Inter-Change: A software support for interpreting land cover changes

G. Büttner, G. Maucha & G. Taracsák
Institute of Geodesy, Cartography and Remote Sensing, Budapest, Hungary

ABSTRACT: The IMAGE&CLC2000 project managed by the European Environment Agency (EEA) and the Joint Research Centre (JRC) has two main components: (1) satellite image acquisition and prepocessing for Europe; (2) interpretation and mapping of land cover changes for Europe. As part of Hungary's preparation for the project, a computer-assisted photointerpretation tool has been developed under ESRI's ArcView software to interpret land cover changes. The system provides interactive facilities for the photointerpreter to simultaneously revise the CLC90 database and interpret land cover changes between 1990 and 2000. Satellite images taken in the 90's and 2000 are used to control both processes. Powerful tools are built in to fulfil specifications of the project and avoid database errors. No sliver polygons are produced during updating.

1 THE CORINE LAND COVER DATABASE AND ITS UPDATING IN EUROPE

The idea of producing a uniform pan-European land cover database dates back to the early 80's. It has been recognised that land cover is a basic information for the management of the environment and natural resources. Land cover mapping has become an integral part of the CORINE (Co-ordination of Information on the Environment) Programme, started in 1985 by the European Commission DG Environment with the main aim of compiling consistent and compatible information on the environment for Member States of the European Union. Information obtained by earth observation satellites gives the base data for the production of a land cover inventory. In 1994, the European Environment Agency (EEA) in Copenhagen undertook the maintenance and use of the CORINE Land Cover (CLC) database.

The CORINE Land Cover project has been implemented in most EU countries, as well as in the 13 Phare partner countries in Central and Eastern Europe and in two North-African countries (Morocco and Tunisia). The last countries to finish their CLC inventory were Bosnia-Herzegovina and Macedonia using satellite images taken in 1996-98. In each country local team(s) implemented the project under a central supervision. 28 European countries have been involved in the CORINE Land Cover mapping project

resulting in a total area of 4.4 Mkm^2 being mapped (Büttner et al. 1998a).

The basic aim of the CORINE Land Cover project is to provide an inventory of the Earth surface features for managing the environment. CLC is consistent and comparable across the continent. Computer-assisted visual interpretation of satellite images has been chosen as preferred mapping technology. The choice of scale (1:100,000), minimum mapping unit (25 ha) and minimum width of linear elements (100 metres) represents a trade-off between the costs of production and the details of land cover information derived (European Commission 1993).

Today, CLC is recognised by decision-makers as an essential reference data set for spatial and territorial analyses on different territorial levels. Within the European Commission Services such as DG-Regional policy, DG-Environment and DG-Agriculture, as well as in EEA and its European Topic Centres (ETCs) there is a growing need of integrating spatial and territorial analysis into the assessment (EEA-JRC-ETC/TE 2002).

A new project called IMAGE&CLC2000 is undertaken to update the standard CLC database (referred to as CLC1990) giving a "snap shot" of Europe for the year 2000. In the course of updating a refined nomenclature is used (Bossard et al. 2000), which accumulates 15 years of CLC experience. The updated CLC database is called CLC2000 (Steenmans 2000).

It was recognised that the updating of CLC can not be automated, but should be based on computer assisted photointerpretation (Perdigão & Annoni 1997).

Table 1. Novelties of CLC2000 (EEA-JRC-ETC/TE 2002)

User requirement	CLC1990 specification	CLC2000 specification
More time consistency	1986-1998	2000 +/- 1 year
Improved geometric accuracy:		
- satellite images:	50 m	25 m
- CLC data:	100 m	better than 100 m
Thematic accuracy	$\geq 85\%$	$\geq 85\%$
Changes smaller than the minimum mapping unit shall be identified	–	boundary displacement should be minimum 100 m; area change should be minimum 5 ha
Faster turnaround time	10 years	3 years
Lower production costs	6 €/km^2	3 €/km^2
Improved documentation	incomplete metadata	standard metadata
Easier access to the data	unclear dissemination policy	agreed dissemination policy from the start

