THE CORINE LAND COVER 2000 PROJECT

George Büttner[1], Jan Feranec[2], Gabriel Jaffrain[3], László Mari[4], Gergely Maucha[1] and Tomas Soukup[5]

1. FÖMI, Budapest, Hungary, and ETC-TE #; {buttner/g.maucha}(at)rsc.fomi.hu
2. IG SAS, Bratislava, Slovakia, ETC-TE #; geogfera(at)savba.savba.sk
3. IGN FI, Paris, France, and ETC-TE #; gjaffrain(at)ignfi.fr
4. Eötvös University, Budapest, Hungary, and ETC-TE #; maril(at)ludens.elte.hu
5. GISAT, Prague, Czech Republic, and ETC-TE #; tomas.soukup(at)gisat.cz

\# European Topic Centre on Terrestrial Environment, Universitat Autonoma de Barcelona; http://terrestrial.eionet.eu.int

ABSTRACT

The objective of the European Environment Agency (EEA) is to provide policy makers with timely and relevant environmental information. Regarding land cover (LC), EEA aims at providing those responsible for and interested in European policy on the environment with qualitative and quantitative LC data, which is consistent and comparable across the continent. As part of the EEA mandate, the CORINE Land Cover (CLC) database initiated by the Commission in 1985 should be further maintained and updated regularly. Consistent geo-referenced LC information has been identified by different national and European policies as a key database for integrated environmental assessment.

In order to reach this goal EEA and the Joint Research Centre (JRC) launched the IMAGE2000 and CLC2000 Project (I&CLC2000), which includes the updating of the CLC database. The satellite image 'snap shot' of Europe (IMAGE2000) is the principal material to undertake the updating of CLC database for the year 2000 (CLC2000) and to identify the main LC changes that occurred in Europe within the period 1990-2000. Presently 29 European countries are participating in the project. The database, which will be finished by the end of 2004, covers about 4.5 million km^2 with 25 ha spatial resolution. The CLC-changes database has a 5 ha spatial resolution.

The paper introduces the methodology of deriving the CLC2000 databases. Some preliminary results are presented with emphasis on major land cover changes in some countries.

Keywords: CORINE, land cover updating, land cover change mapping in Europe

INTRODUCTION

From 1985 to 1990, the European Commission implemented the CORINE Programme (Co-ordination of Information on the Environment) (1). During this period, an information system on the state of the European environment was created and nomenclatures and methodologies were developed and agreed at EU level. The CORINE Land Cover (CLC) project has been implemented in most of the EU countries as well as in the 13 Phare partner countries in Central and Eastern Europe (2).

Following the setting up the European Environment Agency (EEA) and the establishment of the European Environment Information and Observation Network (EIONET), the responsibilities of the CORINE databases, including their up-dates now rely on the EEA. CLC is the largest of CORINE databases, providing information on the physical characteristics of the earth surface. Images acquired by earth observation satellites are used to derive land cover information.

As the CLC inventory was completed and came to use, several users at national and European level expressed their need for an updated CLC database. The I&CLC2000 project is based upon a number of key elements: lessons learnt form earlier CLC projects, a current list of user needs, the options available for satellite images, and the processing and management requirements for the vast amount of data. The overall aim of updating is to produce the CLC2000 database and the database of CLC-Changes between the first CLC inventory and 2000. To guarantee full coverage and to maximise consistency with the previous inventory, the I&CLC2000 project calls upon existing local expertise and requires access to both the ancillary data and the satellite data used for the first CLC inventory. The I&CLC2000 project consists of two main components, which are interconnected (3):

- IMAGE2000: covering all activities related to satellite image acquisition, ortho-rectification and production of European and national mosaics, and
- CLC2000: covering all activities related to updating of the first CLC inventory (called CLC90) based on IMAGE2000 and detection and interpretation of CLC-Changes using CLC90 and IMAGE90.

The project will be finished at the end of 2004. The objective of the paper is to introduce the applied methodology and to present some of the first results.

THE CLC2000 PROJECT

I&CLC2000 is a joint EEA / JRC project in which the JRC has the responsibility for the IMAGE2000 and EEA is responsible for CLC2000. EEA is the overall coordinator of the project (Figure 1). The European Topic Centre on Terrestrial Environment (ETC-TE) has the responsibility to coordinate and supervise national CLC2000 activities as well as to contribute to the promotion of the use of the data. The dissemination and use of the I&CLC2000 products is defined in an agreement between the EEA, the European Commission, and the participating countries.

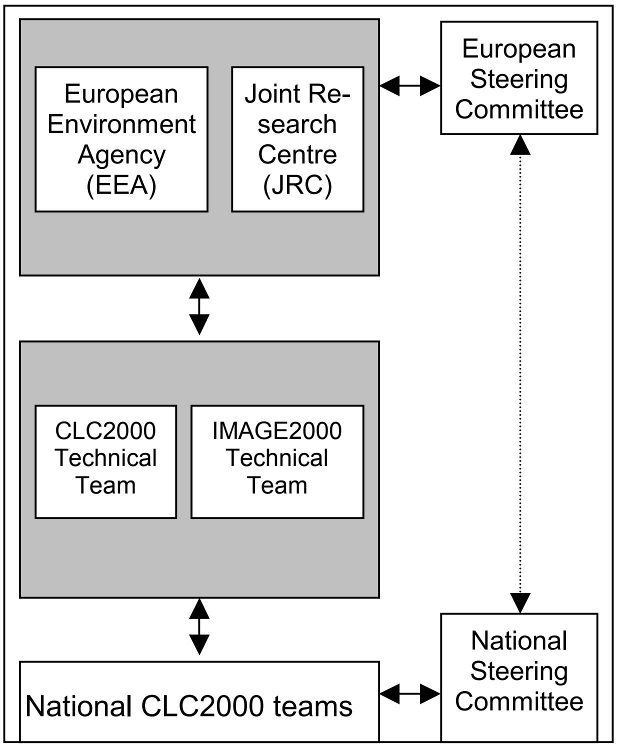

Figure 1. Organisational set-up of the project

The CLC2000 Technical Team (TT) assists both the national teams and the EEA. It consists of experts of ETC-TE. Main tasks of the CLC2000 Technical Team are as follows:

- Compiling the CLC update Technical Guidelines (3).
- Implementing training / technical discussion sessions for national teams according to their specific needs.

- Providing and introducing InterChange software, developed by FÖMI (4) for interested national teams.
- Coordinating the work with national teams on CLC data production.
- Supporting the national teams upon request during CLC2000 national project development.
- Assisting and controlling the national teams in performing the database verification missions (usually two country visits, about 8 % of total area is checked in details).
- Providing final technical control of deliverables (5).
- Merging the national land cover data into a consistent European database. Each national Coordinate Reference System (CRS) definition must be known precisely together with its geometric relationship to a standard European system in order to accurately transfer all national data into the ETRS89 Ellipsoidal Coordinate Reference System (ETRS89).
- Produces a set of derived products for web-based dissemination.

