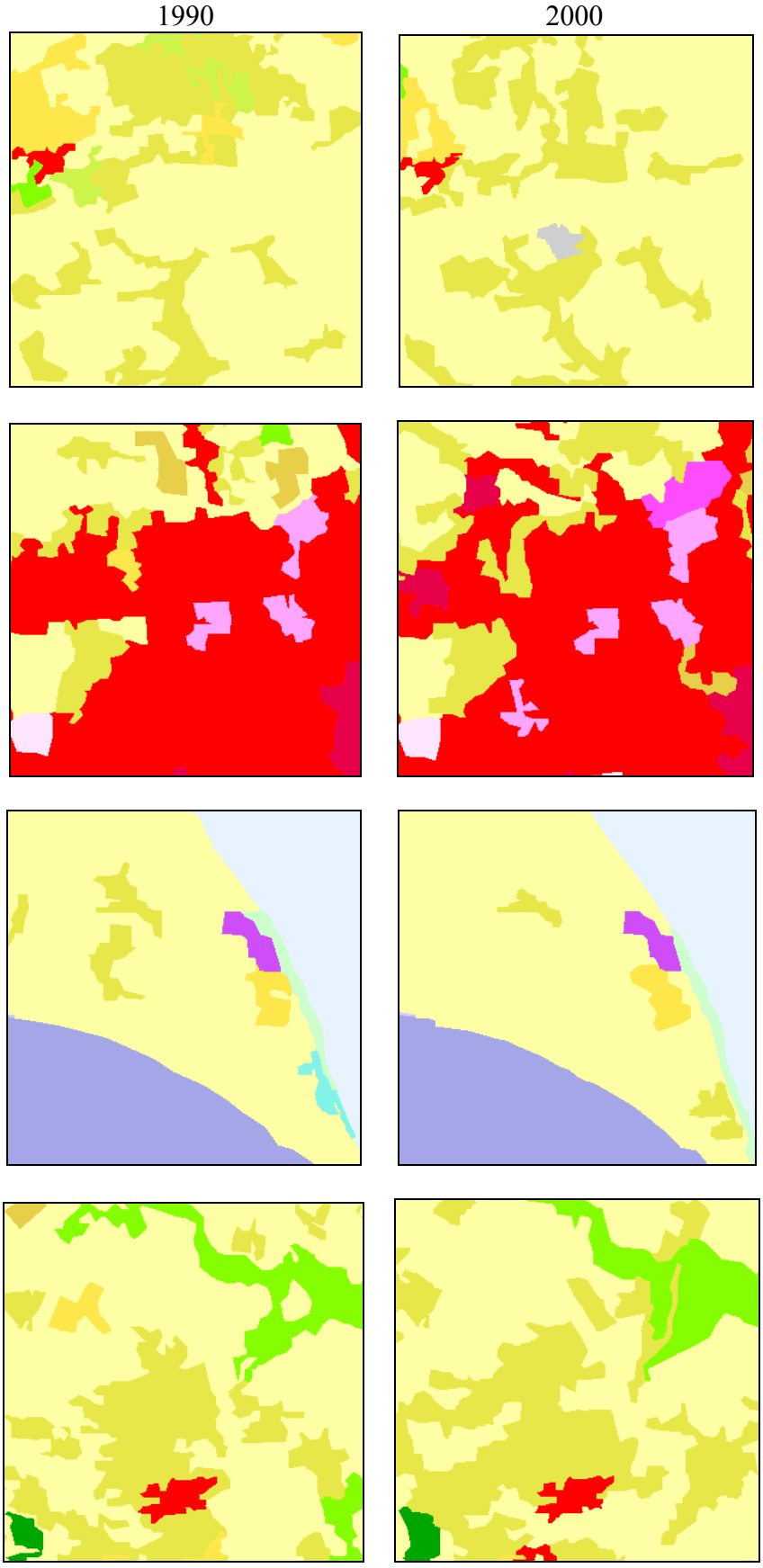
Table 5. Area statistics for CLC2000 data in the TA test site.

