CORINE Land Cover updating for the year 2000

IMAGE2000 and CLC2000

Products and Methods

Edited by

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EUROPEAN COMMISSION
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List of Abbreviation

AC10: The accession countries in year 2001: Bulgaria, Czech Republic, Estonia, Latvia, Lithuania, Hungary, Poland, Slovakia, Slovenia and Romania
CAPI: Computer added Photo Interpretation
CDR: Common Data Repository
CLC: CORINE Land Cover
CLC90: CORINE Land Cover for the 1990s
CLC-Changes. CORINE Land Cover Changes database
CRS: Coordinate Reference System
DBTAR: Data-Base Technical Acceptance Report
DIP: Digital Image Processing
EIONET: European Environment Information and Observation Network
EQC: External Quality Control
ETC/TE : European Topic Centre on Terrestrial Environment
GCP: Ground Control Point
GISCO: Geographic Information System of the European Commission
IMAGE90: Ortho-image used to create the CLC90, after its geometric adjustment against INSPIRE: Infrastructure for Spatial Information in Europe
IP/GIS: Image Processing and Geographic Information System
LCC: Land Cover Change
LUCAS: Land Use and land Cover Area frame Sampling
LUT: Look-Up-Table
MMU: Minimal mapping unit
PSU: Primary Sampling Unit
QA: Quality Audit
RMSE: Root Mean Square Error
RMS: Root Mean Square Error
SSU: Secondary Sampling Unit
TT: CLC2000 Technical Team

Preface

I&CLC2000 was a complex but very successful European and at the same time national project, a cornerstone for the collection of European land cover information. Learning from the experience on the creation of the first CLC in early 1990s and taking into consideration the users' requirements on land cover information for policy support, I&CLC2000 was built upon partnership between several European Commission Services and the national authorities, regarding co-funding and co-ownership of the results, respecting the European and the national users requirements and timing.

With the present joint publication, the Joint Research Centre (JRC) and the European Environment Agency (EEA) aim to provide a general reference source for I&CLC2000, aimed at the various users and uses of its products and in particular at those responsible for future updates. The joint publication is divided into two volumes. Volume 1 (Products and Methods) is the JRC's responsibility. It addresses the process of creating the IMAGE2000 as a European spatial reference and the CLC databases with the national teams and the role of the Technical Team in the quality assurance across countries and quality control of the final product. Volume 2 (Use of CORINE Land Cover and IMAGE2000), coordinated by the EEA, aims to provide the reader with an overview of the possible uses of CORINE Land Cover database from local, regional, national and European level. The applications presented are very diverse and summarise the research carried out exploring the potentials of the CLC database, by operational national or local agencies or by the European Commission Services and EEA to support their daily work. It is presented as a CD-ROM.

This joint publication documents all the information that allows the reader to assess the added value brought by I&CLC2000, namely:

- A harmonised, reliable and comparable snapshot of Land Cover for the year 2000 for the whole Europe (29 countries already finalising in early 2005 and other 4 in process).
- A pan European coverage able to serve EU and national policy needs but also beyond.
- A land cover change database which for the first time enables analysis of the causes of change as well as the impact of various policies for the past 10 years, and creating the conditions for this type of analysis in the future by producing the necessary reliable reference data.
- A European spatial reference as a snapshot of Europe for the year 2000 based on high resolution satellite data with high geometric quality.
- Improved geometric and thematic quality of CLC90 database.
- Build a significant expertise at national level and strengthen cooperation and exchange of experience within Eionet.
- A concrete prototype of the future INSPIRE directive.
- Open and free access to information, through a commonly agreed data dissemination policy for geo-referenced land cover data as well as ortho-corrected satellite imagery.
- Motivation for countries in carrying out the project and using the results, based on the co-ownership arrangement established for the project funding and organisational set-up.
- More regular update of the databases produced like every five years, requested by the stakeholders in recognition of the importance of the CLC database in supporting policies in a dynamic and integrated manner.

Acknowledgements

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I Introduction

1 Background

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 created (the CORINE system), with the development of nomenclatures and methodologies, agreed at EU level.

In 1991 at the Dobris Conference, European Environment Ministers requested that the programme be applied to the Central and Eastern European countries covered by the EC Phare programme. Through the support of this programme, the CORINE databases were implemented in the 13 eligible countries.

Following the European Council decision to set up the European Environment Agency (EEA) and the establishment of the European Environment Information and Observation Network (EIONET), responsibility for the CORINE databases (and their up-dates) now lies with the EEA. The CORINE Land Cover (CLC) is the largest of the CORINE databases. The CLC90 inventory and its updates are key reference data sets, which provide the basis for the development of spatial analysis and integrated environmental assessment.

Today, CLC is recognised by decision-makers as a key reference data set for spatial and territorial analysis at different territorial levels. Within the European Commission Services as well as the EEA and its European Topic Centres (ETCs), there is a growing need to use spatial analysis for integrated environmental assessment. The need for an updated CLC90 database was expressed by several users at national and European level. The CLC90, its updates (CLC2000) and data layer of changes (CLC90/2000) are key reference data sets which provide the basis for a wide variety of environmental analysis and integrated environmental assessment mainly at the European but also national levels.

Preparatory work to update the CLC database for the reference year 2000 started already in the late 1990s and took various forms[1] such as methodological studies, joint EEA/ JRC publications and Workshops. The I&CLC2000 project is based upon a number of key elements: lessons learnt from the earlier CLC90 Project, a current list of user needs, the options available for satellite images and the processing and management requirements for the vast amount of data. The overall aim of updating is to produce the CLC2000 database and the CLC changes database between the 1990's and 2000. To guarantee full coverage and maximise consistency with the previous inventory, the I&CLC2000 project calls upon existing national and European expertise and requires access to both the ancillary data and the satellite data used for the first CLC inventory.

The I&CLC2000 project consist of 2 main components which are interconnected:

- **IMAGE2000**: covering all activities related to satellite image acquisition, ortho-rectification and production of European and national mosaic
- **CLC2000**: covering all activities related to detection and interpretation of land cover changes, including training and correction of CLC90.

The project started officially in early 2000, with the kick-off meeting of IMAGE2000 to launch the ortho-rectification of the Landsat 7 ETM+ satellite images.

[1] Technical and Methodological Guide for Updating the CLC database (Perdigão, V. and A. Annoni, 1997); the LaCoast project (Perdigão, V. et all, 2000); Inventory and Analysis of Major Land Cover Changes in Central and Eastern Europe over the Past 20 Years (PTL/LC, 1999); 3rd Land Cover Workshop- Towards CORINE Land Cover 2000, on 12-13 January 1999; 4th Annual EIONET Land Cover Workshop, on 10-12 April 2000 in Prague (the first with the joint participation of Member States and PHARE beneficiary countries).

