Revised Final draft

Implementation and achievements of CLC2006

Prepared by: G. Büttner, B. Kosztra, G. Maucha and R. Pataki
Institute of Geodesy, Cartography and Remote Sensing (FÖMI)

Submitted: 16.12.2010
Revised: 11.06.2012

Project manager:
Markus Erhard

European Topic Centre
Land Use and Spatial Information

European Environment Agency

Universitat Autònoma de Barcelona
Edifici C – Torre C5 4ª planta
08193 Bellaterra (Barcelona)
Spain, EU

Contact: etclusi@uab.cat

Table of content

Executive Summary

Strategic discussions among EEA member countries and the main EU institutions responsible for environmental policy, reporting and assessment have underlined an increasing need for quantitative information on the state of the environment based on timely, quality-assured data, concerning in particular land cover and land use. Based on these requirements EEA has been collaborating since 2006 with the European Commission and the European Space Agency on the implementation of a fast track service on land monitoring as part of the implementation of GMES.

CORINE Land Cover 2006 is the third European Land Cover inventory (1990, 2000 and 2006). The number of participating countries is increasing, at present being nominally 39. New countries (CH, IS, NO, TR) not participating previous CLC inventories have joined the project. Altogether 38 countries have implemented CLC2006.

CLC2006 project is co-financed by the EEA and the member countries, and covers 5.8 Mkm^2 of the European continent. For production of CLC-Change$_{2000\text{-}2006}$ database "change-mapping first" visual photo-interpretation technology was successfully applied by majority of countries. Scandinavian countries replaced part of labour-intensive photo-interpretation with GIS and image processing. CLC2006 database was usually produced in GIS by adding CLC-Change$_{2000\text{-}2006}$ to revised CLC2000.

A Technical Team under ETC-LUSI was responsible for technical follow-up of the project, i.e. training of national teams and verification of results. National teams used multi-temporal (2 coverages) SPOT-4/5 and/or IRS-P6 imagery to derive the minimum 5 ha land cover changes that occurred between 2000 and 2006. Ortho-corrected satellite images provided a solid geometrical basis for mapping land cover changes. Particular emphasis was placed on mapping real change processes. Several national teams had access to recent topographic maps and digital orthophotos as in-situ data. The standard CLC nomenclature used since the mid 1980's was applicable, although minor modifications were required due to involvement of new countries and occurrence of specific changes. Recent report also presents examples of (1) typical cases of significant change processes, and (2) typical mistakes, which have to be avoided.

Results of the CLC2006 project (CLC2006 and CLC-Change$_{2000\text{-}2006}$ databases) are for free available from the EEA for any users. Results show that land cover changed on 1.24% of the surface of Europe between 2000 and 2006, which is equivalent to the size of Lithuania. Forestry changes (forest felling and growth) constitute the largest change area, also providing the highest number of change polygons. Several policy-relevant processes can be derived from the CLC-Change dataset based on Land Cover Flows, such as urban sprawl, changes in agriculture and forestry, new water bodies etc. Portugal is the country having far more the highest CLC dynamics: the change rate exceeds 1.4 %/year between 2000 and 2006. On the other end, the less dynamic countries are Malta, Switzerland and Slovenia having changed less than 0.01%/year. The average yearly land cover change value in Europe is 0.23%.

Stratified random sampling was used for validating CLC-Change$_{2000\text{-}2006}$. The obtained **87.82%±3.30%** (commission error only) overall accuracy based on 2405 samples is satisfying. Omissions were not possible to measure due to the very large sample size required, being the consequence of small change percentage.

Additional testing of ten important level-3 changes (belonging to eight different Land Cover Flows) showed that all but two change types have more than 85% accuracy. Only two change types were mapped with accuracy lower than 85%: (1) growth of coniferous forests; (2) pasture/set-aside land turned to arable land.

Main reasons of the 3-year-long implementation time are difficulties in providing national contribution and long GIS integration time in some of the 38 participants.

1 History of CORINE Land Cover

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

Following the setting up of the European Environment Agency (EEA) and the establishment of the European Environment Information and Observation Network (EIONET), the responsibilities of the CORINE databases - including the updates - 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 as the main source data to derive land cover information.

As the first CLC inventory (named CLC1990) was completed and came to use, several users at national and European level expressed their need for the updating of the CLC database. Updating was implemented within the IMAGE&CLC2000 project. This project based upon lessons learnt from the first CLC project, a current list of user needs, available satellite images and the processing and management requirements for the vast amount of data. The overall aim of updating was to produce an updated CLC database (CLC2000) and the database of land cover changes (LCC) between the first CLC inventory and 2000 (CLC-Change$_{1990\text{-}2000}$) [2]. IMAGE2000 data are accessible on the JRC website (http://image2000.jrc.it/), while CLC2000 and CLC-Change data are freely accessible from the EEA website (http://www.eea.europa.eu/data-and-maps/find/global#c12=Corine+Land+Cover).

EEA has been collaborating since 2006 with the European Commission (EC) and the European Space Agency (ESA) on the implementation of a fast track service on land monitoring in line with the communication: "Global Monitoring for Environment and Security (GMES): From Concept to Reality" [3]. This initiative includes the third CLC update called CLC2006.

In its more than 20 years history CORINE Land Cover has maintained its basic technical specifications (nomenclature, resolution), but the way of technical implementation has significantly changed.

- In CLC1990 photo-interpretation was carried out on plastic overlays placed atop 1:100.000 scale satellite image printouts. Drawings on the plastic overlay had to be digitized in order to build up a database. Distortions of the plastic often caused geometric problems in land cover data. Today, "drawing" is done on screen - with a geo-referenced satellite image in the background - at a suitable scale selected by the interpreter. Thus, digitization is done simultaneously with the creation of the land cover database.
- In CLC1990 ortho-correction was not routinely applied in producing the base image map for photo-interpretation. Today, with the availability of DEM at the appropriate resolution ortho-correction of satellite imagery is a standard process, providing higher geometric precision of the imagery.
- Ancillary data in CLC1990 were mainly topographic maps and black-and-white photographs on paper support. Today the availability of scanned topographic maps is common, and national coverages of digital colour aerial photography are also frequently available.
- Quality assurance (checking photo-interpretation on plastic overlay) was a difficult task in CLC1990. Computer-assisted quality assurance – applied since the CLC2000 project – provides written, geo-located explanations regarding the problems. This is an efficient tool to standardise / harmonise production all over Europe.
- Data dissemination has improved also. Since CLC2000 data have had dual ownership (EEA and the country). Today CLC data are freely accessible to any person or legal entity.

2 CLC2006 IN THE FRAMES OF GMES

Strategic discussions among member countries, European Parliament and the main EU institutions responsible for environmental policy, reporting and assessment (DG ENV, EEA, ESTAT and JRC) have underlined an increasing need for quantitative information on the state of the environment based on timely, quality assured data, in particular in issues related to land cover and land use.

Based on requirements of DG Environment, DG Agriculture and other users for 2006-2008, in March 2006 EEA put forward a proposal to collaborate with the European Space Agency (ESA) and the European Commission (EC) in the implementation of a fast track service on land monitoring under the umbrella of GMES in line with the Communication from the Commission to the Council and the European Parliament [3]. DG JRC and ESA have defined and implemented the necessary satellite data procurement and processing. This was undertaken in the context of the development of Community satellite-based core products that will serve a number of services to support environmental monitoring and assessment objectives. CLC2006 is just one of the components of GMES FTS Land Monitoring ([4], Fig. 1, Table 1).

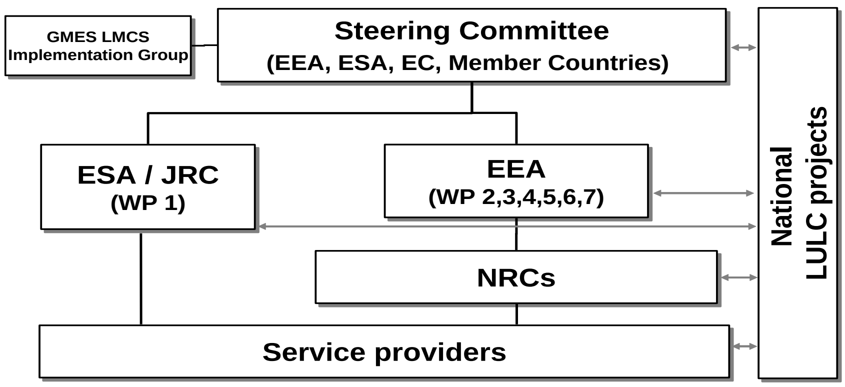


Figure 1 Organisational chart of GMES FTS Land Monitoring [4]

2.1 ORGANISATION OF THE WORK

EEA is the overall technical lead for implementation. Depending on the applied funding mechanisms, the administrative management of the different work packages is shared among ESA, the Commission and EEA. A Steering Committee has been set up with representatives from all contributing organisations, namely the Commission, ESA, EEA and participating countries. The GMES Land Monitoring Core Service Implementation Group established by DG Enterprise plays an advisory role for interlinking with other GMES services.

It was made clear at the start that all produced land cover data will be freely available for any (commercial or non-commercial) applications. Due to copyright restriction set by image suppliers, orthorectified images have been made available to participating organisations only.

Table 1 GMES FTS Land Monitoring work packages and the overview of the role of partners [4].

Tasks	NRC	EEA	ESA	JRC	Data & service providers	Remarks
WP1.1 Satellite data acquisition	x		O	x	O	Done as planned
WP1.2 Ortho-correction			O		O	Done as planned
WP1.3 Satellite image mosaic				O	O	No information
WP2 In-situ and ancillary data collection	x	O			O	Done as planned
WP3.1 CORINE land cover change mapping 2000-2006	x	O				Done as planned
WP4.1 Built-up areas and degree of soil sealing 2006	x	O				Done as planned
WP4.2 Forest area mapping	x	O			O	Implemented
WP5 Validation	x			O	O	Land Cover maps were validated by EEA
WP6 Data dissemination		O				Done as planned
WP7 Project management	x	O	x	x		Done as planned
O = leading organization; X = organisation involved; NRC = National Ref. Centre						

CLC2006 is a direct continuation of previous CORINE Land Cover mapping campaigns, although there are important differences compared to previous projects:

- In CLC2000 there was a strong requirement to improve CLC1990 (geometry and thematic content). Due to its higher quality standard, there is no need for such significant improvement of CLC2000 data in CLC2006 project. However, if a mistake in CLC2000 is found, it has to be corrected; otherwise it will be inherited by CLC2006. Revised CLC2000 was not to be released by EEA as a new product[1]. It is used only for production of CLC-Change and CLC2006.
- In CLC2006 the focus is on generating Land Cover Change data between 2000 and 2006 (CLC-Change$_{2000\text{-}2006}$). Such focus was not declared in CLC2000. In CLC2006 a uniform change mapping methodology was proposed to minimize false changes [9].
- A novelty of CLC2006 project is that all changes > 5 ha are to be mapped, not only those that are associated to existing polygons [9].
- The CLC2006 database is generated in an automatic way (with optional human interaction) by combining revised CLC2000 and the photo-interpreted CLC-Change (see 3.2). In contrary, in the CLC2000 project half of the participating countries interpreted CLC2000 directly, while the other half produced it by GIS operation, using revised CLC1990 and CLC-Change.

The evolution of main technical parameters governing CORINE Land Cover is shown in Table 2.

2.2 IMAGE2006

Because of the malfunctioning Landsat-7 satellite, used in CLC2000 project, new sources of suitable satellite imagery had to be found for purposes of the CLC2006 project. As a result of agreements born between satellite owners and ESA, two kinds of satellites provided imagery for CLC2006 project:

- French SPOT-4&5 (60 km swath width, 20 m pixels; VIS, NIR and SWIR bands), and

[1] Many of the national revised CLC2000 datasets have been collected by ETC-SIA in 2011

- Indian IRS P6 (141 km swath width, 23 m pixels; VIS, NIR and SWIR bands).

IMAGE2006 is a multi-temporal satellite image coverage: coverage-1 is usually taken in summer, while coverage-2 in spring or autumn. According to specifications, the acquisition date of coverage-2 should be more than 6 weeks away from that of coverage-1 in order to provide an optimal basis for photo-interpretation. Altogether 2416 SPOT 4 and 5 images and 1283 IRS P6 images have been acquired and ortho-rectified for the project [5]. Ortho-rectification has been provided by DLR and Metria. Table 3 shows the IMAGE2006 acquisition statistics.

Table 2 Evolution CORINE Land Cover projects

	CLC1990	CLC2000	CLC2006
Main satellite data	Landsat-4&5 MSS/TM single date	Landsat-7 ETM single date	SPOT-4/5 and IRS P6 LISS III dual date
Time consistency	1986-1998	2000 +/- 1 year	2006+/- 1 year
Geometric accuracy satellite images	≤ 50 m	≤ 25 m	≤ 25 m
CLC mapping min. mapping unit/width	25 ha/ 100m	25 ha/ 100m	25 ha/ 100m
Geometric accuracy CLC data	100 m	better than 100 m	better than 100 m
Thematic accuracy	≥ 85% (probably not achieved)	≥ 85% (achieved [6])	≥ 85% (not checked)
Change mapping	not implemented	boundary displacement min. 100 m; change area for existing polygons ≥ 5 ha; for isolated changes ≥ 25 ha	boundary displacement min.100 m; all changes > 5 ha are to be mapped
Production time	10 years	4 years	planned: 1.5 years realised: 3.0 years
Documentation	incomplete metadata	standard metadata	standard metadata
Access to the data	unclear dissemination policy	dissemination policy agreed from the start	free access for all kinds of users (CLC data)
Number of European countries involved	26	30	38

Table 3 IMAGE2006 data acquisition statistics [5]

	Scenes in 1st coverage	Scenes in 2nd coverage	Total scenes
SPOT4	861	663	1524
SPOT5	552	340	892
IRS P6	667	616	1283
Total	2080	1619	3699

2.3 GEOGRAPHIC COVERAGE

The GMES fast track service on land monitoring aims to cover the EU27 and neighbouring countries and all EEA Member countries, namely:

- Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom) as well as the Western Balkan countries, namely
- Albania, Bosnia-Herzegovina, Croatia, FYR of Macedonia, Montenegro, Serbia.
- Kosovo under UNSCR 1244/99 joined the project following her separation from Serbia.
- UK accomplished the project only partially at the time of writing the report.
- Greece has not participated.

Altogether 38 countries were involved, covering 5.8 Mkm^2. Organisations responsible for technical implementation and technical project managers of the participating countries are listed in Annex 1.

3 MAPPING METHODOLOGY

As shown in Table 2, the basic parameters of CLC2006 are the same as those of previous CLC inventories [7] thus maintaining continuity with CLC90 and CLC2000:

- minimum mapping unit (MMU): 25 hectares;
- minimum width of linear elements: 100 metres;
- standard CLC nomenclature, which includes 44 land cover classes on level 3. The five level-one categories are: 1) artificial surfaces, 2) agricultural areas, 3) forests and semi-natural areas, 4) wetlands, 5) water bodies [8].

3.1 CHANGE MAPPING

CLC-Change$_{2000\text{-}2006}$ is the primary product of the CLC2006 project. The aim was to produce the European coverage of real land cover changes that

- consist of polygons larger than 5 ha and wider than 100 m;
- occurred between 2000 and 2006;
- reflect real evolution process (e.g. urban sprawl, new forest plantation, new water reservoir, etc), see Fig. 2.

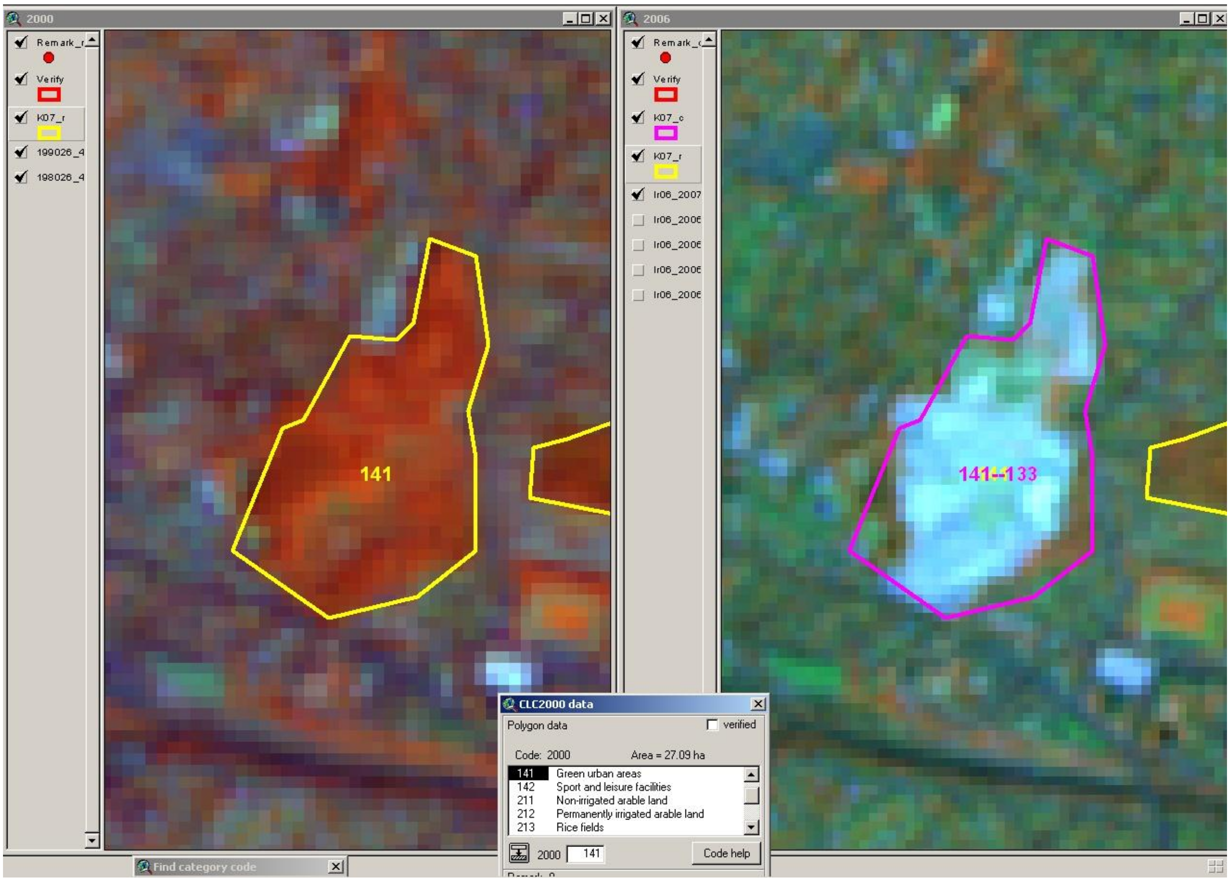


Figure 2 Example of a real change: loss of urban green. A city park has become construction site. Change code pair is 141-133 (example from France).

The proposed method is computer-aided visual interpretation of satellite imagery. (Image-classification-based methods, as alternatives of visual interpretation, are not considered mature enough to handle the large number of CLC classes in the diverse geographic environment of Europe.) National experts interpret CLC changes directly on screen, by comparing IMAGE2000 and IMAGE2006 data in a dual-window environment. Delineation of changes must be based on CLC2000 polygons in order to avoid creating sliver polygons and false changes when producing CLC2006 database (see Ch. 3.2). Interpreter must give two CLC codes to each change polygon: code2000 and code2006. These codes must represent the land cover status of the given polygon in the two dates, respectively. Change code pair thus shows the process that occurred in reality and may be different from the codes occurring on the CLC2000 map and / or in the final CLC2006 map due to generalisation applied in producing CLC2000 and CLC2006 [9]. See Fig. 3.

A "technical change" attribute has been introduced to be able to separate non-real changes in cases when a land cover feature existed in 2000 but could not be mapped due to the 25 ha limit [9] (see Fig. 4).

The main benefits of this approach are: (1) changes are interpreted directly (the interpreter has to think about what the real process was), (2) all changes larger than 5 ha can be easily delineated regardless of their geometric position (attached to an existing CLC2000 polygon or not). The weakness is that some small (< 5 ha) deficiencies in CLC2006 cannot be avoided [10]. Ancillary data, such as topographic maps and orthophotos are highly recommended to use during mapping Land Cover Changes (LCC). In addition, land use and land cover codes and field photographs from EUROSTAT LUCAS2001/2002 and LUCAS2006 projects were made available for national teams.

Due to the three variables (CLC2000, CLC2006 and CLC-Change$_{2000-2006}$), all of them having any of the two statuses: valid (if > MMU) and not valid (if < MMU), in theory 2^3=8 different mapping cases can occur [9].

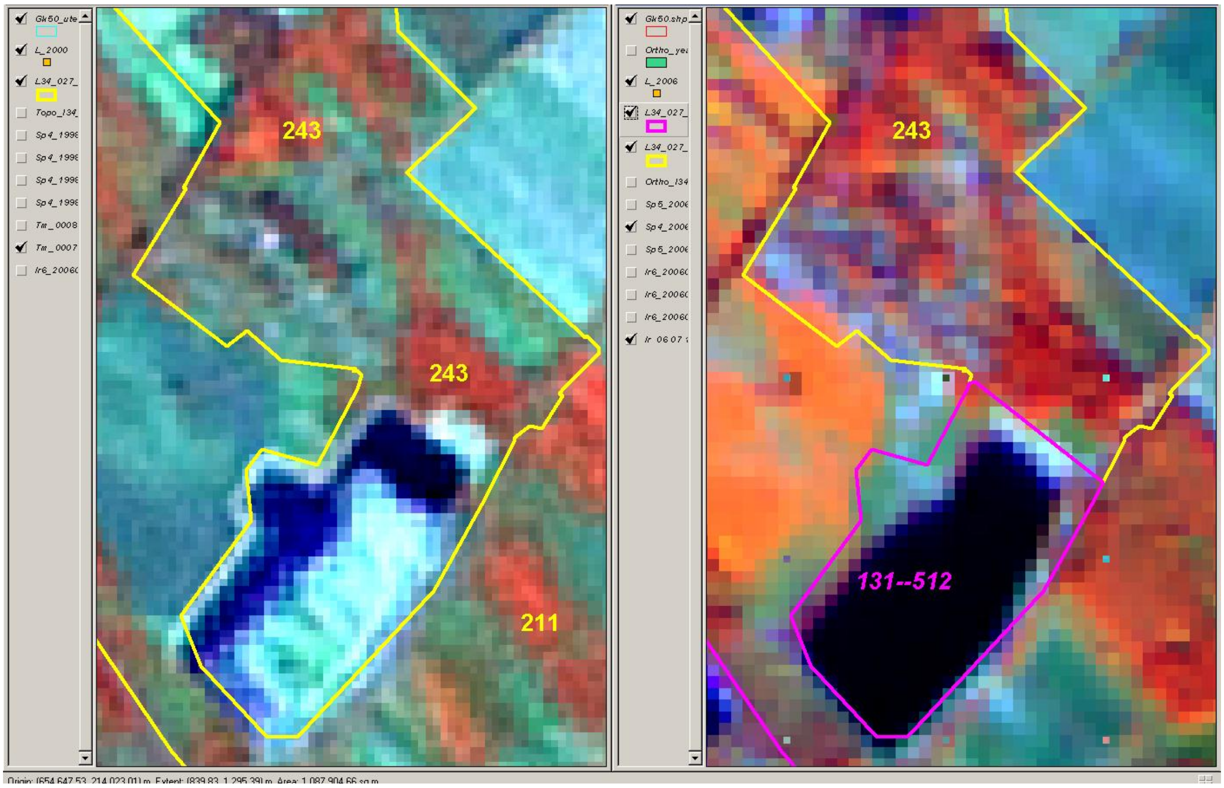


Figure 3 In mapping CLC changes the change code pair (right in magenta) should show the process that occurred in reality. Therefore (due to generalisation applied in producing CLC) it may be different from the codes occurring on the CLC2000 map (left in yellow) and / or those in the final CLC2006 map. In this case a small (17 ha) gravel mine, which is generalised into heterogeneous agricultural area (243) in CLC2000, has been turned into fishing pond (512) by 2006. Change code is therefore 131-512 (example from Hungary).

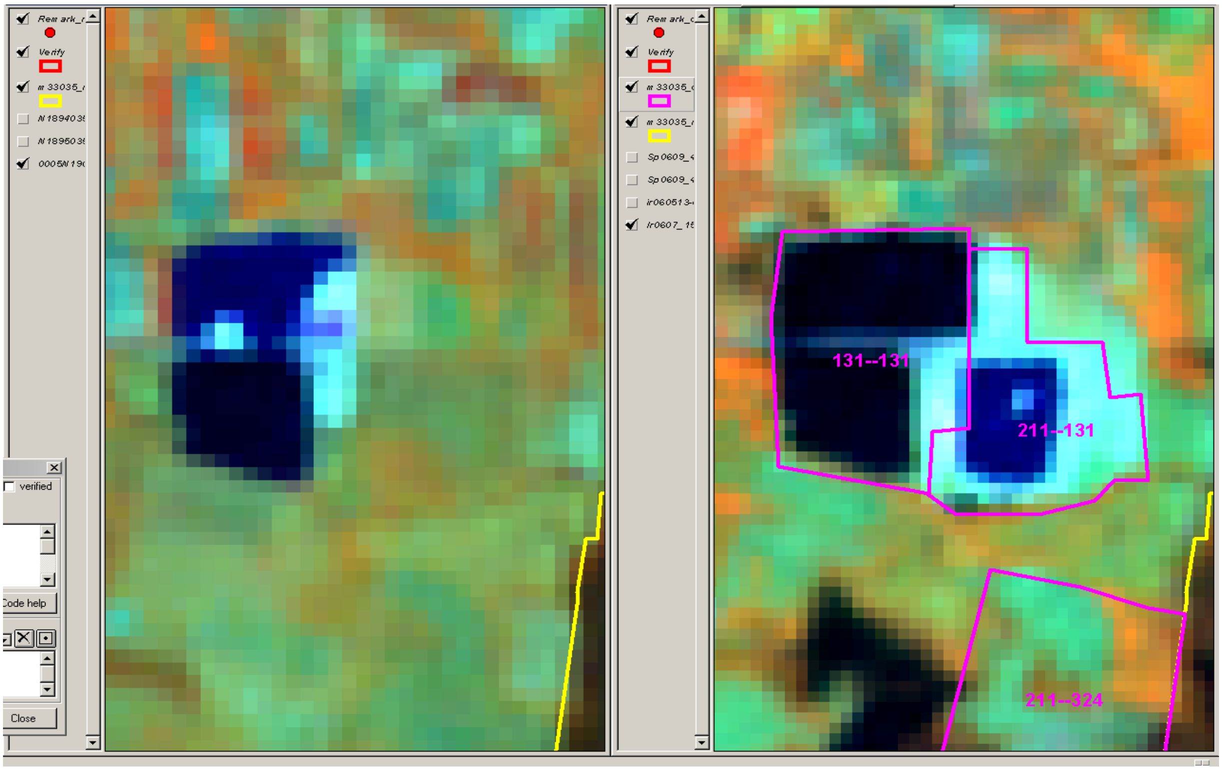


Figure 4 An existing mineral extraction site (16 ha) has increased by 12 ha (211-131). In order to include the whole mine in the CLC2006 database, the already existing part was taken as technical change (131-131), thus they together make up a valid (28 ha) polygon (example from Poland).

Remote sensing data should always support the change mapped. For example in case of 211-324, 231-324 and 243-324 changes, the afforestation or natural colonisation on agricultural land should be visible on satellite images. It is not enough to deduct the occurrence of this change from an administrative database, e.g. a farmer having reduced subsidy claim for the area.

3.1.1 Change mapping by means of CAPI

Softwares developed by ESRI (ArcGIS and ArcView) were the most widely used tools to support CLC change mapping by means of computer aided photo-interpretation (CAPI) technology.