	Class	Area (ha)	Parcels		Class	Area (ha)	Parcels
111	Continuous urban fabric	1293	13	243	Principally agriculture	1399	21
112	Discontinuous urban fabric	16960	85	311	Broad-leaved forest	2807	51
121	Industrial or commercial	1649	15	312	Coniferous forest	369	6
122	Road and rail networks	67	1	321	Natural grassland	31	1
123	Port areas	1063	6	331	Beaches, dunes, sands	83	1
124	Airports	101	1	332	Bare rocks	64	2
131	Mineral extraction sites	325	5	333	Sparsely vegetated areas	913	6
133	Dump sites	105	1	412	Peat bogs	42	1
141	Green urban areas	538	13	421	Salt marshes	484	4
142	Sport and leisure facilities	2284	32	423	Intertidal flats	8901	18
211	Non-irrigated arable land	143308	48	512	Water bodies	174	2
231	Pastures	28886	376	522	Estuaries	23543	2
242	Complex cultivation	4827	40	523	Sea and ocean	200534	1

Direct correspondence

As expected there was a close agreement between the two maps in broad landscape terms. Statistically there is a direct correspondence of just over 87 % between 1990 and 2000. This is the scale of direct correspondence that would be expected when considering the likely amount of real change, the tolerances that are accepted within the methodology and error. Changes are about 14.2% of land area. The main changes are shown in Table 6 and they are discussed in some detail in the next section. Figure 13 below shows some example areas from this test site.

Figure 13. Some example areas from the fixed CLC1990 and CLC2000 data sets displayed at a scale of about 1:100 000 (see Figure 8 for colour key).



Resulting change parcels

The total 'land area' of the classified map is about 215 000 ha and the total area of change is 31102 ha. Therefore 14.2 % of the land area registers change between 1990 and 2000. When finalising the areas of change, account has been taken of areas within 100 m of the parcel boundaries in both maps. Change parcels initially created were overlaid with these buffer zones. These parcels frequently, and significantly, overlap into the 100 m buffer zones. As stated in the CLC technical guides it is not possible to decide whether the change so identified is real, or a result of the tolerances allowed by CLC. Where change parcels were mainly within the buffer zone they have been excluded from the change parcels data. Where significant proportions were outside the buffer zone the parcel has been included in the change data. In all cases the CLC guidance rules for change were applied.

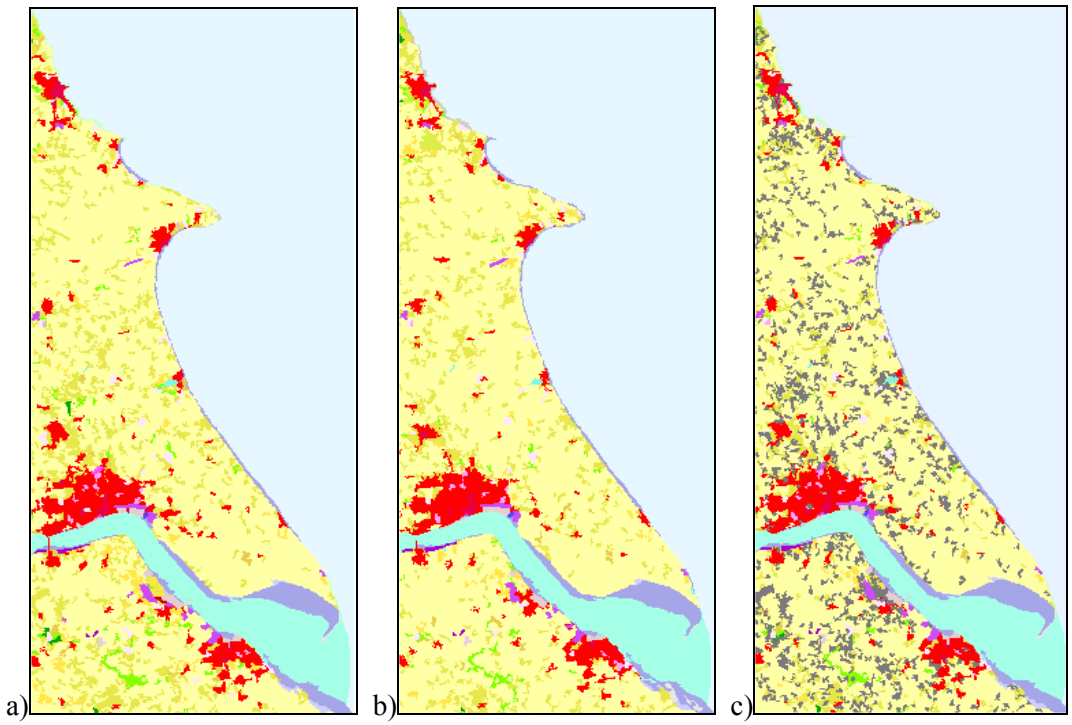
Table 6. Change statistics for square TA in hectares, areas of direct correspondence are excluded and shaded (for class names see Appendix A).