2- Users requirements

Throughout the project design and execution, considerable attention was given to identification of user needs, supporting policy processes and identification of possible applications. A survey was carried out in 1999 by EEA on the main areas where the first CORINE Land Cover data base was and is currently used, with particular attention to the environmental domain. The survey results were based on several thousand requests for European Land Cover data received by EEA. The most frequent domains of CORINE Land Cover data usage appeared to be land management, nature conservation and water management. CORINE Land Cover information is used as well for sectoral analysis in agriculture, forestry, spatial planning, and to a lesser extent in transport, tourism, coastal management and development of spatial indicators based on land cover or land use changes. Several research projects and education programmes are also making intensively use of the data.

Table 1- European needs regarding the products of I&CLC2000 at the project launching date

European Needs	Information users/ Policy framework	Analysis / Assessment land cover information needs
Assessing impacts of policy against regional development perspectives, spatial planning	Regional planning (ESDP, ESPON, Structural Funds)	• territorial analysis • land cover, land use and land quality assessment • land cover changes • landscape assessment.
Assessing impacts of agriculture policies on the environment	Agricultural and environmental policy (CAP reform, Nitrate Directive, UNCCD)	• land cover changes • landscape indicators • watershed analysis for water use, fertiliser input • soil cover management, conservation practices.
Strategy on integrated coastal zone management	Environmental policy (ICZM)	• land use and land cover change along coastal zones.
Implementation of biodiversity conventions, habitats and protected sites	Environmental policy (Habitats Directive, UNCBD)	• development NATURA2000 • habitat mapping • land cover and land use changes; • habitat fragmentation; • pressure on designated areas;
Integrated watershed analysis	Environmental policy (Water Framework Directive)	• support to the development of watershed indicators.
Assessment of air emission and air quality measures	Environmental policy (Air quality directives, IPCC, UNFCCC)	• estimates CO_2 sinks/sources; • land cover around measurement stations • re-allocation of air parameters to land cover;
Strategic environmental assessment of trans-European transport networks, Transport and Environment Reporting Mechanism	Transport and environmental policy (Common Transport Policy, SEA)	• land take • fragmentation of habitats, partitioning of land • tranquil zones • pressure on protected areas.

At the start of the project in 1999, the interested EC Services formulated specific requests concerning more focus to policy areas, such as:

Environmental policy: to give priority on European coastal zones and to produce additional "optional" layers on green areas with urban areas, all habitat types mentioned in the Habitat Directive within NATURA2000 sites and transportation infrastructures, specially airports. This justified the availability of some SPOT images along the coastal zones, seen as an option to get additional layers.

Agricultural policy: a complete update of CLC every 10 years, simultaneous with the Structural Survey, a partial update of CLC every 3-5 years for regions to be defined, additional information on specific classes like evolution of fallow lands, an additional layer with smaller minimum mapping units for specific regions identified by the Structural Survey, for rice fields, vineyards, olive trees. Also identified was a specific interest in a seamless vector database for agri-environmental indicators.

The fulfilment of these requirements is budget-dependent and the final project specifications are a compromise between the requirements and budget available. For the future update and taking into account the experience of I&CLC2000, these can be seen as further improvements of the European land cover database.

At the end of the project in early 2005, the uses of CLC at European and national level in support of policy implementation and legal compliance have increased in such a way to justify the request for more frequent updates of the database. Table 2 gives an overview of current uses. More information on applications is presented in Volume 2.

Table 2. Use of CLC in support to policy implementation and legal compliance, January 2005

Policy/legal needs	**European user**	**National user**	**Examples of specific applications**
Climate change Kyoto protocol	Priority area in 6EAP	Compliance with legal obligations	Changes of forests/ wetlands, carbon sinks. Scenarios on erosion risk due to climate change
Convention Long-range transboundary air pollution	EU is party to the convention	Compliance with legal obligations	Modelling and mapping critical loads, land-use specific deposition rates, location and description of ecosystems
New European Regional development Fund	New EC initiative	Consider and support territorial specificities	New DG Regional policy initiative
Water Framework directive	EU target for 2015 good status of water bodies	Location of driving forces, reporting based on CLC, substance input modelling	Characterisation of river catchment areas
European Soil Thematic strategy	Priority action 6EAP	Erosion risk assessment/land use, agri-env indicators, location driving forces	Soil erosion maps, soil sealing
Nature conservation Biological diversity convention	Priority 6EAP, strategy in place	EU obligation and legal compliance	Description of ecosystems, Natura2000/ EUNIS , designation of environmental sensitive areas
Agriculture	Greening CAP	National Agri-env. Programme	Yield forecast modelling, sustainable farming, preserving landscape values Land use changes related to agriculture

II Project I&CLC2000

1 Organisation

I&CLC2000 is a joint EEA/JRC project, in which the JRC has the responsibility of IMAGE2000 component and the EEA is responsible for the CLC2000 component. Both were co-managing the project. The organisational structure of the I&CLC2000 project is defined in Figure 1.