The InterChange software [11] (as part of the CLC2006 Support Package, developed by MLOG, Hungary) was promoted to participants as a cheap and simple solution for mapping in CLC2006. Its predecessor, the CLC2000 Support Package had been known and used by many participants of the previous CLC inventory.

CLC2006 Support Package operates under ArcView environment. ArcView software is designed primarily for viewing GIS databases with tools for creating maps, menus for handling databases and graphical editing tools. At the same time, ArcView includes only limited and less effective tools for creating and filling new polygon databases or modifying existing polygon databases. As a solution, CLC2006 Support Package under ArcView provides a cheap tool for quick and comfortable editing and handling of CORINE Land Cover databases. CLC2006 Support Package is a macro package written in Avenue, ArcView's own macro language. The software is a supplement to ArcView 3.2/3.3 GIS. The use of the CLC2006 Support Package significantly facilitates updating, change detection, quality control and correction of land cover databases by means of computer assisted visual photo-interpretation.

18 of the participating countries used InterChange in deriving CLC-Change and CLC2006. Two additional countries used InterCheck in their internal quality control [12].

CLC2006 Support Package consists of three interrelated programs, all which can be used independently:

- InterPrepare: can be used for the preparation of source files and work directories for change detection to be carried out with InterChange.
- InterChange: provides a tool for the revision of CLC2000 land cover database and supports the interpretation of land cover changes in order to create the CLC2006 database.
- InterCheck: serves the checking of revised CLC2000 and CLC-Change map sheets. It has been prepared primarily for supporting the CLC2006 Technical Team, although national central teams might apply it as a tool for internal quality control and/or final checking of the completed CLC2006 and CLC-Change databases.

The most important functions of InterChange software [13]:

<u>Polygon editing functions</u>

<u>Tools supporting interpretation</u>

- Double-window interpretation environment, displaying CLC2000 database and the change database in two separate View windows constantly synchronising their content.
- All data belonging to a selected polygon are shown, can be edited and commented/remarked in the CLC data window.
- Interpreter can add technical change attribute to change polygons (special feature of CLC2006).
- Interpreter can search for polygons according to several characteristics, such as CLC code, change type, comment, error, supervisor's remark, progress status, area, change probability or technical change.

<u>Main error prevention functions</u>

- The program does not allow the use of invalid category codes, it warns if the created polygon is smaller than the size limit or is a multi-part polygon.
- In order to avoid topological mistakes, non-adjacent polygons cannot be unified.
- An error checking and correcting tool helps to find and correct overlapping or multi part polygons, selecting polygons below size limit, with shape error, with invalid or zero code.

<u>Information support</u>

- EUROSTAT LUCAS land cover and land use data and field photos can be displayed by a single click (if data available on computer).
- Optional polygon colourings provide additional information to interpreter (standard CORINE colouring, error colouring, change probability colouring, work status coluring).
- Detailed description of a chosen code can be obtained in a separate window with a single click. Description might also be available in national language instead of English (the content being the responsibility of the national project leader).
- With the area measurement tool the area of a planned polygon can be quickly estimated.
- Statistics on CLC code, polygon area and change code can be simply calculated.

3.1.2 Alternative solutions

Table 4 summarises the main features of national CLC2006 projects. In some countries (especially in Scandinavia) procedures different from visual photo-interpretation were used for deriving CORINE Land Cover data. These solutions combine national GIS datasets, satellite image processing technology, on-screen digitization (visual photo-interpretation) and GIS-based generalisation. Some characteristics of the methodology applied by these pioneering countries are presented below.

Finland [14, 15]:

- Satellite imagery was preprocessed; atmospheric correction, topographic normalization and mosaicking was done.
- Artificial surfaces classes (1xx) and Agriculture (2xx) were taken from a national land use database (SLICES). Building and dwelling register was also used to map built-up area.
- Forests were interpreted based on National Forest Inventory data, providing estimation of continuous forestry parameters such as crown cover and tree height.
- All land use data (SLICES) as well as Water (5xx) were checked with satellite images.
- Changes were derived mostly by using image-to-image comparison in an automated way. Its results were compared with CLC2000 and CLC2006.
- Sophisticated generalisation converted high-resolution national data to lower-resolution European data.

Iceland [16]:

- Data collection from various authorities: municipalities provided Artificial surfaces classes (1xx); Farmers Association provided data on arable land (211); Iceland Forestry Service provided data on forest (31x, 324); National Energy Authority provided data on glaciers (335); Icelandic Institute of Natural History provided data on wetlands (411, 412, 421).
- Water courses and water bodies were taken from the National Land Survey database.
- Pixel classification of satellite images by Agricultural University of Iceland (Nytjaland) – with manual corrections – were used for identification of natural surfaces (321, 322, 331, 332, 333, 412).
- Pastures (231) were digitized from satellite images because of the lack of official data.
- Change areas were partly provided by relevant authorities (e.g. for melting of glaciers by National Energy Authority), partly derived by photo-interpretation.
- The database has been generalized in order to comply with EEA requirements. A high-resolution version for national purposes for some of the CLC classes has also been produced.

Norway [17]:

- On areas below the tree line the so called AR5 land use database was used.
- For mapping areas above the tree line AR50 and semi-automatic satellite image classification were applied, supplemented by use of topographic maps and various public databases.
- For mapping CLC changes visual interpretation was used assisted by national registers of buildings and by datasets on forest felling.
- Generalization has been applied to yield resolution requested by EEA.

Sweden [18]:

- High-resolution national LC database was derived using segmentation-based satellite image classification.
- CLC changes, non-forest: a layer of potentially changed area was derived by subtracting the year-2000 version of topographic map from the year-2006 version. The difference image is evaluated by photo-interpreters.
- CLC changes, forest: information on forest felling from National Board of Forestry was automatically integrated into CLC-Changes.
- CLC changes, artificial surfaces: Geological Survey of Sweden provided data on new mineral extraction sites established between 2000 and 2006. Statistics Sweden provided data on areas built up between 2000 and 2006.

Table 4 Main features of national CLC2006 projects

country	main features of implementation
Albania	No CLC2000 was implemented; CLC1990 have been used; lots of corrections. Technical implementation by an Austrian team
Austria	Standard methodology; emphasis on mapping glaciers and ski resorts
Belgium	Standard methodology
Bosnia and Herzegovina	No CLC2000 was implemented; CLC1990 have been used; lots of corrections
Bulgaria	Standard methodology
Croatia	Standard methodology, 2 teams
Cyprus	Standard methodology
Czech Republic	Standard methodology; difficulties in mapping small clearcuts
Denmark	Standard methodology
Estonia	Standard methodology
Finland	Non-standard sophisticated methodology: digital change mapping
France	Standard methodology; fast implementation (< 1 year)
Germany	Standard methodology, 3 teams
Greece	Not participating
Hungary	Standard methodology; many corrections due to first time systematic use of orthophotos
Iceland	First time participant. Method partly based on ground data collection. CLC2000 has been produced also by backdating from 2006 to 2000.
Ireland	Standard methodology
Italy	Standard methodology
Kosovo under UNSCR 1244/99	Standard methodology; produced by the Serbian team
Latvia	Standard methodology
Liechtenstein	Produced by the Austrian team
Lithuania	Standard methodology
Luxemburg	Standard methodology
F.Y.R Macedonia	No CLC2000 was implemented; CLC1990 have been used. Lots of corrections in CLC1990
Malta	Standard methodology, one change was found
Montenegro	Standard methodology
Netherlands	Standard methodology
Norway	First time participant. CLC2000 was produced from resource maps. CLC-Change produced by standard methodology and ancillary data
Poland	Standard methodology; fast implementation (< 1 year)
Portugal	Standard methodology; the largest percentage of CLC changes
Romania	Standard methodology
Serbia	Standard methodology
Slovak Republic	'Update-first' methodology was used
Slovenia	Standard methodology; very few changes. Technical implementation by a Croatian company
Spain	SPOT-5 images (2005) were used; standard methodology; several teams (by autonomous regions); large regional differences in changes
Sweden	Forestry changes are automated; other changes are derived from differencing topographic maps and checked by photointerpreter
Switzerland	First time participant. Standard methodology. CLC2000 has been produced also
Turkey	First time participant. Largest participating country by area. CLC2000 and CLC2006 datasets were produced nearly simultaneously[2]
United Kingdom	Semi-automated production based on high res national LCM2007

[2] Lately Turkey has produced CLC1990 by backdating CLC2000 with support of the EEA (ETC-SIA)

3.2 PRODUCTION OF CLC2006

Having the CLC-Change database completed, CLC2006 is generated in an automated process [9]:

CLC2006 = CLC2000 (+) CLC-Change

Where (+) means the following operation: CLC2000 (revised CLC2000) and CLC-Change databases are intersected, then CLC-Change polygons' code2000 is replaced by code2006, and finally neighbours with similar code are unified (Fig. 5). Small (<25 ha) polygons are generalized according to a priority table [19] (Fig. 6). As an option, polygons slightly below the 25 ha limit (e.g. 24 ha) can be manually enlarged by a photo-interpreter. ETC-LUSI partner FÖMI has made available for all interested countries software dedicated to derivation of CLC2006 [23].

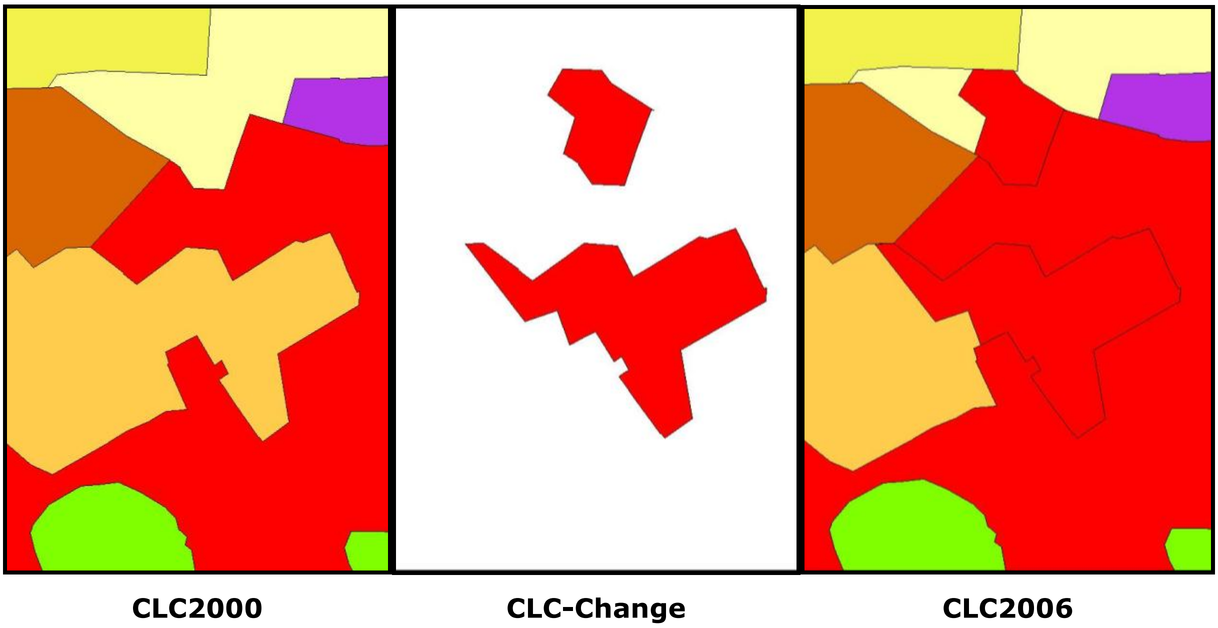


Figure 5 Growths of a settlement (112 – red) replacing arable land and vineyard. In CLC2006 new patches of 112 are generalized into existing 112.

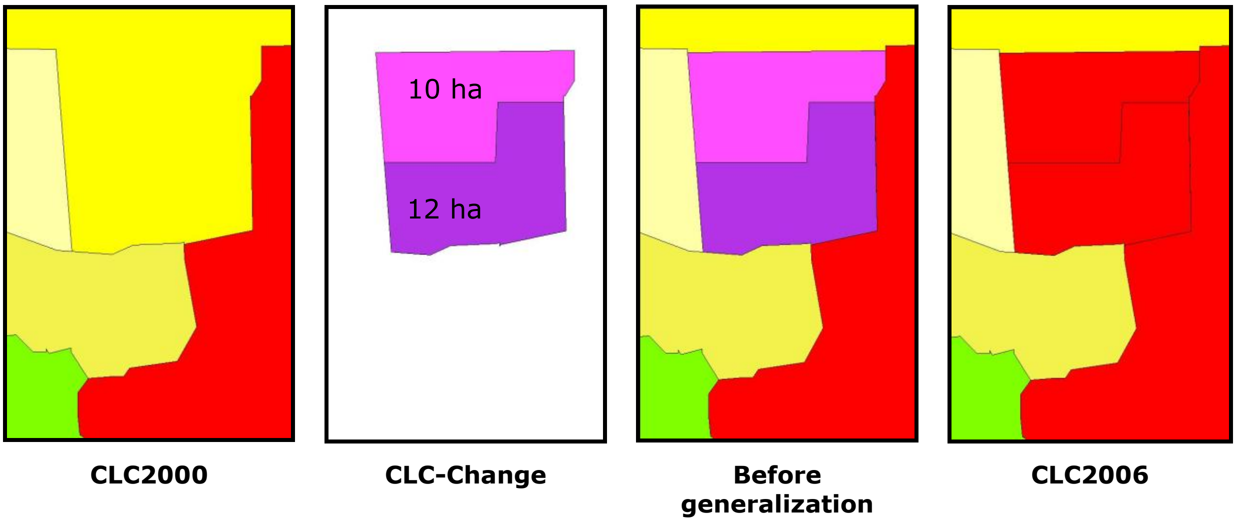


Figure 6 New construction site (133 - pink) and industry (121 - lilac) on former arable land appearing next to a settlement (112 - red). In CLC2006 133 and 121 below MMU (25 ha) are generalized into existing 112.

4 QUALITY ASSURANCE

4.1 TRAINING AND VERIFICATION MISSIONS

The CLC2006 Technical Team working under ETC-LUSI was responsible for the training and verification missions. During the CLC2006 project 15 training missions and more than 70 verifications were organised (Table 5).

Upon request, training sessions for the national teams were held at the start of implementation of CLC2006. The usual programme of the training was as follows:

- Overview of the GMES Fast Track Service Land Monitoring Precursor Programme;
- Principles of change mapping in CLC2006;
- Implementation of CLC2006 in the country (national presentation);
- InterChange basics: functional introduction of a dedicated software running under ArcView (Ch. 3.1.1);
- Interpretation exercises on national areas (urban area, natural/forest area etc.) using InterChange. IMAGE2000, CLC2000, IMAGE2006 (or equivalent), topomaps and optionally LUCAS data had to be available.

Usually two verification missions in each country were planned. The first was organised when the country processed around 50% of the area, while the 2^{nd} was organised at the end of production. Technical as well as thematic parameters of both datasets (revised CLC2000 and CLC-Change) were tested using software InterCheck. Some of the verification missions were organised as "remote verification", i.e. without travelling to the country. It had a definite drawback having no access to local data, knowledge and personal discussions, but saved time, travel costs and human efforts.

The following technical parameters were examined during verification:

- validity of codes (attributes),
- merge errors (neighboring polygons with the same code),
- minimum mapping unit size (5 ha, 25 ha) and
- geometric precision.

Visual photo-interpretation was used as a tool of thematic quality control. Options for thematic control were:

1) Verification units were selected as sample (10 km x 10 km sample units), within which all CLC polygons and all CLC changes were checked.
2) Polygons with selected codes were examined in the revised CLC2000 database. E.g. all or some of 112 (discontinuous urban fabric) polygons were checked. Usually most of codes examined at least through a subset of the population. Additionally, change polygons with selected codes were examined. E.g. all or a subset of 324-312 (clearcut of coniferous forests) change polygons were checked. Usually most, or if time allowed all change polygons were examined.

In case of large countries not the whole territory was examined with the above methods, but approximately 10% of the prepared area was selected for systematic control.

Mistakes and comments were recorded into the database usually with instructions for improvement. The verifications did not provide any quantitative figures for the national team. Working units (map sheets) were evaluated in a qualitative way as **accepted** (small amount of mistakes only), **conditionally accepted** (many mistakes but easy to correct) and **rejected** (several, different kinds of mistakes, requiring more efforts to correct). Table 5 summarises the CLC2006 missions.

Table 5 Training (T) and verification (V1, V2, V3) missions in the CLC2006 project

Country	2007	2007	2008	2008	2008	2009	2009	2010	remark
AL	T		V1	V2					Organised in Innsbruck
AT-LI	T		V1			V2			Training with LU
BA	T		V1	V2					
BE					V1	V2			V1 was a RV
BG			V1	V2					V1 was a RV
CH						T		V1,V2	V1,V2 were RV
CR			V1	V2					
CY		V1		V2					V1 was a RV
CZ		V1		V2					
DE						V1	V2		
DK				V1		V2			V1 was a RV
EE	T	V1		V2					
ES					V1	V2			
FI			T	V1		V2			
FR			V1	V2					
HU						V1	V2		
IE		V1	V2						
IS				V1	V2	V3			CLC2000 produced also
IT						V1	V2		
KO		V1				V2			Organised in Beograd
LT		V1		V2					
LU	T	V							Training with AT
LV		V1		V2					
ME	T		V1	V2					
MK			T	V1	V2				V1 was a RV
MT	T-V								Joint T and V
NL		V1		V2					
NO						T-V1	V2		Joint T and V1
PL				V1	V2				
PT	T			V1	V2				
RO		V1		V2					
RS	T			V1	V2				
SE	T		V1			V2			
SI	V1	V2							V1 was a RV
SK				V1	V2				
TR			T			V1,V2	V3		large size of TR
UK								V+	RVs for parts of UK

RV = remote verification

4.2 QUESTIONS OF APPLYING THE NOMENCLATURE

The CORINE Land Cover Nomenclature [8] was successfully used during the CLC2006 project. However, some minor deviations from the official class descriptions were applied, which are listed below:

4.2.1 Mineral extraction sites (131)

Former mineral extraction sites under reclamation by trees or grass should be classified as 324 or 231 depending on the way of reclamation. Abandoned former mineral extraction sites not under formal reclamation are classified as 131 until natural succession starts. If natural succession is visible 333 or 231 or 322 or 323 is the right code. 333 (sparse vegetation) should not be used for areas of forestation even the trees are small / sparse.

4.2.2 Sport and recreation (142): Ski resorts with artificial snow facility

In recent years many ski resorts have been equipped with facilities for producing artificial snow (snow canons). Essential part of this infrastructure is a pond providing water. Due to the artificial snow the length of the season is about doubled, lasting from November to April in Austria, therefore the human impact on the environment has increased. Sometimes the slopes are also fully changed, the uneven ground is levelled, rocks are removed etc. Chemicals are also mixed into the artificial snow to assure higher melting point. For the reason of higher human impact, in such areas the surface of ski pistes is also mapped as 142. The "indicator" of these facilities (therefore the use of 142 for the pistes) is the presence of the water pond. (Proposed by the Austrian team.)

4.2.3 Pastures (231)

In the lack of proper category, 231 code was used for mapping "degraded grasslands", usually situated in the outskirts of larger settlements. These areas, currently not in use should by no means be classified as 321, because of the large human impact.

4.2.4 Forests (31x)

According to nomenclature forest codes should be used where trees are higher than 5 m with a canopy closure of 30 % at least [8]. Height and canopy closure limits can be reduced in exceptional cases, when due to climatic conditions national forest definition requires this. E.g. in Iceland tree height limit had to be reduced to 2 m (!) in order to comply with the national forest definition [16].

4.2.5 Moors and heathland (322)

In arctic areas 322 can be comprised of surfaces covered exclusively by mosses and lichen. (Proposed by the Icelandic team.)

4.2.6 Beaches, dunes and sand planes (331)

The class includes barren sand and gravel plains that occur close to end of active glaciers and glacial rivers. These plains are flat or almost flat and without any distinct morphology or texture but can be characterised by braided riverbeds that may either be dry or wet. This class also includes volcanic ash and lapilli fields of recent volcanic activities inside the neovolcanic zone [16]. (Proposed by the Icelandic team.)

4.2.7 Bare rock (332)

This class includes also terminal moraines of glaciers [16]. (Proposed by the Icelandic team.)

4.2.8 Burnt areas (334)

The colour of burnt area on the satellite image is not necessarily black (Fig. 7). The burnt natural/seminatural (except natural grassland) components of 243 class (e.g. small forest patch inside an arable vineyard complex) should be mapped if larger than 5 ha.

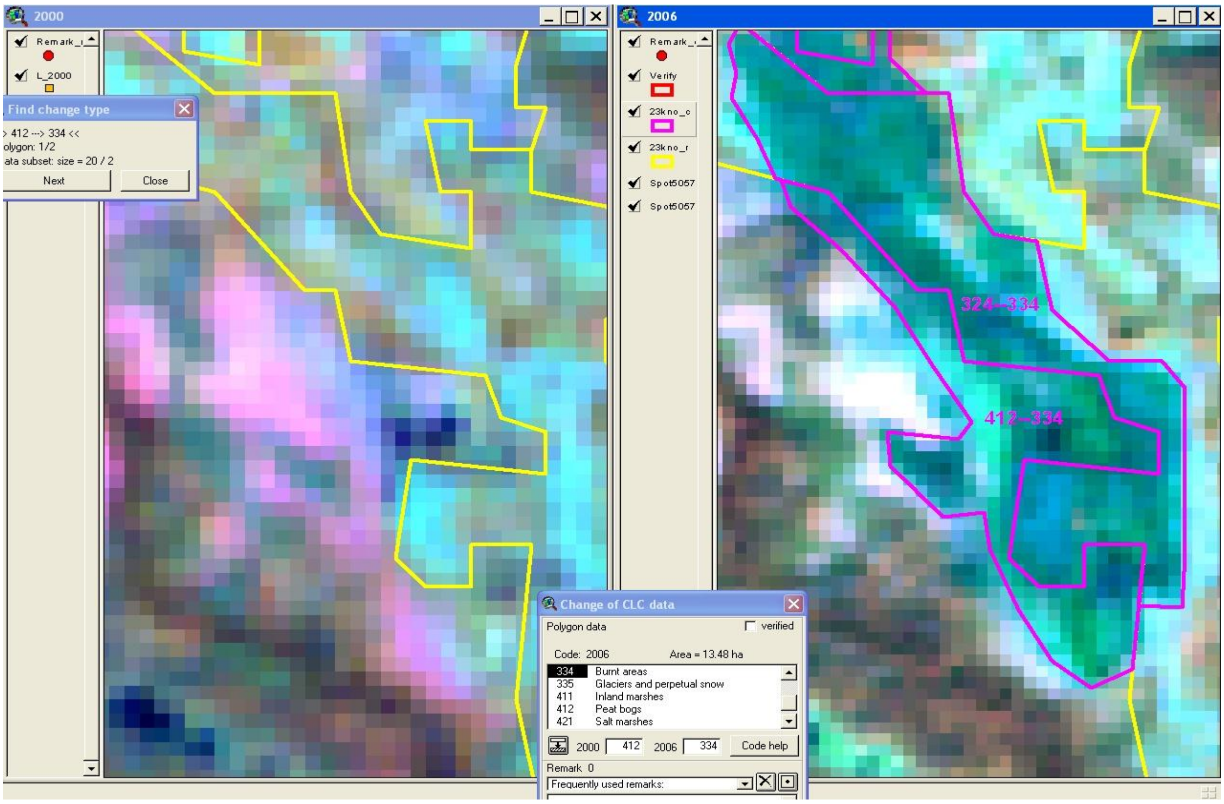


Figure 7 Burnt peatland. Left: 2000 (non-burnt), right: 2006 (burnt). Burnt areas can occur even in humid climate (example from Sweden).

4.2.9 Wetlands (411): Artificial wetlands

A special case of 411 is the so called “artificial wetland”. In the Netherlands for example, some of the agricultural land is transformed to wetlands (artificial nature). The construction phase is classified as 133, while the artificial wetland is classified as 411 (Fig. 8). This is an exceptional case when wetlands are formed in short time.

4.2.10 Salines (422): Inland salines

In Turkey several salt lakes exist covering large areas. In some cases there is salt extraction around, similar what exists along seashores (Fig. 9). The salt extraction sites (salines) class in the hierarchical CLC nomenclature is under the coastal wetlands, and inland salines are proposed to be classified as 131 [8]. We proposed to put the inland salines under the 422 class as they do not show similarity to any mineral extraction sites.

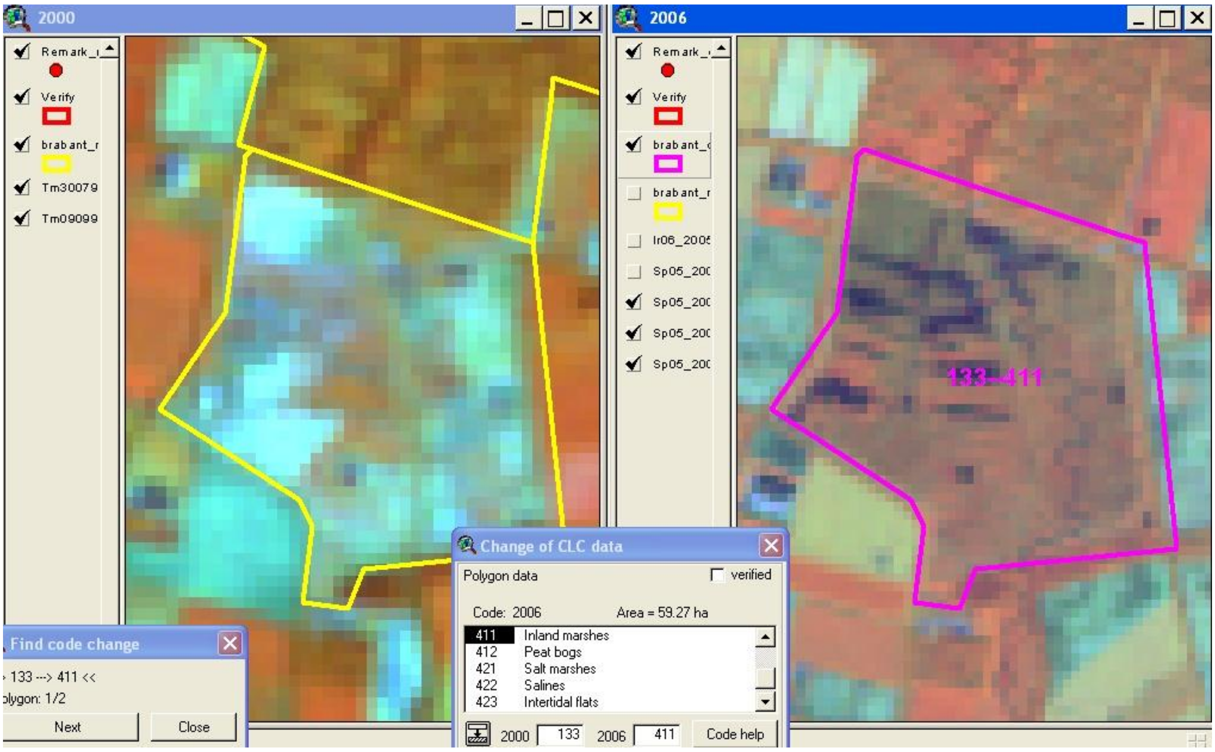


Figure 8 "Artificial nature" created – nature reconstruction site (right) on former agricultural land. In 2000 (left) the status of "construction", i.e. removing the topsoil is visible (example from the Netherlands).