									2000									
1990	111	112	121	122	123	133	141	142	211	231	242	243	311	312	321	332	421	423
111																		
112	222		102	65	107	17	33	106			80	74						
121																		
122																		
123	26																	
133																		
141											78							
142																		
211	37	1093	33					135		14403	2222	525	1098	150		35		
231		291						126	6843		204	82	163	25				
242		26	20		19				903	225								
243		16				27			366	45	9		27	45				
311								79	359	52	36							
312									15	29								
321									135	75								
332																		
421																		
423																25	40	

Table 7. The most significant changes between 1990 and 2000

CLC1990		CLC2000		Area (ha)
	Class		Class	
211	Non-irrigated arable land	111 112	Continuous urban fabric Discontinuous urban fabric	1163
211	Non-irrigated arable land	231	Pastures	14403
231	Pastures	211	Non-irrigated arable land	6843
211	Non-irrigated arable land	242 243	Complex cultivation patterns Principally agriculture	2747
242	Complex cultivation patterns	211	Non-irrigated arable land	903
231	Pastures	242 243	Complex cultivation patterns Principally agriculture	286

Figure 14. The TA test site in a) 1990, b) 2000 and c) with changes between 1990 and 2000 highlighted in grey.



Discussion and explanation of differences and similarities

68 % of the recorded change is a swap between 'non-irrigated arable land' (211) and 'pastures' (231) in both directions. Both of these level 3 classes are constituents of the level 1 'Agricultural Areas' class. We have visited many of these parcels in both the 1990 and 2000 maps. With satellite imagery displayed beneath the parcel outlines, in some cases, we were able to change the attribute, where there was a clear error in the initial classification. However, in many instances it is not possible to distinguish consistently between these two classes using single date imagery. This is primarily because of the similarity in the state of the vegetated cover at certain times of the year. The source CEH land cover data is largely created using summer and winter composite imagery, specifically to allow for differentiation between 'non-irrigated arable land' (211) and 'pastures' (231), because of the bare nature of the ground cover in 'non-irrigated arable land' (211) in the winter imagery. Therefore the majority of these recorded differences remain in the data.

Where 'non-irrigated arable land' (211) has changed to a level 1 'artificial surface' class they probably represent real change, for instance, where an arable field has been encroached upon by building development on the edge of urban areas. These changes constitute about 4.2 % of the recorded change.