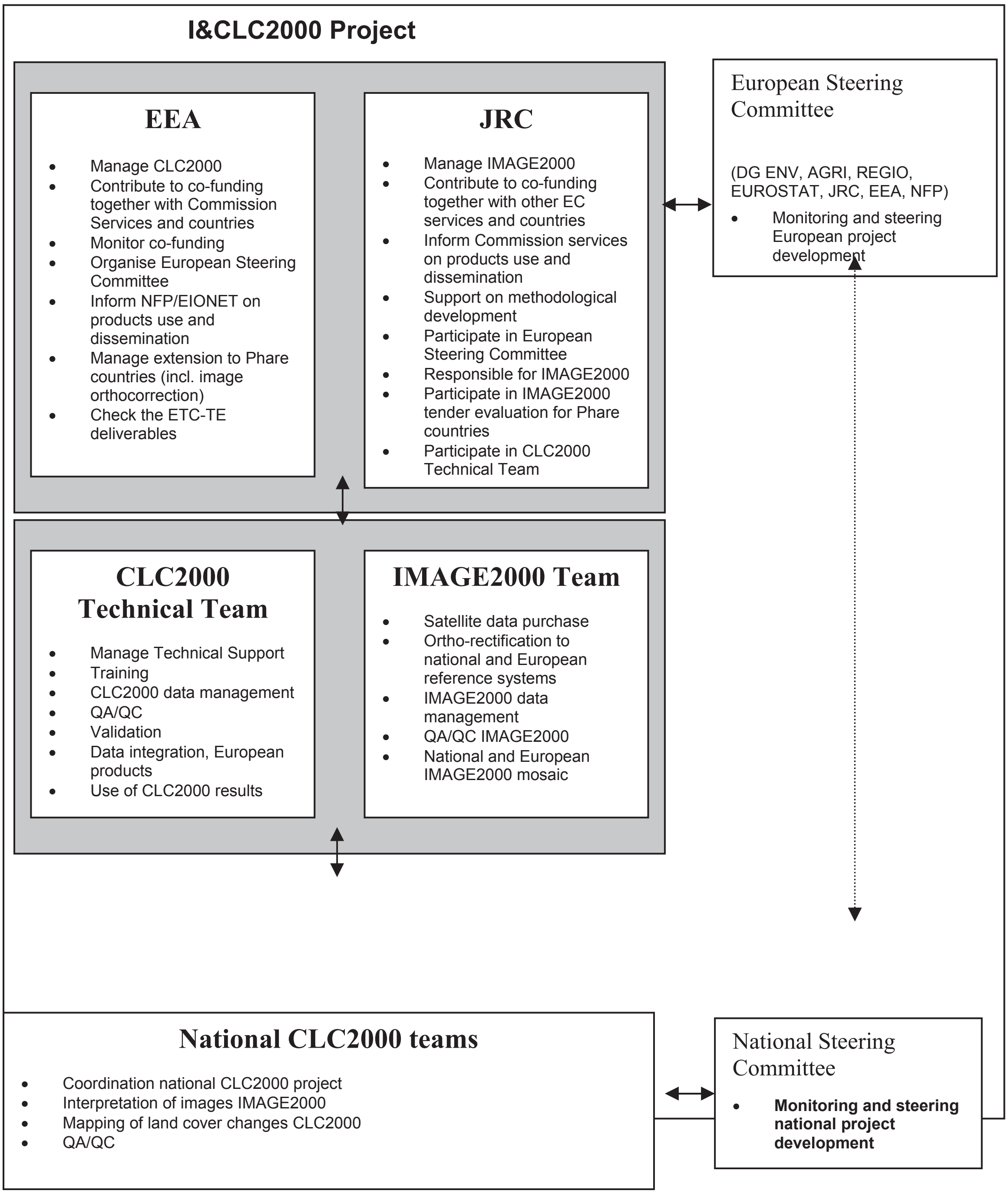


Figure 1- Organisational set-up of I&CLC2000

The **European Steering Committee** consists of representatives of the EEA, DG JRC, DG-Environment, DG-Regional Policy, DG-Agriculture, Eurostat, EEA Scientific Committee, national authorities in charge of national project, National Focal Point / Eionet and ETC-TE. The EEA and JRC reported to the Steering Committee on a regular basis on the ongoing work, time-table, budget commitments, data dissemination, tendering and sub-contracting to external contractors, problems encountered and proposed solutions. The Steering Committee met twice a year during the lifetime of the project. The Steering Committee meetings were organised through the EEA Advisory Group on Spatial Analysis.

The **I&CLC2000 National Steering Committee** was set up by each participating country in order to monitor the national project development. The liaison with the European Steering Committee was ensured through the national authority and the NFP.

The **EEA** has overall responsibility for the CLC2000 component and the relationship with the network represented by the national authorities in charge of the project. Therefore EEA established an information chain to ensure that all bodies involved had access to information on the ongoing CLC inventory and reports to the European Steering Committee. EEA coordinated the CLC 2000 Technical Team.

The **JRC** has the overall responsibility for the IMAGE2000 component- management, coordination and technical developments. The JRC coordinated the IMAGE2000 team. JRC established the link with other Commission services and initiatives like COGI and the Framework Programmes 5 and 6, to promote the use of I&CLC2000 products inside the Commission.

Coordination meetings between the EEA and the JRC were held regularly to help the implementation of the I&CLC2000 project. More frequent at the beginning of the project life, they were held anytime it was necessary to plan and to organise important project steps, sometime with the participation of the Technical Team.

The **IMAGE2000 team** comprised JRC staff and the contractors responsible for satellite image purchase and ortho-correction. The IMAGE2000 team coordinated, defined, monitored, controlled and reported all activities of IMAGE2000 component. It included:

1- Definition of the technical specifications of Tenders related to the implementation of IMAGE2000.
2- Definition of methods and procedures for image selection.
3- Definition of methods and procedures for quality control of products.
4- Manage and monitor the ortho-rectification of the images covering the previous EU15.
5- Manage and monitor the development of the European mosaic.
6- Evaluate the progress reports prepared by contractors.
7- Technical support for the purchase and ortho-rectification of images covering the previous AC10 in full harmonisation with EU15.
8- Prepare reports to DG ENV corresponding to the Administrative Arrangements with this DG
9- Participate in the CLC2000 Technical Team.
10- Develop and implement the IMAGE2000 database and dissemination system.

The IMAGE2000 Team worked in close cooperation with the participating countries and the EEA.

The **CLC2000 Technical Team** (TT) assisted both the national teams and the EEA. It consists of experts of ETC-TE and an expert from the IMAGE2000 team in order to ensure coordination of the work. The tasks of the CLC2000 TT were as follows:

1. Participate in Steering Committee meetings.
2. Coordinate the work with national teams on land cover data collection.
3. Coordinate the quality assurance and quality control of CLC2000.
4. Support the national teams upon request during CLC2000 national project development (country visits)
5. Implement training sessions for national teams.

6. Assist and control the national teams in performing the database validation.
7. Merge the national land cover data into one consistent European database.
8. Use of the CLC2000 results in combination with other data and spatial analysis.
9. Production of a set of derived products for dissemination via the EEA website (e.g. 100 m and 250 m grid data, 1 km^2 statistics, land cover changes 1990-2000)

The **National CLC2000 Teams** were responsible for the Land Cover interpretation to produce the CLC2000 database and the CLC changes database, by using the satellite images and the revised CLC90. National teams collaborated with IMAGE2000 team for image selection and validation. The National Team Leader was responsible for the project implementation, organisation of the training and verification missions with the CLC2000 Technical Team. The national team organised the data delivery to the EEA. The national teams submitted to the EEA the following reports:

- Quarterly progress reports presenting the status of the work, difficulties encountered, solutions proposed, cooperation with other partners involved in the process etc.
- Final report presenting the main conclusions of the work, an overall assessment of the results, proposals for improvement, etc.

To ensure harmonisation of the final European CLC products, the organisation of **training sessions** was planned for all participating countries, upon request and depending on their readiness to start with the interpretation activities. The training of national teams led to the same level of understanding of I&CLC2000 methodologies, criteria and quality of the end products, taking into account the national environmental specificities.

A network was established between the different national CLC2000 teams. A dedicated web-site was organised and maintained first by the IMAGE2000 team to facilitate a fast communication between partners as a fundamental step of project implementation. Once the national activities on CLC2000 were started, a dedicated web-site was organised and maintained by the CLC2000 Technical Team.