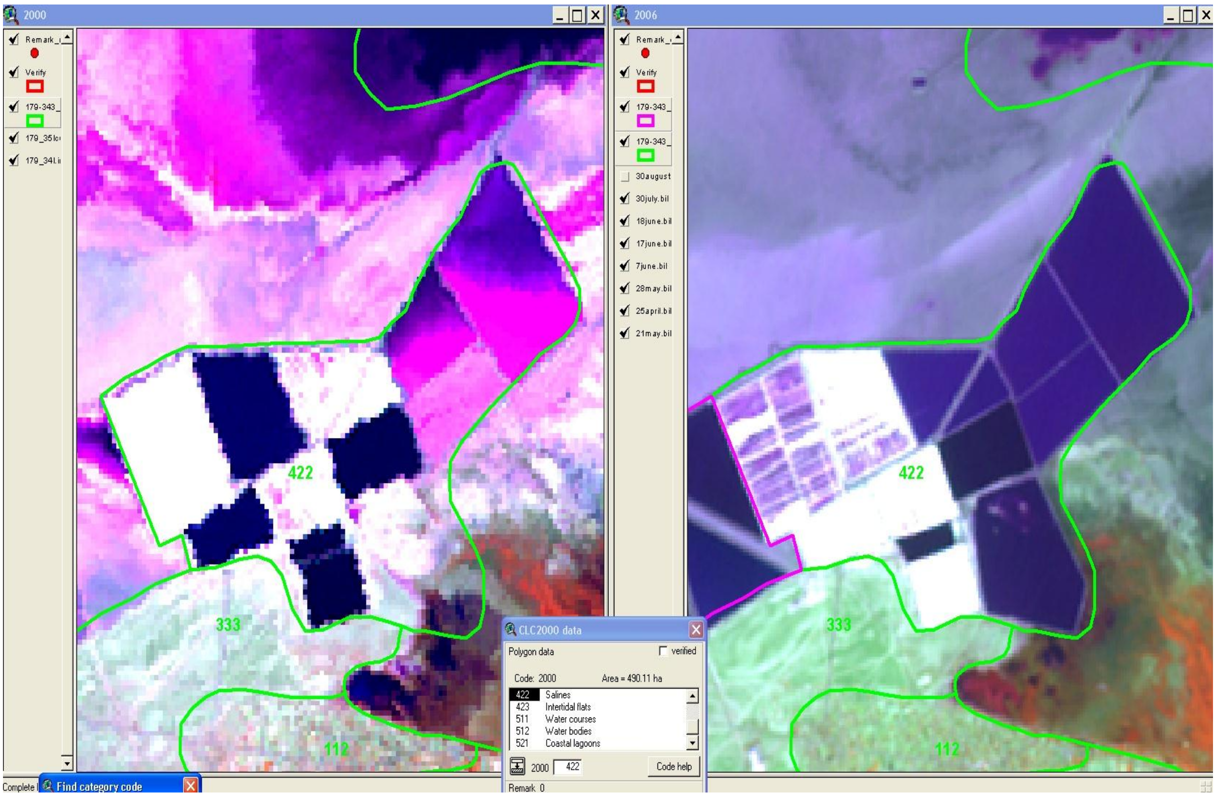


Figure 9 Inland salines associated to salty inland lakes. In the lack of proper CLC code, 422 has been used (coastal wetland / salines) (example from Turkey).

4.3 MOST FREQUENT MISTAKES

The aim of this chapter is to summarise the most frequent mistakes in mapping CLC changes, found by the Technical Team during verification missions to the countries. Examples are illustrated with InterCheck screen shots. The image on the left is IMAGE2000 with revised CLC2000 layer on it (usually yellow), while the image on the right is IMAGE2006 with CLC2000 (yellow) and CLC-Change (usually magenta) polygons.

4.3.1 Mistakes of revised CLC2000

Mistakes in CLC2000 affect CLC2006, as well as CLC-Change. In case of no CLC-Change polygon the mistake in CLC2000 is simply inherited into CLC2006. In case of a changed polygon, the 2000 code of CLC-Change will be false. Countries that did not intend to correct mistakes in CLC2000 used technical change [9] of any size to prevent error-propagation to CLC2006. Similarly, some other participants corrected the CLC2000 attributes of CLC-Change polygons instead of formal correction of CLC2000. This option was possible as EEA did not request a revised CLC2000 as deliverable.

Typical mistakes of revised CLC2000 were as follows:

(For sake of simplicity, CLC codes instead of class names are used in the coming chapters. List of CLC codes and names are found in Annex 2.)

- Code mistakes, usually caused by mistyping: e.g. 112 mistaken by 211; 311 mistaken by 331. As the "wrong" code is also a valid CLC code, it is not possible to find this kind of mistake automatically.
- Missing detail: e.g. large 243 that could be further divided into homogenous patches; missing mineral extraction sites; missing afforestation in peatland.
- Features missing because higher resolution data or ancillary information is not applied / considered: e.g. missing plantations (orchards, olives, forests); agroforestry (dehesa / montado) (244) not distinguished.
- Mixing of 112 and 242 classes in suburban areas.
- Abandoned/unused mineral extraction sites (131) are still coded as 131 and not according to actual land cover.
- Mixing up agriculture classes 211/231/242/243.
- Instead of 231, 321 applied for intensively used grasslands (parcel structure, referring to strong human impact is visible).
- Mixing up classes 322 (Atlantic shrub) and 323 (Mediterranean shrub) or interpreting them in locations right beside each other, which in naturally not possible.
- Beaches, sand, dunes (331) used for areas with significant amount of shrubs and trees. 331 should be used for less than 10%-vegetated surfaces and the grey dunes, which have more or less closed perennial grassland cover. If trees and bushes are visible on the image 333, 322 or 31x should be used.
- Instead of 324, class 333 is used for reclaimed mineral extraction areas where forestation has started.
- Mixing up classes 332 and 333. 332 should be used for areas with lass than 10% vegetation cover.
- Vegetation that has already recovered after fire, coded as 334. Only recently burnt (black or dark green/blue) areas should be coded as 334, regenerated area should be coded according to actual vegetation cover (e.g. 333, 323).
- Glaciers (335) mapped using the early summer images. 335 should be mapped using images with the minimum extent of annual snow (late August, early September).

- Using classes 411 and 412 for wet areas having field structure with grass cover. These polygons are not anymore wetland, but 231.
- 422 used for long ago abandoned salines. 422 should be used for areas of active (or recently abandoned) salt extraction. Long abandoned salines should be classified as salt marsh (421).

4.3.2 CLC-Change: technical problems

The simplest technical mistakes are: polygon size is smaller than the minimum mapping unit (MMU error); neighbouring polygons have the same CLC code (merge error); invalid CLC code; narrow (<<100 meter wide) polygons; geometrical imprecision exceeds 100 m (compared to IMAGE2000 or IMAGE2006).

In some cases, change polygon outlines do not match CLC2000 polygon boundaries, which would be a basic requirement. This might be a result of modification of CLC2000 after change mapping and might cause false changes. Non-matching might produce false changes or wrong change code pairs in the database. This kind of problem mostly occurs in countries applying non-standard methodology, where CLC2006 and CLC-Change are created in an independent process (Fig. 10).

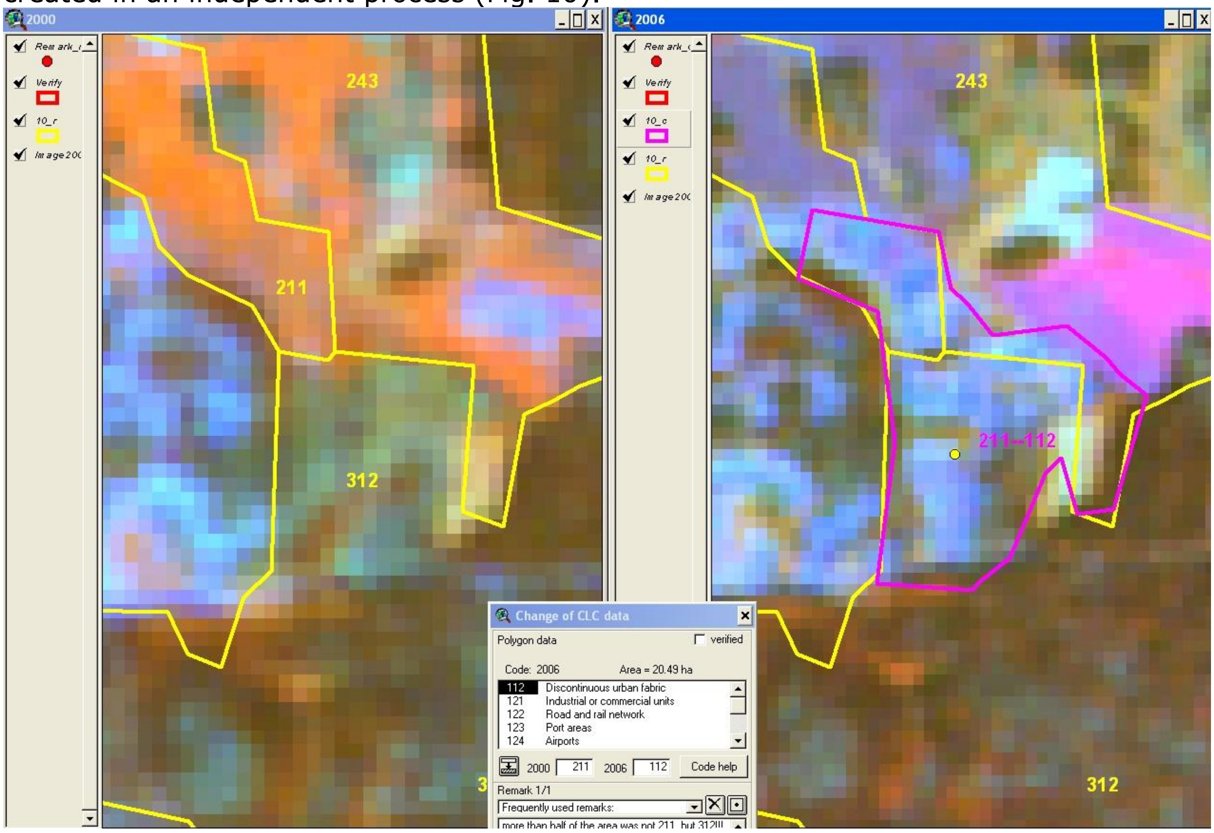


Figure 10 Change polygons sometimes cover more than a single CLC2000 polygon, resulting false changes. Here creation of a new part of settlement (112) is simplified to loss of arable land (211-112), although larger part of the area was formerly forest (312-112).

4.3.3 Missing changes (omissions)

Omitted changes lead to underestimation of CLC changes. Omission errors can be discovered when photo-interpreter re-examines the area at scale cca. 1:40.000 after completing the work (see Fig. 11).

- Special case of missing changes relates to "transient" classes, like construction sites (133) and burnt area (334). It is inherently expected that these classes change during the update cycle of CLC (Fig. 12).

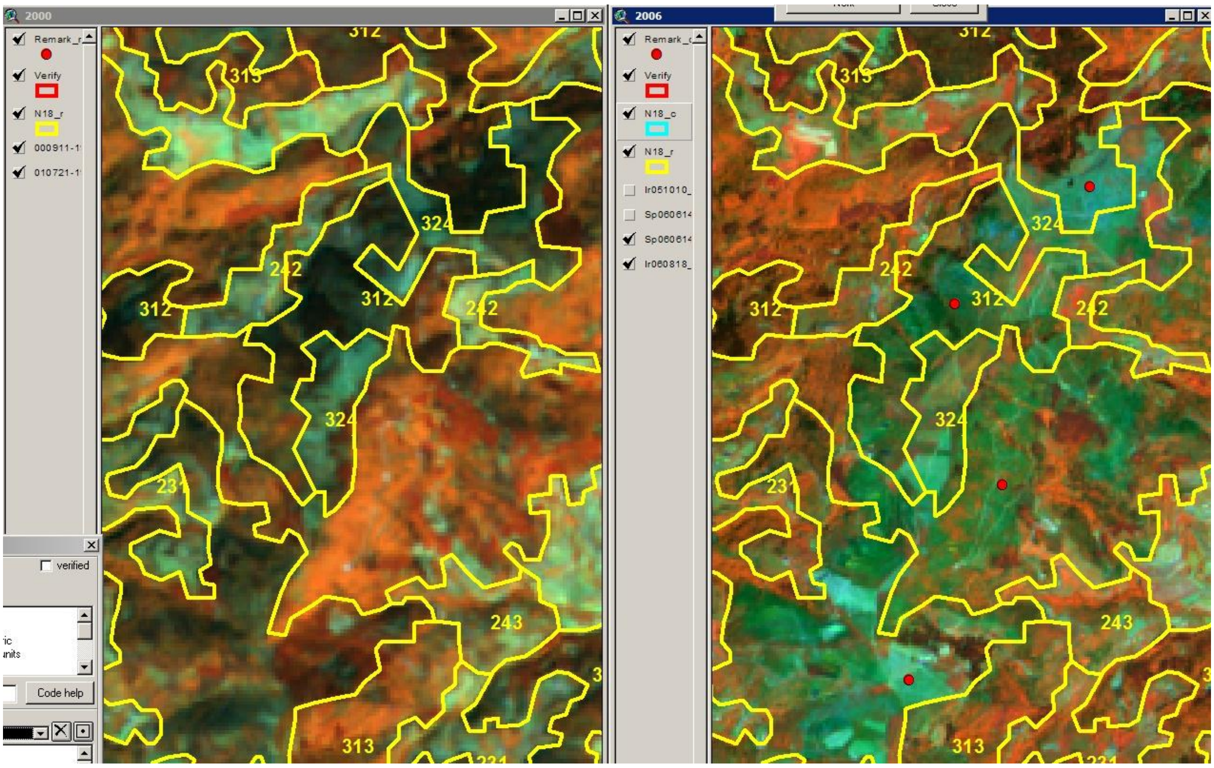


Figure 11 Large missing new forest clear-cut or damage area (311-324) around the red dots on the right. Note colour difference between IMAGE2000 (left) and IMAGE2006 (right).

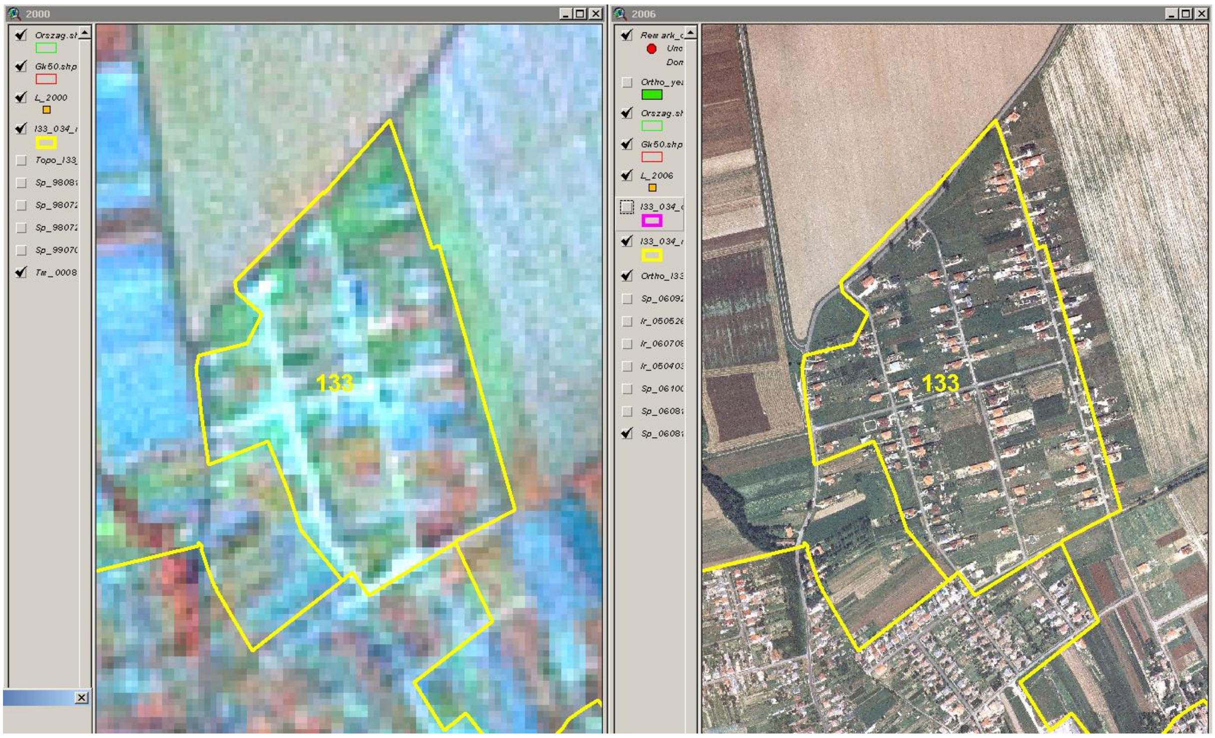


Figure 12 Omitted finished construction (133-112). The polygon on the left shows less structure, while on the corresponding 2006 orthophoto on the right street pattern and houses are visible.

- Changes are often missed if not the latest available image is used. The two IMAGE2006 coverages usually provided multi-temporal imagery, often with 3-5 image dates for the same location. Construction sites and forest clearcuts are especially dynamic, changing very rapidly; in mapping these a few months difference in image acquisition can be important (Fig. 13).

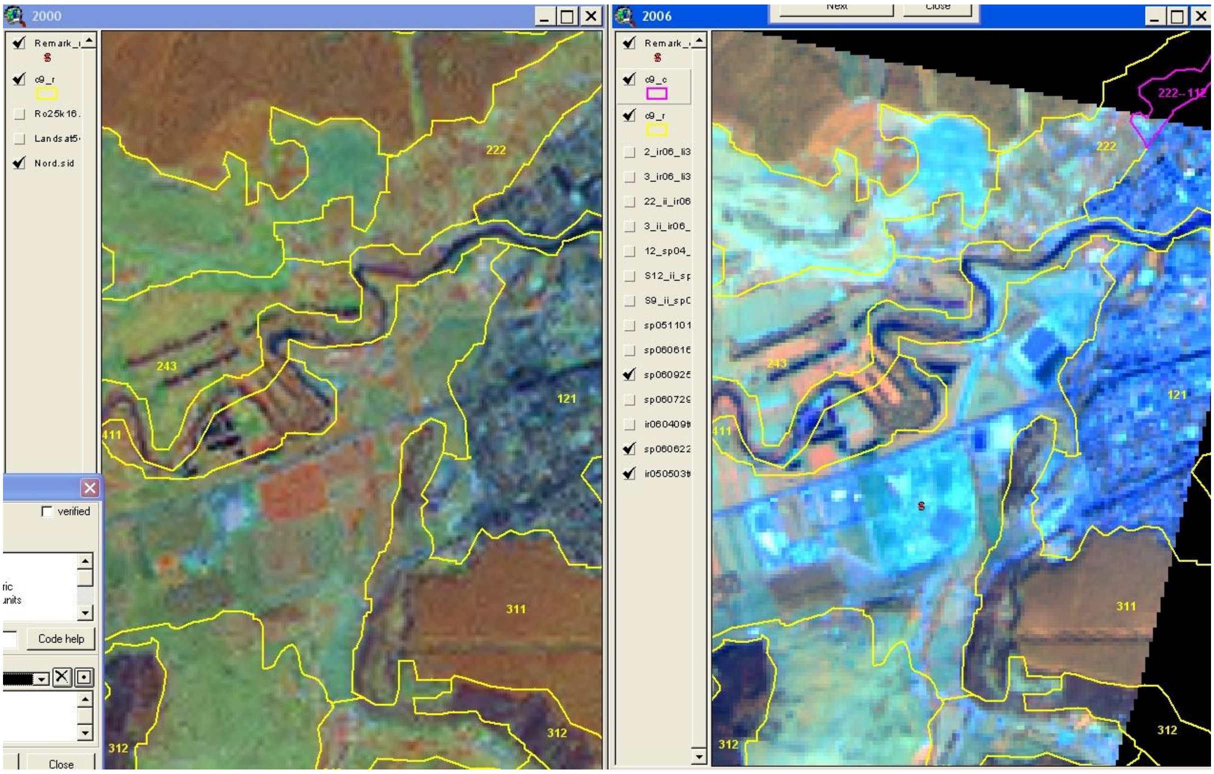


Figure 13 Large missing construction areas in an urban fringe zone, due to not the latest image being interpreted. Always the latest available satellite image has to be interpreted.

4.3.4 False changes

- Change mapped instead of correcting CLC2000. False changes are typically mapped due to mistakes (missing corrections) in CLC2000. (Fig. 14) If mapping strongly relies on applying GIS data (and not photo-interpretation), fore-dating of ancillary data might be a problem also, i.e. a feature to be built in the future is mapped as existing.
- Temporal change in vegetation mapped as land cover change. A typical mistake is the interpretation of phenological changes in forests as CLC change (Fig. 16). Fall of leaves in autumn is not considered CLC change.
- Temporal water level change in water bodies mapped as land cover change. Seasonal changes in water level in rivers and water bodies (e.g. low water / high water in rivers; spring / autumn status of reservoirs; tidal differences in coastal water) are not CLC changes.
- Temporal changes in wetlands mapped as real change. Seasonal changes in wetlands are not considered CLC changes.
- Temporal snow cover might be confusing, causing false changes, when interpreting changes of glaciers. This can be avoided by comparing images showing the yearly minimum snow cover (end August/early September).
- Non-changed part is not cut from change polygons. The 5 ha limit of CLC change mapping refers also to non-changed areas inside larger CLC change polygons. I.e. > 5 ha area inside a CLC change polygon remained unchanged, it has to be cut-out as no-change area (e.g. non-felled area inside a clearcut, see Fig. 15).
- Not always the real process is reflected in the code pairs applied. E.g. if a small forest patch in a large 243 polygon is cut, the right process is 311-324, not 243-324 (Fig. 17).

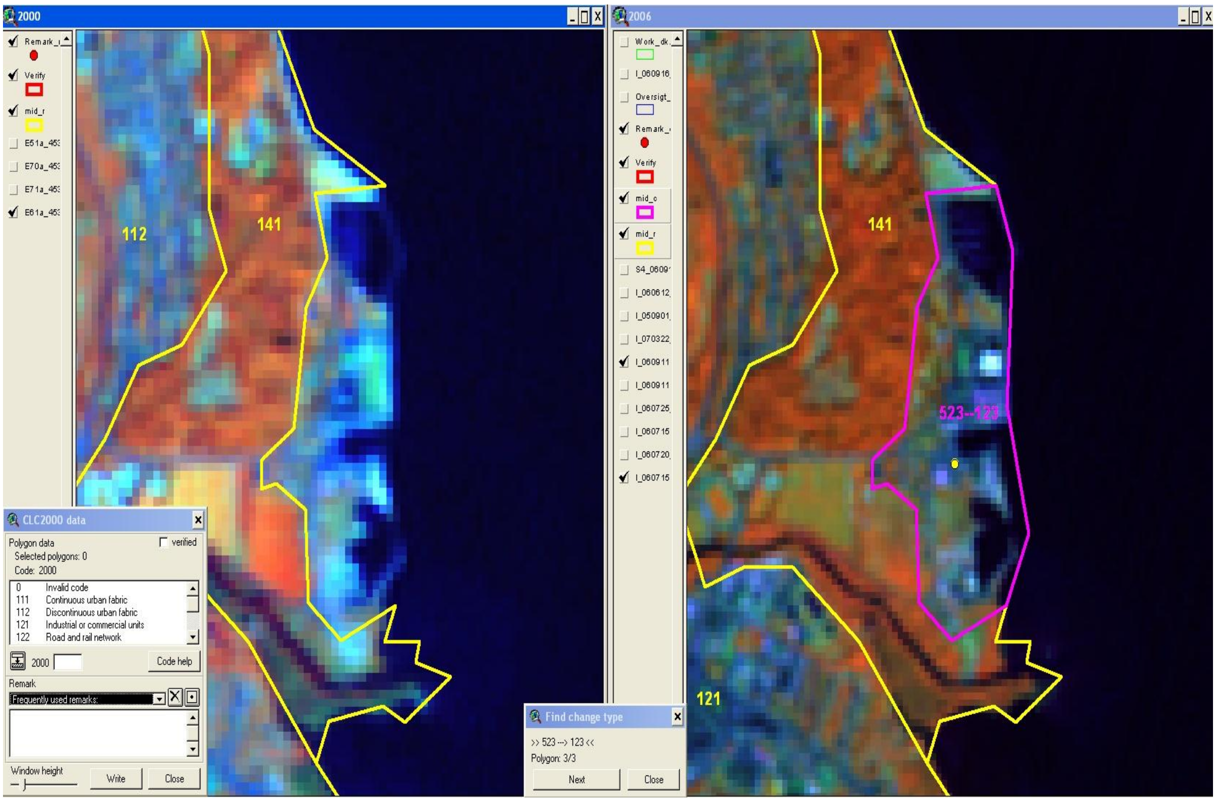


Figure 14 False change: new port (123) mapped instead of correcting CLC2000 (missing port).

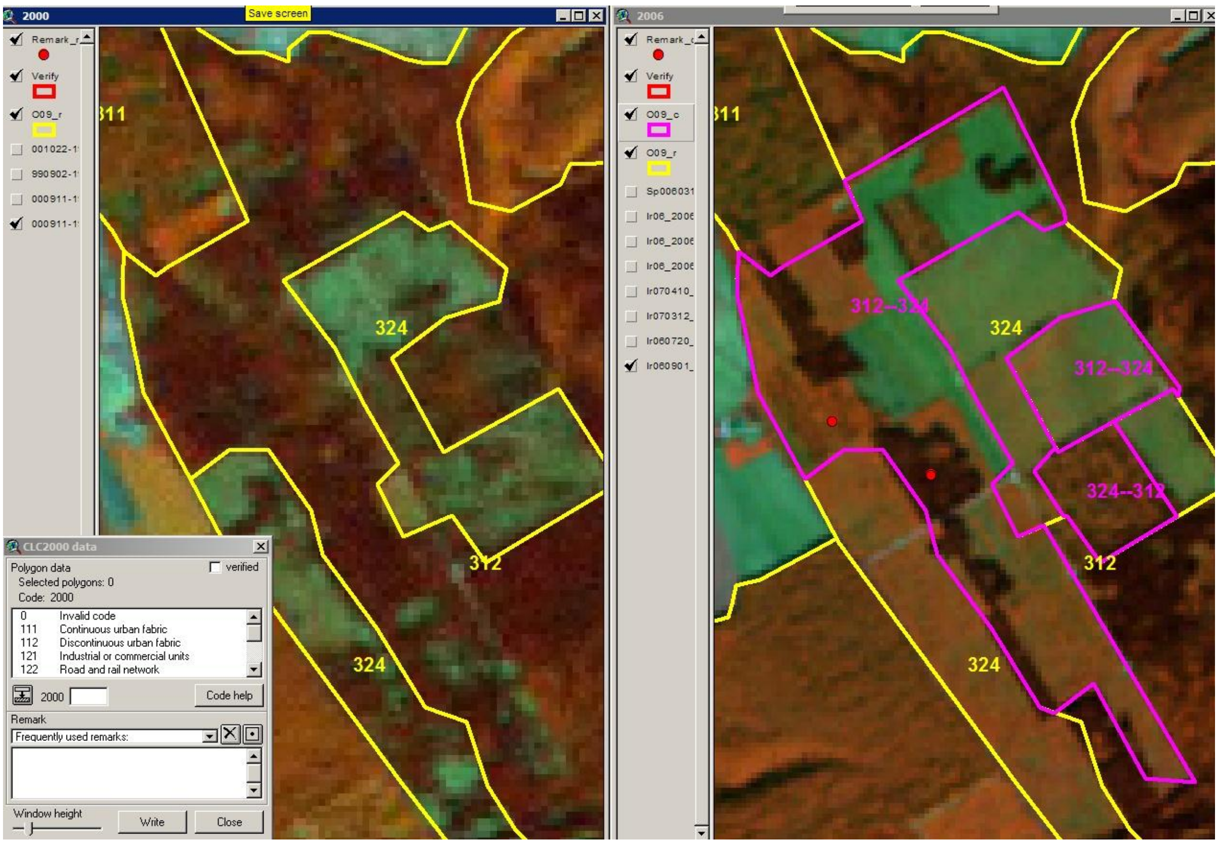


Figure 15 The non-felled areas marked with red dots have to be cut (if >5 ha) as non-changed from large CLC change polygon in order to derive realistic change statistics.