Presently 29 countries of Europe are participating in the project: EU25, Bulgaria, Croatia, Liechtenstein and Romania (Appendix 2). The respective National Authority decides on the project implementation, provides a commitment on the minimum 50% co-financing of the project and appoints (or selects by tender) the implementing organisation(s). EU institutions provide the rest of the funding.

From CLC90 to CLC2000

The approach of computer-assisted visual interpretation of satellite images has been chosen as the CLC mapping methodology. The choice of scale (1:100,000), minimum mapping unit (MMU) (25 hectares) and minimum width of linear elements (100 metres) represents a trade-off between cost and detail of land cover information (1). These two basic parameters are the same for CLC90 and CLC2000. In CLC90 some of the countries had not kept the 25 ha limit, which made comparisons among countries difficult.

The standard CLC nomenclature includes 44 land cover classes (Appendix 1). These are grouped in a three-level hierarchy. The five level-one categories are: 1) artificial surfaces, 2) agricultural areas 3) forests and semi-natural areas, 4) wetlands, 5) water bodies. All national teams had to adapt this standard nomenclature according to their landscape conditions. Although the 44 categories have not changed since the implementation of the first CLC inventory (1986-1998), the definition of each nomenclature element was significantly improved (6).

Raw satellite images first have to be pre-processed and enhanced to yield a geometrically correct document in national projection. For CLC2000, ortho-correction of Landsat-7 ETM satellite images was provided by the IMAGE2000 component, with an RMS error below 25 meter. Detailed topographic maps and in some cases orthophotos were used to achieve this accuracy. In IMAGE90 usually only a polynomial correction was applied, and GCPs were usually selected from 1:100,000 scale maps. The accuracy of IMAGE90 products is usually significantly poorer than that of IMAGE2000.

During the first CLC inventory a "traditional" photointerpretation method was used: an overlay was fixed on top of a satellite image hardcopy and the photointerpreter drew polygons on it with a CLC code. Later on the overlay was digitised, topology was created and the CLC code entered (1). This procedure often resulted in several types of errors in geometry as well as in thematic content. When comparing CLC90 with IMAGE2000 (as a basic geometric reference), geometric errors sometimes larger than 200 meters were observed. In some of the countries thematic accuracy of CLC90 hardly achieved the target 85% value (Table 1).

In CLC2000 the method of drawing on transparencies was discarded, and the use of computer-assisted photointerpretation (CAPI) was required (7).

Land Cover changes

One of the most important novelties of CLC2000 is the database of Land Cover Changes (LCC). It was a policy requirement to map LCC less than the 25 ha MMU size of CLC. The MMU of the LCC database was set to 5 ha (Table 1). The 100 meter minimum width is also valid for the LCC polygons for practical reasons. Changes should refer to real evolution processes and not to different interpretations of the same subject. Therefore, amendments of CLC90 and real changes have to be clearly distinguished (3).

*Table 1. Novelties of CLC2000 (*3)

User requirement	CLC90 specification	CLC2000 Specification
More time consistency	1986-1998	2000 +/- 1 year
Improved geometric accuracy: - satellite images: - CLC data:	 50 m 100 m	 25 m better than 100 m
Thematic accuracy	≥ 85%	≥ 85%
Changes smaller than the minimum mapping unit shall be identified	–	boundary displacement should be minimum 100 m; change area should be minimum 5 ha
Faster turnaround time	10 years	4 years
Lower production costs	6 €/km^2	3 €/km^2
Improved documentation	incomplete metadata	standard metadata
Easier access to the data	unclear dissemination policy	dissemination policy agreed from the start

Products of the CLC2000 project

The CLC2000 project creates a number of defined standard output products. All vector products should have ArcInfo format. National Teams deliver CLC2000, CLC-changes and the revised CLC90 (optional), together with metadata. ETC-TE produces the following products: European CLC2000 and CLC-changes, raster CLC data with 100 m and 250 m grid size, and statistics referring to 1km^2 cells. National products are created in national projection, while European vector data are provided in geographical coordinates (ETRS89 system). European raster products are delivered in Lambert Azimuthal Equal Area projection (3).

REALISATION OF CLC2000

The change detection process and the mapping of the CLC-Changes are carried out by means of image comparison using computer-assisted visual image interpretation tools. The CLC90 is used as reference data set. The methodology was developed by the JRC in collaboration with the ETC Land Cover (7).

Geometric adaptation of IMAGE90

IMAGE90 data (Landsat TM images used to derive CLC90 database) had to be made available for the project. Without IMAGE90 data, it would not have been possible to correct thematic errors of CLC90, and consequently false changes might have been identified. Geometry of IMAGE90 data and IMAGE2000 data was compared. If a systematic deviation larger than 50 m was observed, the IMAGE90 data had to be corrected (3).

Systematic geometric correction of CLC90

CLC90 data might have had several different types of errors: systematic or non-systematic geometric shifts, topology problems, holes (not interpreted areas), etc. The severity of these errors varied from country to country. CLC90 data and the geometrically correct IMAGE90 data were compared. If a systematic deviation larger than 50 m was observed between CLC90 data and IMAGE90 data, CLC90 had to be corrected (3). A rubber-sheeting technology proved to be superior to linear transformation, as distortions were usually only locally systematic.

The topology of the coverage had to be checked and topological errors (dangles, more than one labels, unnecessary boundaries, etc.) had to be corrected.

Polygon level corrections of CLC90

These corrections include removing residual geometrical errors and thematic errors. The polygons of CLC90 had to be examined concerning validity of CLC code and polygon area (and width). It was necessary to generalise all polygons smaller than 25 ha. This was a heavy task in some countries, where MMU < 25 ha was applied in CLC90 (e.g. 10 ha in Belgium).

Any random geometric errors had to be corrected, if the inaccuracy of the delineation (as seen on the IMAGE2000 data or on the corrected IMAGE90 data) was larger than 100 m. If a thematic error was discovered, the CLC code of a polygon had to be corrected.

In some countries correcting CLC90 needed significantly more efforts than the subsequent updating.

Methodology of updating

According to Technical Guidelines (3) a change has to be interpreted, if a polygon in CLC90 increased or decreased by at least 5 ha (a contiguous area), and the change polygon has a width of at least 100 m. This means that in order to produce results for Europe within the available time and budget not all detected (visible) changes have to be interpreted.

As an additional requirement, changes should be valid, reflecting real land cover evolutions (e.g. increase of settlements, forest clear-cutting, etc.), and not just a subjective difference between the two interpretations or a mistake in one of them.