2 Participating countries

Twenty nine countries of Europe participated in the project: EU25; Bulgaria; Croatia; Liechtenstein and Romania (Annex 1). In 1999, the European Commission agreed to assist execution of the project through a co-funding mechanism equally shared with each participating country. I&CLC2000 was initially designed for the EU15: Austria (including Liechtenstein); Belgium; Denmark; Finland; France; Germany; Greece; Italy; Ireland; Luxembourg; Netherlands; Portugal; Spain; Sweden and UK.

Responding to the growing interest of the EU candidate countries to join the project, a similar co-funding mechanism was agreed and provided from the EEA budget in 2002 when these countries officially became EEA members. Consequently, I&CLC2000 was extended to Bulgaria, Czech Republic, Estonia, Latvia, Lithuania, Hungary, Poland, Slovakia, Slovenia and Romania (then called Accession Countries - AC10), followed later on by Malta and Cyprus. In late 2003, Croatia started a similar activity under the LIFE programme funding and technically supervised by the EEA, in order to ensure consistency and, in the end, pan-European coverage. In 2004 Turkey initiated the project under the EU Twinning programme with Germany and in 2005 the remaining EFTA countries - Norway, Iceland and Switzerland - are expected to run similar activities under the same co-sharing principle.
Figure 2 shows the geographic coverage of I&CLC2000. Since I&CLC2000 is also a national project, a pre-condition for the start of the activity in each participating country was the national commitment for the project execution and consequently for funding at least 50% of its total cost, appointing as well the implementing organisation(s).

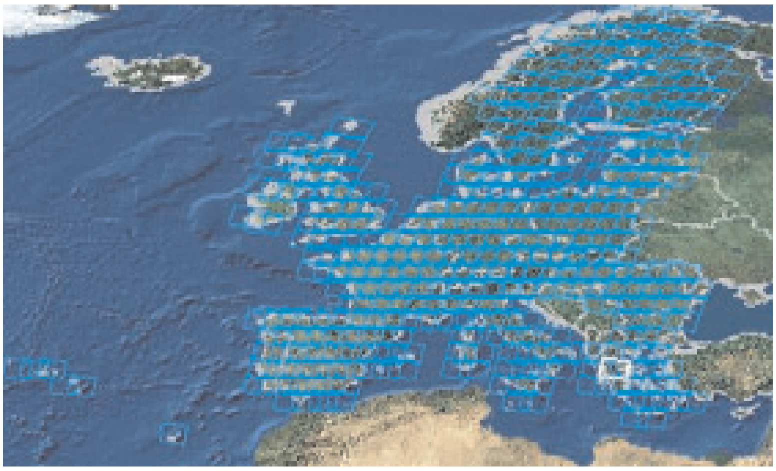


Figure 2- Geographic coverage of I&CLC2000

3 Budget

The I&CLC2000 was set up as a joint activity between each participating country and the Commission services. The EU contribution to I&CLC2000 project was done with the support of DG REGIO, DG AGRI, DG ENV and DG JRC. EEA also provided substantial financial support both directly to the countries as well as through the work done by the European Topic Centre on Terrestrial Environment (ETC/TE), as described in Table 3. The management of the project provided by the EEA and the JRC in person-days was not included in the project cost estimate and consequently not financially quantified in the table. It was agreed in the preparation period that the project management was the institutional contributions to the execution of the project.

Table 3- Project cost structure per main contributor (KEURO)

	Total Cost	*Contribution by countries*	*DGs REGIO/ AGRI*	*DG ENV*	*EEA*	*JRC ***	*PHARE DG ELARG*
EU15	*10 100*	*5 050*	*Images: 700 2001/2: 883 2003: 2000*	*300*	*Spain:40 ETC/TE: 900*	*Spot Images:169 514 341*	
AC10	*1791*	*895*			*750*		*150*
Cyprus, Malta	*60*	*30*			*30*		
Total General	*11 950*	*5 975*	*3 583*	*300*	*1 720*	*683 341***	*150*
*Other * Sources Turkey Croatia*	*2000 500*						

* Turkey funded through a Twinning project with Germany; Croatia funded through Life; Serbia-Montenegro to start in 2005 with Cards funding

**The contribution of the JRC was to implement the infrastructure to be used by further updates and to allow the dissemination of IMAGE2000 in agreement with the project objectives. It comprises the costs of image archiving, data quality control, external quality control, contribution to the mosaic, database implementation, development of the dedicated dissemination service and the corresponding hardware. SPOT images were an optional use for a compatible coastal zone additional layer. Only Specific credits are accounted. Personal credits are not included in the Table as it was decided to be the institutional contribution of each EC service involved.

In Table 4, the cost of I&CLC2000 are grouped by main activities. The financing from different sources in an annual basis led to more than one contract for the same type of activity which slightly increased the cost on management and implementation.

Table 4- I&CLC2000 Costs (KEURO)

Activity	Cost (KEUR)	Comment
Scenes purchase, orthorectification	845	Two contracts, 765 KE (EU15) and 80 KE (AC10)
Control of test scenes	31	
External quality control	47	Two contracts, 34 KE (EU15) and 13 KE (AC10)
European Full resolution Mosaic	86	It includes the European Pan-sharpened mosaic
European Small scale Mosaic	53	2 contracts, 41 KE EU15 and 12 KE AC10.
National Mosaic	13	Derived from the full resolution mosaic, different hard and software environment
CLC2000 and CLC-Change	7 577	Part of this used to correct CLC90 and create Image90
National managements	800	
Cyprus and Malta	60	It includes Image and CLC
Technical Team (TT)	865	TT under ETC/TE to support CLC 180KEx4 years; TT under JRC to support IMAGE2000 and 3person months to support CLC
Image2000 database, dissemination system	180	Hardware and informatic infrastructure only; not included 2 person/year for db and system implementation + 2 person/year for quality control of deliverables, archiving, db population
European management	8 person/year	1 person/year EEA and 1person/year JRC x 4 years

Table 5 gives the cost estimated for each task (KEUR), produced by the EEA for the I&CLC2000 project outline in 1999, including the EU15 countries at that time. Task 2 has the highest percentage of the total cost.

