CENTRE FOR ECOLOGY AND HYDROLOGY
(NATURAL ENVIRONMENT RESEARCH COUNCIL)

Project. C02041A

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

Interim Report

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21 November 2002

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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. On the border between Ireland and Northern Ireland a site was selected which offered the opportunity to test the correction of CLC1990 produced by the standard approach and compare the UK and standard updating approaches. 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 so far in the operationalisation phase has been extremely success, but has identified a number of issues which need to be addressed before the CLC2000 for the UK goes into full production. A Training Meeting with the CLC Technical Team has been organised for mid-December 2002 at which the UK approach will be evaluated and issues identified will be discussed.

1. Introduction

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.

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 accuracy against British National Grid and I2000.
- 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

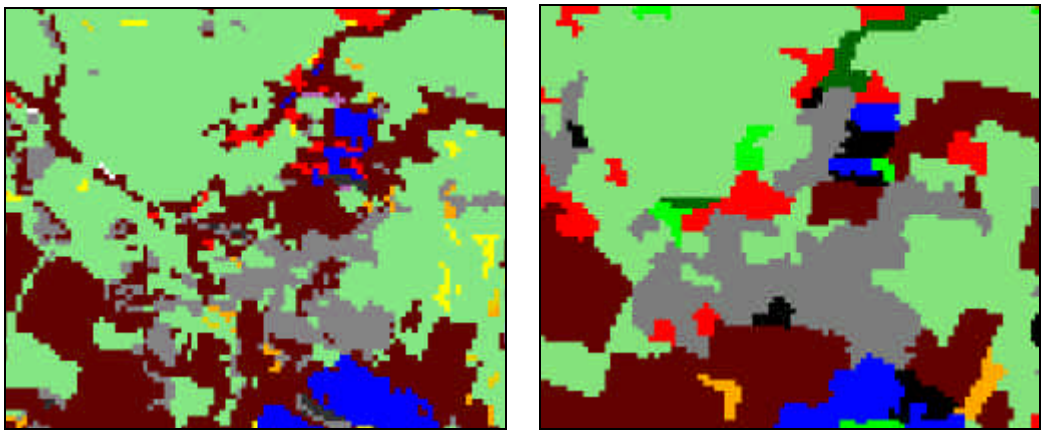
To produce the 'pseudo CLC2000', the first stage is create a set of land use parcels which are not specifically mapped in LCM2000. The land use parcels are extracted from the corrected CLC1990 and stored as a new dataset. With the help of the I2000 images and ancillary data (scanned raster maps, feature (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.