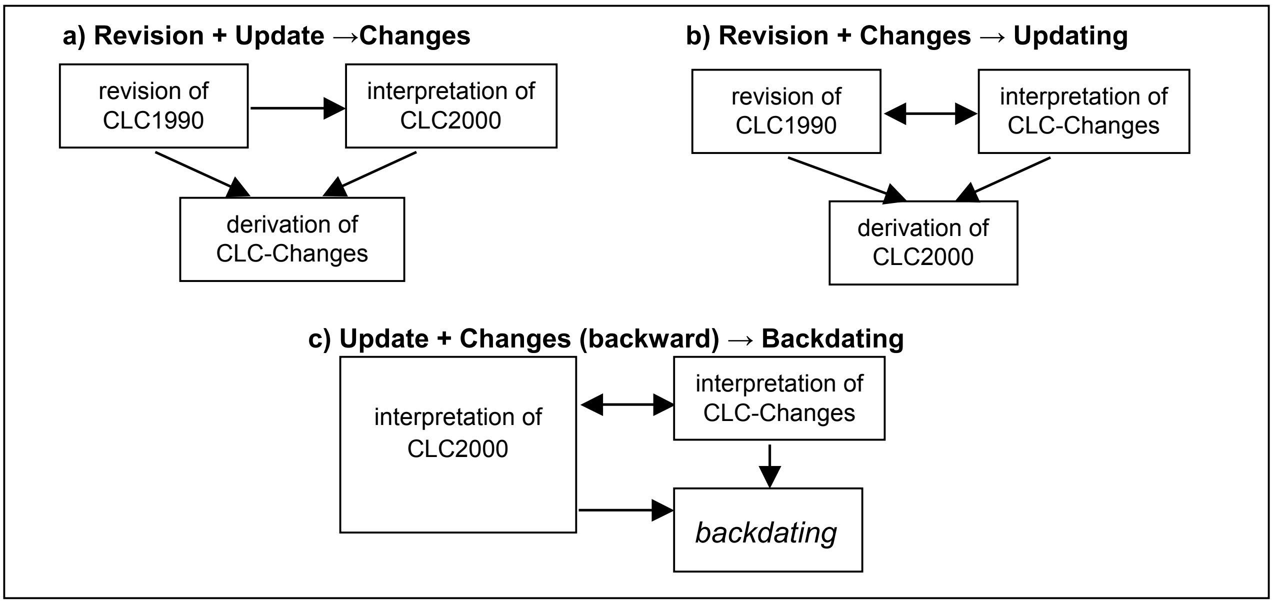

Figure 2: Approaches of CLC2000 implementation

There are three different approaches of updating CLC data by means of CAPI (8). According to approach a) in Figure 2, first CLC90 is revised and corrected using IMAGE90 data, and then the photointerpreter modifies the database according to the new status seen on IMAGE2000 imagery. This yields the CLC2000 database. CLC-Changes will be computed accordingly:

$$\text{CLC-Changes} = \text{CLC2000} \; (\,|\,) \; \text{CLC90}$$

Symbol (|) in the formula means: CLC90 and CLC2000 are intersected; all polygons will have two CLC codes: $code_{old}$ and $code_{new}$; then polygons with $code_{old}$ = $code_{new}$ are deleted.

Benefits of approach a) are: it focuses directly on producing CLC2000, and checking of minimum mapping unit in CLC2000 is easy. Weaknesses of approach a) are: improving CLC90 should be stopped before starting updating (additional CLC90 improvements introduce sliver polygons in CLC-Changes), does not enforce full thematic improvement of CLC90, and the minimum change area (5 ha) is difficult to control. After computing CLC-changes, elimination of small and false changes is advised.

According to approach b) in Figure 2: after some basic revision of CLC90, CLC-Changes are first delineated on IMAGE2000. This means that revision and correction of CLC90 can be accomplished in parallel, not necessarily in sequential order. This method is implemented in the InterChange software, developed by FÖMI (4) and offered free for any interested CLC2000 national teams. The CLC2000 database is computed accordingly:

CLC2000 = CLC1990 (+) CLC-Changes

Symbol (+) in the formula means: CLC90 and CLC-Changes are intersected; in polygons of the CLC-Changes $code_{old}$ is replaced by $code_{new}$; then neighbours with the same code are unified.

Benefits of approach b) are: focuses on directly producing CLC-Changes, requires the full thematic improvement of CLC90, modification of CLC90 is possible at any time and checking of parameters of change polygon is easy. Weaknesses of approach b) are: changes composed of more than a single part are interpreted in parts and after derivation of CLC2000 additional editing is needed (for polygons shrunk below 25 ha). CLC2000 will include max. 5 ha inaccuracies (because changes below 5 ha are not considered).

According to approach c) in Figure 2, first the CLC2000 database is interpreted (e.g. because of no CLC90 is available (like in Croatia), or due to the existence of a recent higher resolution CLC compatible database, which is generalised to yield CLC2000 (e.g. Luxembourg, Hungary)). CLC-Changes are then interpreted using CLC2000 and IMAGE90 data. This means a reverse process compared to approach b). The revised CLC90 database will be computed. Although approach b) and c) are similar concerning benefits and weaknesses, an important difference is, that in approach c) both primary deliverables (CLC2000 and CLC-change) are produced directly under human control.

Consequences of the two different MMUs

The MMU in CLC90 and CLC2000 is 25 ha. The similar parameter for CLC-Changes is 5 ha. Understandably, decision makers are interested in changes smaller than the 25 ha limit of CLC. However, the change mapping instruction saying: "a change inside a polygon of an area between 5 and 25 ha will not be recorded as change" (3) will result in a biased change database in the size range of 5-25 ha. Changes between 5 and 25 ha will be mapped only if they are increments or decrements of an existing polygon (8). Isolated changes will be mapped only if larger than 25 ha. E.g. a new industry of 20 ha will be mapped as a change if it is an increment of an existing industry polygon in CLC90, but will not be mapped as a change if it is built isolated inside an arable land polygon. The severity of this bias depends on the typical size and distribution of changes in the country.

Another consequence is that the "trivial" relation between the three databases (see above) is not entirely fulfilled considering the final databases. The reasons are as follows:

- In countries applying approach a), the result of intersecting the revised CLC90 and CLC2000 databases have to be considered a "difference" database. The "difference" database has to be checked and non-real changes should be deleted from the CLC-Changes database based on photo-interpretation and logics (by considering what changes are not possible in a country or region).
- In countries applying approach b) the result of adding together CLC-Changes and revised CLC90 is to be considered a "raw" CLC2000 database. The "raw" CLC2000 database has to be checked and polygons smaller than 25 ha have to be "intelligently" generalised to yield a final CLC2000.
- The same situation exists when applying approach c), when the backdated CLC90 needs generalisation.