Table 5 - I&CLC2000 cost estimate per task, as presented in the Project outline (EEA, 1999)

	Description	Tasks to be performed by		Total task (KEUR)	% of the total budget
		NRC	EC/EEA		
Task 1	IMAGE2000: Image acquisition Image processing Production of mosaic, disse.	 50 50	 200 700 150	1 150	11
Task 2	CLC2000: Topological checks, geometry adjustment 1990, LC change mapping, field survey, metadat	6 500	0	6 500	65
Task 3	Data integration Data validation Data dissemination		200 100 100	400	4
Task 4	Quality assurance/Quality control and metadata	600	200	800	8
Task 5	Project management: European management and technical support team National management	 800	450	1 250	12
TOTAL		8 000	2 100	**10 100**	100

Some assumptions made for the cost estimates changed during implementation. The centralised approach decided for image acquisition and processing, together with the price of the Landsat 7 ETM+ scenes decrease the cost of these issues. The estimation for Task 1 didn't consider the cost of external quality control and the cost of archiving, database implementation and dissemination system, which is considered a structural cost for a Commission service, taken charge of by the JRC (Tables 3 and 4) and not included in the total project's cost. This spatial database management system is fundamental to make available to users the European spatial reference created by the project and its future updates, in line with the INSPIRE principles. Therefore, its cost should not be seen as a cost of I&CLC2000 but the cost of a service which relevance is larger than the updating of CLC90 for the year 2000.

Taking this into account, comparing the figures in Table 3 and 5, the total cost of the enlarged CLC2000 almost didn't change. The fact that ten countries joint the project at the time it was running, implied savings on the overall cost by sharing the European management cost, the technical support with the Technical Team in place, border images shared by more than one country and reducing the time of implementation. The cost of I&CLC2000 in each country was calculated based on the total cost of the project as presented in Table 5 and *proportional to the national area*. The indicative breakdown of the project cost by country is shown in Tables 6 and 7 (in KEUR).

Table 6- Breakdown of indicative cost by country (EU15), based on proportional area (EEA 2000)

Country	Area	Task 1 IMAGE 2000	Task 2 land cover changes	Task3 Integr. Valid. Disse.	Task4 Quality Control/ Assur.	Task5 Manag. Technical support	Total cost per country	Cost covered by EC/EEA centralised services*	Maximum financial EC contribution to countries **	Costs covered by countries
AT	83855	30	169	10	21	32	262	55	77	131
BL	30520	11	61	4	8	12	95	20	28	48
DK	43075	15	87	5	11	17	135	28	39	67
FI	337030	120	678	42	83	130	1054	219	308	527
FR	543965	194	1094	67	135	210	1701	354	497	850
DE	357868	127	720	44	89	138	1119	233	327	559
GR	131985	47	266	16	33	51	413	86	120	206
IR	68895	25	139	9	17	27	215	45	63	108
IT	301245	107	606	37	75	117	942	196	275	471
LX	2585	1	5	0.3	1	1	8	2	2	4
NL	41160	15	83	5	10	16	129	27	38	64
PT	88940	32	179	11	22	34	278	58	81	139
SP	504880	180	1016	63	125	195	1578	328	461	789
SW	449790	160	905	56	111	174	1406	292	411	703
UK	244755	87	492	30	61	95	765	159	223	383
Total	3230548	1150	6500	400	800	1250	10100	2101	2949	5050

Table 7- Breakdown of indicative cost by Accession Country, based on proportional area (EEA 2000)

Country	Area (Km²)	Task 1 IMAGE 2000	Task 2 land cover changes	Task3 Integr. Valid. Disse.	Task4 Quality Control/ Assur.	Task5 Manag. Technical support	Total cost per country	Cost covered by EC/EEA centralised services*	Maximum financial EC contribution to countries **	Costs covered by Accession Countries
BU	110910	15	111	7	17	35	185			92
CZ	78863	10	79	5	12	25	130			65
ES	45100	6	45	3	7	14	75			38
HU	93030	13	93	6	14	29	155			78
LV	63700	9	64	4	10	20	106			53
LT	65200	9	65	4	10	20	108			54
PO	312685	42	313	19	48	98	520			260
RO	237500	32	238	15	37	74	395			198
SK	49036	6	49	3	8	15	81			41
SL	20250	3	20	1	3	6	34			17
Total	1076274	144	1077	67	166	337	1791			895

* 20.8 % of total cost; ** maximum29.2% of total cost. All costs are in KEURO.

An analysis of the project costs shows that part of those costs are the effective costs to produce the I&CLC2000 deliveries and other part are costs to implement a service, which is optimised if further updates of CLC database will be done. As previously explained, those are mainly the costs to develop and to implement the database and dissemination system for IMAGE2000. Since IMAGE2000 should produce the image based European spatial reference, determining the geometry of the CLC2000 and CLC-Changes databases, much care was taken with the quality control. This increased the total cost of Task 1, justified by the production of the reference image geometry and its quality documentation. In future updates, these costs should be reduced since the ancillary data such topographic maps and Digital Elevation Models (DEM) will be not necessary in most cases, using the existing IMAGE2000 GCPs, described by their coordinates and "imagettes" (see §III). Even so, the total cost of Task 1 was lower than foreseen in Table 5. The cost of CLC2000 and CLC-Changes was influenced by the cost of corrections on CLC90 database and to bringing the satellite images used in 1990s to the correct geometry of IMAGE2000 (see § IV). On the other hand, the yearly based budget in a 3 years project with many funding partners, increased the total expenses by obliging to launch more than one contract to complete several services related to the same task, increasing the management and implementation costs. So, the effective cost of updating needs still to be evaluated in the situation of optimizing the time for production and quality control, derived from a regulated obligation to update the land cover information in Europe.

4 Basic specifications

The CLC main specifications were defined during the CORINE Programme in 1985. The three determining elements are (Heymann, Y, et. al., 1994):

- A mapping scale of 1:100 000 has been chosen. Mapping accuracy is at least 100 m for national and European products.
- The minimum unit for inventory is 25 ha,with a minimum width of unit is 100 m. Only area elements (polygons) are identified. Areas smaller than 25 ha are allowed in the national land cover database as additional thematic layers, but should be aggregated/generalized in the European database.
- The CLC nomenclature is hierarchical and distinguishes 44 classes at the third level, 15 classes at the second level and 5 classes at the first level. The nomenclature has been developed in order to map the whole Community territory (EC, CLC Technical Guide 1994; Addendum 2000, EEA), including the foreseen extension to other eligible countries. The use of the CLC nomenclature with 44 classes at three hierarchical levels is mandatory. Additional national levels can be mapped but should be aggregated to level 3 for the European data integration. No unclassified areas should appear in the final version of the data set.

For the updating of the CLC, other requirements were added:

- The update is for the year 2000, with ± 1 year.
- The CLC2000 should produce the CLC database for the year 2000 and the database of land cover changes between the 1990s and 2000. Only Land Cover Changes are mapped, being the minimal unit of change of 5 ha and a width of at least 100 m.
- The orthorectified satellite images used for the CLC2000 should have a RMSE ≤ 25 m and they should become the European spatial reference (IMAGE2000).
- For the first time, the satellite data were used to produce a thematic database and a spatial reference, being a multi-purpose and multi-user product.
- The geometric quality was the key requirement at national and at European levels. The I&CLC2000 datasets should be documented by structured and standardised metadata.