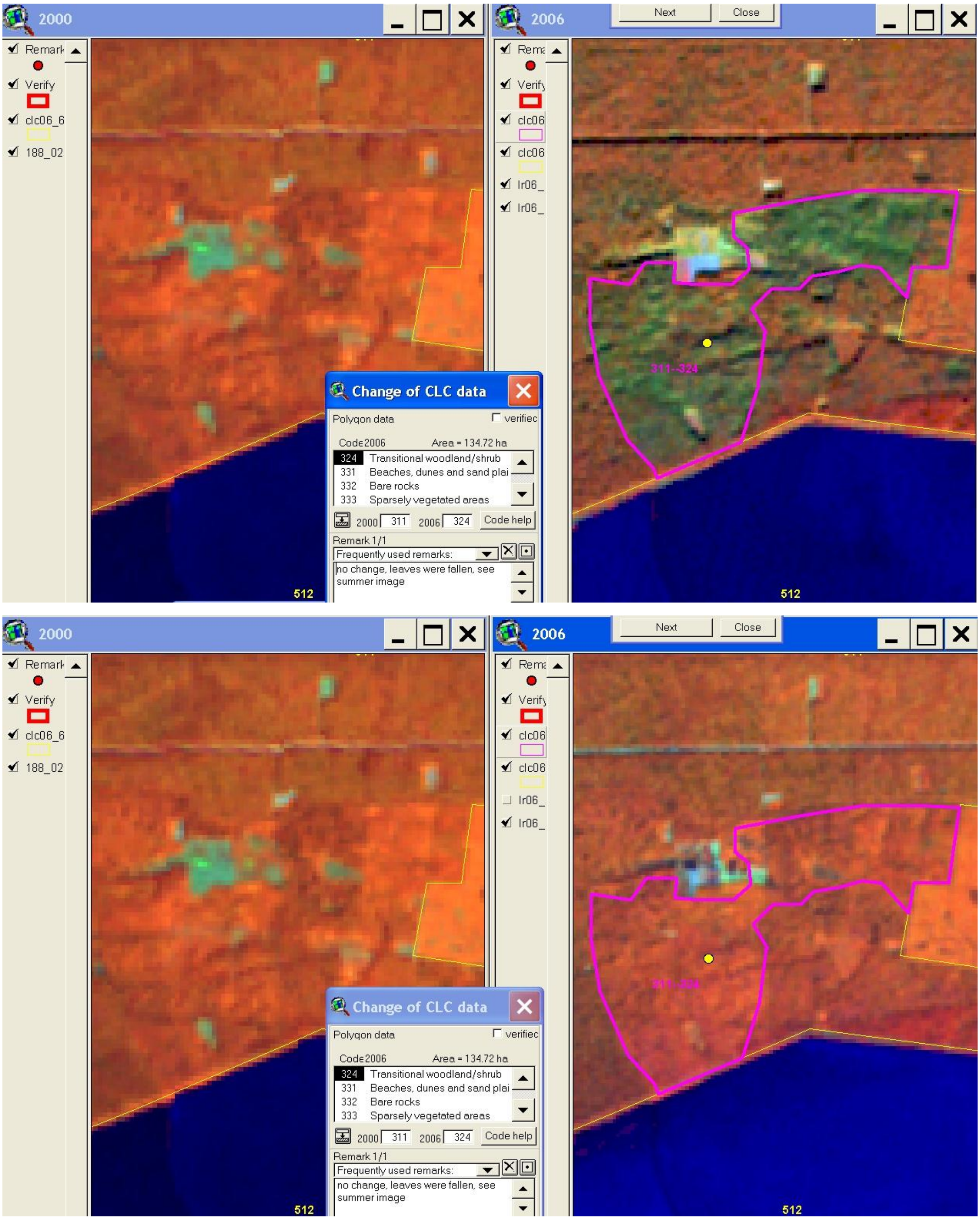


Figure 16 Example of a seasonal/temporal change in forest, mapped erroneously as CLC change. The summer 2000 / autumn 2006 comparison (top) suggests a CLC change. On the bottom the summer 2000 / summer 2006 comparison shows that no change took place.

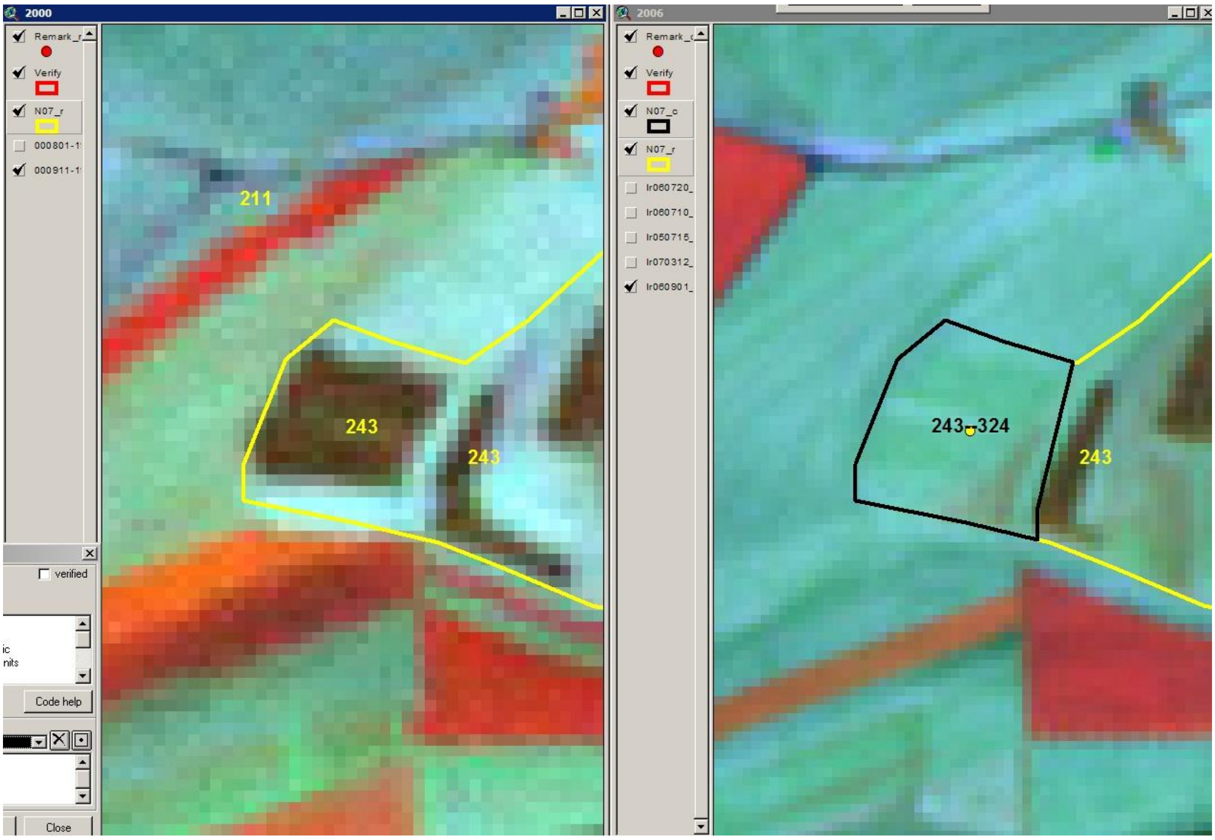


Figure 17 In a 243 polygon (dominantly agriculture with significant amount of natural vegetation) a piece of forest is felled. The right process in 311-324 and not 243-324, because the 243-324 process (agriculture turned to forestation) is just the opposite what actually happened.

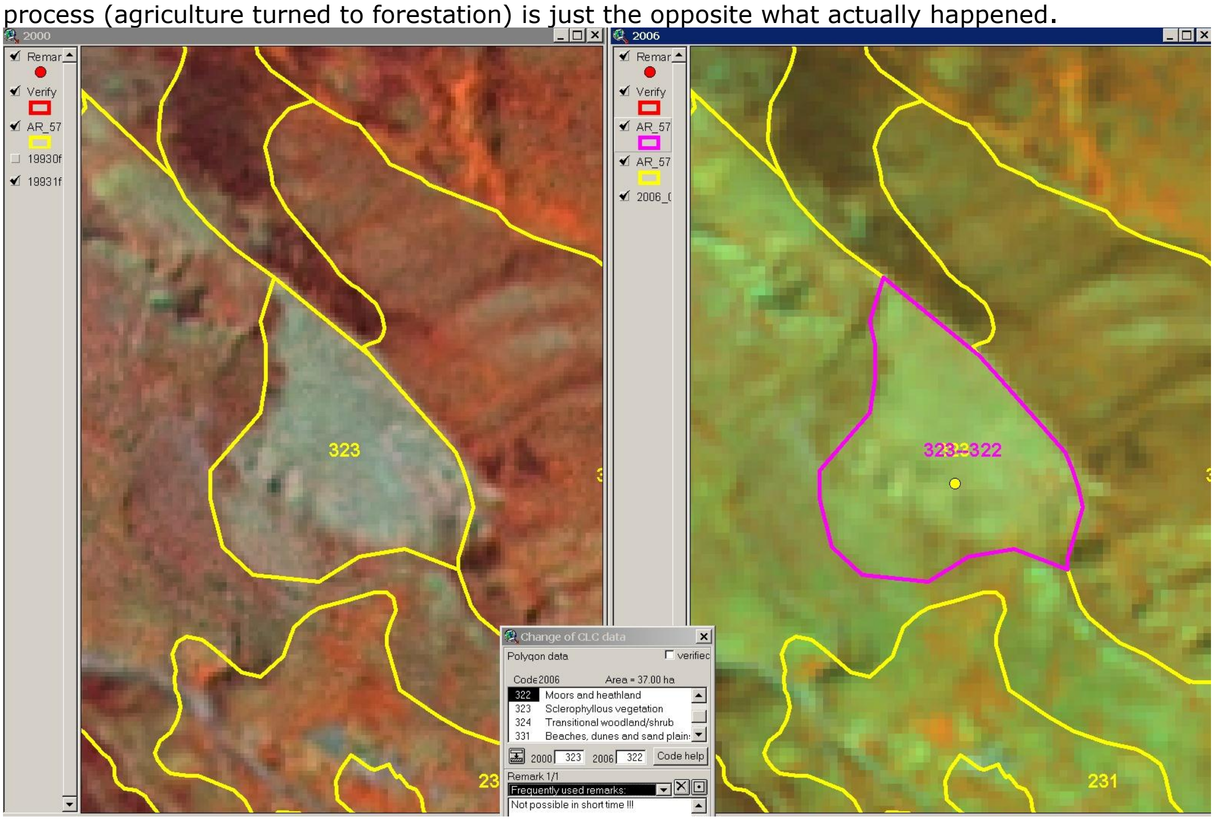


Figure 18 Changes between the two kinds of shrubs in CLC is not possible. Moors and heathland (322) is characteristic of Atlantic climate, while sclerophyllous shrub (323) is typical in the Mediterranean.

4.3.5 Impossible changes

Some CLC changes are impossible (or highly improbable) because of geographical or other constrains (e.g. new vineyards above the Polar Circle). Changes between different (climate-dependent) climax shrub types of CLC are not possible (Fig. 18).

4.4 FINAL TECHNICAL EVALUATION OF CLC2006 PRODUCTS

All deliverables have to conform to the CLC2006 technical specifications as defined in the Technical Guidelines [9] and listed more in detail in Guidelines for delivery document [21].

Technical specifications for data deliveries include:

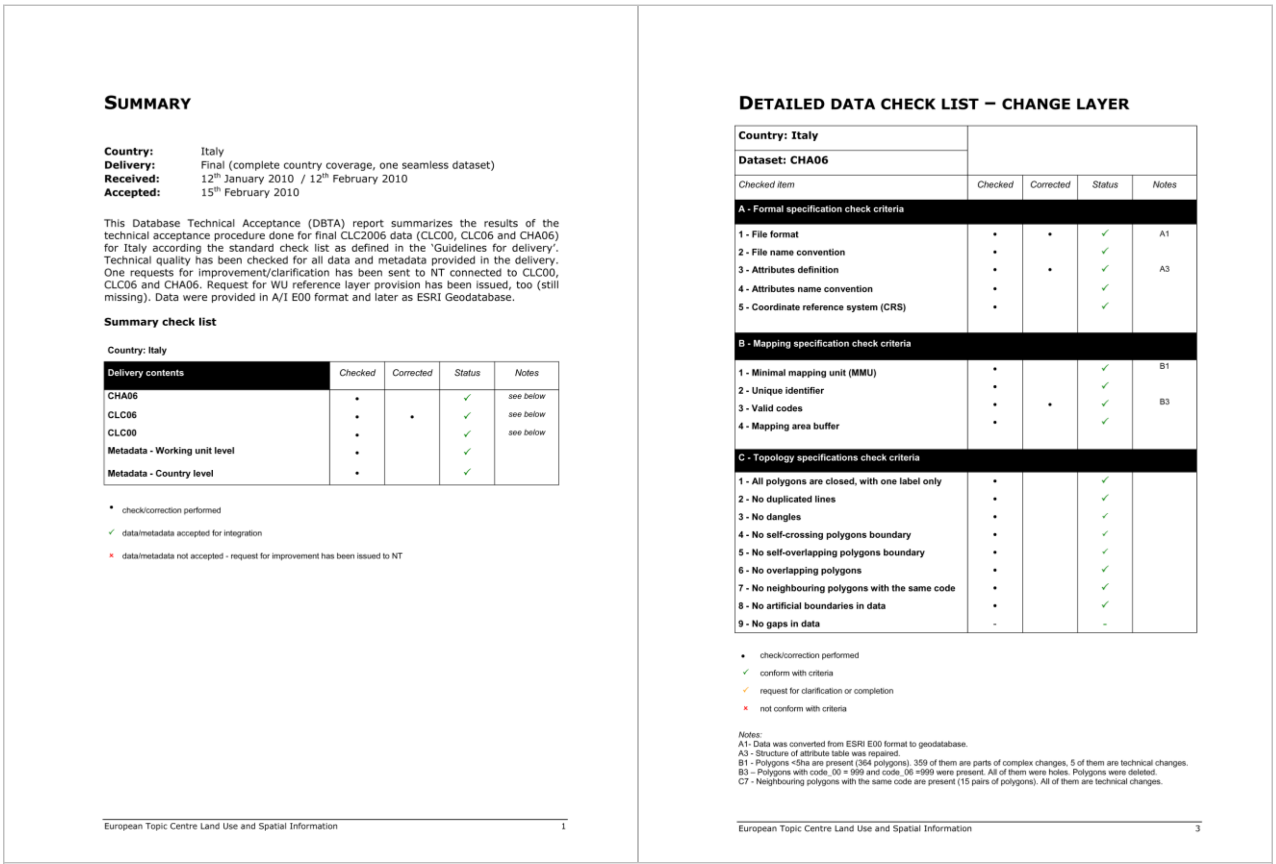
- Formal specifications - format, CRS, naming and structure conventions at file and attribute level
- Mapping specifications - standards based on CLC methodology (e.g. MMU, CLC codes)
- Topology specifications - standards assuring topological integrity and correctness of data
- Metadata specifications - standards allowing integration of accompanying metadata documentation

Role of the final technical evaluation is to assure that all these specification will be respected and that the final data accepted for integration into European products will fully conform to the technical standards defined for CLC2006. In practice, the process of the final technical evaluation includes technical checking of data deliveries from the national teams against defined criteria, communication regarding clarifications or enhancements of issues found in data provided (often in several iterations) as well as the final acceptance and subsequent final acceptance protocol provision - Database Technical Acceptance (DBTA) report. Example of the standard DBTA report is shown on Fig. 19.

The delivery process and exchange of dataset versions is supported by the EEA Central Data Repository (CDR).

In Table 6, the most frequent technical error cases are listed (in the order of number of occurrences). Errors listed in *italic* are usually subject to correction by the National CLC team experts and therefore require new (corrected) data delivery.

Compared to the CLC2000 update, the whole process of technical acceptance has been improved; number of delivery iterations has been reduced and consequently speeded up. Nevertheless, as seen, there is still a room for improvement both on technical support and organizational level, which shall be further exploited with respect to the tight schedule of new CLC update (CLC2012).



SUMMARY

Country: Italy
Delivery: Final (complete country coverage, one seamless dataset)
Received: 12th January 2010 / 12th February 2010
Accepted: 15th February 2010

This Database Technical Acceptance (DBTA) report summarizes the results of the technical acceptance procedure done for final CLC2006 data (CLC00, CLC06 and CHA06) for Italy according the standard check list as defined in the 'Guidelines for delivery'. Technical quality has been checked for all data and metadata provided in the delivery. One requests for improvement/clarification has been sent to NT connected to CLC00, CLC06 and CHA06. Request for WU reference layer provision has been issued, too (still missing). Data were provided in A/I E00 format and later as ESRI Geodatabase.

Summary check list

Country: Italy

Delivery contents	Checked	Corrected	Status	Notes
CHA06	•		✓	see below
CLC06	•	•	✓	see below
CLC00	•		✓	see below
Metadata - Working unit level	•		✓	
Metadata - Country level	•		✓	

- • check/correction performed
- ✓ data/metadata accepted for integration
- × data/metadata not accepted - request for improvement has been issued to NT

European Topic Centre Land Use and Spatial Information 1

DETAILED DATA CHECK LIST – CHANGE LAYER

Country: Italy
Dataset: CHA06

Checked item	Checked	Corrected	Status	Notes
A - Formal specification check criteria				
1 - File format	•	•	✓	A1
2 - File name convention	•		✓	
3 - Attributes definition	•	•	✓	A3
4 - Attributes name convention	•		✓	
5 - Coordinate reference system (CRS)	•		✓	
B - Mapping specification check criteria				
1 - Minimal mapping unit (MMU)	•		✓	B1
2 - Unique identifier	•		✓	
3 - Valid codes	•	•	✓	B3
4 - Mapping area buffer	•		✓	
C - Topology specifications check criteria				
1 - All polygons are closed, with one label only	•		✓	
2 - No duplicated lines	•		✓	
3 - No dangles	•		✓	
4 - No self-crossing polygons boundary	•		✓	
5 - No self-overlapping polygons boundary	•		✓	
6 - No overlapping polygons	•		✓	
7 - No neighbouring polygons with the same code	•		✓	
8 - No artificial boundaries in data	•		✓	
9 - No gaps in data	-		-	

- • check/correction performed
- ✓ conform with criteria
- ✓ request for clarification or completion
- × not conform with criteria

Notes:
A1- Data was converted from ESRI E00 format to geodatabase.
A3 - Structure of attribute table was repaired.
B1 - Polygons <5ha are present (364 polygons). 359 of them are parts of complex changes, 5 of them are technical changes.
B3 – Polygons with code_00 = 999 and code_06 =999 were present. All of them were holes. Polygons were deleted.
C7 - Neighbouring polygons with the same code are present (15 pairs of polygons). All of them are technical changes.

European Topic Centre Land Use and Spatial Information 3

Figure 19 Extracts from a DBTA report - page 1 (left) and page 3 (right)

Table 6 Main errors found during DBTA report preparation (in order of frequency.)

Errors detected during DBTA process	Number of occurrences (in delivered CLC datasets)
Attribute definition	36
File format	33
Neighbouring polygons with the same code	24
Minimum mapping unit	21
Valid codes	13
File name convention	12
Coordinate reference system	12
Attributes name convention	7
Mapping area buffer	7
Unique identifier	6
Dangles	5
Self-crossing polygons boundary	4
Overlapping polygons	4
Artificial boundaries in data	4
Gaps in data	3
Duplicate lines	2

5 RESULTS

38 countries have implemented the project. Only Greece could not participate. Iceland, Norway, Switzerland and Turkey appeared on CLC maps and statistics for the first time. Portugal extended her CLC database to the Madeira archipelago. Maps (see Figs. 20 and 21) and statistics (Tables 8-12) refer to V15 of the European CLC2006.

5.1 PRODUCTS OF THE CLC2006 PROJECT

The CLC2006 project created standard output products. The vector products are in ArcInfo format. National Teams delivered CLC2006 and CLC-Change together with metadata. Revised CLC2000 was not a standard deliverable, as EEA was not interested in releasing an amended CLC2000 following the completion of CLC2006[3].

Two kinds of metadata were delivered: (1) The purpose of working-unit-level metadata is to collect the relevant processing parameters regarding each working unit. Working units are usually areas of the 1:100.000 scale map sheets, or a group of such map sheets. In a few countries other solutions were seen. E.g. in Turkey the IMAGE2000 outlines ("frames") were applied as working unit, while in Iceland the municipality boundaries were used. (2) The main role of country-level metadata (ISO 19115 standard) is informing the users about the national CLC2006 products.

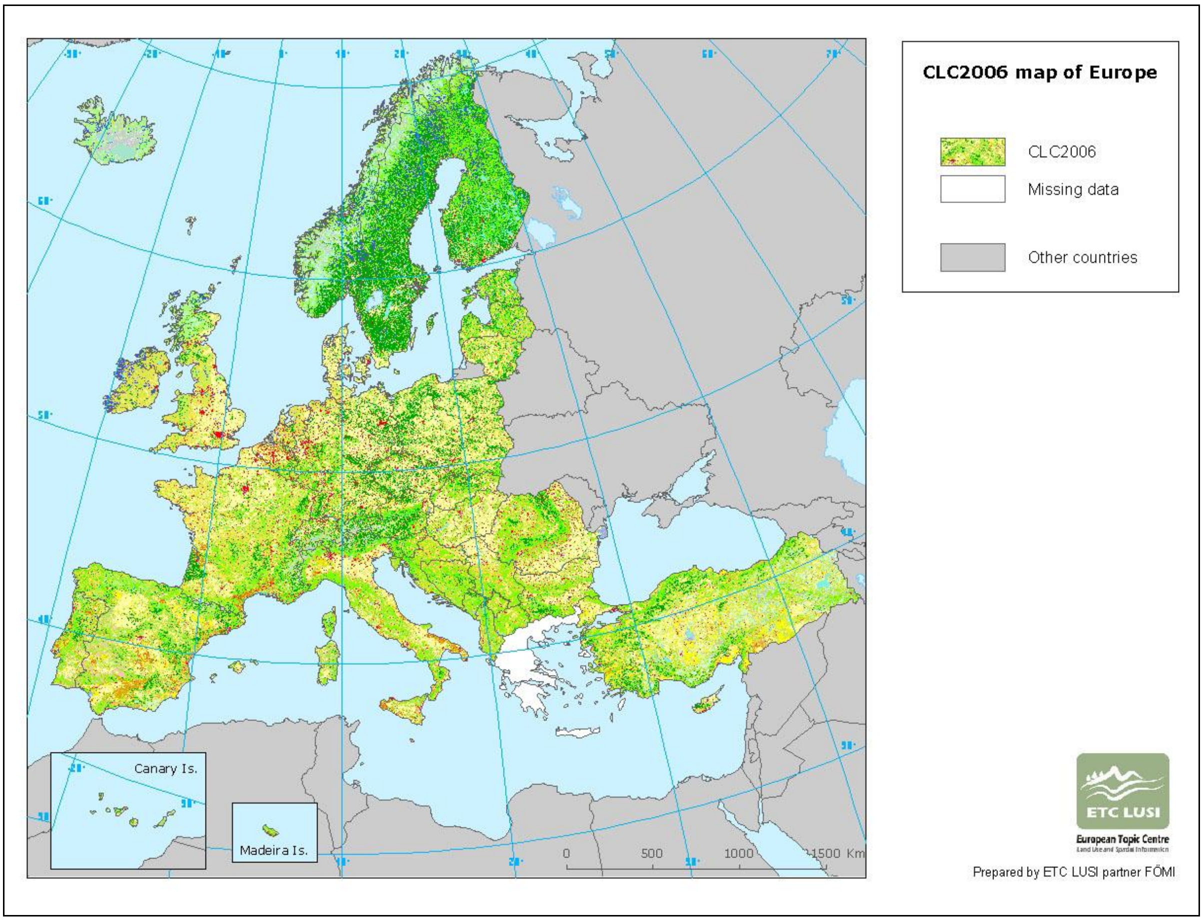


Figure 20 CLC2006 map of Europe (V15)

[3] Many of the national revised CLC2000 datasets have been collected by ETC-SIA in 2011

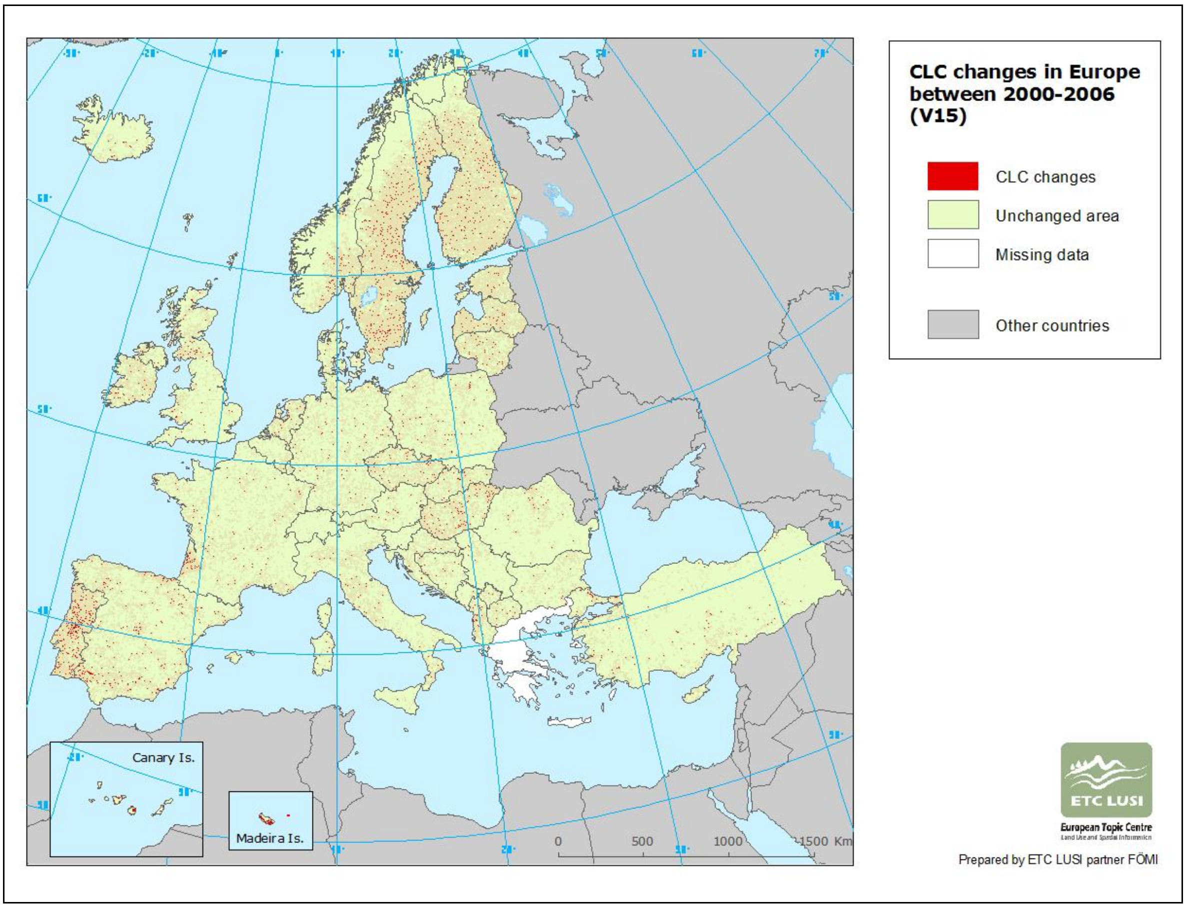


Figure 21 CLC-Change map of Europe. Changed areas are coloured in red (V15)

The CLC2006 Technical Team has produced the following final European products:

- European CLC2006 and CLC-Change;
- raster CLC data with 100 m and 250 m grid size;
- statistics referring to 1 km^2 cells (produced by the ETC-LUSI Central Team).