Realisation by countries

The Technical Guidelines (3) describe a photointerpretation approach (more specifically approach a) in Figure 2). Other solutions were also allowed if discussed and agreed on with the CLC2000 Technical Team. Three countries of the 29 participants (Finland, Sweden and UK) apply a digital image processing (DIP) based technology. It starts with an automated classification of the Landsat ETM imagery, which is further processed by various GIS procedures using several existing national databases to yield a high resolution (2 ha, 5 ha) national LC database. The last and most critical step is to produce CLC2000 by means of generalisation. These methodologies are rather country specific (9, 10, 11). In Table 2 CAPI-A, -B and -C refers to the variant of a computer-assisted photointerpretation methodology shown in Figure 2.

Table 2: Approaches and tools used to realise CLC2000

Country	Approach	Base sw	Application sw	Remark
Austria and Liechtenstein	CAPI-B	ArcView	InterChange	
Belgium	CAPI-B	Arc Map		
Bulgaria	CAPI-B	ArcView	InterChange	
Croatia	CAPI-C	ArcView	InterChange	
Cyprus	CAPI	na	na	only CLC2000 is produced
Czech Republic	CAPI-A	Topol (self development)		
Denmark	CAPI-B	ArcView	Self-customized	
Estonia	CAPI-B	ArcView	InterChange	
Finland	DIP/GIS	na	na	only CLC2000 is produced
France	CAPI-A	ArcView	Self-customized	
Germany	CAPI	ERDAS ArcView	IMAGINE Self-customized	
Greece	CAPI-B CAPI-B	Intergraph ArcView	Geomedia InterChange	
Hungary	CAPI-C	ArcView	InterChange	
Ireland	CAPI-B	ArcView	InterChange	
Italy	CAPI-A	ArcView		
Latvia	CAPI-A	ArcGIS	Self-customised	
Lithuania	CAPI-B	ArcView	InterChange	
Luxembourg	CAPI-C	ArcInfo	ArcEdit	
Malta	CAPI	na	na	only CLC2000 is produced
Netherlands	CAPI-B	ArcInfo	ArcEdit	
Poland	CAPI-B	ArcView	InterChange	
Portugal	CAPI-B	ArcView	InterChange	
Romania	CAPI-B	ArcView	InterChange	
Slovak Republic	CAPI-A	ArcView		
Slovenia	CAPI-B	ArcView	InterChange	
Spain	CAPI-A	ArcGIS		
Sweden	DIP/GIS	na	na	only CLC2000 is produced
UK	DIP/GIS	na	na	

PRELIMINARY RESULTS

The goal is to finish 80% of the project area by the end of 2004 (12). Some countries have already finished the project and these results (together with partial deliveries) are available on TERRIS, the data server of ETC/TE. The actual status of the project is shown in Figure 3. Some LCC examples are presented in Figures 4-7.

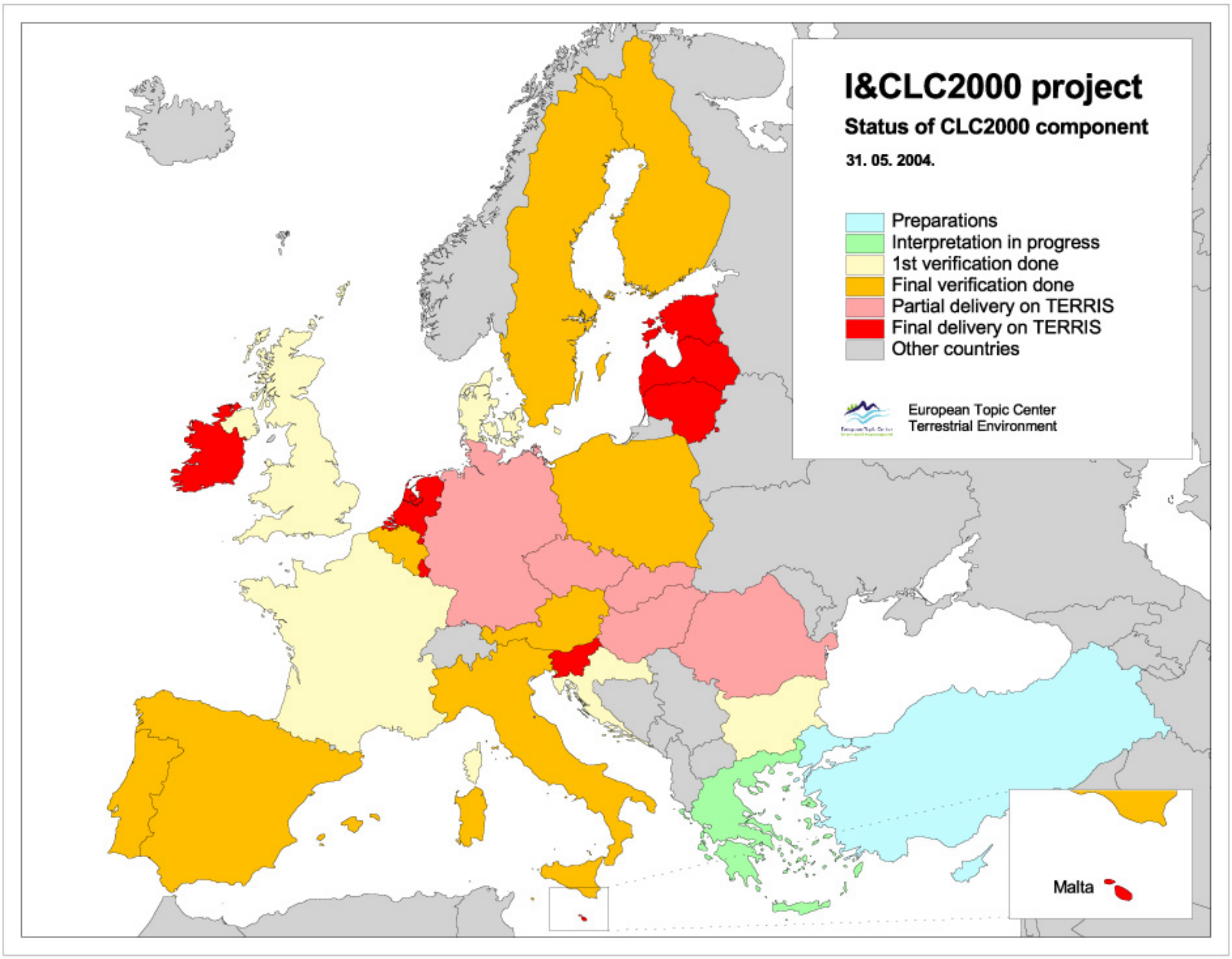

Figure 3: Status of CLC2000 project on 31 May 2004

Technical quality of products

Compared to the original CLC90 the geometrical accuracy of the corrected CLC90 and consequently the updated CLC2000 has improved significantly, and the specification (better than 100 meter positional error) is fully met. Heterogeneity concerning the MMU has been eliminated so data sets produced by different countries are comparable. Topological errors, unclassified areas, invalid codes, which were frequent in original CLC90, disappeared owing to the national QC/QA and the technical control of the CLC2000 TT.