The spatial datasets produced by I&CLC2000 were described by geo-information metadata, following the principles of the Infrastructure for Spatial Information in Europe (INSPIRE). The structure of the I&CLC2000 metadata is represented in Figure 3. According to the type of information, three groups can be introduced:

- Metadata for Inventory (information supporting management of the database development),
- Metadata for Discovery (database accessibility information – who, where, how),
- Metadata for Use (information needed to judge the relevance and fitness-for-purpose of the database before to access it).

All three groups of metadata were referenced to the CLC basic object (polygon), working unit (map sheet), country (national product) and to the whole CLC project region (European product). To avoid repeating the same information on every level, relevant links and appropriate metadata structure using database and HTML tools were incorporated.

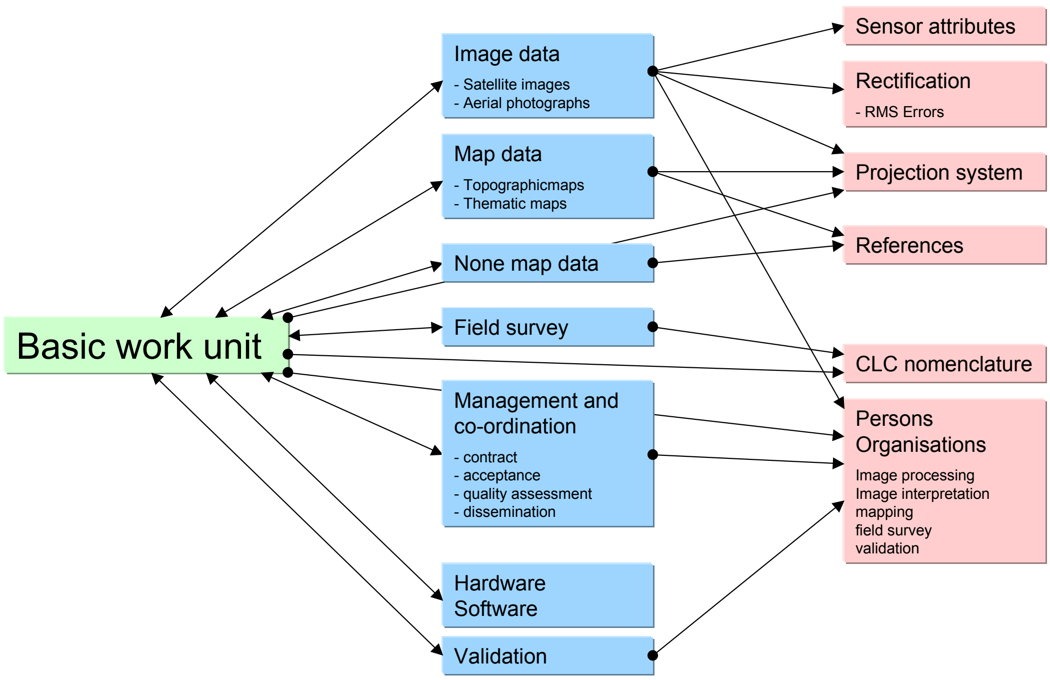


Figure 3- I&CLC2000 metadata structure

The **duration** of I&CLC2000 project was defined as three years. However, the partial results of the project were made available before to the European and national authorities when necessary and justified by the urgency of the information. It was a very complex project organisation due to the high number of participating countries and organisations involved, coordinating 3 years of project activities with annual budgets of the Administration and important requests for immediate results. So, a delay in a single step or country could have consequences for the entire project.

5 Improvements regarding the first CLC inventory

From the first CLC inventory done in the 1990s the technological trend led to the common work on a GIS environment, facilitating the integration of georeferenced data from different sources but also requiring the definition of standards and consistency between datasets. I&CLC2000 started when many of those standards were not yet defined at European level and it became part of the technical specifications of the project to define the standards that allowed the final products to be harmonised and consistent all over the Europe, fully compatible with other European initiatives like INSPIRE. Furthermore, the increasing number of users and applications of CLC data highlighted the limitations of the 90's version and led to the need to improve the geometric and thematic quality. Table 8 resumes the improvements that were obtained with I&CLC2000 regarding the first inventory.

Table 8- Improvements introduced with I&CLC2000

User requirement	CLC1990	CLC2000
The updated CLC inventory shall be more time consistent	mainly 1986-1995	2000 +/- 1 year
The geometric accuracy shall be improved. RMS error of: • satellite images • thematic LC data	 50 m 100 m	 < 25 m better than 100 m
The thematic accuracy remains the same	≥ 85 %	≥ 85 %
Changes smaller than the minimum mapping unit (25 ha) shall be identified	-	area change should be minimum 5 ha (for a contiguous area)
The results shall be provided faster (project duration as short as possible)	10 years	3 years
The production costs shall be substantially lower than those of the first inventory (average cost/km^2)	6 €/km^2	3 €/km^2
The documentation of the data and the production process shall be improved	incomplete metadata	standard metadata
The access to the data shall be easier	unclear data dissemination policy	agreed dissemination policy from the start
The basic geographical databases, including the satellite images and LC used for spatial analysis at European level shall be harmonised	inconsistencies between GISCO reference DB and CLC90	close cooperation with JRC and Eurostat for a common GI/GIS policy

6 Products

The outputs of I&CLC2000 are the following products:
Product 1: Individual satellite scenes, ortho-rectified using national projection systems, resampling with cubic convolution, all spectral bands; 25 m resolution for multispectral bands and 12.5 m panchromatic band, in BIL format and including metadata.
Product 2: National IMAGE2000 mosaic by basic working unit (map sheet) using national projection, all spectral bands, 25 m resolution for multispectral bands and 12.5 m panchromatic band, in BIL format, including metadata and image layer with boundaries for stitching between individual scenes.
Product 3: National CLC2000, land cover database for year 2000 as result of the data collection and processing exercise performed by each national team including generalisation to 44 classes, 25 ha minimum mapping unit, in geographical coordinates, in vector format.
Product 4: National land cover database on land cover changes larger than 5 ha, between CLC1990 and CLC2000, in geographical coordinates, in vector format.
Product 5: European IMAGE2000- European reference mosaic for year 2000 using a European projection, all spectral bands, 25 m resolution for multispectral bands and 12.5 m panchromatic band, the full resolution mosaic and 250 m resolution – 125 m resolution the small scale mosaic. Both mosaic have associated metadata.
Product 6: European CLC2000- European land cover database for year 2000 as result of mosaic of national datasets, including 44 classes, 25 ha minimum mapping unit, in geographical coordinates, vector format.
Product 7: CLC-Change, the European database on land cover changes (larger than 5 ha) between CLC1990 and CLC2000, in vector format.