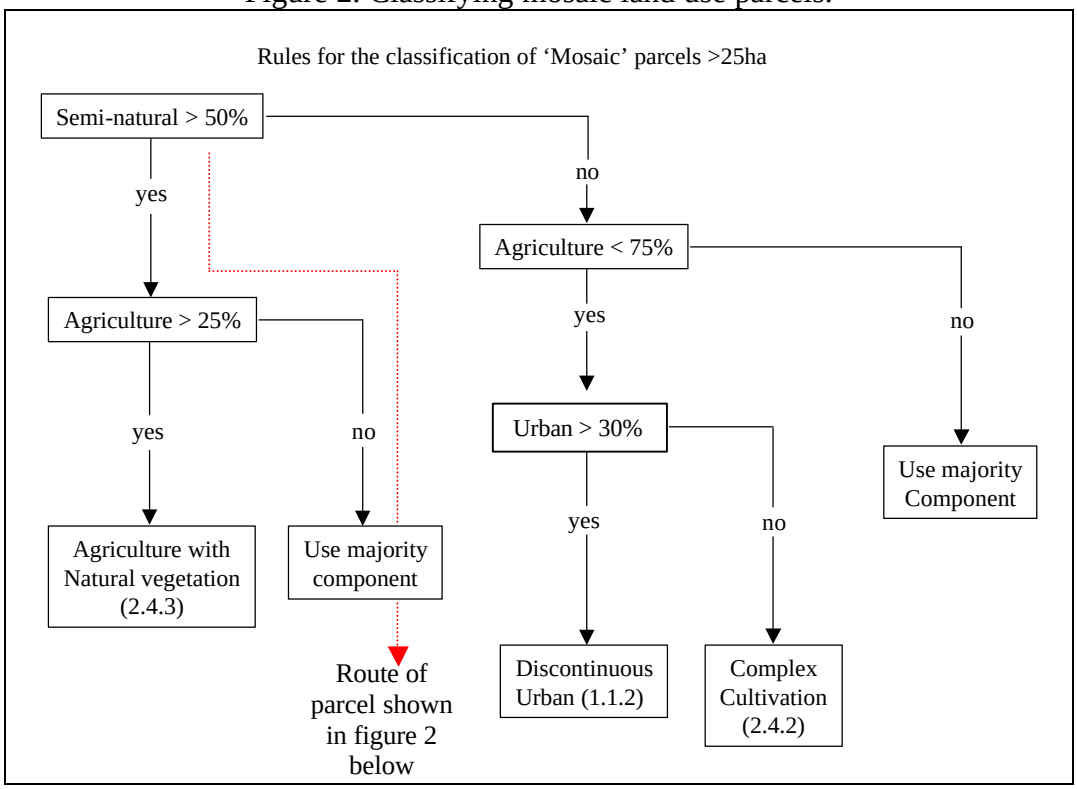


Figure 3. An example of the application the CLC mosaic rules.