National products are created in national projection. All European CLC2006 data products (raster and vector) are in European ETRS89-LAEA projection.

5.2 STATISTICAL CHARACTERISATION

The CLC2006 (V15) land cover statistics for Europe is presented in Table 7. The statistics has been computed from 100 m raster data, which includes very large area of the Sea and ocean (523) class. Therefore the 523 code areas have been excluded from statistics (including inland seas as well).

Forests and semi-natural area is the largest level-1 class, covering almost half of the surface of Europe (48.64%). The second largest is the Agriculture class (42.65%). The three remaining level-1 classes have rather similar coverage, i.e. Artificial surfaces: 3.75%, Water (excluding sea and ocean): 2.59% and Wetlands: 2.36%.

Concerning level-3 classes: the largest class is Arable land (211: 21.25%), followed by Coniferous forests (312: 12.95%) and Deciduous forests (311: 9.59%).

Some figures related to the CLC-Change database are shown in Table 8. While the total CLC-Change covers only 1.24% of the European territory, the extent of CLC-Change is roughly equal to the size of Lithuania. The total number of CLC-Change polygons is 358969. The three largest change types (concerning area as well as number of polygons) are all forestry changes.

Table 7 CORINE Land Cover statistics for CLC2006 raster data (V15, without class 523)

CLC code	Short class name	No. of polygons	area (km^2) level-3	area (km^2) level-1	% of total
111	Continuous urban fabric	6041	6727	214938	3.75
112	Discontinuous urban fabric	140338	153544		
121	Industrial or commercial units	31193	23710		
122	Road and rail networks	3224	2568		
123	Port areas	1130	1147		
124	Airports	1586	3379		
131	Mineral extraction sites	10306	7213		
132	Dump sites	1518	1120		
133	Construction sites	2832	1899		
141	Green urban areas	4650	3099		
142	Sport and leisure facilities	15131	10533		
211	Non-irrigated arable land	180133	1216467	2441791	42.65
212	Permanently irrigated land	9666	81841		
213	Rice fields	969	8074		
221	Vineyards	20314	40441		
222	Fruit trees and berry plantations	17185	28822		
223	Olive groves	11589	37870		
231	Pastures	184484	395863		
241	Annual crops with permanent crops	5492	9563		
242	Complex cultivation patterns	184242	302529		
243	Agriculture land with significant natural vegetation	242572	287390		
244	Agro-forestry areas	6286	32930		
311	Broad-leaved forest	195289	549314	2784970	48.64
312	Coniferous forest	175634	741147		
313	Mixed forest	182630	342001		
321	Natural grassland	67968	208283		
322	Moors and heathland	42309	163149		
323	Sclerophyllous vegetation	27319	86846		
324	Transitional woodland-scrub	255631	338577		
331	Beaches, dunes, sands	4204	8081		
332	Bare rocks	17040	90667		
333	Sparsely vegetated areas	56825	239253		
334	Burnt areas	584	1169		
335	Glaciers and perpetual snow	1711	16484		
411	Inland marshes	9444	14203	135021	2.36
412	Peat bogs	58575	104624		
421	Salt marshes	1675	3318		
422	Salines	200	632		
423	Intertidal flats	2092	12244		
511	Water courses	2109	13584	148520	2.59
512	Water bodies	49931	126495		
521	Coastal lagoons	487	5818		
522	Estuaries	261	2625		
523	Sea and ocean	0	0.00		
Total		2232799	5725240	5725240	100.00

Table 8 Figures characterising the CLC-Change Europe database (V15)

Total changed area:	70 824 km2
Part of Europe (without sea and ocean) that changed between years 2000 and 2006	1.24 %
Number of change polygons	358 969
Number of change types occurring	935
Number of change types altogether providing 90% of total change area	73
Number of sporadic change types (each giving less than 0.1% of total change area)	853
Change types providing 50% of total change area	312-324, 24547 km2 324-312, 6311 km2 311-324, 5729 km2
Largest change in Artificial surfaces classes	133-112, 2492 polygons
Largest change in Agriculture classes	231-211, 3210 polygons
Largest change in Forests and semi-natural classes	312-324, 146596 polygons
Largest change in Wetlands and Water classes	412-324 1017 polygons
Country with the largest amount of changes in CLC-Change(2000,2006)	Portugal (1.4 % / year)

5.3 CHANGE TYPES COVERING THE LARGEST AREA

The change types that occurred between 2000 and 2006 in 38 countries are rather diverse. Almost half of the theoretically possible change types (44 x 43) actually appeared. However, the majority of change types is sporadic in appearance, i.e. a few polygons exist covering small total change area. Forestry-related changes predominate concerning both change area and number of change polygons. Three of the change types together cover over 50% of the total change area in Europe (Table 8). These are (1) felling/clear-cutting of coniferous forests (312-324), (2) growth of coniferous forests (324-312) and (3) clear-cutting of deciduous forests (311-324). Concerning number of change polygons results are very similar. Change types with the largest polygon number are 312-324, followed by 324-312 and 311-324. Most frequent change types on level-1: construction of residential areas has completed (133-112), pastures / set-aside land turned to arable land, clearcutting of coniferous forests (312-324) and afforestation on peatland (412-324).

The most important change types are grouped according to level-1 classes. Four tables below summarise the most important processes mapped by CLC2006 (Tables 9-12). The largest change types, providing 90% of the total change area are listed in these tables.

Changes dominating the Artificial surfaces class are mostly related to construction / re-construction or infrastructure development (Table 9).

Table 9 Most important changes related to the Artificial surfaces class in Europe (V15)

Change type	Description	Change polygons	Change, % of total
131-231	Reclamation of mineral extraction sites with grass	235	0.11
131-324	Reclamation of mineral extraction sites with plantation of trees (Fig. 23)	405	0.23
131-512	Mineral extraction site transformed to water body	191	0.10
133-112	Construction finished and turned to discontinuous urban area (Fig. 22)	2492	0.71
133-121	Construction finished and turned to industrial & commercial area	1365	0.45
133-122	Construction finished and turned to road and rail network	370	0.23

Changes dominating the Agriculture classes are mostly related to loss of arable land because of urban sprawl and internal changes between agriculture classes. Afforestation on agriculture land is also remarkable (Table 10).

Table 10 Most important changes related to the Agriculture class in Europe (V15)

Change type	Description	Change polygons	Change, % of total
211-112	Converting arable land to discontinuous urban area (Fig. 27)	5983	0.98
211-121	Converting arable land to industrial & commercial area	4031	0.81
211-122	Converting arable land to road and rail network	690	0.20
211-131	Converting arable land to mineral extraction site	1980	0.48
211-133	Converting arable land to construction site	3528	1.05
211-142	Converting arable land to sport and recreation	522	0.21
211-212	Converting non-irrigated arable land to irrigated arable land	1089	0.99
211-221	Changing arable land to vineyards	1439	0.59
211-222	Changing arable land to orchard / fruit plantation	1531	0.58
211-223	Changing arable land to olive plantation	1573	0.79
211-231	Changing arable land to pasture / set-aside land (Fig. 24)	2583	1.26
211-242	Non-irrigated arable land converted to agricultural mosaic	292	0.26
211-324	Afforestation on non-irrigated arable land (Fig. 26)	3182	1.07
211-512	New water body on non-irrigated arable land	800	0.20
212-222	Changing irrigated arable land to orchard / fruit plantation	247	0.14
221-211	Converting vineyards to non-irrigated arable land	284	0.12
222-211	Converting fruit plantation to non-irrigated arable land	547	0.21
231-121	Converting pasture / set-aside to industrial & commercial area	968	0.18
231-112	Converting pasture / set-aside to discontinuous urban area	2399	0.36
231-131	Converting pasture to mineral extraction site	612	0.12
231-133	Converting pasture / set-aside to construction site	1353	0.31
231-211	Changing pasture/set-aside to arable land (Fig.25)	3210	1.30

231-242	Pasture converted to agricultural mosaic	266	0.20
231-324	New afforestation on pasture / set-aside land	1993	0.58
242-112	Converting agricultural mosaic to discontinuous urban area	3386	0.72
242-121	Converting agricultural mosaic to industrial & commercial area	1284	0.23
242-133	Converting agricultural mosaic to construction site	1457	0.31
242-223	Changing agricultural mosaic to olive plantation	152	0.10
243-112	Converting agricultural mosaic with natural vegetation to discontinuous urban area	847	0.20
243-133	Converting agricultural mosaic with natural vegetation to construction site	527	0,11
243-324	Afforestation on agricultural mosaic with natural vegetation	755	0.27
244-324	Afforestation or abandonment of agro-forestry areas (appears in ES and PT)	335	0.20

Changes in the Forest and semi-natural class are rather diverse. In addition to the largest changes concerning area (forests clearcut, forest growth) forest / grassland conversion to agriculture, burning of forests and shrubs, afforestation, opening of new mineral extraction sites, regeneration after fire, melting of glaciers etc. also occurred (Table 11).

Table 11 Most important changes in the Forests and seminatural areas class in Europe (V15)

Change type	Description	Change polygons	Change, % of total
311-244	Deciduous forest turned to agro-forestry (cleaning) (appears in ES, PT)	245	0.16
311-324	Damage or clear-cutting of deciduous forest	24633	8.09
311-334	Forest fires (deciduous)	205	0.18
312-131	Converting coniferous forest to mineral extraction	820	0.14
312-133	Converting coniferous forest to construction site	558	0.11
312-211	Coniferous forest converted to arable land	1027	0.11
312-323	Coniferous forest turned to sclerophyllous vegetation	79	0.15
312-324	Damage or clear-cutting coniferous forest (Fig. 28)	146596	34.66
312-334	Forest fires (coniferous)	321	0.48
313-324	Damage or clear-cutting mixed forest	21625	4.44
313-334	Forest fires (mixed forest)	227	0.18
321-133	Natural grassland turned to construction area	350	0.11
321-211	Natural grassland converted to arable land	319	0.26
321-324	Afforestation / natural succession on natural grassland	652	0.46
322-324	Afforestation on moors and heathland	369	0.16
323-133	Sclerophyllous vegetation turned to construction site	386	0.13
323-231	Sclerophyllous vegetation turned to pasture	241	0.13
323-324	Afforestation on sclerophyllous vegetation	693	0.80
323-334	Burnt sclerophyllous vegetation	148	0.25
324-131	Converting transitional woodland to mineral extraction site	687	0.15

324-211	Transitional woodland converted to arable land	1770	0.24
324-244	Transitional woodland/shrub changed to agro-forestry (cleaning) (appears in ES, PT)	428	0.33
324-311	Growth of deciduous forest	12327	4.49
324-312	Growth of coniferous forest (Fig. 29)	34719	8.91
324-313	Growth of mixed forest	19491	4.07
324-323	Transitional woodland/shrub changed to sclerophyllous vegetation	65	0.13
324-334	Burnt shrubs	428	0.34
331-511	Gravel / sand changed to river (unregulated, meandering rivers)	118	0.22
333-324	Sparsely vegetated area became transitional woodland shrub (afforestation)	140	0.12
334-323	Natural re-colonisation after fire (no forest regeneration / re-plantation) (Mediterranean)	91	0.41
334-324	Partial forest regeneration or reforestation after fire (Fig. 30)	630	1.44
335-332	Melting of glaciers (Fig. 31)	589	0.33

Wetlands have two dominating changes, peatland turns to arable land and afforestation on peatland. Water classes are rather stable, few changes have occurred only (Table 12).

Table 12 Most important changes in Wetlands and Water in Europe (V15)

Change type	Description	Change polygons	Change, % of total
412-211	Peatland turned to arable land (Fig. 32)	949	0.29
412-324	Peatland turned to transitional woodland shrub, afforestation	1017	0.44
511-331	River changed to gravel / sand (unregulated, meandering rivers) (Fig. 33)	175	0.21

In the following pages some of the important change types are illustrated by means of InterCheck screen shots made during the verification missions. The image on the left is IMAGE2000 with revised CLC2000 layer on it (usually yellow), while the image on the right is IMAGE2006 with the CLC2000 (yellow) and change polygon(s) (usually magenta).

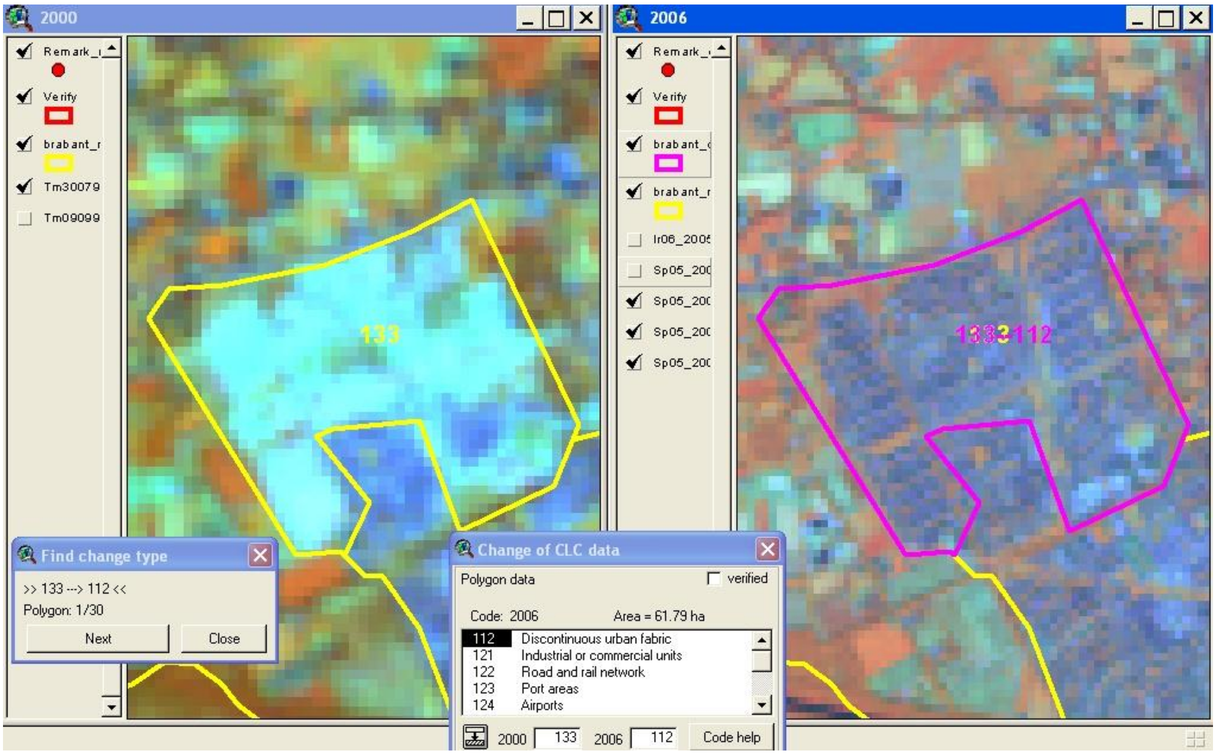


Figure 22 Change 133-112 means: construction site turned to discontinuous urban area. There are 2430 such polygons in the European CLC-Change database. Note the colour and structure difference between construction and residential areas (example from the Netherlands).

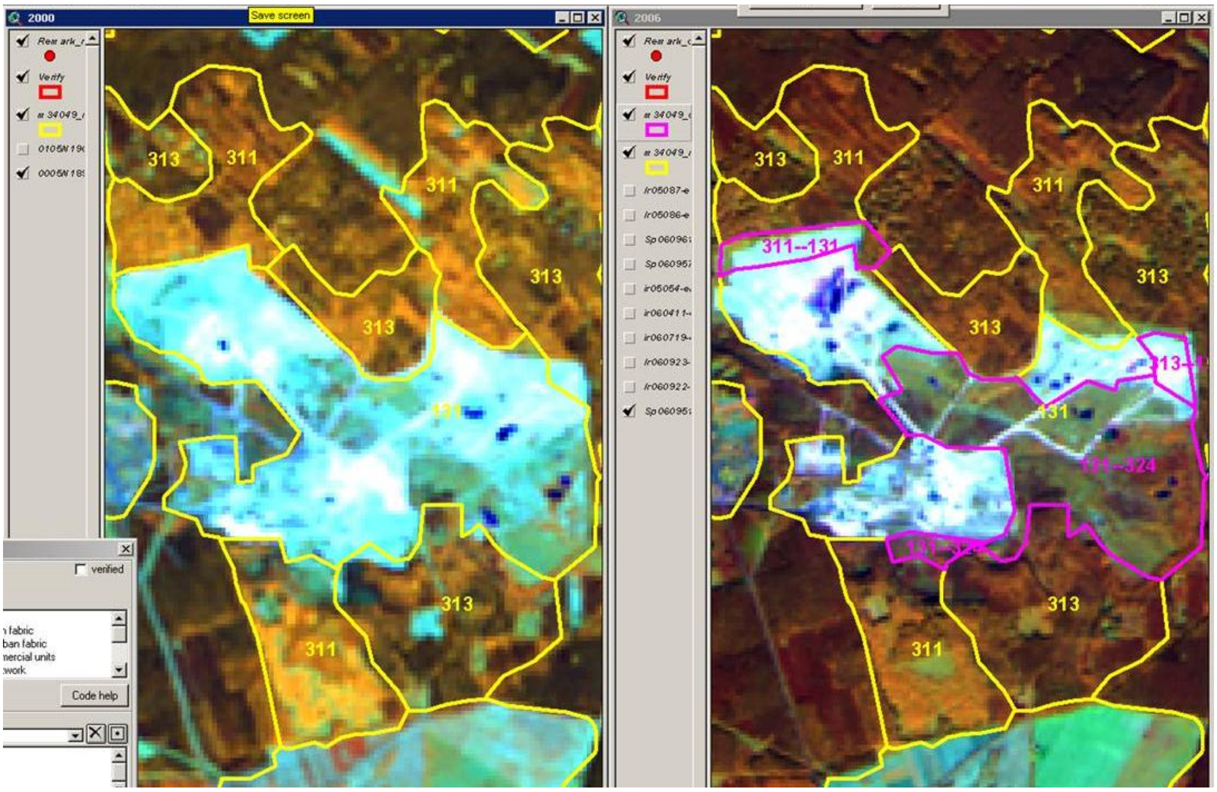


Figure 23 Change 131-324 means: mineral extraction site reclaimed by forest plantation. There are 405 such polygons in the European CLC-Change database (example from Poland).

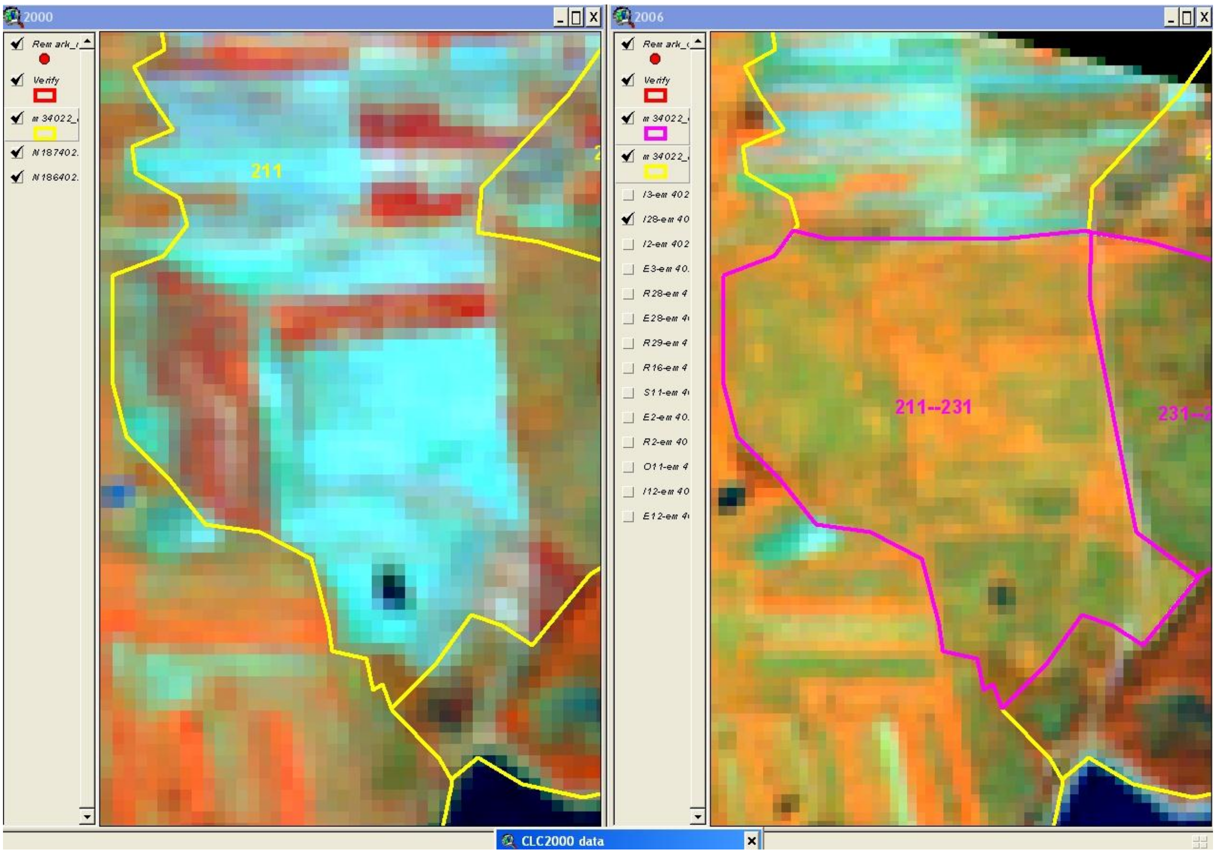


Figure 24 Change 211-231 means: arable land turned to pasture or set-aside land. There are 2584 such polygons in the European CLC-Change database. Note the disappearance of field structure from 2000 to 2006 (example from Poland).

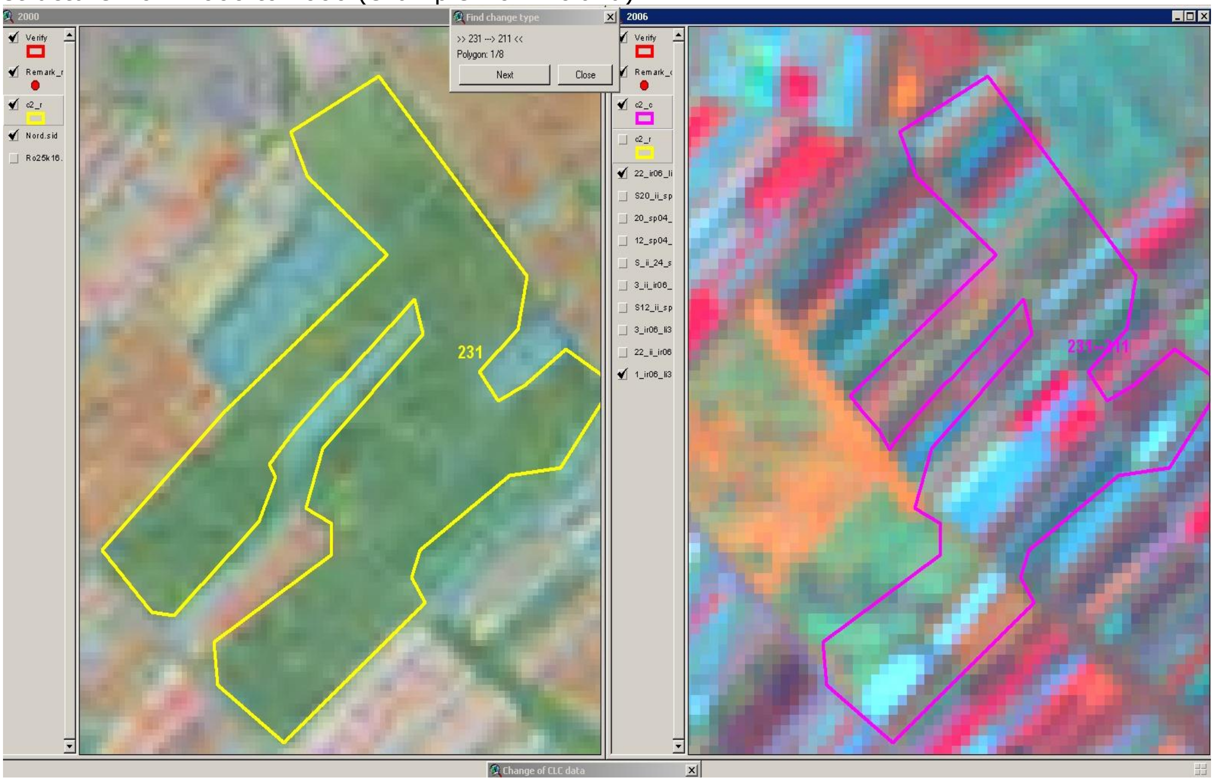


Figure 25 Change 231-211 means: pasture or set-aside land turned to arable land. There are 3215 such polygons in the European CLC-Change database. Note the fields with different colours (i.e. different crops) in 2006, compared with the single colour in 2000 (example from Romania).

Figure 26 Change 211-324 means: afforestation on arable land. There are 3181 such polygons in the European CLC-Change database (example from Hungary).

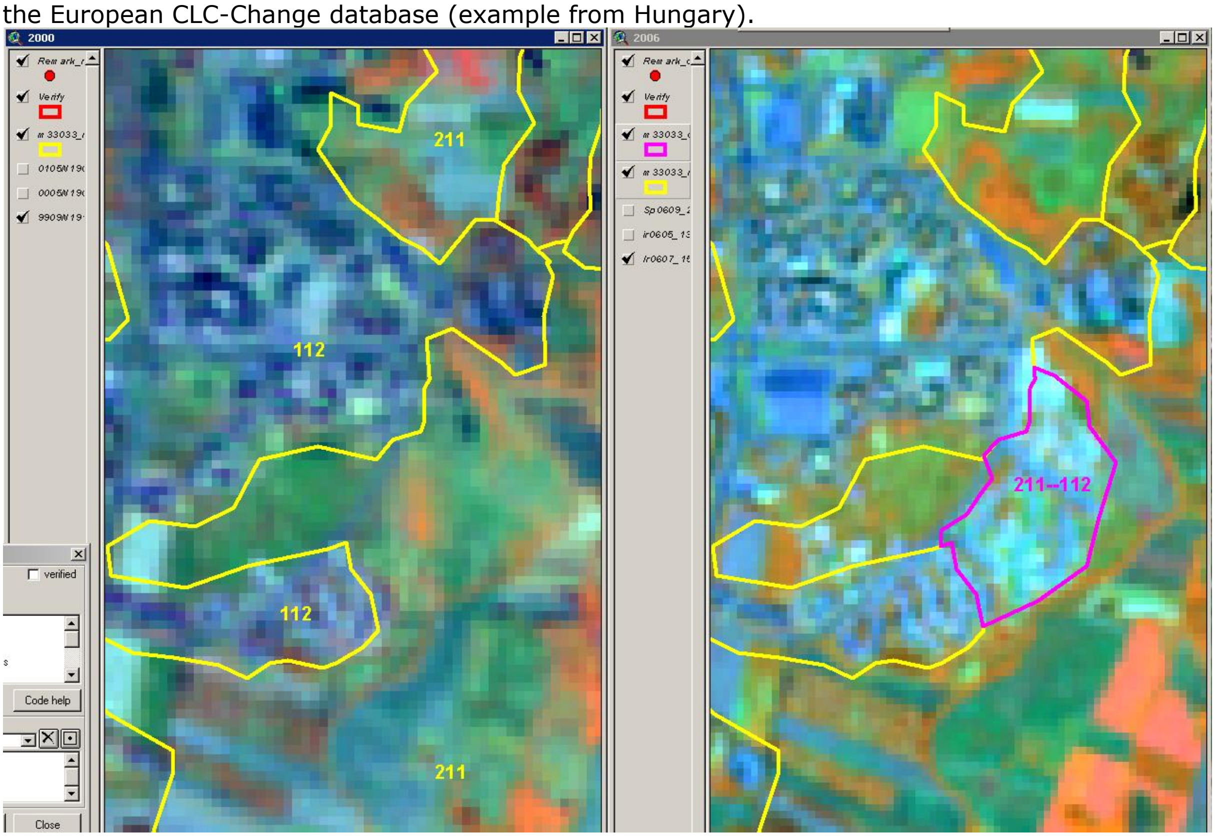


Figure 27 Change 211-112 means: arable land changed to built-up area, i.e. urban sprawl. There are 5802 such polygons in the European CLC-Change database. See the field structure in 2000, which has changed to a textured residential area (example from Poland).