To ensure a wide use and to facilitate a broad dissemination of the I&CLC2000 products, a number of aggregated products were produced from the I&CLC2000 main outputs at European level (namely products 6 and 7). Most of the users are interested in grid-based land cover datasets, allowing easy data handling for analysis of the land cover information at European scale. The following products were derived:

Product 8: CLC 250 m grid-based database, as a result of a vector to raster conversion. It is produced in Lambert Azimuthal Equal Area projection, based on the European LC vector databases (products 6 and 7).
Product 9: CLC 100 m grid-based database, as a result of a vector to raster conversion. It is produced in Lambert Azimuthal Equal Area projection, based on the European LC vector databases (products 6 and 7).
Product 10: CLC 1km² land cover statistics database, derived from product 6 and 7. The selection of 1km² raster was based on recommendations from the EC Working Group on Reference Systems, coordinated by the JRC.
Product 11: National CLC2000 metadata, produced according to the structure provided by the Technical Guide (EEA-ETC/TE, JRC, 2002). Two different metadata sheets were produced, one for working unit level, filled in for each working unit, and one for the country level, characterizing the country databases.
Product 12: European I&CLC2000 metadata, based on the metadata as provided by the National Reference Centres (NRCs), namely product 11, with the information on the procedures used and person responsible for the development of the European products.

7 Implementation Plan

Some milestone dates of I&CLC2000 are reported below, together with the general implementation plan in each country, divided by year quarters (Table 9).

Table 9 - General implementation plan per country

Country	Starting year	Training	Verifications	Deliver db
Austria	2002 CLC	Q2 2002	Q3,2003/Q2, 2004	Q1 2005
Belgium	2002 CLC	Q1, 2002	Q3, 2003/Q2,2004	Q4 2004
Bulgaria	2003 CLC	Q4,2002	Q4,2003/Q3,2004	Q4, 2004
Cyprus	2004 CLC	Q1, 2004	Q1, 2005	Q1, 2005
Czech Rep	2003 CLC	Q1, 2003	Q2,2003/Q4, 2003	Q4, 2004
Croatia	2003	Q4,2003	Q2,2004/Q4,2004	Q1, 2005
Denmark	2003 CLC	Q4, 2002	Q2,2003/Q2, 2004	Q4, 2004
Estonia	2003 CLC	Q4, 2002	Q3,2003, Q4,2003	Q4, 2003
Finland	2002 CLC	Q4,2002	Q3,2003/Q2,2004	Q4, 2004
France	2003	Q1,2003	Q3,2003/Q3,2004/Q4,2004	Q1, 2005
Germany	2002	Q2, 2002	Q4,2002/Q4,2003/Q4,2004	Q1, 2005
Greece	2004 CLC	Q1 2004	Q2/Q4 2004	Q1 2005
Hungary	2003 CLC	Q2, 2003	Q4,2003/Q2, 2004	Q4, 2004
Ireland	2002 CLC	Q1,,2002	Q4,2002/Q1,2003	Q4, 2003
Italy	2003 CLC	Q1,2003	Q2,2003/Q2,2004	Q3, 2004
Latvia	2003 CLC	Q1, 2003	Q2,2003/Q3, 2003	Q4, 2003
Lithuania	2003 CLC	Q2, 2003	Q4,2003/Q1, 2004	Q2, 2004
Liechtenstein	See Austria			Q1, 2005
Luxembourg	2002		Q1, 2003	Q1, 2003
Malta	2003	No need	Q3,2003	Q3,2003
Netherlands	2002	Q1, 2002	Q4,2002/Q1, 2003	Q3,2003
Poland	2003 CLC	Q2,2003	Q4,2003/Q2,2004	Q3, 2004
Portugal	2003 CLC	Q1,2003	Q4,2003/Q2,2004	Q1, 2005
Romania	2003 CLC	Q1,2003	Q3,2003/Q3,2004	Q4, 2004
Spain	2003 CLC	Q3,2003	Q4,2003/Q1,2004	Q1, 2005
Slovenia	2003 CLC	Q1, 2003	Q3,2003/Q4,2003	Q4, 2003
Slovak Rep.	2003 CLC	Q1, 2003	Q4, 2003/Q2,2004	Q4, 2004
Sweden	2002 CLC	Q4,2002	Q2,2003/Q2, 2004	Q3, 2004
UK	2002 CLC	Q4,2002	Q2,2003/Q3,2004/Q4, 2004	Q1, 2005

I&CLC2000 started with the signature of the first contract to purchase and to ortho-rectify the satellite data to cover at that time EU15. The date of the corresponding kick-off meeting was decided to be the official starting date of the project. Each National project started only after the national commitment on budget and the nomination of the national authority responsible for the project. The national training session marks the starting of the operational project's production for the country, although it was preceded by intense activity of organisation of national team(s) and project set-up.

Milestones:

Contract E.C./ Swedish Space Cooperation	08 March 2000
Kick-off meeting IMAGE2000	22-23 March 2000
Fourth Annual EIONET Land Cover Workshop	10-12 April 2000
Open IMAGE2000 web site Envicat	July 2000
Contract EEA/Eurimage	August 2001
First selection of quick-looks covering AC10 in CIRCLE	November 2001
Contract EEA/Gisat	October 2001
Workshop on I&CLC2000 Project Implementation	5-7 December 2001
Steering Committee meetings	March; September 2000 March; May; Oct. 2001 June; November 2002 October 2003; July 2004
Launch of I&CLC2000 databases	17 November 2004
Technical Workshop on Lessons Learned and Way Forward	27-28 January 2005

8 I&CLC2000 Products Dissemination Policy

The I&CLC2000 established from the beginning a clear and consistent dissemination policy across all participating countries. This was achieved with ad-hoc agreements with all parts involved: an Agreement on use and dissemination of I&CLC2000 products and a End user agreement for the use of I&CLC2000 products by third parties for non-commercial purposes, signed by each of the participating countries, an agreements with the satellite image provider and an agreement with the enterprises in charge of the ortho-rectification.

Products are available free of charge for non-commercial purposes. EEA and JRC play a central role in the dissemination of the results through the corresponding systems put in place for that purpose. Each country has rights to unlimited use of all the products. It is the strength and the step ahead made by this project comparatively with the first CLC inventory. In particular, for Product 1, the dissemination for non-commercial purposes is done by the JRC and by the national authorities that decided to implement a dissemination system for the national products. For commercial purposes, users must address Metria, Sweden, if product covers EU15, or Eurimage, Italy. For Product 2, dissemination for non-commercial purposes is done by the national authorities or by the JRC for the European Commission services only. For Product 5, dissemination for non-commercial purposes is done by the JRC.

Commercial purposes are not allowed for Products 2 and 5. Other national Products are disseminated by the national authorities (or by EEA if the country prefer) and other European Products are disseminated by EEA. All IMAGE2000 Products or extracts of Products, as well as CLC2000 Products or extracts, must acknowledge following the form agreed and present in the respective web sites.