2 BASIC CONSIDERATIONS

2.1 *Characterisation of CLC1990 data*

The CLC1990 database is produced with a traditional photointerpretation technique. A transparent overlay was fixed on top of the satellite image hardcopy and the photointerpreter drew polygons on it. The polygons were coded according to the CLC nomenclature (European Commission 1993). Although the display and interpretation of satellite imagery using an image processing system was recommended to compensate the drawbacks of using hardcopy images, these facilities were not always available. After completing the interpretation and supervision, the polygons were digitised, a topology was created and the CLC codes were entered. This procedure often resulted in several different types of error:

− geometrical errors caused by an imprecise hardcopy image size, distortions of the hardcopy image, improper alignment of overlay and image, errors of digitisation;
− thematic errors made by the photointerpreter because of the limited interpretability of hard copy image and / or because of misuse of the nomenclature. Thematic mistakes could have been introduced also during the database-coding phase.

2.2 *Approaches of updating*

For the reasons above, national CLC1990 databases frequently include several mistakes and in several cases, the geometric and thematic accuracy is below the specification (Table 1). In many countries the 25 ha minimum mapping unit was not respected, which makes data hardly comparable among countries. Therefore the updating strategy should also include revision and correction of CLC1990, otherwise some of the differences between CLC1990 and the updated CLC2000 would be not real changes, but due to the mistakes of CLC1990.
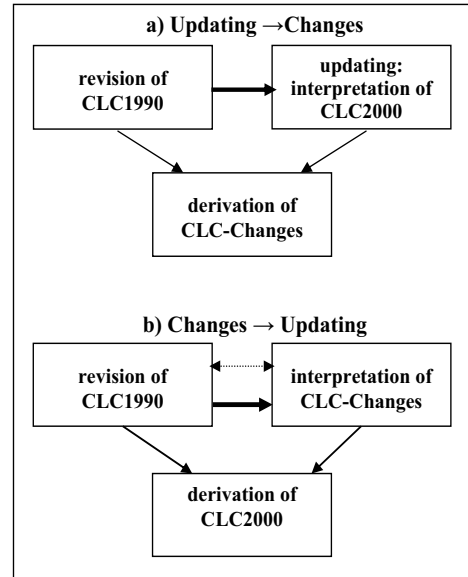

Figure 1. Approaches of updating and derivation of CLC changes

There are different approaches of updating CLC data. According to approach a) on Figure 1, first CLC1990 is revised and corrected using IMAGE1990 data, and then the photointerpreter modifies the database according to the status seen on IMAGE2000 imagery, which yields the CLC2000 database. CLC-Changes will be computed accordingly:

CLC-Changes = CLC2000 ( ) CLC1990

Where ( ) means the following operation: CLC1990 and CLC2000 is intersected; all polygons will have two CLC codes: $code_{old}$ and $code_{new}$; then polygons with $code_{old} = code_{new}$ are deleted. Experience has shown that the revision and the updating can not be fully sequentially organised. If during the updating process a new mistake is discovered in CLC1990 (e.g. missing LC polygon), it has to be drawn into the CLC2000 database as well. Because the lines in the two databases will differ in some extent, slivers

will be produced in the CLC-Changes database. Elimination of slivers is difficult to automate (Büttner et al 1998b).

According to approach b) in Figure 1 after some basic revision of CLC1990 first CLC-Changes are interpreted. This means that if a polygon in CLC1990 has changed, it will be taken over into the database of CLC-Changes, where only that part will be kept, which has changed. This means that revision and correction of CLC1990 can be accomplished in parallel, not necessarily in sequential order. This method is implemented in the InterChange software. The CLC2000 database will be computed accordingly:

CLC2000 = CLC1990 (+) CLC-Changes

Where (+) means the following operation: CLC1990 and CLC-Changes are intersected; in polygons of the CLC-Changes $code_{old}$ is replaced by $code_{new}$; then neighbours with similar code are unified. An additional benefit of this approach, that it allows for easier checking of the parameters defining the changes (100 m, 5 ha, see Table 1).