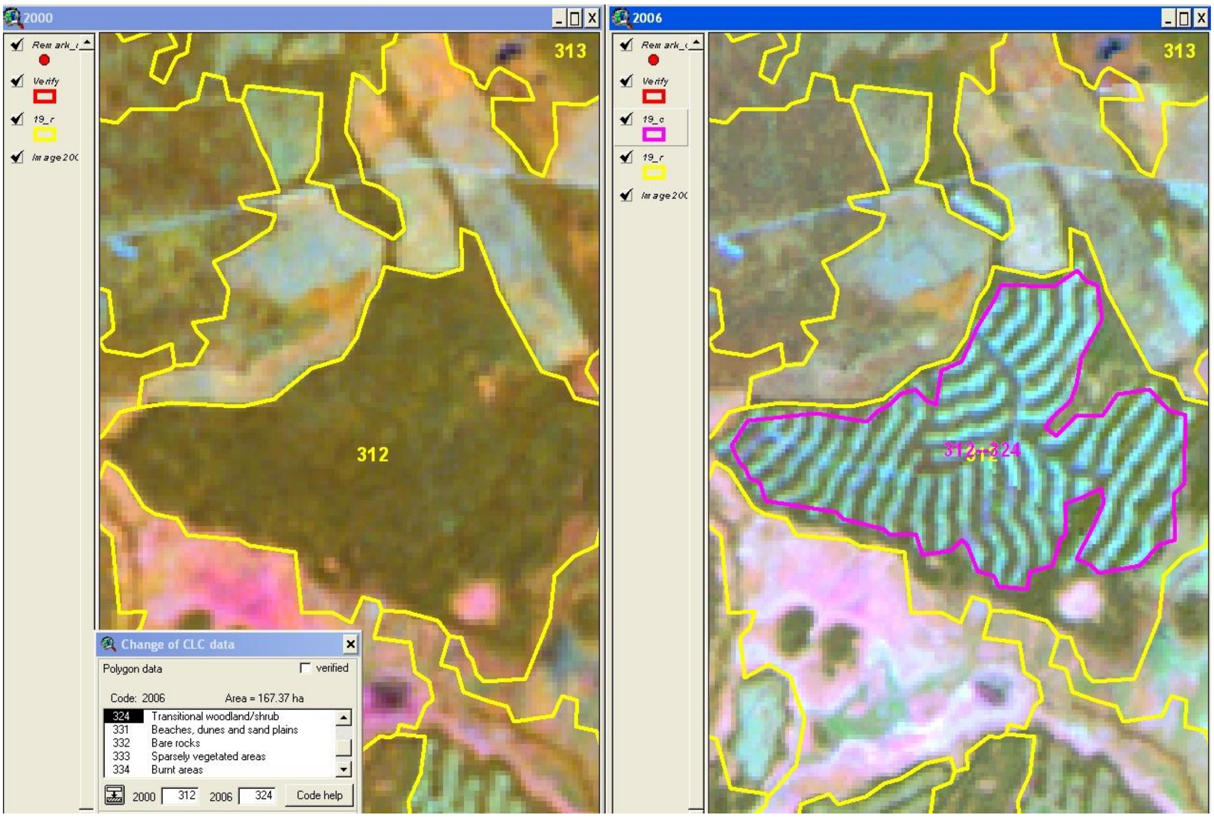


Figure 28 Change 312-324 means: felling of coniferous forests. This is the change type with largest area and polygon number. There are 144012 such polygons in the European CLC-Change database. The stripped pattern is 1 line felling, 1 line forest (example from Finland).

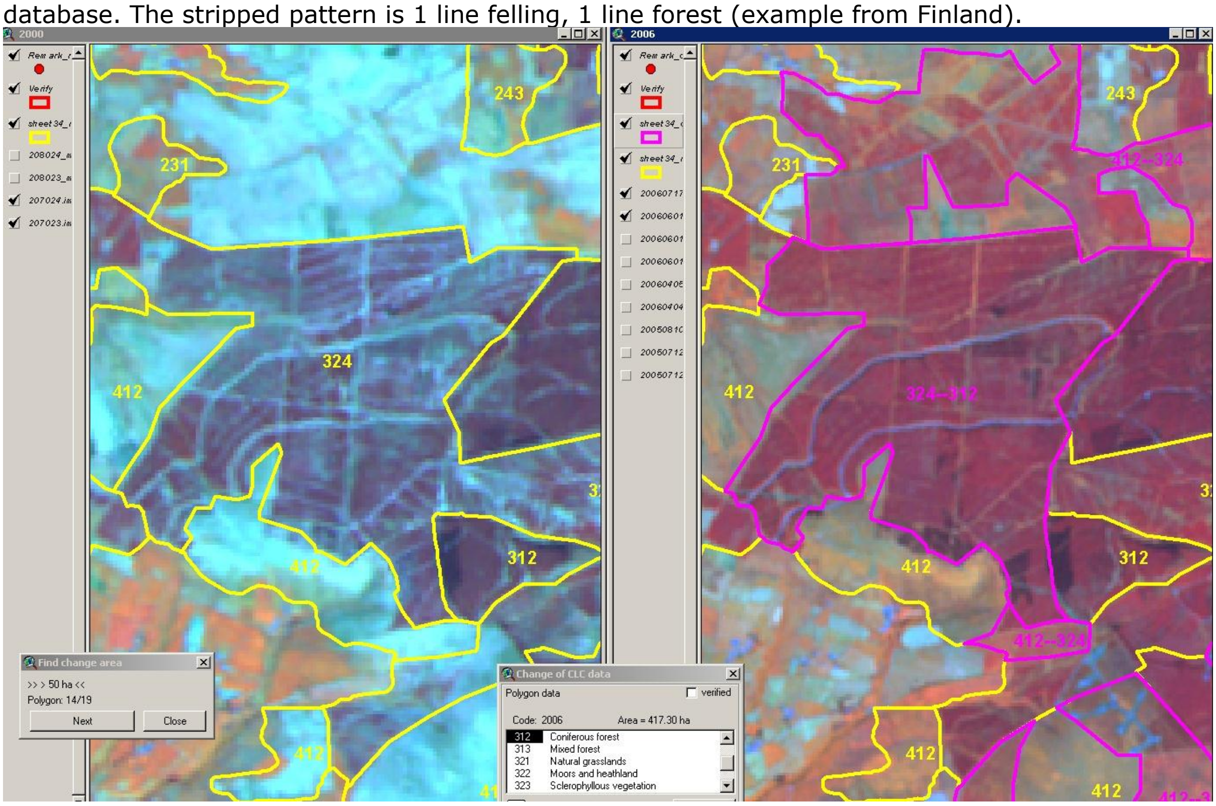


Figure 29 Change 324-312 means: change from transitional woodland to coniferous forest, i.e. forests growth. There are 33335 such polygons in the European CLC-Change database. Forest growth might be underestimated in CLC (see Ch. 5.4, Fig.42) Note that the colour of 324 is different from neighbouring forest in 2000, while became the same in 2006 (example from Ireland).

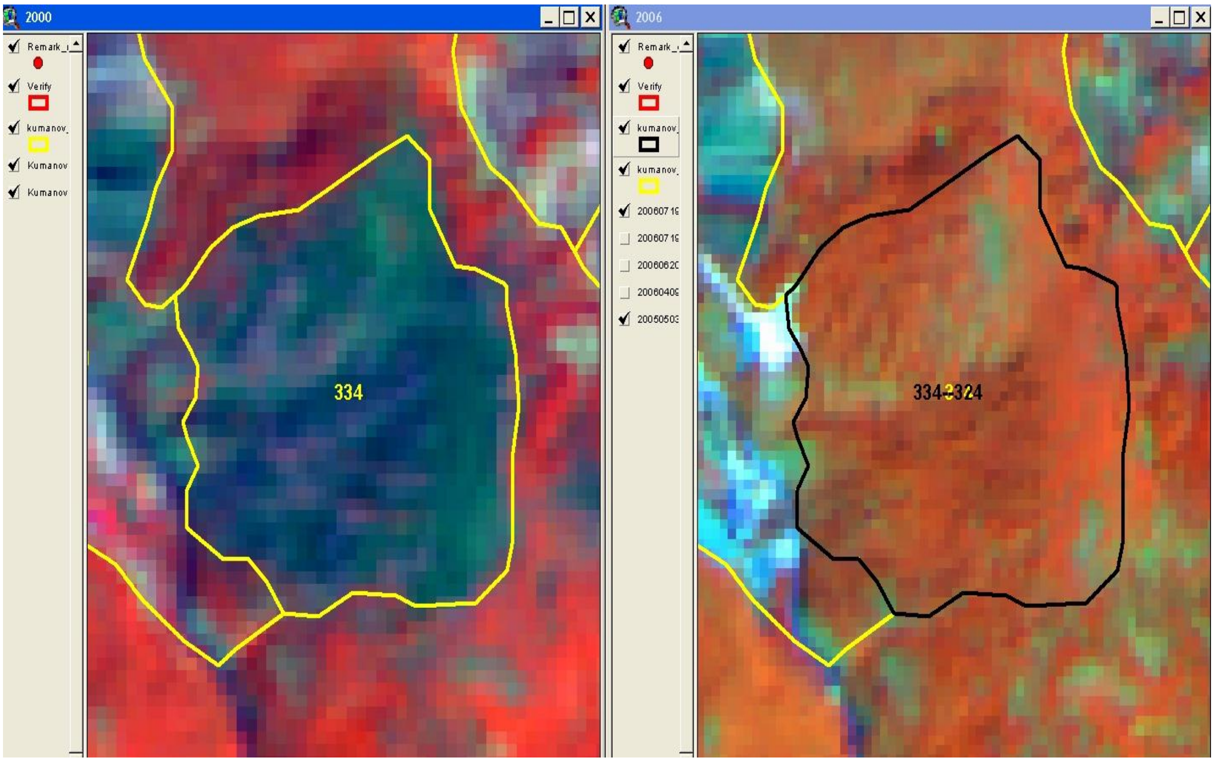


Figure 30 Change 334-324 means: burnt area has changed to transitional woodland following natural regeneration or artificial reforestation. There are 630 such polygons in the European CLC-Change database. Note the dark (burnt) area in 2000 became similar to neighbour forest (example from Kosovo).

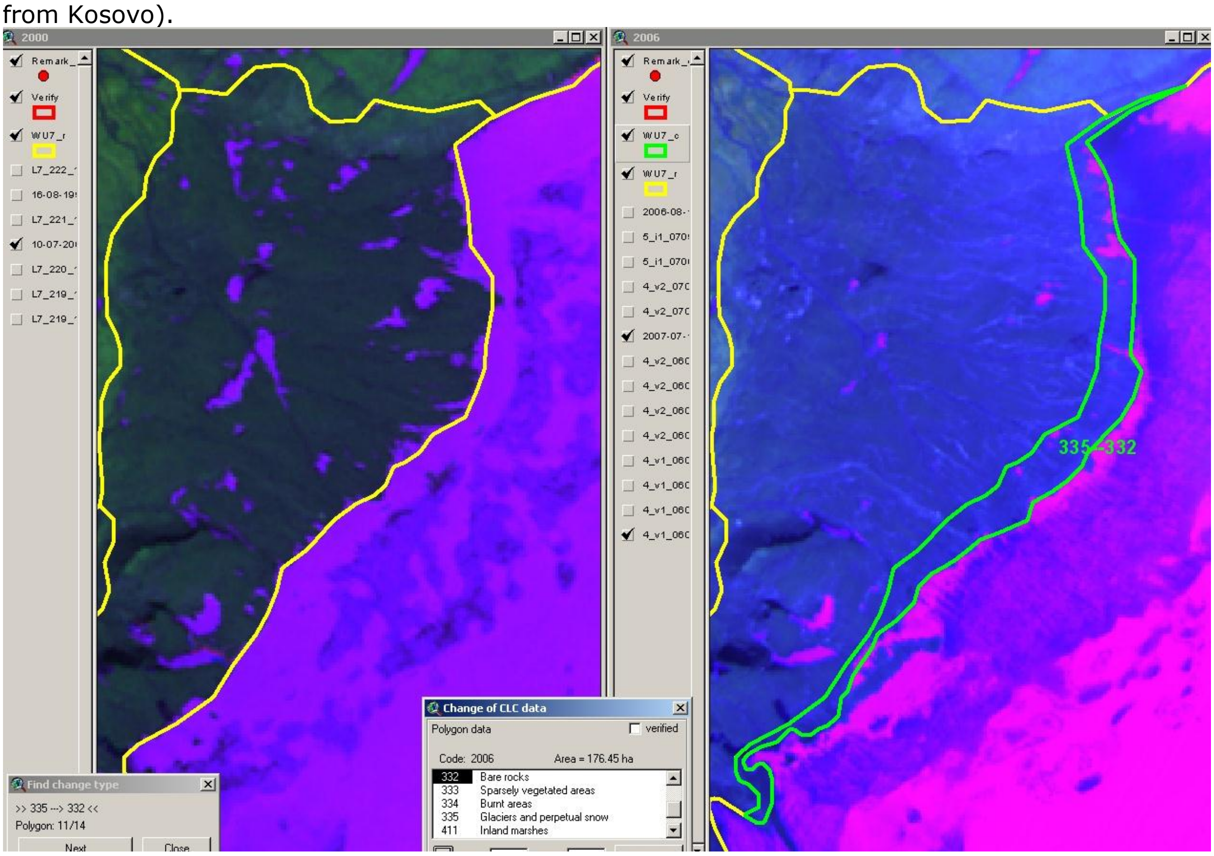


Figure 31 Change 335-332 means: glaciers changed to bare rock, i.e. melting of glaciers. There are 490 such polygons in the European CLC-Change database. The narrow, elongated area became bare rock (bluish), because melting of the ice (magenta colour) (example from Iceland).

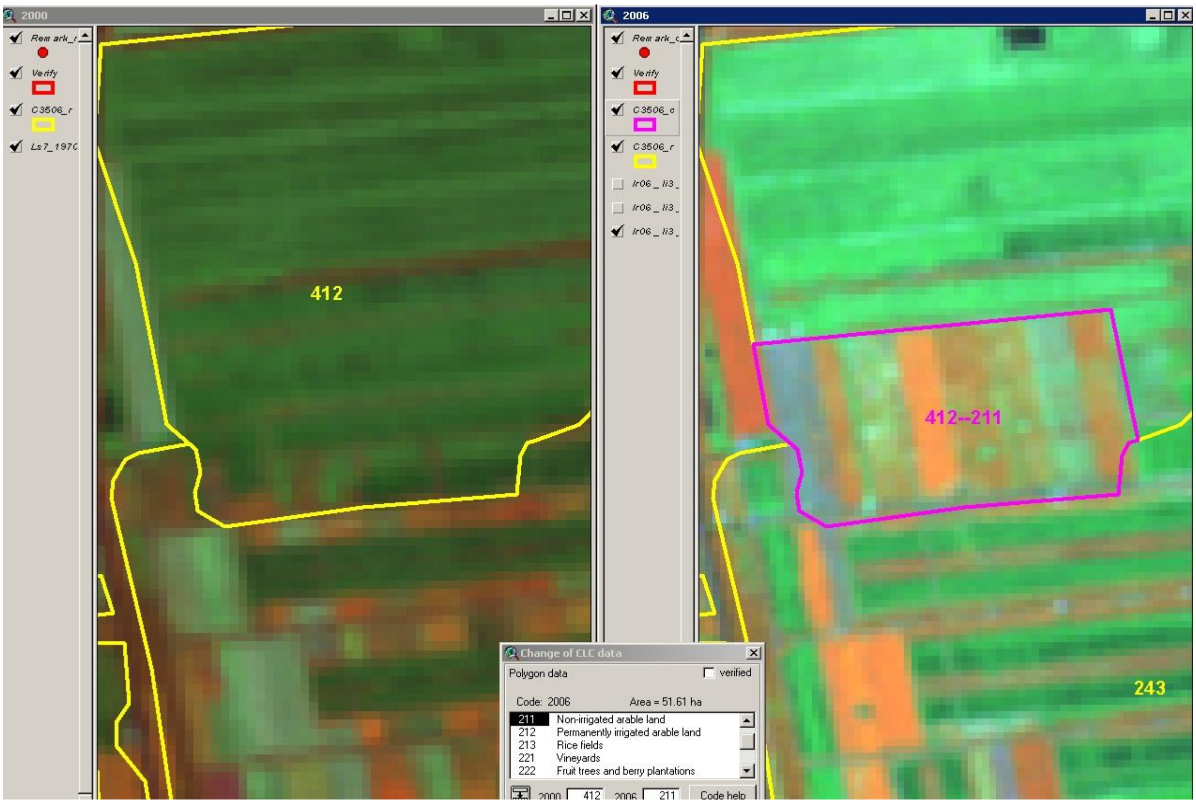


Figure 32 Change 412-211 means: peatland turned to arable land. There are 949 such polygons in the European CLC-Change database. In 2000 the peat is under exploitation. By 2006 part of it was turned to arable land (see the parcels) (example from Germany).

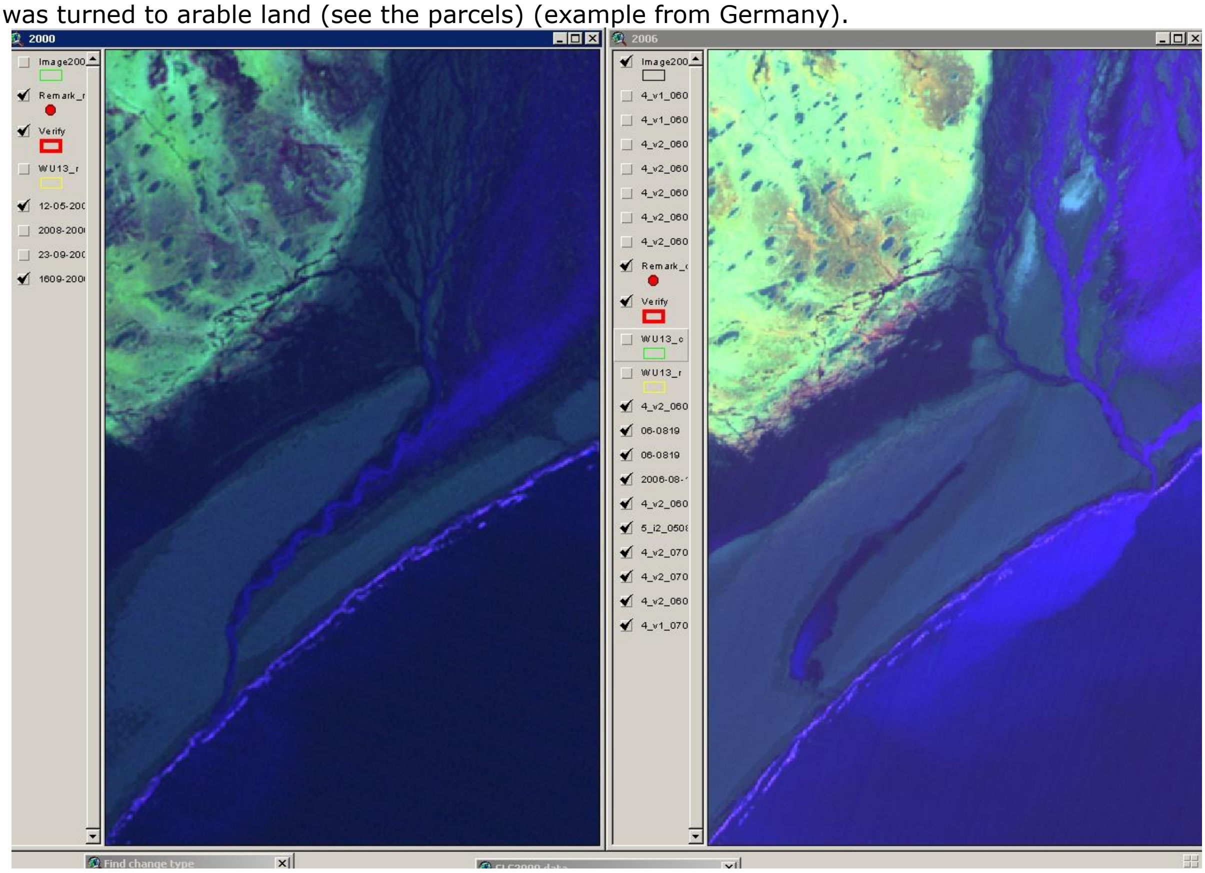


Figure 33 Illustration of the change 511-331: part of an unregulated river turned to sand / gravel. There are 175 such polygons in the European CLC-Change database. The river has changed its direction between 2000 and 2006 and flows directly to the ocean. Light blue means high sediment content of seawater (example from Iceland).

5.4 COMPARING COUNTRIES BY MEANS OF LAND COVER FLOWS

A simple evaluation of CLC changes based on Land Cover Flows (LCF) is presented below. Primarily Land Cover Flows [20] are used to simplify the demonstration of existing great number of change types. The graphs, comparing countries, shown in the next few pages are examples of the many "indicators" that can be calculated using CLC data. Two balance-type indicators are also shown for forests. These are not LCF-type representations of CLC data.

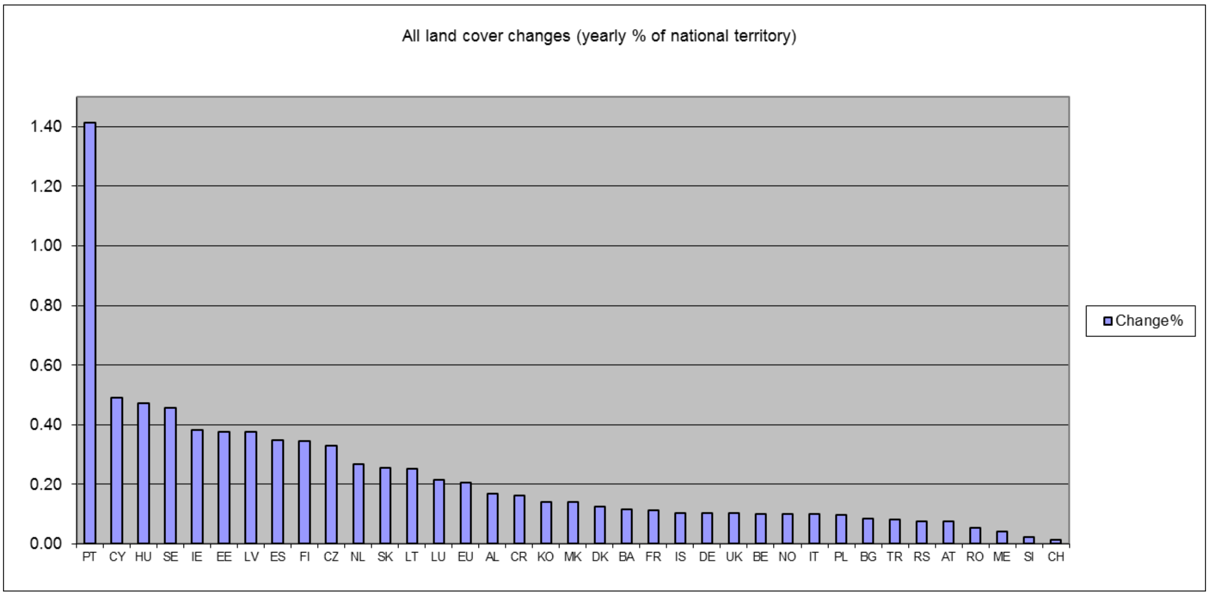


Figure 34 Comparison of total land cover changes in Europe provided by CLC-Change$_{2000\text{-}2006}$ (V15)

Fig. 34 compares European countries regarding CLC dynamics. Sum of the areas of land cover changes (LCC) has been normalised by the area of the country and by the number of years elapsed between CLC2000 and CLC2006. This time span is usually 6 years, but in case of Albania it is 11 years, F.Y.R. Macedonia 10 years and Bosnia and Herzegovina 8 years. The reason is that these countries did not participate in CLC2000, and their CLC1990 data (created in the late 1990's) were used for mapping changes. In case of Spain the time span is 5 years, because Spain worked on its own SPOT-5 imagery taken in 2005.

PT is the country having by far the highest CLC dynamics; land cover change rate exceeds 1.4 %/year between 2000 and 2006. This is explained by several factors: significant infrastructure developments (including the very large Alqueva water reservoir); changes in agriculture (abandonment of farms, internal changes in agriculture and emerging new agricultural areas); lots of forest fires, forest felling, forest growth and afforestation /reforestation. Other countries' dynamics is far below this value. Yearly LCC is gradually decreasing from the value of 0.5 %/year (CY, HU, SE) towards countries with low LCC (around 0.01%/year: BG, TR, RS, AT, RO, ME, SI, CH, MT), which means rather stable LC at the resolution of CLC. The average yearly LCC value in Europe is 0.21%.

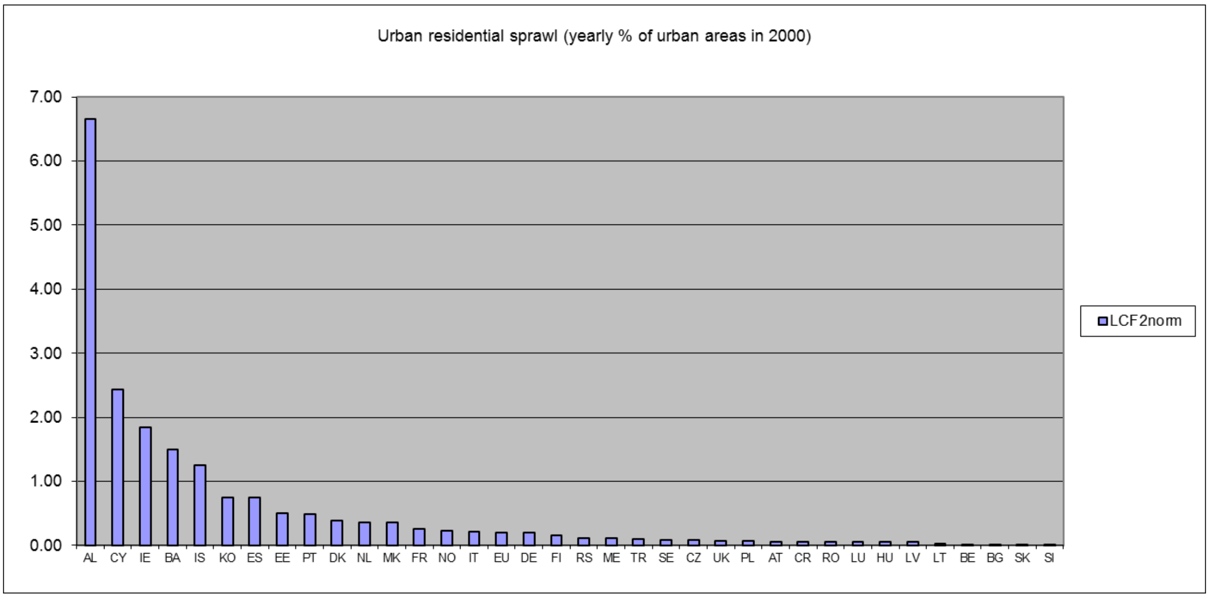


Figure 35 Comparison of residential sprawl in Europe provided by CLC-Change$_{2000\text{-}2006}$ (V15)

Fig. 35 compares areas of urban sprawl, as mapped by CLC, divided by the total urban area in 2000 and normalised by the time elapsed between CLC2000 and CLC2006. It is the highest in countries with (1) economic / touristic boom between 2000 and 2006, such as CY, IE, IS, ES and (2) in countries having a transitional political period behind, like AL, BA, KO. The extreme large value in AL is, at least in part the result of the underestimation of built-up in previous CLC (CLC1990 in this case), and underlines the need to save the corrected previous (CLC2000) inventory.