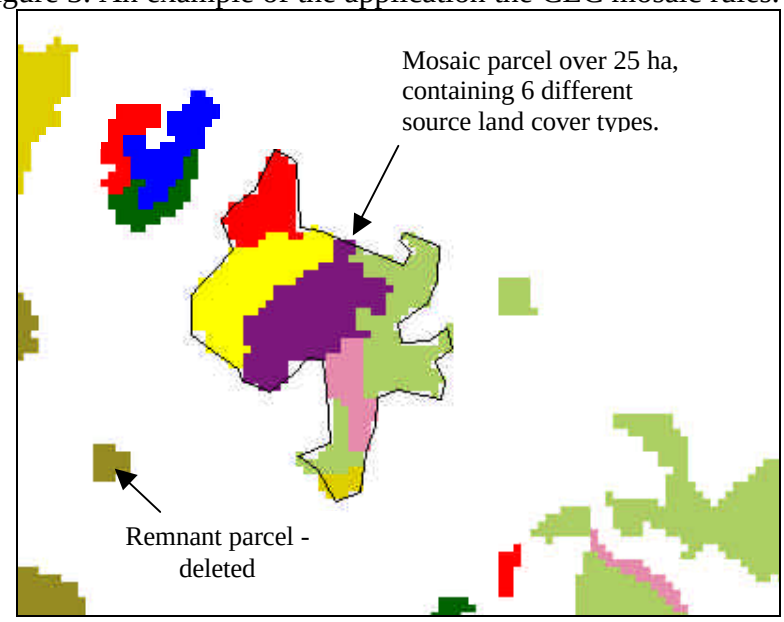
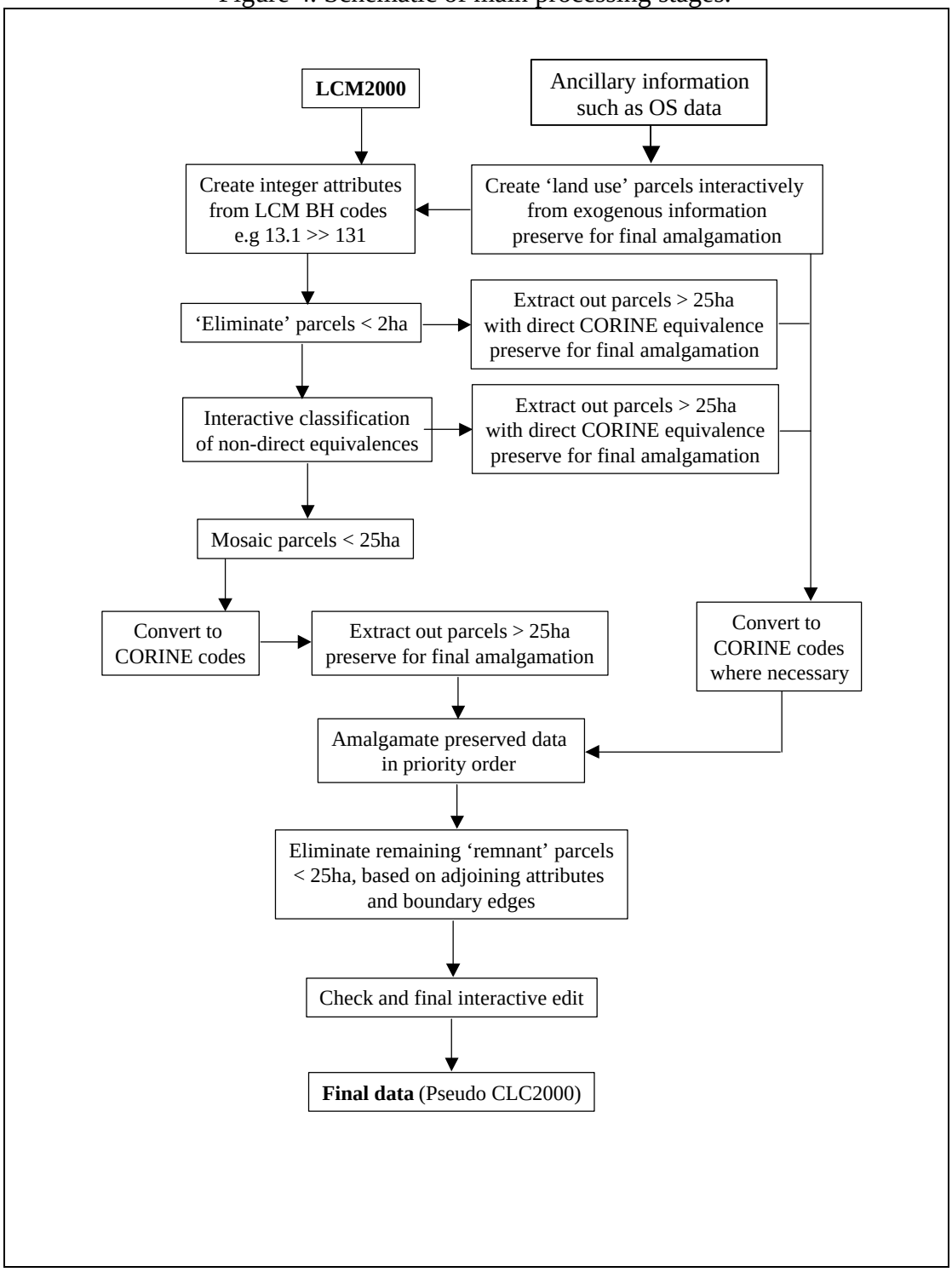


Figure 4. Schematic of main processing stages.



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. Description of test sites

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.