Thematic quality of products

Based on experiences from nearly 40 verification missions, the CLC2000 TT can conclude that the thematic quality of CLC2000 has improved significantly, and the European harmonisation of national data sets is also better. The main factors of improvements are the following:

- Better technology (interpretation on screen not on hardcopy)
- More precise definition of nomenclature elements (6)

- Easier and frequent use of ancillary data (digitized topographic maps, orthophotos, other thematic data)
- Properly organised support by the CLC2000 TT.

CLC90 data have not been improved in the same way in all countries because of the lack of appropriate ancillary data or the reluctance of interpreters to change a code given by the former interpreter during the first inventory. Intersection of a good quality CLC2000 and a CLC90 with thematic errors yielded many false changes in some countries. Comparing IMAGE90 and IMAGE2000 and logic could help to solve these problems and keep only real changes. The most remarkable thematic improvements are:

- Interpretation of ‘discontinuous urban fabric’ (112) has improved; several rural settlements omitted in CLC90 were interpreted (due to the better image quality and a change in generalisation rules). However, the class ‘continuous urban fabric’ (111) is still often overestimated.
- All green areas (not only formal parks but forests also) inside urban fabric have been interpreted as 141.
- Separation of class 211 (annual crops or fallow land) from the class 231 (pastures) is difficult, because their spectral characteristics are often very similar. There are evident improvements in this field as well because of the use of aerial photographs and/or multitemporal satellite imagery.
- There were many discussions on distinguishing ‘pastures’ (231) from ‘natural grassland’ (321). This issue has also improved, by understanding that grass communities free from (or under very limited) human impact are classified under ‘natural grassland’. If they are under human impact, which mostly supports the increased biomass production (e.g. fertilising, mowing, etc.), grass communities are classified as ‘pastures’ under class 231. Areas of class 321 mostly occur in high mountains, on steep slopes with difficult access, in territories under nature conservation, or in military areas.
- Identification of natural vegetation in heterogeneous agricultural areas has also improved. Presence of small enclaves (< 25 ha) of trees and shrub vegetation, swamps, etc. is typical of the class 243. It has been applied in areas that were previously interpreted as homogeneous class (e.g. arable land) in CLC90.
- Separation of bushy vegetation – ‘moors and heathlands’ (322) in Atlantic and Alpine areas, and ‘sclerophyllous vegetation’ (323) in Mediterranean areas from ‘transitional woodland/shrubs’ (324) has improved also by using maps of natural vegetation and by better understanding of the meaning of these classes. However, there are still some problems in transitory areas (e.g. Iberian Peninsula), where all shrub types occur together.
- There is a definite improvement and harmonised understanding of the class ‘transitional woodland/shrub’ (324). All clear-cut areas and young plantations are classified here (it was not the case in CLC90 in all countries) together with woodland degradation, forest damages of any causes, and natural recolonisation.
- There has been an improvement in interpreting processes with a short life time or periodicity (hours, days, seasonal), such as tidal effects, seasonal changes in water surface of rivers, fish ponds, reservoirs or karstic lakes, flood events, seasonal changes of natural vegetation, etc. These are not land cover changes in terms of CLC and were not to be considered in mapping changes.

Comparison of change databases

CLC-changes are compared and analysed for seven countries that have already finished the project (databases on TERRIS): Estonia, Ireland, Latvia, Lithuania, Luxembourg, Netherlands, and Slovenia. Table 3 shows that there is a very large difference between these countries concerning CLC-change magnitude: most dynamic countries are Ireland and Latvia, while the most stable ones are Luxembourg and Slovenia.

Table 3: Comparison of CLC-Changes in seven countries

Country	Area (km^2)	Time span (year)	Total changes (km^2)	Relative change (%)	Yearly relative change (%)
Ireland	70283	10	5645	8,03	0,80
Latvia	63700	5	2552	4,01	0,80
Lithuania	65200	5	1656	2,54	0,51
Estonia	45226	6	1214	2,68	0,45
Netherlands	35398	14	1716	4,16	0,35
Luxembourg	2590	11	41	1,60	0,15
Slovenia	20273	5	24	0,12	0,02

By analysing the CLC-change matrix, one can get an insight into the dominant processes in each country. The following analysis considered those changes that together provided at least 75% of the total area of changes in a country. Dominant changes in each country are listed below in descending importance.

Ireland (13):

- Changing 'pasture' (231) to 'arable land' (211) and 'arable land' to 'pasture', as a traditional practice in Ireland with a net increase of arable land
- 'Peat bogs' are afforested (412-324)
- 'Coniferous forests' are clear-felled (312-324)
- 'Coniferous plantations' mature (324-312)

Latvia (14):

- Felling of 'mixed forest' (313-324)
- Changing 'pasture' (231) to 'arable land' (211) and 'arable land' to 'pasture', almost balanced.

Lithuania (15):

- Intensification in agriculture (231-211)
- Felling of forests (31x-324)
- Diversification of agriculture (211-242)

Estonia (16):

- Changing 'pasture' (231) to 'arable land' (211) and 'arable land to pasture', with a net increase of arable land
- Felling of forests (31x-324)
- Diversification of agriculture (231-242)

The Netherlands (17): Dominant changes include several processes:

- Urbanisation (urban growth, new sport and leisure areas) on former agricultural land
- Internal changes in agriculture (e.g. new greenhouse areas)
- Industrialisation (loss of agricultural land)
- Agricultural areas converted to seminatural areas (211-311, 211-321)
- New 'wetlands' on former 'pasture' (231-411)
- New 'water bodies' on former 'pasture' (231-512)

Luxembourg:

- Forest degradation by storm damage (31x-324) (18)
- Urbanisation, loss of agricultural land (2xx-112)
- Converting 'pastures' (231) to 'arable land' (211)

Slovenia:

- Forest degradation, clear-cut (311-324)
- Forest regeneration after fire (334-324)
- Highway construction (133-122, 311-122)
- Conversion of natural areas into agriculture (311-243, 411-231)
- A lake has changed into wetland (512-411)

If we compare processes described above we can conclude:

- Internal changes in "Forests and seminatural" classes are important in all countries, except the Netherlands.
- Internal changes in "Agriculture" classes are important in all countries, except Slovenia.
- "Artificial surfaces" classes increase most significantly in the Netherlands and Luxembourg (urban expansion, industrialisation) and in Slovenia (highway construction).
- Felling of forests is significant in all three Baltic countries (driving force is the commerce).
- In Estonia and Lithuania agriculture has become more intensive (an evidence of improving economy).
- In Ireland afforestation of peat bogs is an exceptionally important process. It has the purpose of increasing the low percent of forests in the country.
- The Netherlands is the only country where conversion of a "Agricultural areas" into "Forest and seminatural areas", "Wetlands" and "Water bodies" is significant.