3 FUNCTIONALITY

3.1 *Basic philosophy*

InterChange is a macro package written in Avenue, ArcView's own macro language (ESRI 1996). The software is a supplement to ArcView 3.2 GIS. It can be run on IBM PC computers, under Windows 95/98 or Windows NT/2000 operation system. Inter-Change program was designed specially for revision of CLC databases and interpretation of CLC changes (Taracsák 2002). It is unsuitable for primary interpretation of satellite images and for building up an independent land cover database. For these purposes FÖMI developed a separate program called Inter-View (Taracsák 2001), which has been used in the national CORINE 1:50.000 program for two years (Büttner et al. 2001). Actually, InterChange benefitted from the 2,5-year-long development of Inter-View.

InterChange displays CLC1990 database and the CLC change database in two separate view windows referred to as Revision and Change, constantly synchronising their content (Figure 2). Interpreter can change from split-screen mode to full screen view any time. IMAGE1990 satellite data provides support for revision of CLC1990 in the Revision window. In Change window the photointerpreter examines IMAGE2000 data superimposed with CLC1990 data. Polygons that have changed are taken over into the change database and edited in the Change window to produce the CLC-Changes database. The interpreter can add comments to any polygons in each database. A list of 'frequently used comments' is available (e.g. "field checking is necessary"). An additional text field could be used to enter remarks by the supervisor during quality control. This field is "read-only" for the photointerpreter. Parameters like validity of CLC code, change type and area limits are constantly monitored by the software during interpretation.
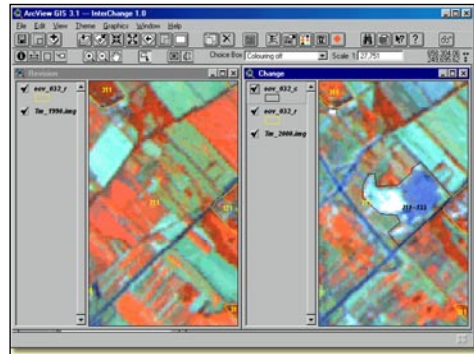

Figure 2. Left: Revision window, right: Change window

3.2 *Polygon editing functions*

During revision, the CLC1990 database is corrected by modifications of the polygon borderlines (splitting a polygon, unifying two adjacent polygons, cutting out a polygon) and modification of the CLC code. Once a polygon was taken over into the CLC Changes database, it can be edited by splitting, cutting out and deleting functions. Figure 2 illustrates an example of a new 'construction site' inside an 'arable land' polygon. Deleting is allowed only in the Change window, in order to avoid creating holes in the CLC1990 database. Editing boundary lines is not allowed by any means in order to avoid errors in topology.

When editing polygons, the program warns if the created polygon is smaller than the size limit or is a multi-part polygon. Non-adjacent polygons cannot be unified. An error checking and correcting tool helps to find and correct overlapping or multi-part polygons, to select polygons below size limit, with shape error (having average width below 100 meter), with invalid or zero code (see 3.4).

3.3 *Tools supporting interpretation*

All data belonging to a selected polygon are shown in the CLC data window (Figure 3). In the upper frame of the window one finds the information that cannot be changed by the interpreter:
– the area of the selected polygon expressed in hectares;
– the error(s) of the polygon;
– remarks by the supervisor;
– the XY co-ordinate button.

If there is at least one XY co-ordinate reference in the remark text box, clicking the XY co-ordinate button brings the given location to the centre of the window and labels it with a cross.

In the lower frame one finds data that can be modified and the tools for their modification:
- the whole CORINE 1:100 000 land cover nomenclature (with shortened names);
- the original CLC code ($code_{old}$) for the selected polygon;
- the text box where the $code_{new}$ can be given;
- the button for opening CLC code help to consult detailed definitions (Bossard et al. 2000);
- list of most frequently used comments;
- text box for displaying and writing in a comment;
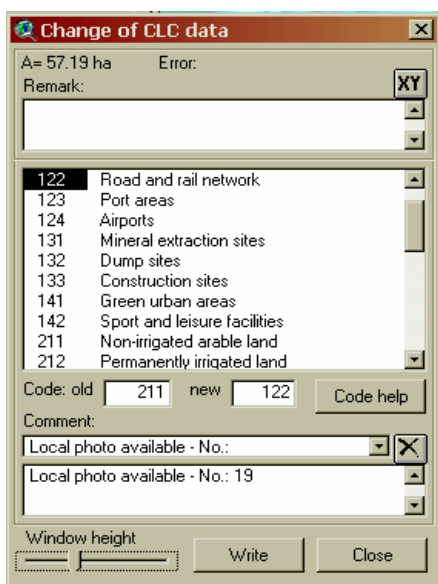- button for clearing the comment text box.