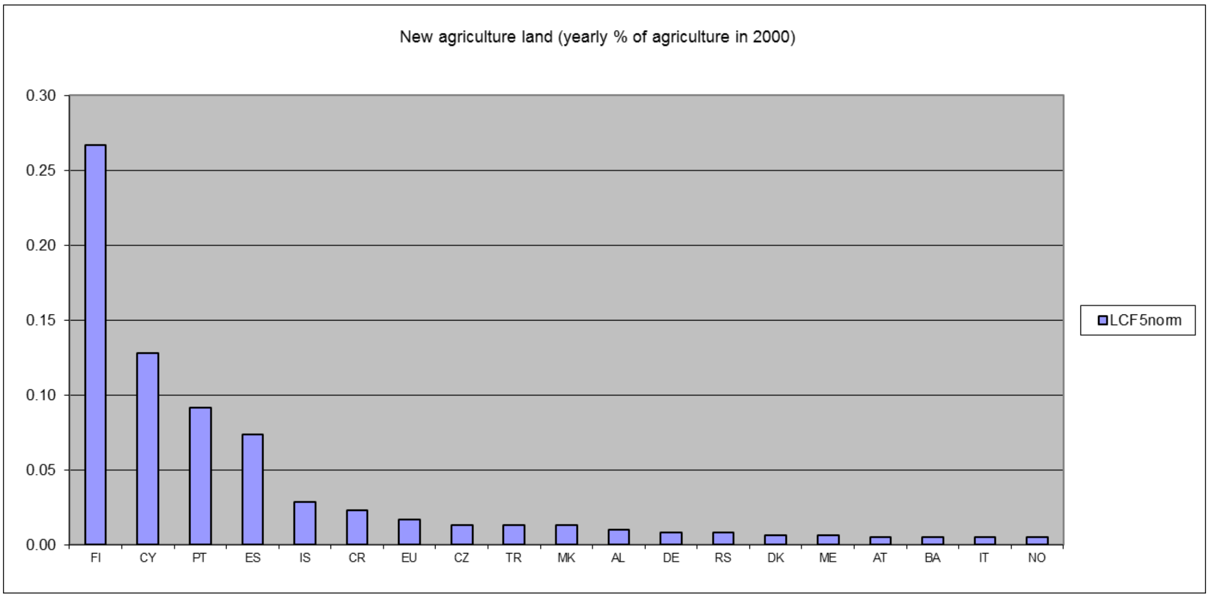


Figure 36 New agriculture land in Europe, provided by CLC-Change$_{2000\text{-}2006}$ (V15)

Fig. 36 shows areas of new agricultural land in Europe, as mapped by CLC, divided by the total agricultural area in 2000 and normalised by the time elapsed between CLC2000 and CLC2006. In most European countries the size of agricultural areas has been stabilized or decreasing over past years. Countries with increasing agricultural land (FI, CY, PT, ES) all have difficult natural conditions for agriculture. The increase of agricultural land might indicate the increase of profitability of agricultural production. In Iceland, where agricultural area is very small, a relatively small increase in agricultural territory was enough to cause a significant percentage increase.

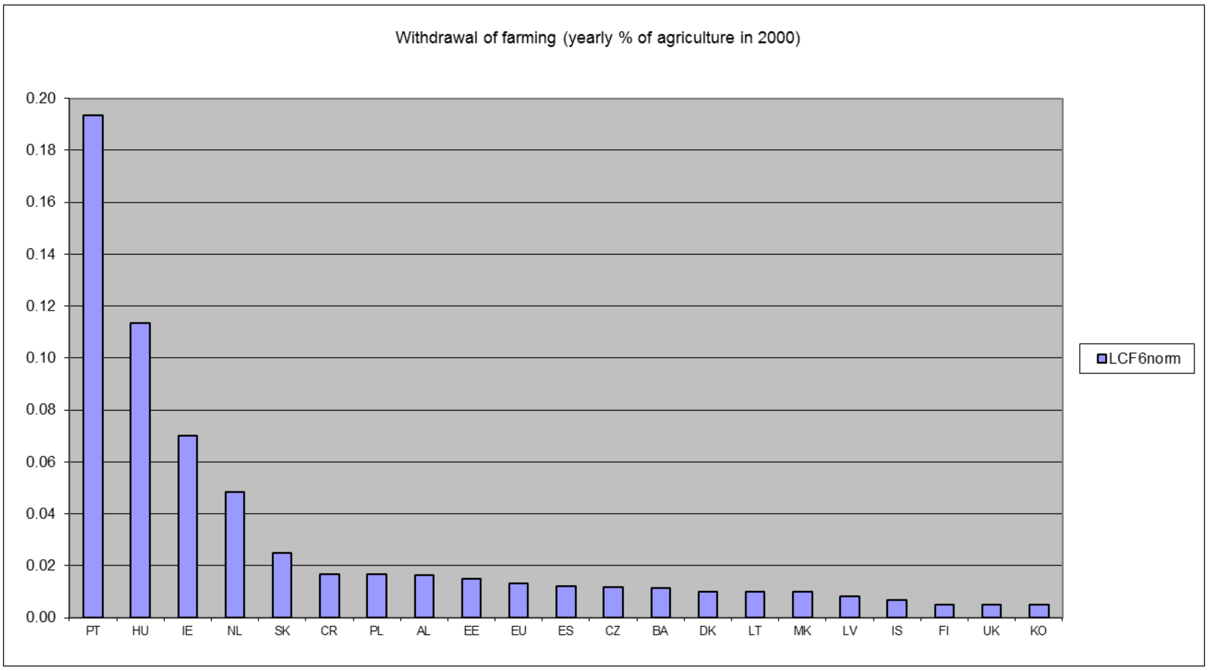


Figure 37 Withdrawal of farming in Europe, as indicated by CLC-Change$_{2000-2006}$ (V15)

Fig. 37 shows areas where farming withdrew (as mapped by CLC), divided by the total agricultural area in 2000 and normalised by the time elapsed between CLC2000 and CLC2006. The relatively low percentages mean rather large areas due to the large share of agriculture in the area of most European countries. A common driver in most countries might be the decrease of rural population, because of the low profitability of agricultural production. The three leading countries (PT, HU, IE) have "historically" high rural population. In the Netherlands "artificial nature" areas replace farming.

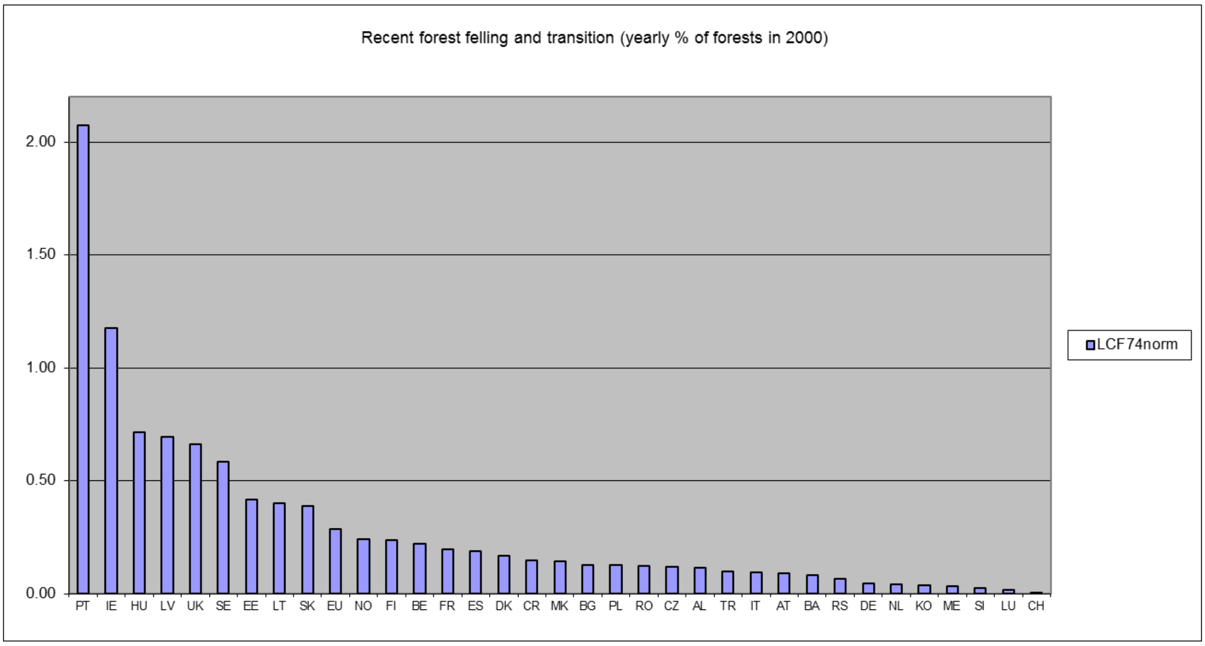


Figure 38 Forest felling and transition in Europe, as indicated by CLC-Change$_{2000-2006}$ (V15)

Fig. 38 shows areas of forest felling and forest damage (e.g. wind brake) in Europe, as mapped by CLC, divided by the total forest area in 2000 and normalised by the time elapsed between CLC2000 and CLC2006. Forest felling rate is by far the largest in PT, followed by IE, HU, LV and SE. In all of these countries forest growth is also important (see Fig. 39), which compensates for the loss of woods.

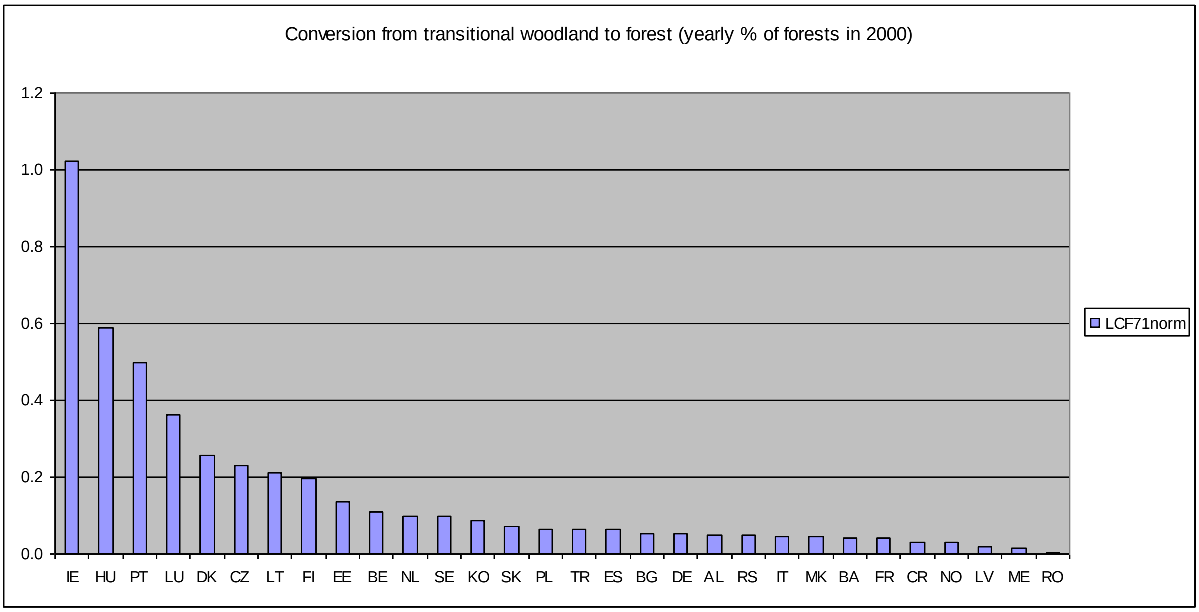


Figure 39 Conversion of transitional woodland to forest (forest growth) in Europe, as indicated by CLC-Change$_{2000\text{-}2006}$ (V15)

Fig. 39 shows areas of conversion of transition woodland to forests in Europe, as mapped by CLC, divided by the total forest area in 2000 and normalised by the time elapsed between CLC2000 and CLC2006. The rate of forest growth is the largest mostly in the same countries as for forest felling (Fig. 38). However, in LV and SE felling rate strongly exceeds the growth rate, while in LU there is much more growth than felling.

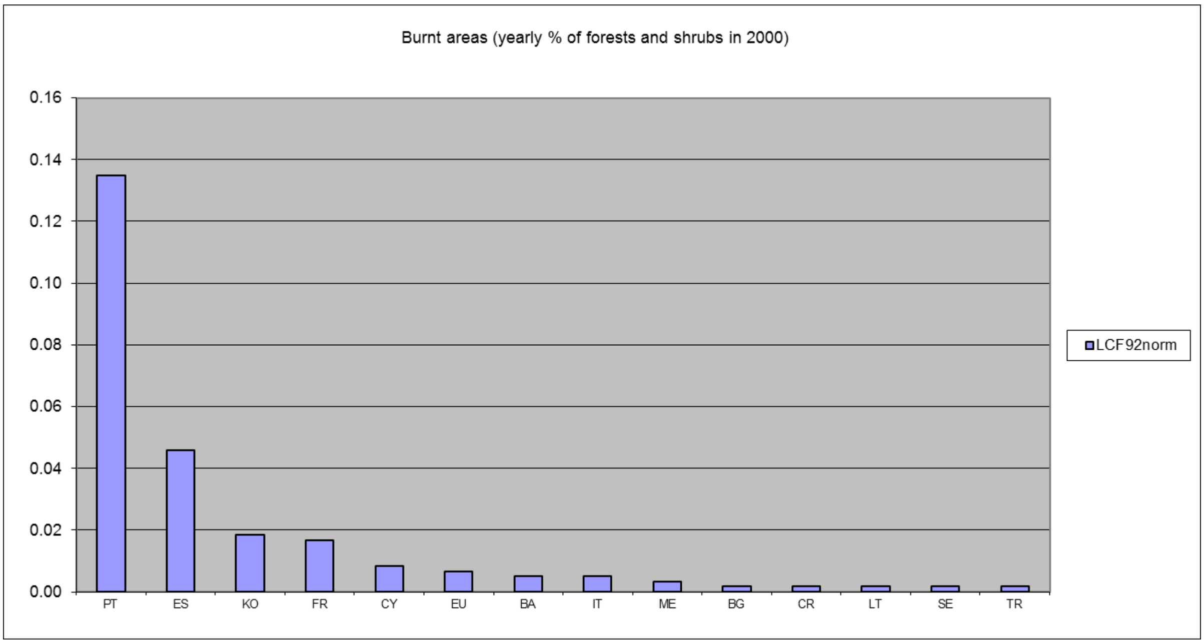


Figure 40 Burnt natural / semi-natural areas in Europe, as indicated by CLC-Change$_{2000\text{-}2006}$ (V15)

Fig. 40 shows burnt natural areas in Europe, as mapped by CLC, divided by the total flammable areas (forest, shrubs but not grassland and agriculture![4]) in 2000 and normalised by the time elapsed between CLC2000 and CLC2006. By no surprise burnt natural areas occur mostly in South Europe (PT, ES, FR, CY). Burnt areas however also appear in the Balkan (KO, BA) and Baltic (LT) countries and even in Scandinavia (SE). In

[4] The CLC burnt areas class do not include burnt grassland and agriculture only seminatural classes [8]

PT the percentage of yearly burnt area is three times more than in the country (ES) showing the second most burnt.

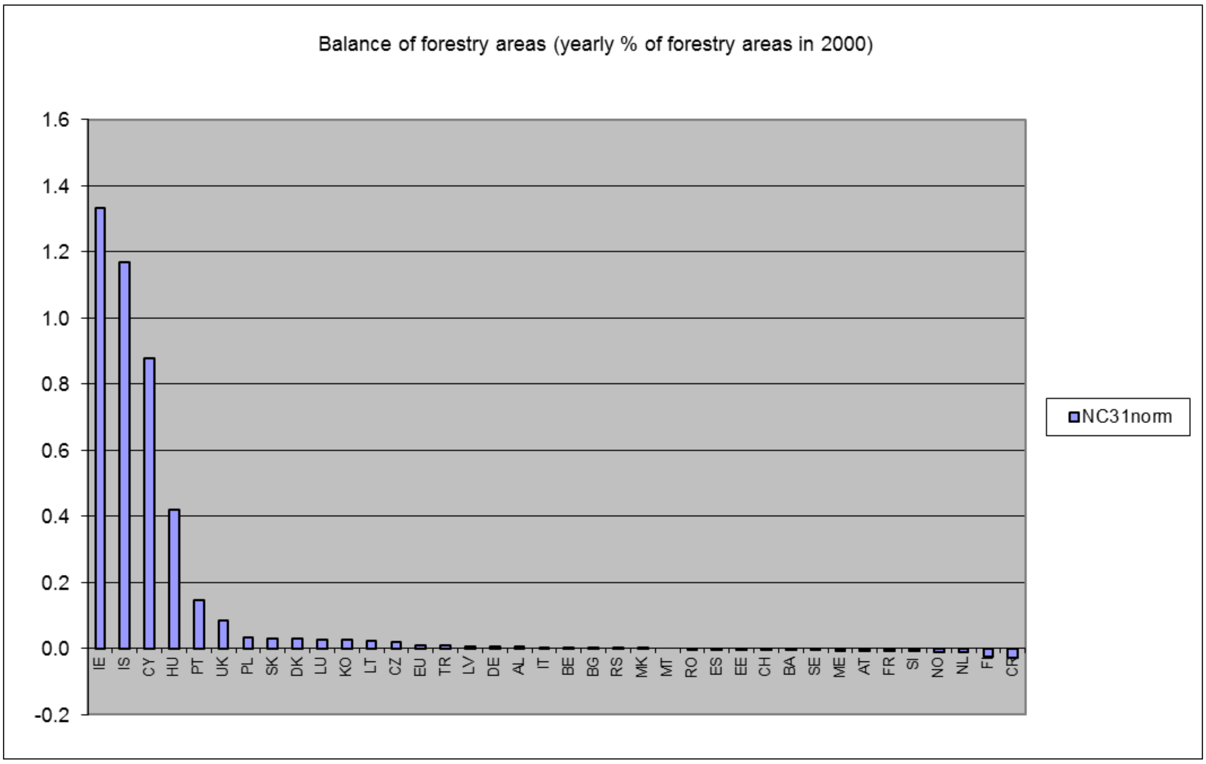


Figure 41 Balance of forestry areas in Europe as indicated by CLC-Change$_{2000\text{-}2006}$ (V15)

Fig. 41 shows the balance of forest areas in Europe, as mapped by CLC (forest areas in 2006 less forest areas in 2000), divided by the total forest area in 2000 and normalised by the time elapsed between CLC2000 and CLC2006. Forest areas mean the sum of CLC classes 311, 312, 313 and 324. In majority of countries we see a situation of area gains and losses close to equilibrium (value close to 0). Largest increase in forestry area is shown by IE, IS, CY, HU and PT. In case of IS the very small forest area grew in significant rate. Decreases are mostly explained by infrastructure development (e.g. NO, FI, CR).

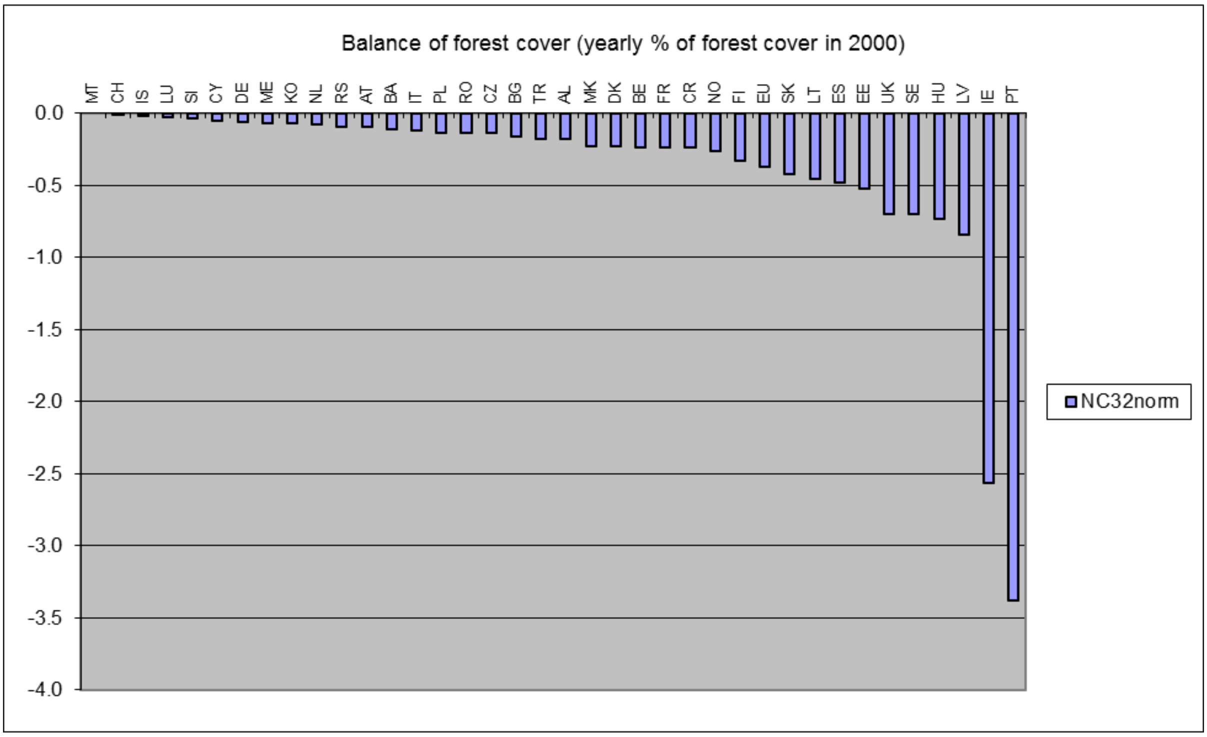


Figure 42 Balance of forest cover in Europe as indicated by CLC-Change$_{2000-2006}$ (V15)

Fig. 42 shows the balance of forest cover, as mapped by CLC (forest cover areas in 2006 less forest cover areas in 2000), divided by the total forest cover area in 2000 and normalised by the time elapsed between CLC2000 and CLC2006. Forest cover means the sum of CLC classes 311, 312 and 313, but not the 324. By surprise, a generally decreasing trend in forest cover was obtained. Largest (>0.5%) decrease is shown for PT (large burnt forests can be an explanation, see Fig. 40), IE, LV, HU, SE and EE.

As the process of decreasing forest cover in Europe is not supported by any other sources, the way of mapping of forest growth (324-31x), which is difficult to visually interpret, has to be revised in the next CLC update.

5.5 Accessibility of data

This report is based on CLC2006 Version 15 (08/2011) data. The most recent version of CLC2006 data are available, freely for any users at:

http://www.eea.europa.eu/data-and-maps/data/ds_resolveuid/T6PRZCBBN2 (vector data)

http://www.eea.europa.eu/data-and-maps/data/ds_resolveuid/SH04UZP80M (raster data)

The most recent version of CLC-Changes (vector and raster data) is available at:

http://www.eea.europa.eu/data-and-maps/data/ds_resolveuid/Q4T9TYUK84

All data are in ETRS89 LAEA (EPSG: 3035) projection.

Table 13 presents the dissemination of European CLC data by the EEA Data Service. Rights of use are explained through EEA standard re-use policy, which states that, unless otherwise indicated, re-use of content on the EEA website for commercial or non-commercial purposes is permitted free of charge, provided that the source is acknowledged: http://www.eea.europa.eu/legal/copyright. The copyright holder is the European Environment Agency.

Table 13 The European CORINE Land Cover products, distributed by EEA (V15)

Products	Type	Characteristics
CLC1990	raster	100 m and 250 m grid
CLC2000	raster	100 m and 250 m grid
CLC2006	raster	100 m and 250 m grid
CLC2000	vector	by CLC codes, 44 classes/files
CLC2006	vector	by CLC codes, 44 classes/files
CLCC(1990,2000)	vector	
CLCC(1990,2000)	raster	100 m grid
CLCC(2000,2006)	vector	
CLCC(2000,2006)	raster	100 m grid

CORINE Land Cover$_{2000\text{-}2006}$ changes (CLCC) data in raster format should be understood as:

- “Consumption” code in change areas (this means 1st code of CLC-Change polygons);
- “Formation” code in change areas (this means 2nd code of CLC-Change polygons);

CLC2006 vector data (as well as CLC2000 and CLC1990) consists of 44 separate files according to the 44 standard CLC classes.

6 VALIDATION

6.1 SAMPLING STRATEGY

According to the minutes of the Eionet meeting (23-24 April 2009) the layer of CLC-Change$_{2000\text{-}2006}$ has to be validated. The method of stratified random point sampling was selected to compile a list of locations (samples) for independent interpretation and comparison with the CLC-Change layer. This solution is considered to provide relevant information on the database quality with affordable efforts. Some of the participating countries have already completed the validation of their national project independently [22].

As seen in Ch.5, there are over 900 different level-3 change types in the European CLC-Change$_{2000\text{-}2006}$ database. It is not possible to test all of them. If the goal of the validation is to provide an overall picture about the accuracy of CLC-Change, some kind of selection or grouping of level-3 changes has to be done.

Two kinds of sampling exercises were implemented. Samples were drawn from:

- Sampling of level-1 changes. There are 25 different level-1 changes in CLC coming from the five level-1 CLC classes (Table 14). Max. 100 randomly placed sampling points were selected for each level-1 change type (i.e. 2405 samples altogether, as the smallest change type (from class 1 to class 4 (abbreviated as 1-4) included only 5 small polygons). These samples were used to estimate the commission error for CLC-Change (level-3), grouped according to level-1 change types. In this exercise the whole population of CLC-Change polygons was sampled.
- Additional samples (about 100 samples for each case) for a number of level-3 change types of special interests were selected. Land Cover Flows (LCF) [20] were used to select which of the level-3 changes are to be considered. Based on CLC-Change statistics, the largest constituents of each major LCF were identified (Table 15). In this exercise about half of all CLC-Change polygons were sampled.

Table 14 Number of CLC-Change polygons (upper figures) and percent of total area of CLC-Change types (lower figures) grouped on level 1 of the nomenclature

2000/ 2006	**1**	**2**	**3**	**4**	**5**	**Sum**
1	5 573	834	651	5	287	**7 350**
	1.81%	0.36%	0.38%	0.00%	0.15%	**2.70%**
2	34 956	16 137	7 748	124	1 870	**60 835**
	7.67%	8.33%	2.65%	0.08%	0.57%	**19.30%**
3	10 961	7 748	261 572	422	1 038	**281 741**
	2.32%	2.48%	70.92%	0.13%	0.66%	**76.51%**
4	147	1 010	1 090	11	86	**2 344**
	0.03%	0.34%	0.48%	0.06%	0.04%	**0.95%**
5	243	85	294	62	33	**717**
	0.06%	0.05%	0.34%	0.04%	0.05%	**0.55%**
Sum	**51 880**	**25 814**	**271 355**	**624**	**3 314**	**352 987**
	11.90%	**11.56%**	**74.77%**	**0.31%**	**1.47%**	**100.00%**

1: Artificial surfaces; 2: Agriculture; 3: Forests and semi-natural vegetation; 4: Wetlands; 5: Water

Putting the same number of samples into frequent change types (e.g. 2-1, 3-3), as into rare changes (e.g. 4-4, 5-5) provided a good statistical basis to avoid bias due to different population size of different change types. In case of rare change types several sampling points might have been placed into a single polygon.