CONCLUSIONS

In the frames of the I&CLC2000 project managed jointly by EEA and JRC, a harmonised Land Cover database is produced in 29 countries, covering an area of 4,5 million km2. CLC2000 is based on IMAGE2000 data, a high precision (<25 m RMSE) orthocorrected Landsat-7 ETM imagery. In most of the participating countries CLC2000 is an update of a former CLC90 database. As a by-product, national CLC90 databases, which had been derived with a simpler technology, were significantly improved concerning geometry as well as thematic content. The spatial resolution of CLC90 and CLC2000 is 25 ha.

The CLC-change database has also been derived with 5 ha resolution. The CLC-change database indicates dominant land cover change processes in the participating countries, as shown by the examples under 4.3. As described under 3.5, the consequence of two different MMUs and the proposed methodology (3) is, that not all changes between 5 and 25 ha will be mapped. To delineate all changes exceeding 5 ha would require more efforts.

The dissemination and use of the I&CLC2000 products is defined in an agreement between the EEA, the European Commission, and the participating countries. Several applications are foreseen 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). The 2004 work plan of the ETC/TE includes European-wide computation of agri-environmental indicators (IRENA project), assessment of fragmentation by urban and transport infrastructures, mapping urban sprawl, mapping forests within 1, 25, and 50 km from major urban agglomerations, and coastal zone assessment (12).

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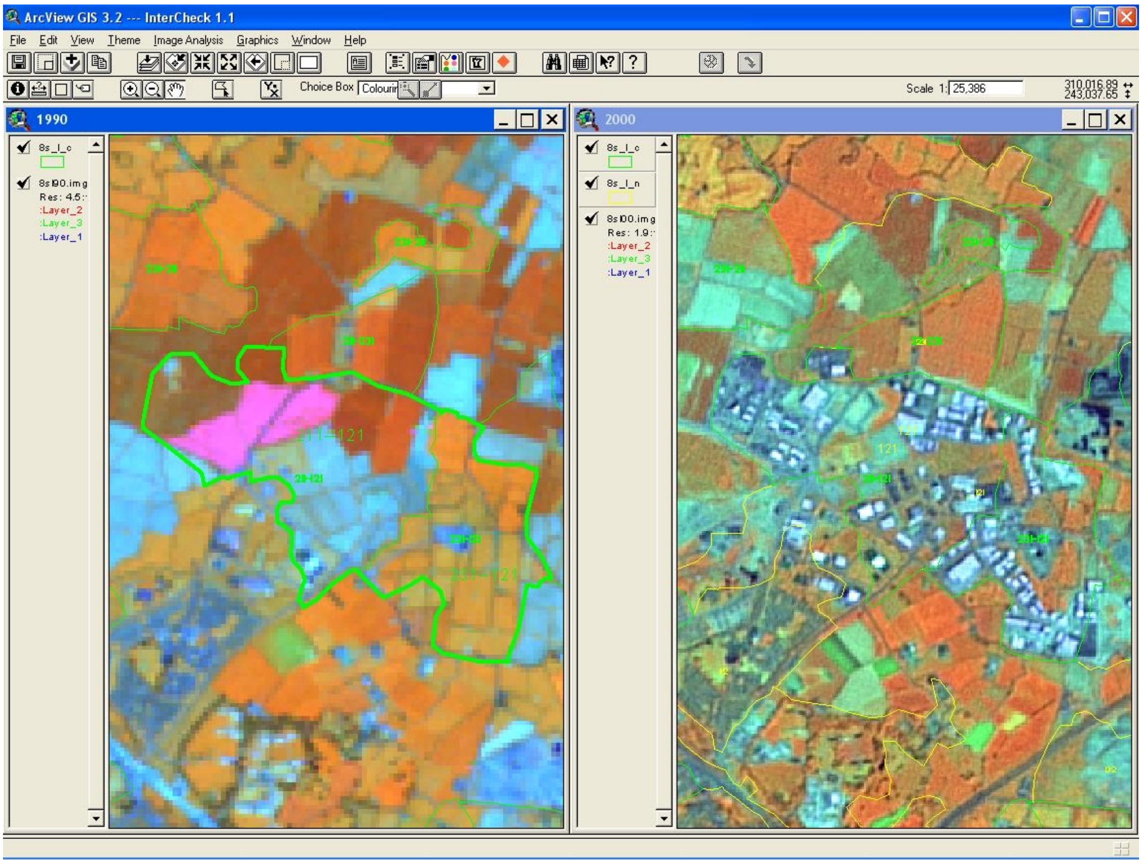

Figure 4: Land Cover change: industrialisation, loss of agricultural land - Dublin area (left: 1990, right: 2000)