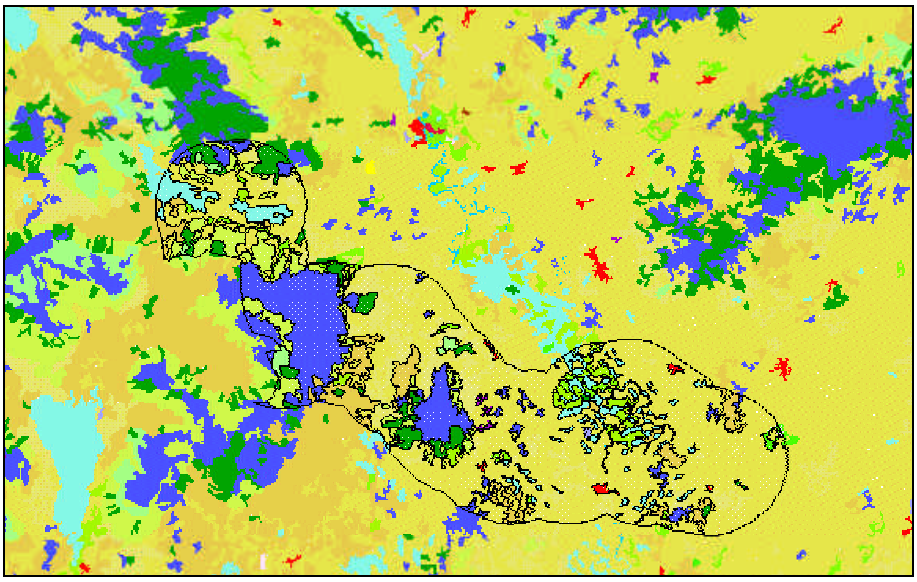
Cross border area in Ireland

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 the EEA / JRC standard methods allowed an opportunity for comparison with the UK methods.

The test area 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 area was not covered by LCM2000 data due to cloud cover, but was decided to press on using the slightly reduced test area limits.

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

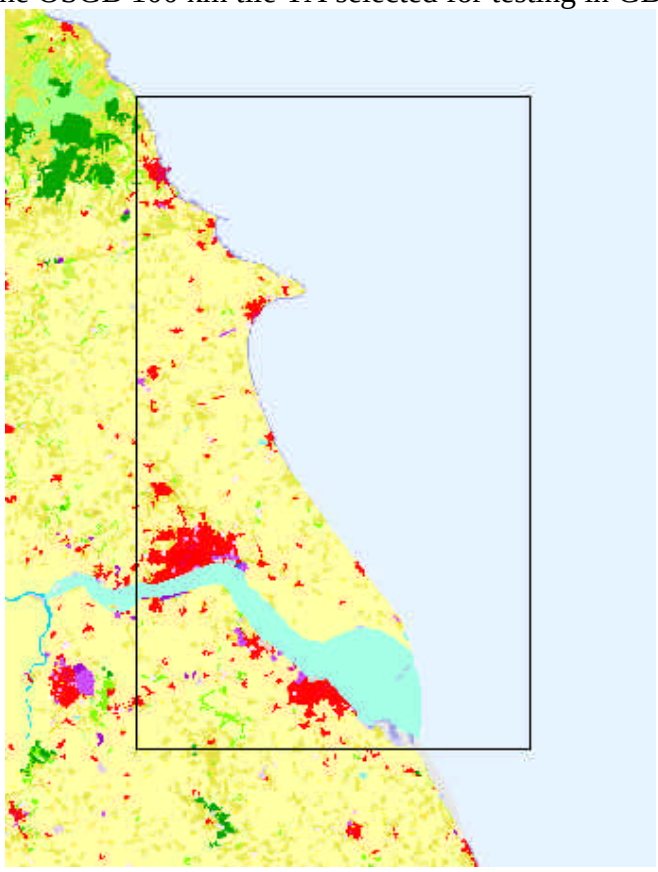


The cross-border test area follows the border from just east of Clones, west across Slieve Rushen and Cuilcagh to around the middle of Lough Macnean Upper and covers an area of approximately 58 000 ha.

Coastal / agricultural area in Great Britain

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 area 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 6 contrasts with the area in Ireland by having large areas of agricultural land and a number of large urban areas.

Figure 6. 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 north west is the upland area of the North Yorkshire Moors. This test site covers an area of approximately 215 000 ha.

5. Discussion

During the final part of CLC2000 Phase 1 in the UK and through communication with the CLC Technical Team at a Training Meeting in the UK a number of issues will be addressed to finalise the UK approach to CLC update.

- The conformity of the UK approach to the standard CLC approach will be assessed.
- The UK approach will be using increased amount of interactive examination compared to that originally envisaged.
- A relatively high level of correction required in Northern Ireland CLC1990. Corrections are not required to the same level for the rest of GB.
- 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 presence of mosaics of many small, semi natural parcels in Northern Ireland, where the CORINE rules enforce the ‘dominant class’, even though it may occupy a relatively small percentage of an area.

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