Figure 3. The main information panel of InterChange: the CLC data window

CLC code changes are under computer control. Three code change 'probabilities' are discerned (Figure 4):
- probable change (P=1); example: 211-121 (arable land changed to industrial area.
- rarely occurring change (P=2); example: 311-111 (forest changed to densely built-up area. The program gives a warning: "careful checking recommended".
- improbable change (P=3); example: arable land changed to bare rock. The interpreter is warned: "very careful checking and documentation recommended".

Additionally, P=0 means a code error, when the new code is zero.

The interpreter can search for polygons either in CLC1990 database or in CLC Changes database according to several search criteria, such as CLC code, CLC code change, comment (any word or character sequence can be searched for) and error (see 3.4). After specifying the search target, the program displays all polygons matching the search criteria in sequence. During this process the interpreter can accomplish the necessary modifications.

A summary table of changes can be calculated to collect all different $code_{old}$ - $code_{new}$ pairs in the change database. It shows the number of polygons in each change type and their total area. The last column of the table contains the P probability of the given change type (Figure 4). Selecting any row in the table, the program starts a search for polygons with the selected change type.

Figure 4. CLC code change statistics

3.4 Error checking and correction functions

InterChange has an efficient error finding and correcting tool in order to check the CLC1990 database and filter the results of any other 'accidental' mistakes produced in the course of revision and change interpretation processes. Error types are related to topology (as ArcView doesn't handle real polygon topology), size and shape of polygons and validity of attribute. The following checks are performed:

3.4.1 Intersecting overlapping polygons
Overlaps are those parts of the map sheet that belong to more than one polygon. Finding and correcting overlaps might take several minutes depending on number and complexity of polygons and the computer's performance.

3.4.2 Taking apart multi-part polygons
Multi-part polygons consist of more polygons in terms of topology, but a single common data record belongs to them. They could be created by unifying non-adjacent polygons or by splitting a polygon with

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a single splitting line into three parts instead of two. However, these possible mistakes are checked and indicated during polygon editing, so they are unlikely to be created. InterChange automatically takes apart multi-part polygons, which lose the content of code, comment, error and remark data fields, because they were presumably originally incorrect in case of at least one of the parts.

3.4.3 *Marking polygons under size limit*
The program writes the "size" notice into error field of those polygons' data record that are smaller than then size limit specified for the given task (5 ha and 25 ha, see Table 1). These small − sometimes undetectable − polygons might also be born during intersection of overlapping polygons. Error checking does not mark those small polygons that were intentionally kept by the interpreter during the interpretation.

3.4.4 *Marking polygons with shape error*
The program searches for polygons with average width under the width limit of 100 m. It writes the "shape" notice into error field of these polygons' data record. The program is unable to find polygons whose width is under the limit only in some places.

3.4.5 *Marking polygons with invalid category code*
This operation serves finding those polygons that have an empty code field in their data record (the interpreter forgot to give a code when creating it; it lost code or was created during earlier parts of error checking and correction) or the code field contains an invalid value (which is impossible if interpretation tools were properly used). For these polygons the program writes "0" into the code field and "code=xxx" notice into the error field. The number xxx written to the error field is the invalid code value (usually zero) the program found in code field during error checking.

3.4.6 *Marking neighbours with similar code*
This time-demanding process is performed only for the Revision window, i.e. the CLC1990 database. The program searches for neighbours with identical category code and writes a "to be unified" notice to the beginning of their comment text. Revealing neighbours with similar code is an important error-preventing step, as these polygons will be unified automatically in a later phase of the project.

3.5 *Information support*
Several tools are available to provide optimal visualisation and display of information. The colour of polygon outlines, as well as colour and size of code labels can be set separately for the two windows. Code labels can be switched on and off any time. A "rewrite codes" command is available to delete and rewrite code labels in cases when code labels appear outside the polygon they belong to (e.g. after significant zooming in). The environment of selected polygon(s) can be masked out. This feature is especially useful in avoiding mistakes when splitting or cutting out a polygon. It is also useful when the polygon under examination has a complicated shape. Size check tools (width and area) help the photointerpreter to quickly decide whether the polygon is worth to delineate precisely. There are four different colouring options to support photointerpretation:

3.5.1 *Colouring polygons by error*
Polygons appear in different colours according to their error type: invalid (missing) code, size error and both errors. Colouring by error type helps localisation and subsequent correction of database errors.