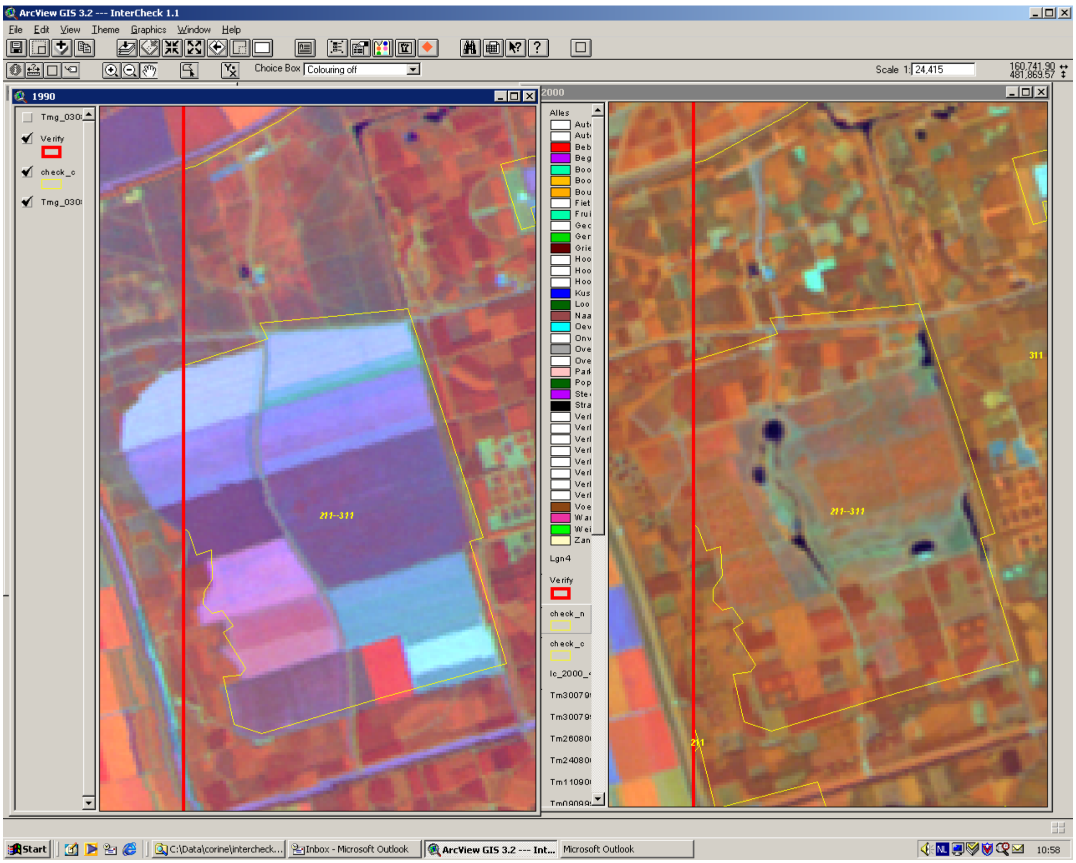

Figure 5: Land Cover change: arable land to forest, Netherlands (left: 1986, right: 2000)

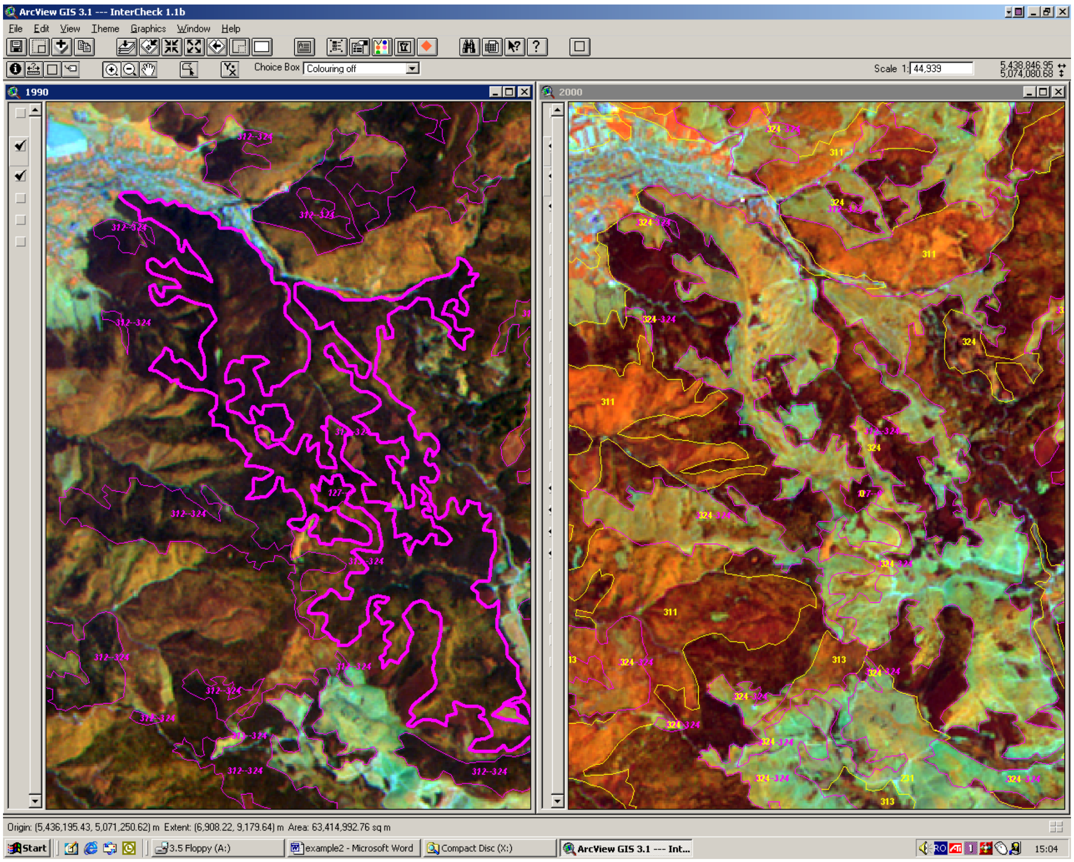

Figure 6: Land Cover change: forest clear-cutting, Slovak Republic (left: 1990, right: 2000)