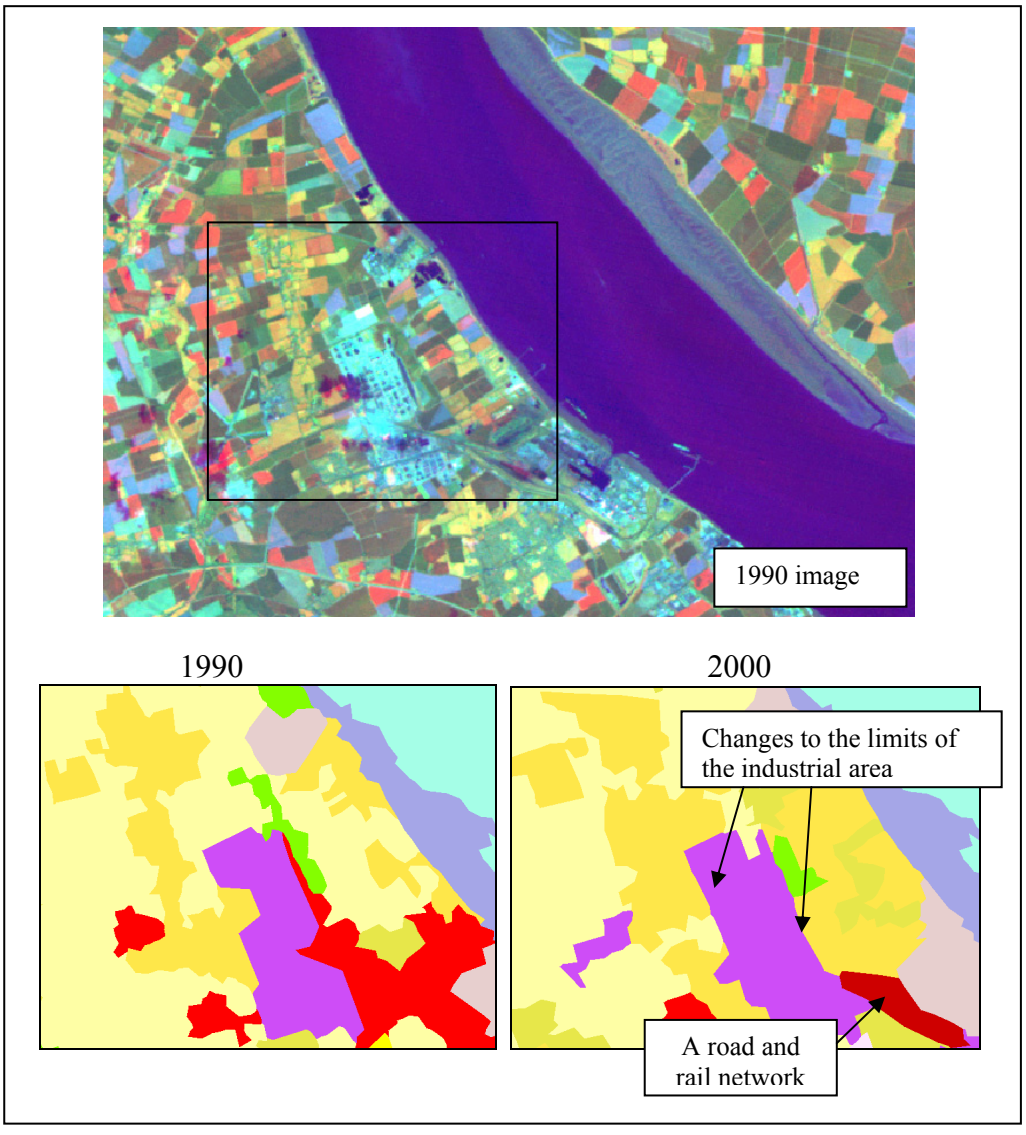
8.8 % of the change is from 'non-irrigated arable land' (211) to 'complex cultivation patterns' (242) and 'land principally occupied by agriculture with significant areas of natural vegetation' (243). Strictly speaking this may not identify real change, as 'non-irrigated arable land' (211) is often a significant constituent part of 'complex

cultivation patterns' (242) and 'land principally occupied by agriculture with significant areas of natural vegetation' (243).

Similarly a change from 'pastures' (231) to 'complex cultivation patterns' (242) and 'land principally occupied by agriculture with significant areas of natural vegetation' (243) may not identify real change. However this combination only occurs in about 286 hectares, i.e. about 0.9 % of the change.

An area on the south side of the Humber Estuary has been examined in some considerable detail, as a result of advice from the technical team, who looked closely at this area during their visit. This is a complex area involving mixes of discontinuous urban, industrial, road and rail etc. Figure 15 shows its general situation, the original 1990 map and the result in 2000. The issues were related to the types of areas that could / should adopt the industrial class rather than the discontinuous urban class; also an increased area of railway clearly needed to adopt the 'road and rail networks and associated land' (122) class in 2000.

Figure 15. Dealing with a complex mixture of land use classes.



6. Report of the CLC2000 Technical Team Training Mission

The following notes were prepared during the CLC2000 Technical Team Training Mission to the UK 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).

CLC2000-Project overview *(Susan Christensen)*

The aims of the project and it's products wee outlined. These include the necessity for revising CLC1990 national maps (product optional) and the provision of national metadata for each country and each working unit. Examples of uses of results at European level were listed along with the basic data requirements for CLC2000 and details of CLC2000 national teams.