3.5.2 *Colouring polygons by CLC code*
This colouring shows polygons with colour coding specified for the third level (three digit) CLC categories as a thematic map.
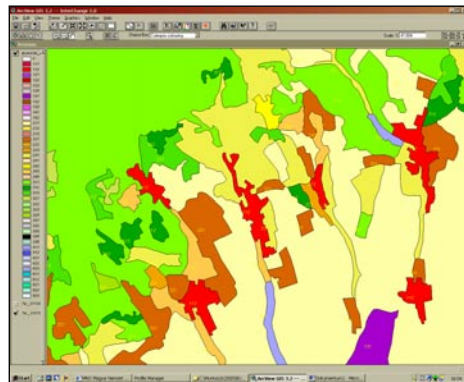

Figure 5. Example of colouring according to CLC code

3.5.3 *Colouring CLC1990 polygons by status*
If the whole area of a CLC1990 polygon is checked during creating the change database, the CLC1990 polygon is classified as "ready". Status colouring shows these polygons in a colour different from those polygons' yet to be checked. Thus the interpreter can check how much progress have been made in the change detection and also the size and position of areas yet to be examined.

3.5.4 *Colouring by probability of change*
To each change type (pair of $code_{old}$ − $code_{new}$) belongs a value indicating the probability of that land cover change. Change colouring renders different colour to polygons according to their respective change probability. This colouring draws attention to areas of less probable changes, which should be checked and documented with special care.

3.5.5 InterChange help system

The help window is similar to that used in any Windows programs. The user can choose a help topic in the Contents or search for key words and expressions in the help index. A context-sensitive help is also available to provide information on function buttons, tools or menu commands.

CLC code help, a special feature is also available. This provides the interpreter with a detailed description of the category code selected in the code list or written to the code text box in the CLC data window. Category names and their definition can be input to the programme in national language instead of English. Categories up to level-5 are supported in order to allow for more detailed interpretation at national level.
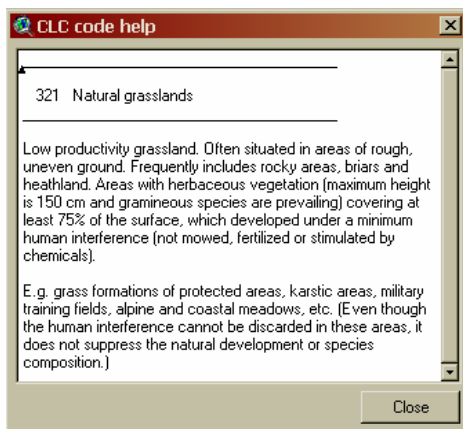

Figure 6. Example of CLC code help

4 CONCLUSIONS

A computer assisted photointerpretation tool was produced to support mapping land cover changes within the frames of the IMAGE&CLC2000 project launched by EEA and JRC. InterChange is running under ESRI ArcView 3.2 software and capable of revision of the baseline land cover database and delineation of changes. These two processes can be executed in parallel, in a way that no sliver polygons are created. The functionality of the software provides high level of interactivity. Area limits, validity of codes, probability of code changes and certain topological errors are checked by the computer.

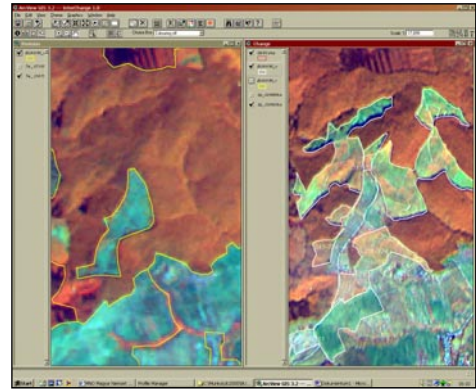The software is provided free for national CLC2000 teams requesting it.

Figure 7. Example of changes in forest cover

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