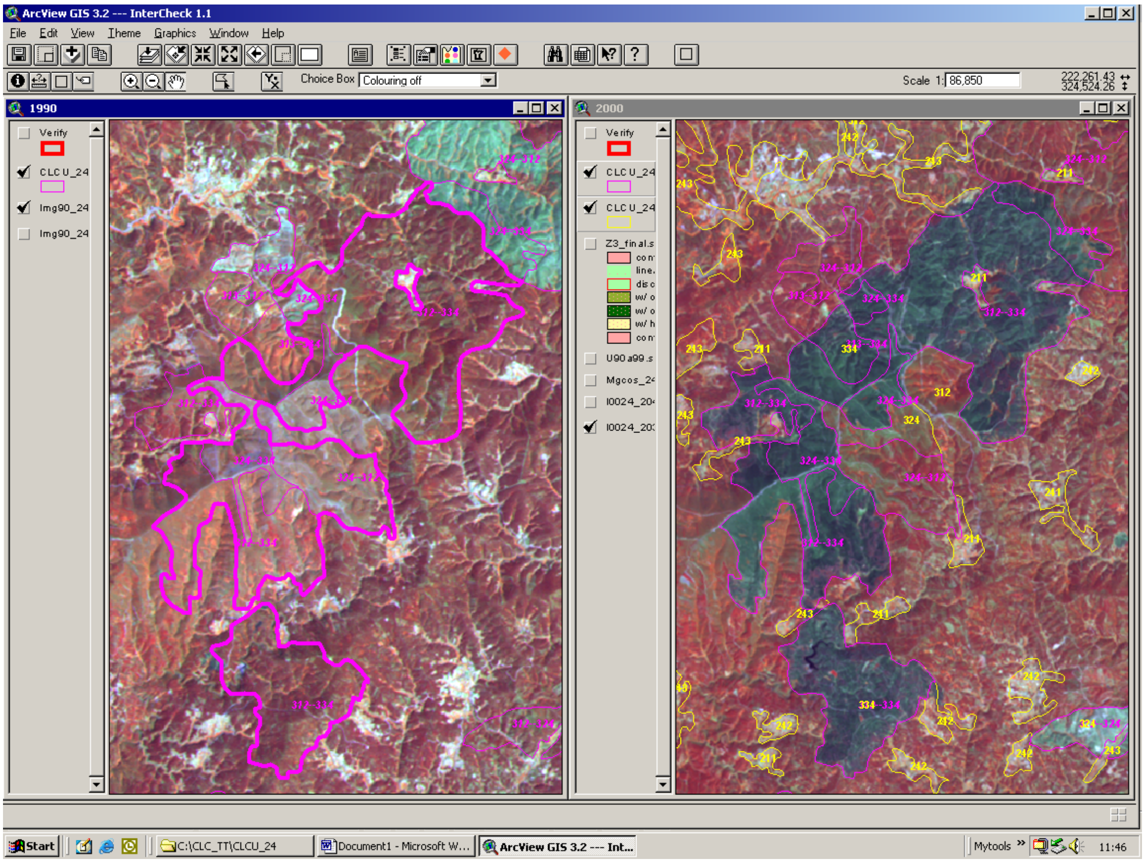

Figure 7: Land Cover change: forest fire, Portugal (left: 1986, right: 2000)

APPENDIX 1: CORINE Land Cover nomenclature (1)

LEVEL 1	LEVEL 2	LEVEL 3
1. ARTIFICIAL SURFACES	1.1. Urban fabric	1.1.1. Continuous urban fabric 1.1.2. Discontinuous urban fabric
	1.2. Industrial, commercial and transport units	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. Mine, dump and construction sites	1.3.1. Mineral extraction sites 1.3.2. Dump sites 1.3.3. Construction sites
	1.4. Artificial, non-agricultural vegetated areas	1.4.1. Green urban areas 1.4.2. Port and leisure facilities
2. AGRICULTURAL AREAS	2.1. Arable land	2.1.1. Non-irrigated arable land 2.1.2. Permanently irrigated land 2.1.3. Rice fields
	2.2. Permanent crops	2.2.1. Vineyards 2.2.2. Fruit trees and berry plantations 2.2.3. Olive groves
	2.3. Pastures	2.3.1. Pastures
	2.4. Heterogeneous agricultural areas	2.4.1. Annual crops associated with permanent crops 2.4.2. Complex cultivation patterns 2.4.3. Land principally occupied by agriculture, with significant areas of natural vegetation 2.4.4. Agro-forestry areas
3. FOREST AND SEMI-NATURAL AREAS	3.1. Forests	3.1.1. Broad-leaved forest 3.1.2. Coniferous forest 3.1.3. Mixed forest
	3.2. Scrub and/or herbaceous associations	3.2.1. Natural grassland 3.2.2. Moors and heathland 3.2.3. Sclerophyllous vegetation 3.2.4. Transitional woodland-scrub
	3.3. Open spaces with little or no vegetation	3.3.1. Beaches, dunes, sands 3.3.2. Bare rocks 3.3.3. Sparsely vegetated areas 3.3.4. Burnt areas 3.3.5. Glaciers and perpetual snow
4. WETLANDS	4.1. Inland wetlands	4.1.1. Inland marshes 4.1.2. Peat bogs
	4.2. Marine wetlands	4.2.1. Salt marshes 4.2.2. Salines 4.2.3. Intertidal flats
5. WATER BODIES	5.1. Inland waters	5.1.1. Water courses 5.1.2. Water bodies
	5.2. Marine waters	5.2.1. Coastal lagoons 5.2.2. Estuaries 5.2.3. Sea and ocean

APPENDIX 2: Participants of the CLC2000 project

Country	National Authority	Implementing organisation(s)
Austria	Federal Environment Agency (UBA)	Federal Environment Agency (UBA)
Belgium	Institut Géographique National (IGN)	Institut Géographique National (IGN)
Bulgaria	Environmental Executive Agency within the Ministry of Environment and Water	Space Research Institute and DATECS
Croatia	Ministry of Environment Protection and Physical Planning	OIKON and GISDATA
Czech Republic	Czech Environmental Institute	Help Service Ltd
Cyprus	Ministry of Agriculture, Natural Resources and Environment (MANRE)	Ministry of Agriculture, Natural Resources and Environment (MANRE)
Denmark	National Environmental Research Institute (NERI)	National Environmental Research Institute (NERI)
Estonia	Estonian Environment Information Centre (EEIC)	Estonian Mapping Centre
Finland	Ministry of Environment	Finnish Environment Institute (SYKE)
France	French Environmental Institute (IFEN)	GEOSYS, SCOT and SIRS
Germany	Federal Environmental Agency (UBA)	DLR – based on contract with private companies
Greece	Hellenic Mapping and Cadastral Organisation (HEMCO)	Eratosthenes S.A. and Geoapikonosis Ltd.
Hungary	Ministry of Environment and Water	Institute of Geodesy, Cartography and Remote Sensing (FÖMI)
Ireland	Environmental Protection Agency (EPA)	ERA MAPTEC
Italy	Environmental Protection Agency (APAT)	Univerity of Roma 'La Sapienza'
Latvia	Latvian Environment Agency (LEA)	Envirotech
Liechtenstein	Ministry of Environment	Federal Environment Agency (UBA, Austria)
Lithuania	Ministry of Environment	University of Vilnius
Luxembourg	Ministère de l'Environnement	Geographic Information Management sa (G.I.M.)
Malta	Malta Environment and Planning Authority (MEPA)	Malta Environment and Planning Authority (MEPA)
Poland	Head Inspectorate for Environmental Protection	Institute of Geodesy and Cartography (IGIK)
Portugal	Portuguese Environmental Institute (IA)	Instituto Superior de Estatística e Gestão da Informação (ISEGI) and Instituto Geográfico Portugués (IGP)
Romania	Ministry of Water and Environmental Protection	Danube Delta National Institute (DDNI)
Slovak Republic	Slovak Environmental Agency (SEA)	Slovak Environmental Agency (SEA)
Slovenia	Ministry of the Environment and Spatial Planning, Geoinformation Centre	GISDATA
Spain	National Centre for Geographic Information (CNIG) – National Geographic Institute (IGN)	National Geographic Institute (IGN) with regional teams
Sweden	National Land Survey of Sweden (Lantmäteriet)	METRIA
The Netherlands	Alterra Centre for Geo-Information	Alterra Centre for Geo-Information
United Kingdom	Centre for Ecology and Hydrology (CEH)	Centre for Ecology and Hydrology (CEH)

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