The generalized workflow was described as including:

- the requirement for a seamless national database respecting the minimum limits of 25 ha area and 100 m width for polygons,
- the need for validation (both geometric and thematic) and quality assessment and control,
- the recommended the use of merged TM/PAN images (PAN=12.5 m resolution) especially for checking final results.

So far, 25 counties are participating – including all EU counties except Greece. The deadline for completion is the end of 2003.

Methodology for up-dating *(Jan Feranec)*

Theoretical background and practical examples of the methodology were provided. The need for the 2000 update is driven by the need to monitor and understand the temporal elements of landscape. Different types of change that can occur between CLC1990 to CLC2000: changes to the contents of a polygon, changes of area (increase or decrease) – this is the most common change, disappearance of a polygon and the inception of a polygon. 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 were emphasised.

CLC in the UK *(Geoff Smith)*

The background to national and European level land cover mapping in the UK was described including: the production of LCMGB, the conversion of LCMGB to CLC1990, the production of LCM2000 and the general overview of UK approach for CLC2000. The intended procedures for CLC2000 are to; generalize LCM2000 to produce a pseudo-CLC2000, correct CLC1990, and produce a final CLC2000 with reference to the corrected CLC1990, Image2000 and other data.

Detailed description of UK approach to CLC2000 *(Nigel Brown)*

A detailed description of the methodology was provided with illustrations from the 100 km grid square TA (Humberside, see section 5). This included details of the procedures used for detecting differences and changes between 1990 and 2000.

Because of the existence of the detailed land cover datasets, LCMGB (for 1990) and LCM2000, the UK team is following non-standard procedures compared to those recommended for the CLC2000 project. The other countries using non-standard procedures are Sweden (that has no CLC1990 data) and Finland (where no change assessment will be undertaken due to poor CLC1990 data).

Demonstration of CLC2000 procedures - Northern Ireland *(Andy Thomson)*

This demonstration illustrated a number of issues that had arisen during the operationalisation phase. Some of the issues were the result of CLC1990 and CLC2000 being carried out by different teams using different methods. The UK team had already addressed some of the issues, but further support and advice were provided by the Technical Team. For example:

- Peat bogs (class 412) had been mapped too extensively in 1990 and are too restricted in 2000 – both datasets should be changed with reference to satellite imagery and field data. Change from 412 to 322 in 10 years is unlikely, therefore, for NI, CEH should change some 1990 peat (412) to moors & heath (322) and also change some 2000 moors and heath to peat. CEH felt this was achievable fairly quickly interactively using their extensive experience of these cover classes in Landsat imagery through the recent production of LCM2000.

- Some urban "land use" polygons in the port area of Belfast needed to be changed in both 1990 and 2000 datasets.

- Coastal areas should include the intertidal zone in both datasets – this is a general requirement for all UK. This issue varies across the UK to some extent. CEH should aim at making the coastal (below HWM) classes more similar, removing the artificial effect caused by the varying tidal levels present in LCM2000 and LCM1990. This problem is not present in large parts of GB, mainly due to the use of summer winter composites in LCM2000 mapping.

- Other issues include the depiction of water bodies; the 100 m minimum width must be adhered to and rivers have to be set to class 511 (not 512). JF is not necessarily expecting 'continuous linear river features'. 'Wider' river portions should be coded as water bodies. CEH is correct to update 1990 NI data accordingly.

- Complex mosaic polygons near the coast must be split and terraced cliffs placed in class 333 (sparsely vegetated areas).

- Mosaic/mixture classes, especially class 242 (complex cultivation patterns), have been applied differently in the two datasets and need some modification to avoid showing spurious change. CEH should re-examine CLC2000 parcels

formed from the 'mosaic process. In particular, we should look at those parcels that were allocated a 'dominant' class and see if they could be more appropriately given a 242 or 243 code etc.

- For coniferous woodland class (312). The CLC2000 technical group accepts our proposed interactive edit of these parcels. Specifically CEH will consider using the transitional class (324) in CLC2000 where clear-felling etc has taken place since 1990.