Table 15 The nine main LCFs and their most dynamic level-3 constituent provided by CLC-Change

Indi-cator	Name of Land Cover Flow	Sampled change	Size of the change class compared to CLC2000
LCF1	Internal transformation of urban areas	133-112	40.5% of all 133 has changed
LCF2	Urban residential sprawl	211-112	0.06% of all 211 has changed
LCF3	Sprawl of economic sites and infrastructure	211-133	0.07% of all 211 has changed
LCF4	Agriculture internal conversions	231-211	0.24% of all 231 has changed
LCF4	Agriculture internal conversions	211-231	0.08% of all 211 has changed
LCF5	New agriculture land	324-244	0.09% of all 324 has changed
LCF6	Withdrawal of farming	211-324	0.07% of all 211 has changed
LCF7	Forest creation and management	312-324	3.28% of all 312 has changed
LCF7	Forest creation and management	324-312	2.24% of all 324 has changed
LCF8	Creation of new water bodies	211-512	0.01% of all 211 has changed
LCF9	Changes of land cover due to natural and multiple causes	312-334	0.05% of all 312 has changed

As Table 15 shows:

- In two cases (LCF4 and LCF7) we have selected two change types under the same Land Cover Flow. These are balancing processes, which provide a close to equilibrium status in agriculture and forestry.
  - In case of LCF4 (agriculture internal conversions): 231-211 and 211-231: meaning pasture changing to arable land and back.
  - In case of LCF7 (forest creation and management): 312-324 and 324-312: meaning felling of coniferous forest and growth of coniferous forest (the most frequent change types of all).
- In LCF5 (new agricultural land) the largest constituent (324-244) has an uneven European coverage (practically limited to the Iberian Peninsula), and its interpretation is usually not possible without local knowledge / high-resolution ancillary data, therefore it was not considered.

Based on the above considerations 10 level-3 change types were selected for additional sampling (100 samples for each). These represent 49.67% of total CLC change areas.

While commission errors are relatively easy to estimate by sampling within CLC-Change polygons, reliable estimation of omission errors would require an enormous number of samples (Table 16) and effort. This can be easily understood from the following example:

CLC changes cover only 1.24% of European territory (see Ch.5). Considering 15% omission error (measured relative to the area of present CLC changes), the probability of finding omission errors if sampling all non-changed areas is only

$$P^*_{omission} = P_{omission} \cdot \frac{P_{class}}{1-P_{class}} = 0.15 \cdot \frac{0.0124}{1-0.0124} = 0.0019 \rightarrow 0.19\%$$

In other words: by using 1000 samples most probably we get 2 samples falling on omission errors, but the standard deviation of calculated omission error is very high.

Mean value for the binomial distribution was calculated as follows:

$$mean^* = n \cdot p = 1000 \cdot \frac{2}{1000} = 2 \text{ samples (0.2\% of all samples)}$$

Standard deviation was calculated for the binomial distribution:

$$sd^* = \sqrt{n \cdot p \cdot (1-p)} = \sqrt{1000 \cdot 0.002 \cdot 0.998} = 1.41 \text{ samples (0.14\% of all samples)}$$

Where n=1000 (the number of all samples) p = 2/1000 (probability of finding omission error within all non-changed area).

The above mean and standard deviation values are related to the whole unchanged European area. We can calculate these values related to the total area of mapped changes, as follows:

$$P_{omission} = mean \pm sd = (mean^* \pm sd^*) \cdot \frac{1-P_{class}}{P_{class}} = 0.157 \pm 0.111 \rightarrow 15.7\% \pm 11.1\%$$

Theoretically the stratification could help to increase the efficiency of the sampling. Some of the CLC2000 classes show a high rate of changes, e.g. 40.5% of the CLC2000 class 133 changed to 112 class during the 2000-2006 period (Table 15). In this case an omission error around 15% could be estimated with ± 4.4% standard deviation using only 100 samples. For all other cases the number of samples required (see Table 16) for a meaningful result, obviously made the exercise difficult or not accomplishable.

Table 16 Number of samples to estimate 15% omissions (with ± 5% standard deviation)

Selected change type in CLC-Change$_{2000-2006}$	Percent changes relative to CLC2000	Number of necessary samples	Number of samples expected to find the 15% omission error	Calculated omission error (related to class area)
133-112	40.5%	100	10	14.7%± 4.4%
312-324	3.28%	1 800	9	14.7%± 4.9%
231-211	0.24%	25 000	9	15.0%± 5.0%
312-334	0.05%	120 000	9	15.0%± 5.0%
211-512	0.01%	600 000	9	15.0%± 5.0%
All changes	**1.24%**	**5 000**	**10**	**15.7%± 5.0%**

CLC2000 class 133 was sampled with 100 samples to estimate the omission errors for any 133-xyz change types. In the practice, however, it turned out that many of the selected 133 were not construction sites in 2000, in other words the European CLC2000 layer contradicted CLC-Change$_{2000-2006}$. The reason for this was that in many countries CLC2000 database was revised prior to / in parallel with change mapping, however these revised versions were not saved on a European basis.[5] Thus European CLC2000 database often does not correspond to the revised national CLC2000 databases, which was the basis of change mapping. Therefore the results of this exercise were misleading and were not used further in this study.

[5] Many of the national revised CLC2000 datasets have been collected by ETC-SIA in 2011

6.2 MATERIALS USED

In the optimal case the materials for validation would consist of:

- VHR satellite imagery or orthophotos taken in the years of 1999-2001 at resolution better than the resolution of IMAGE2000;
- VHR satellite imagery or orthophotos taken in the years of 2005-2007 at resolution better than the resolution of IMAGE2006;
- topographic maps at scale 1:50.000 or finer.

Field photographs from LUCAS2006 project would have been very useful for the validation, but they were used by some of the countries during the production, thus being not independent, were not relevant for the validation.

The large number of participating countries made it unrealistic to collect high-resolution orthophotos or satellite imagery and even topographic maps for the purposes of validation. Therefore re-interpretation of IMAGE2000 and IMAGE2006 was done support by use of Google Earth (GE) imagery.

EEA made available all IMAGE2000 and IMAGE2006 data. Multi-temporal imagettes around the 5 km x 5 km surroundings of each sample point were extracted for IMAGE2006 as well as for IMAGE2000. The date of each imagette was precisely known, as this was mandatory for the re-interpretation.

GE was extremely useful support, especially due to its time-series feature. In many parts of Europe GE has provided the required very high resolution base for the validation (Fig. 43).

Figure 43 High resolution GE images if available are perfect tools for validation. Left: Sept 2003, Right: Sept 2006. Arable land changed to construction site (Turkey).

6.3 WAY OF VALIDATION

The enhanced plausibility approach was selected to validate CLC-Change. This means that the validation point was first blindly interpreted by the validation expert, i.e. without knowing the delineation and CLC-Change attribute of the area. Interpretation meant a decision: what type of valid (at least 5 ha) CLC-Change was visible in the surroundings of the sample point. In the second step outlines the CLC-Change database on the area were displayed and a new validation code should have been provided. In the second step the validating expert had to decide whether the mapped change is correct (OK) or not correct (NOK). Decision “Other” could be chosen if it was not possible to make a decision (i.e. missing or bad quality images). For the NOK case one of the following standard explanations could be provided:

- No change
- No change, temporal difference only
- No change and CLC2000 code is not corrected
- No change and CLC2006 code is not correct
- Change exists, but with different attributes

6.4 RESULTS

The results of the validation of CLC-Change are presented in Tables 17 and 19. In both tables the accuracy figure is followed by a standard deviation of accuracy (see above). The accuracy refers to cases when the change was found by the original photo-interpreter and the given attributes were correct. The last column shows the "importance" of the change type by providing the percent of the area of given change type related to the total area of changes.

Table 17 Accuracy figures for CLC-Change grouped on level 1 (commission error only)

Level-1 class CLC2000	Level-1 class CLC2006	No. of samples used	Accuracy (%)	Standard deviation (%)	Size of the class (change % of total)
5	5	84	97.62%	1.66%	0.05%
2	5	100	97.00%	1.71%	0.57%
4	4	57	94.74%	2.96%	0.06%
1	5	100	94.00%	2.37%	0.15%
5	1	100	93.00%	2.55%	0.06%
3	5	96	91.67%	2.82%	0.66%
3	3	95	89.47%	3.15%	70.92%
3	4	100	88.04%	3.38%	0.13%
1	1	92	88.00%	3.25%	1.81%
2	3	99	87.88%	3.28%	2.65%
4	1	95	87.37%	3.41%	0.03%
4	2	85	87.06%	3.64%	0.34%
4	3	98	86.73%	3.43%	0.48%
1	2	99	84.85%	3.60%	0.36%
2	1	98	83.67%	3.73%	7.67%
2	2	97	83.51%	3.77%	8.33%
4	5	95	82.11%	3.93%	0.04%
3	1	98	80.61%	3.99%	2.32%
5	3	99	79.80%	4.04%	0.34%
3	2	95	77.89%	4.26%	2.48%
2	4	93	74.19%	4.54%	0.08%
1	3	98	66.33%	4.77%	0.38%
1	4	5	60.00%	21.91%	0.00%
5	2	93	59.14%	5.10%	0.05%
5	4	89	21.35%	4.34%	0.04%
Overall Accuracy		**2 260**	**87.82%**	**3.30%**	**100.00%**

The overall accuracy was calculated as a weighted sum: class accuracies were weighted with the relative area, meaning the class cover within all changes. The overall accuracy of CLC-Change database (commission error only) is 87.82%, i.e. exceeds the target value of 85%.

More than 2/3 of the change types have accuracy higher than 85% (with standard deviation taken into account). In Table 17 these change types are listed above the bold line. The most frequent of these successfully mapped change types are emphasize here:

- The far largest change type is the internal changes in forest / semi-natural level-1 class (3-3; dominated by forest clearcut and forest growth). Almost ¾ of all changes belong to this type, therefore its 89.47% accuracy is very important.
- Agriculture area changed to forest / semi-natural area (2-3; e.g. afforestation)
- Internal changes within artificial areas (1-1; e.g. construction site changed to residential area)
- Agriculture area changed to water (2-5; e.g. new reservoir on agricultural land)
- Forest / semi-natural area changed to water (3-5; e.g. new reservoir on area originally covered by sclerophyllous shrub)
- Wetland changed to forest / semi-natural class (4-3; e.g. afforestation on peatland)
- Wetland changed to agriculture (4-2; e.g. peatland converted to arable land)
- Artificial areas changed to agriculture land (1-2; e.g. reclamation of mineral extraction sites)
- Agricultural area turned to artificial surface (2-1; e.g. highway construction on agriculture land)
- Agriculture internal conversions (2-2; e.g. arable land turned to olive plantation).

There are 8 change types on the lower end of the accuracy list (below bold line in Table 17). Two of them almost reached the 85% accuracy; 2 others are between 70-80%, while 4 change types have accuracy below 70%. In this latter group 3 changes have marginal frequency (see Table 17).

Important change types with accuracies below 85%:

- Forest-semi-natural area changed to artificial surface (3-1; almost reached the 85% limit, e.g. new highway replacing former forest)
- Water changed to forest / semi-natural area (5-3; almost reached the 85% limit, e.g. changes of unregulated rivers)
- Forest / semi-natural area changed to agriculture (3-2; e.g. forest changed to arable land)
- Artificial area changed to forest / semi-natural area (1-3; e.g. reclamation of mineral extraction site by forest)

Table 18 Summary statistics of samples used in validation

Validation case	Explanation of errors	No. of samples with error explained	No. of samples
OK			1859
Not-OK; no change			229
	Temporal difference only	51	
	CLC2000 code not correct	28	
	CLC2006 code not correct	4	
Not-OK; Change exists but wrong attributes			172
Other (not interpretable)			145
Total		**83**	**2405**

The summary statistics of samples show (Table 18) that:

- A significant number of mistakes (51/229) show that short-term differences (seasonal or shorter) in land cover were misinterpreted as CLC change. This fact underlines the need of further training on mapping CLC changes.
- Still there are mistakes (28/229) related to mistakes in CLC2000. Because these mistakes are usually inherited to CLC2006, the "retrospective" correction is important in the next CLC update.

Table 19 Accuracy figures for selected level-3 CLC changes (commission error only)

CLC2000 class	CLC2006 class	No. of samples	Accuracy (%)	St.dev. (%)	Size of the change class (% of total)	represented Land Cover Flow
211	133	101	96.04	1.94	1.08	LCF3
211	512	100	96.00	1.96	0.20	LCF8
312	334	96	93.75	2.47	0.50	LCF9
133	112	100	93.00	2.55	0.71	LCF1
312	324	110	92.73	2.48	34.21	LCF7
211	324	100	83.00	3.76	1.11	LCF6
211	112	96	82.29	3.90	0.97	LCF2
211	231	100	82.00	3.84	1.30	LCF4
324	312	99	76.77	4.24	8.25	LCF7
231	211	97	76.29	4.24	1.34	LCF4
Total:	**-**	**999**	**-**	**-**	**49.67**	**-**

Considering the ten level-3 changes selected as "flagships" of major land cover flows we found that all but two change types were above the 85% limit (with standard deviation taken into account). The following five change types have extra high accuracy (above 90%):

- Arable land changed to construction site (belonging to "urban residential sprawl")
- Arable land converted to water body (belonging to "creation of new water bodies")
- Coniferous forest burnt (belonging to "changes of land cover due to natural and multiple causes")
- Construction of residential area finished (belonging to "internal transformation of urban areas")
- Coniferous forest changed to transitional woodland-shrub (felling) (belonging to "forest creation and management"). This is the largest level-3 change, providing more than 1/3 of area of all CLC changes.

Two change types were mapped with accuracy lower than 85%:

- Growth of coniferous forests (belonging to "forest creation and management"). This change type concerns rather significant area in Europe. Mapping it consistently is difficult without in-situ data (this lower accuracy might be responsible for the imbalance in forest cover shown in Ch.5, Fig. 42).
- Pasture/set-aside land changed to arable land (belonging to "agriculture internal conversions"). Its consistent mapping is difficult without in-situ data.

Level-3 changes presented in Table 19 represent almost 50% of area of all CLC changes. Because not the whole CLC change polygon population was sampled in this second exercise, overall accuracy was not calculated.

7 CONCLUSIONS, RECOMMENDATIONS

CLC2006 was the 3rd land cover mapping project of the European territory. It has provided updated, harmonised land cover and land cover change information for 5.8 Mkm^2 of the European continent under the GMES FTS Land Monitoring programme. Good quality multi-temporal satellite imagery, adequate reference data (topographic maps, ortho-photos, Google Earth etc.), national expertise from the 38 participating countries and strong coordination on behalf of EEA were key elements of the success. New countries, not participating previous CLC inventories have joined the project (CH, IS, NO, TR). The proposed "change-mapping first" photo-interpretation technology applied by the majority of countries was successful. Scandinavian countries used more GIS and image processing and less human-work intensive photo-interpretation. From the EEA, CORINE Land Cover data are available for free for any users.

Land cover has changed on 1.24 % of the surface of Europe between 2000 and 2006, which is equivalent to the size of Lithuania. Forestry changes (forest felling and growth) constitute the largest change area; they also provide the largest number of change polygons. Several policy-relevant processes can be characterized using the CLC-Change dataset based on Land Cover Flows [20], e.g.:

- urban land management: internal transformation of urban areas,
- urban residential sprawl,
- sprawl of economic sites and infrastructures,
- agriculture internal conversions,
- new agricultural land,
- withdrawal of farming,
- conversion from transitional woodland to forest,
- forest creation, afforestation,
- recent forest felling and transition,
- creation of new water bodies,
- burning of natural areas etc.

Stratified random sampling was used to generate samples for validating the CLC-$Change_{2000-2006}$ database. This solution is considered to provide relevant information for the database quality with affordable efforts. Samples were interpreted by using IMAGE2000, IMAGE2006 and Google Earth imagery. Samples were drawn from two different kinds of arrangements of the change population: (1) 100 samples from each of the 25 different level-1 change types to represent all the CLC-Change polygons, and (2) 100 samples from each of the 10 "highly important" level-3 changes. The Land Cover Flow scheme was used to determine which are the changes to be sampled. This sampling represents almost 50% of the whole change polygon population. Both cases provided only commission errors. Due the low percentage of changes, deriving omission errors would have needed extremely large number of samples and consequently lots of work. Therefore deriving omission errors was out of the scope of this study.

The **overall accuracy** of CLC change database (commission error only) is **87.82% ±3.30%,** i.e. **exceeds the target value of 85%.** 17 of the 25 change type groups have accuracy higher than 85%, 13 types of which having accuracy higher than 90%. Among the less accurate ones two almost reached the 85% accuracy; 2 others have accuracy between 70% and 80%, while 4 change types are below 70% accuracy. In this latter group 3 change types have marginal frequency.

Considering the ten level-3 changes selected as “flagships” of major land cover flows we found that all but two change types had more than 85% accuracy (regarding commission error). Five change types have accuracy above 90%. Two change types were mapped with accuracy lower than 85%: (1) growth of coniferous forests, and (2) pasture/set-aside land changed to arable land.

The most criticized issue regarding CLC2006 is its 3-year-long implementation period. Reasons for this are as follows:

- Long administrative preparation, including safeguarding the financial commitment in some countries.
- Elongated implementation time in some countries due to difficulties in mobilizing national contribution (approved before).
- Long GIS integration phase (months in some countries).

On the other hand, some larger countries provided very positive examples with fast (5-8 months implementation time (e.g. FR, PL, TR).

Recommendations regarding the next update are summarized in Table 20.

Table 20 Some recommendations for the next CLC update

Problem	Recommendation
Long administrative preparation, including safeguarding the financial commitment	Planning future CLCs by EEA in a longer term to allow for timely preparation by the countries
Elongated implementation time in some countries due to difficulties in mobilizing national contribution (which was already approved before)	
Long GIS integration phase (several months in some countries)	Based on lessons learnt the Technical Team compiles an extended “Guidelines” document
Slight deviations in the application of the standard CLC nomenclature	As written in this document
Difficulties in consequent mapping of changes	Based on lessons learnt from CLC2006 project a “Guidelines of mapping CLC changes”) has been prepared. This will be a recommended document for the teams implementing CLC2012
Lack of GIS support in mapping changes	Develop a centralized GIS support (e.g. change probability layer)[6] to speed up mapping of changes. The objectivity of mapping forest growth would also increase

[6] Not realised for CLC2012

8 REFERENCES

[1] EEA Task Force: CORINE Land Cover. A European Community project, 1992.

[2] G. Büttner, J. Feranec, G. Jaffrain, L. Mari L, G. Maucha, T. Soukup, The CORINE Land Cover 2000 Project, EARSeL eProceedings 3(3 (2004, 331-346,. http://las.physik.uni-oldenburg.de/eProceedings/

[3] European Commission, Global Monitoring for Environment and Security (GMES: From Concept to Reality), COM 2005 565 final.

[4] C. Steenmans, G. Büttner: Mapping land cover of Europe for 2006 under GMES. Proceedings of the 2nd workshop of the EARSeL SIG on land use and land cover, Bonn, Germany, 28-30 September, 2006 pp. 202-207, 2006.

[5] V. Lima: Report on Progress WP1.3, 3rd Steering Comm. Meeting, EEA, 22-04-09 (available on CIRCA).

[6] G. Büttner, G. Maucha: The thematic accuracy of Corine land cover 2000. Assessment using LUCAS. EEA Technical Report No 7/2006. ISSN 1725-2237, 2006.

[7] Y. Heymann, C. Steenmans, G. Croissille., M. Bossard, CORINE Land Cover. Technical Guide. EUR12585 Luxembourg, Office for Official Publications of the European Communities, 1994.

[8] M. Bossard, J. Feranec, J. Otahel, CORINE Land Cover Technical Guide – Addendum 2000. EEA Technical Report No 40, 2000.

[9] G.°Büttner,°B.°Kosztra:°CLC2006°Technical°Guidelines,°EEA,°Technical°Report 17/2007

[10] G. Maucha, G. Taracsák, G. Büttner, Methodological questions of CORINE Land Cover change mapping, Proceedings of the 2nd International Workshop on the Analysis of Multi-Temporal Remote Sensing images, MultiTemp-2003 Workshop, pp. 302-313. World Scientific Publishing Co., 2004.

[11] G. Büttner, G. Maucha & G. Taracsák: Inter-Change: A software support for interpreting land cover changes. In: Proceedings of the 22nd EARSeL Symposium, Prague, 4-6 June 2002; pp. 93-98, Millpress, 2003

[12] http://www.mlog.hu/CLC2006/services.html

[13] http://www.mlog.hu/CLC2006/references.html#table

[14] H. Markus et al, Finnish CORINE 2006 project: determining changes in land cover in Finland between 2000 and 2006, SPIE European Remote Sensing Conference, 2008.

[15] CLC2006 Finland – Final Technical Report; Finnish Environmental Institute, 2009.

[16] National Land Survey of Iceland: CLC2006, CLC2000 and CLC-Change in Iceland, Final Report, October 2009.

[17] L. Aune-Lundberg, G-H. Strand: CORINE Land Cover Classes – Examination of the content of CLC classes in Norway; Report from the Norwegian Forest and Landscape Institute, 2010

[18] CLC2006 Update Project Plan Sweden, Landmateriet, 2006

[19] G. Büttner, J. Feranec, G. Jaffrain: CORINE Land Cover Update 2000, Technical Guidelines, Technical Report No. 89, European Environment Agency, 2002

[20] R. Haines-Young, J-L- Weber: Land accounts for Europe 1990-2000. Towards integrated land and ecosystem accounting. EEA Report No. 11/2006. ISSN 1725-9177. 2006.

[21] T. Soukup: Guidelines for CLC2006 delivery_final_v2, 2007

[22] M. Caetano et al.: Accuracy assessment of the CORINE Land Cover 2006 map of Continental Portugal, 2009.

[23] R. Pataki: A macro program for generating CLC2006 from CLC2000 and CLC-Changes, 2008.

ANNEX 1 IMPLEMENTING ORGANISATIONS AND PROJECT MANAGERS

country	Implementing Organisation	technical project manager
Albania	Centre of Agricultural Techn. Transfer GeoVille Austria	Vangjo Kovaci Nina Schuldner
Austria	Umweltbundesamt GmbH	Gebhard Banko
Belgium	IGN Belgium	Yvan Van der Vennet
Bosnia and Herzegovina	University of Sarajevo	Hamid Custovic
Bulgaria	Geomatics Department BAS	Anton Stoimenov
Croatia	GISDATA d.o.o. and OIKON	Ivana Lampek Vladimir Kusan
Cyprus	MANRE, Environment Service	Nicos Siamarias
Czech Republic	Help Service Ltd.	Stanislav Holý
Denmark	NERI	Michael Stjernholm
Estonia	Regio AS	Helle Koppa
Finland	Finnish Environment Institute (SYKE)	Pekka Härmä
France	SIRS	Lionel Mequignon
Germany	German Aerospace Center (DLR	Manfred Keil
Greece	*Not participating*	
Hungary	Institute Geodesy, Cartography and Remote Sensing (FÖMI)	Gergely Maucha
Iceland	National Land Survey of Iceland	Kolbeinn Árnason
Ireland	ERA Maptec Ltd.	Martin Critchley
Italy	Università degli Studi del Molise	Gherardo Chirici
Kosovo under UNSCR 1244/99	EvroGeomatika	Ivan Nestorov
Latvia	Envirotech	Harijs Baranovs
Liechtenstein	Umweltbundesamt GmbH (Austria)	Gebhard Banko
Lithuania	Institute of Ecology	Mindaugas Dagys
Luxemburg	GeoVille Luxemburg	Stefan Kleeschulte
Macedonia	GOVe d.o.o.	Zoran Velickov
Malta	MEPA	Saviour Formosa
Montenegro	Geological Survey of Montenegro	Slobodan Radusinovic
The Netherlands	WUR-Alterra	Gerard Hazeu
Norway	Norwegian Forest and Landscape Institute	Linda Aune-Lundberg
Poland	IGiK	Elzbieta Bielecka
Portugal	Portuguese Geographic Institute	Mário Caeteno
Romania	Danube Delta National Institute	Jenica Hanganu
Serbia	EvroGeomatika	Ivan Nestorov
Slovak Republic	Slovak Environmental Agency	Nada Machova
Slovenia	GISDATA d.o.o.	Sandra Radi Goljak
Spain	IGN Spain	Antonio Arozarena
Sweden	METRIA	Jan-Peter Mäki
Switzerland	BAFU	Tom Klingl
Turkey	Ministry of Forest and Environment	Ahmet Çivi
United Kingdom	Centre for Ecology and Hydrology (CEH)	Ian Simson

ANNEX 2 CORINE LAND COVER NOMENCLATURE

(European Commission, 1993)

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-agri-cultural vegetated areas	1.4.1. Green urban areas 1.4.2. Sport 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

ANNEX 3 ABBREVIATIONS

AR5, AR50	Norwegian land use databases (scales 1:5.000 and 1:50.000) applied in CLC2006-NO
CAPI	Computer Assisted Photo-Interpretation
CDR	Central Data Repository (EEA)
CLC, CLC2000, CLC2006	CORINE Land Cover; CORINE Land Cover for year 2000; CORINE Land Cover for year 2006
CLCC	CORINE Land Cover Change
CORINE	Coordinated Information on the Environment
CRS	Coordinate Reference System
DBTA	Data Base Technical Acceptance [Report] (CLC)
DG ENV	Directorate General Environment
DLR	German Aero-Space Centre
GMES	Global Monitoring for Environment and Security
EEA	European Environment Agency
EC	European Commission
EIONET	European Environment Information and Observation Network
ESA	European Space Agency
ESTAT	Eurostat
ETC-LUSI	European Topic Centre on Land Use and Spatial Information (EEA)
ETRS89-LAEA	European Lambert Azimuthal Equal Area projection for spatial analysis and display
EU	European Union
FÖMI	(Hungarian) Institute of Geodesy, Cartography and Remote Sensing
FTS	Fast Track Service (GMES)
GIS	Geographic Information System
GMES	Global Monitoring for Environment and Security
IMAGE2000	Set of orthocorrected Landsat ETM satellite images taken in 2000 (±1 year) covering Europe
IMAGE2006	Set of orthocorrected high-resolution SPOT 4&5 and IRS-P6 satellite images taken in 2006 (±1 year) covering Europe
IRS	Indian Remote Sensing Satellite(s)
JRC	Joint Research Centre (Research Establishment of the EU)
LCC	Land Cover Change
LCF	Land Cover Flows
LISS	Linear Imaging Self Scanning Sensor: LISS-III is an optical sensor on board of IRS satellites, working in four spectral bands (green, red, near infrared (NIR) and short wave infrared (SWIR). It covers a 141km-wide swath with a resolution of 23 metres in all spectral bands.
LUCAS	European Agro-environmental database developed by Eurostat

Metria	Swedish mapping and cartography centre
MMU	Minimum mapping unit
NIR	Near infrared (spectral band)
SLICES	Finnish land use database applied in Finnish CLC
SPOT	French Remote Sensing Satellite(s)
SWIR	Short wave (middle) infrared (spectral band)
TM, ETM	Thematic Mapper, Enhanced Thematic Mapper: imaging sensors of Landsat-5 and Landsat-7 satellites
VIS	Visible (spectral band)

ACKNOWLEDGEMENT

Ana Sousa (EEA) was the initial project manager on behalf of the EEA.

Access to the vast amount of IMAGE2006 data was made possible by Jan Bliki and Paul Hasenohr (EEA) and supported by Walter Simonazzi (ETC-LUSI core team).

Ottó Petrik (ETC-LUSI partner FÖMI) provided assistance in collecting imagettes from IMAGE2000 and IMAGE2006 satellite images.

Chapter 4.4 of this report was written by Tomas Soukup (ETC-LUSI partner GISAT).

Jan Feranec (Inst. Geography, Slovak Academy of Sciences), Gabriel Jaffrain (IGN France) and László Mari (Eötvös University, Hungary) have contributed to the verification missions.

Last but not least the authors would like to acknowledge the contribution of all national project managers and national teams for the successful implementation of the project.