- For the 'grass recode issue'. CEH should interactively examine those parcels given the 231 and 321 codes, looking for possible miss-coding. 231 must have evidence of management.

- Some montane areas, and possibly some coastal areas (see above) should be allocated the code 3.3.3.

Cross border comparison for Ireland *(Geoff Smith)*

An exercise covering a cross border area near Enniskillen was described. Results were available from the Irish and UK methods for CLC2000 for the same area and could be directly compared. There was a direct correspondence of approximately 70 %, which could be raised to over 80% if thematic issues such as different assessment of peatbog / moorland / natural grass are considered.

Quality assessment of CLC2000 *(Susan Christensen)*

The procedures for checking quality of results during and after completion of CLC2000 will be as follows:

- Internal procedures within national teams for the documentation of methodology used, the supervision of all production steps with standardized checks, and the production of an internal report with documentation of results of tests.
- External procedures from the CLC2000 Technical Team will be exhaustive and include a verification phase during production (a corrective process) and a validation phase after the end of production but before product dissemination (with no corrective purpose).
- Quality assessment will check for geometric accuracy (errors must be less than 100 m) and thematic accuracy (minimum correspondence of 85 %).
- Verification Phase will involve two checks, the first after approximately 50 % of the work has been completed and the second after 100 % completion. Each check will involve a 1-3 day visit by an external team of two experts who will complete verification sheets describing geometric and thematic accuracy for approximately 10 % of the national coverage. Verification units will be pre-selected 10 x 10 km areas (at least one per "working unit") chosen to cover a wide range of landscape types, CLC classes and areas with many/few/or no changes. Datasets, equipment and necessary assistance must be provided. Results will be accepted or rejected; if rejected, requirements for correction will be given.
- Validation Phase will be based on the thematic accuracy of the entire CLC2000 product based on representative samples. The final product will be compared

with "ground truth" as assessed by independent data such as aerial photographs or other data sources (of known accuracy); the LUCAS Project with regular sampling points across the EU might be used.

Validation in the UK *(Geoff Smith)*

The use of Countryside Survey 2000 Field Data to validate LCM2000 was described. Field data for 569 1x1 km squares recorded by field surveyors in 1998/99 have been compared with LCM2000 data on a per-pixel basis and using Field Survey parcels and LCM polygons with variable results.

Demonstration of CLC2000 procedures for TA test site (Humberside) *(Nigel Brown)*

CLC2000 for this test site was almost complete – change statistics were being compiled. A comparison of CLC1990 and CLC2000 showed that the urban class 111 had to be increased in Hull for 1990 but was too extensive in 2000 – all urban areas in CLC1990 should be checked to see that core areas are classified as 111 and revised where necessary. As in Northern Ireland, mosaic/mixture class 242 needs some revision – perhaps it should be more extensive in CLC2000, existing polygons of 242 could be used as target areas for more interactive editing with reference to the satellite imagery. A good example of 242 was identified by the Technical Team on the south side of the Humber Estuary.

Plans for production

In discussion, tentative dates for the external Verification Phase Checks were suggested: late May / June 2003 for the 50 % completion check and September / October for the final check. The extent of "working units" will be decided soon – possibly the 100 x 100 km OS squares (and also the order in which they will be completed).

The Technical Team requested copies of the following documents / items for themselves and / or for forwarding to other teams team:

- CD of CEH presentations
- UK 100 km grid picture in digital form
- PDF of interim report
- CD of photographs taken on LCM2000 field trips to illustrate a range of land cover classes such as moorland and peat bogs (with explanatory text)

7. Discussion

Overall, this operational phase has been extremely successful, both in terms of assessing the UK approach to CLC2000 production, and placing the results of the UK CLC2000 in a sounder European context.

During this phase in the UK and through communication with the CLC Technical Team at a Training Meeting in the UK a number of issues were addressed to finalise and operationalise the UK approach to CLC update.

- The conformity of the UK approach to the standard CLC approach.
- The UK approach will be using increased amount of interactive examination.
- The relatively high level of correction required in Northern Ireland CLC1990.
- Nomenclature issues between LCM2000 and CLC2000.
- Nomenclature issues identified by cross-border comparison.
- Structural issues identified by cross-border comparison.
- Nomenclature problems for mosaic areas.

The four main sections (3, 4, 5 and 6) of this report address the issues outlined above. The UK approach to the production of CLC2000 was approved by the CLC Technical Team after a number of recommendations. Due to the quality of some of the 1990 data and the use of a change only update, it was accepted by all parties that the UK approach would require a higher level of manual intervention than was first thought. The nomenclature and structural issues that were identified at the two test sites were discussed with the CLC Technical Team, and solutions agreed that were suitable for the UK approach and acceptable to the standards of the CLC specification.

The comparison of the CEH and ERA data sets has proved that the adoption of different methodologies each side of the border will not seriously influence the production of all island products, or create artefacts related to the border in analyses that include both Ireland and Northern Ireland.

The work on the TA test site highlighted a number of interpretation issues that had not been covered in Ireland due to the different composition of the landscape. These included the use of mosaic classes in complex agricultural areas and the definition and use of the land use classes from the ‘artificial surfaces’ level 1 class. These clarifications were required, both for fixing the 1990 data, and for improving the 2000 data.

The visit of the Technical Team was very rewarding as was described in the test site sections, and has helped to improve the quality and consistency of the UK contribution to CLC2000.

This phase has been an important exercise for normalising the UK approach to the CLC update as closely as possible to the standard approach that is being applied over most of Europe. This study has formed a sound basis for the production of CLC2000 products in the UK that are consistent with the rest of Europe. This work may also

include the only study to consider the CLC2000 data produced by different national groups in such detail.

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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

Appendix B : CLC1990 GB geometric accuracy assessment (m).

CORINE 1990		Ordnance Survey		CLC90-OS	Image2000		CLC90-I2K	Map feature
E	N	E	N	Error	E	N	Error	
NE England								
514814	429801	514803	429822	24	514798	429811	19	Green urban corner
501178	490071	501189	490092	24	501194	490071	16	Urban/river junction
517361	465890	517367	465907	18	517367	465890	6	Urban corner
512806	467015	512796	467001	17	512796	467000	18	Wood corner
507718	449574	507675	449509	78	507686	449498	82	Lake edge
519609	447494	519634	447504	27	519604	447484	11	Lake edge
519345	446785	519345	446717	68	519340	446725	60	Lake edge
			Average	**37**		**Average**	**30**	
SE England								
557289	176455	557277	176463	14	557273	176463	18	Jetty on R Thames
541571	179255	541542	179293	48	541533	179321	76	Thames barrier
552667	167918	552685	167914	18	552681	167869	51	M20/M25 junction
558513	162046	558531	162069	29	558528	162031	21	Wood/road junction
552155	164085	552137	164100	23	552129	164085	26	Wood corner
541248	162752	541226	162741	25	541202	162775	51	Orchard corner
545399	169051	545414	169051	15	545425	169036	30	Urban corner
			Average	**25**		**Average**	**39**	
NW England								
352213	329011	352223	329016	11	352218	329017	8	Urban corner
344957	337896	344912	337887	46	344918	337904	40	Park/wood corner
355960	339313	355971	339315	11	355938	339330	28	Wood corner
343524	332887	343521	332910	23	343540	332900	21	Lake shore corner
342072	322158	342069	322158	3	342069	322162	5	Road/urban junction
348533	326657	348527	326698	41	348491	326693	55	Airfield corner
352600	321601	352635	321590	37	352607	321586	17	Wood/road junction
357502	327394	357441	327349	76	357483	327341	56	Wood/burial ground
358588	329566	358551	329569	37	358567	329587	30	Park/road junction
			Average	**32**		**Average**	**29**	
SW Scotland								
231691	574789	231695	574773	16	231699	574793	9	Wood/lake edge
237453	568430	237445	568410	22	237449	568426	6	Conifer corner
229426	552675	229415	552659	19	229405	552675	21	Lake promontory
233938	543630	233900	543607	44	233923	543592	41	Urban corner
227435	558249	227427	558202	48	227427	558225	25	Wood corner
220583	553862	220553	553825	48	220568	553847	21	Coastline promontory
			Average	**33**		**Average**	**20**	
			Overall average	**31**		**Overall average**	**30**	