III IMAGE2000

1 Short description

The IMAGE2000 products were elaborated in a centralised way to facilitate the consistency in quality and to reduce the delay of production, without being dependent from the national arrangements to start the national projects. The key elements for the implementation of the I&CLC2000 project were:

- Allocation and commitment of the European and the national budgets.
- Nomination of the national authorities responsible for the execution of the national CLC2000.
- Availability of ortho-rectified satellite images to start the national CLC2000, immediately after the starting date defined by the corresponding country.

Taking into account these three elements, I&CLC2000 started by launching the contract that allowed to purchase and to orthorectify the images covering the previous EU15, for which the budget was available. This was awarded on 8th of March 2000 to Swedish Space Corporation and performed by its subsidiary Satellus. In January 2001 all Satellus activities was taken over by Lantmateriet, the National Land Survey of Sweden and integrated into its business division, Metria that finalised this product. The activity started with the Kick-off meeting held on 22-23 of March 2000, where the main procedures, communication rules and reporting were decided.

The purchase and ortho-rectification of the satellite images covering the previously called AC10 was possible to start in 2001 with a proposal for data provision over the candidate countries- Bulgaria, Czech Republic, Estonia, Latvia, Lithuania, Hungary, Poland, Slovakia, Slovenia and Romania, submitted by Eurimage in August 2001. The ortho-rectification for those countries was performed by a Consortium lead by Gisat under a contract signed with the EEA in December 2001. The JRC furnished the technical advice to keep the harmonisation and consistency of the European product, providing the technical specifications and evaluating technical reports. As a unique European project, scenes covering the EU15 countries bordering the AC10 coverage were shared by both.

The existence of two contracts explains the presentation of tasks making the distinction between the two groups of countries by practical and documental reasons. Nevertheless, there was a unique IMAGE2000 team, the procedures were standardised and results are consistent as a single European coverage.
Other than the ortho-rectified images used for the updating of the CLC database, IMAGE2000 implemented the national (Product 2) and the European (Product 5) mosaics, as described in point 7 and 8.

2 Networking with National Teams

Image2000 should meets both National and European requirements. To reach this purpose, the JRC interface with National Administrations and National Teams, creating a network to assist in National project implementation, technical support on IMAGE2000 and problem solving. During the implementation phase of Image2000, the JRC provided on a regular basis the Member States with:

- General information about the project and production status during selection, ordering and delivery of images, through direct contact, I&CLC2000 Info-letter, Image2000 catalogue and web site.
- Technical support related to Image2000 products (e.g. radiometric and geometric aspects) and assistance in problem solving.
- Interface between contractor in charge of image ordering and ortho-rectification and National Administrations.
- Quality control, defining the methods, procedures and their implementation.
- Assistance in image selection for each acquisition campaign (1999, 2000 and 2001), and ensuring image optimisation at country and European level.

During image selection, the production phase and after delivery of Image2000 products, the JRC assisted on a daily basis and upon request from National Teams and Administrations with needed information or reply to specific technical questions. The JRC assured interface between National Administration and contractor in charge of ortho-correction, in solving specific problems related to planning of deliveries, selection of images with countries, quality of the product, analysis of remaining gaps due to cloud coverage or availability of images.

The chapter on *Data problems reported by Member States* summarises the information provided by the national teams on the problems found. This role of interface was fundamental considering the number of countries and interlocutors involved, to keep the balance between the national and European requirements and respecting the time schedules for each national project. The network with the national teams helped to have an extensive quality control of all the ortho-images delivered, only possible when there are people using the data, giving a better knowledge about the effective quality of the products, even if sometime it is a qualitative assessment.

3 Satellite images

The Landsat 7 ETM+ satellite images are the basis of I&CLC2000. Regarding the CLC90, this brings the advantage of having the panchromatic band with 12.5 meters of spatial resolution.

Band	1	2	3	4	5	6	7	PAN
µm *	45-.52	.52-.60	.63-.69	.76-.90	1.55-1.75	10.42-12.50	2.08-2.35	.52-.90

*wave length. The pixel size is 30 m except the panchromatic band with 15m and band 6 with 60m.

The satellite Landsat 7 ETM+ was launched in April 1999. IMAGE2000 was the first application of its data at pan-European scale. Such massive use of data at the very beginning of the distribution service involuntary allows to test the ESA system corrected Landsat 7 scenes distributed during the period April- November 2000 and to contributing in a very significant way to improve their quality.

3.1 Technical problems with the first Landsat 7 ETM+ data

3.1.1 Introduction

These paragraphs describe the errors observed by the IMAGE2000 team on the system corrected Landsat 7 scenes during the period April to November 2000. Most of those errors have caused that orthocorrected images were not possible to produce with the required standard quality set up in the IMAGE2000 project. Connected to each error, it is mentioned the dates of notification to ESA and of the correction by ESA.

3.1.2 Error in image corner coordinates

The corner coordinates in the ESA Fast Format product is the only way to geo-reference the product. SSC / Metria was required to produce ortho-rectified images, which makes necessary setting up a satellite model. To be able to do this, an initial geo-referencing was necessary.

The ESA product corner coordinates were not referred to the raster corners, but to the raw scene corners, which positions were not exactly known. They could only be approximated by visual inspection, and even then only at an accuracy of 2-3 pixels. SSC / Metria notified ESA of this problem in April 2000. The problem was corrected by ESA at their receiving station software version 1.5.0 of June 1st.

3.1.3 Mis-registration between spectral bands

A mis-registration was identified between the Pan, Reflective and Thermal bands, amounting to about 3 pixels. This error would result in bad multispectral classifications and poor possibilities for enhancements such as pan-sharpened products. SSC / Metria notified ESA of this problem on May 15, 2000. The problem was corrected by ESA at their receiving station software version 1.5.0 of June 1st.

3.1.4 Incorrect resampling of the thermal band

ESA delivers the Thermal band re-sampled to 30 m pixel-size (in contrast to USGS who retains the 60 m pixel-size in the thermal band). The resampling was done in an incorrect way, resampling first to 30 m by nearest neighbour method, and then doing the geometric resampling by cubic convolution method. This mix gave a product with unrecoverable radiometric artefacts. SSC / Metria notified ESA of this problem on May 15, 2000. The problem was corrected by ESA by introducing cubic convolution also in the first step at their receiving station software version 1.5.1 of June 21.

3.1.5 Misalignment between swaths

It was identified that the ESA products suffered from an irregular misalignment between swaths. Differences up to 50 m between forward and reverse scans gave local discontinuities in the image, which were impossible to recover in any geometric correction. It also added to the mis-registration between bands. The errors were difficult to detect and important effort from SSC / Metria was necessary to verifying and document this problem (Annex 2). SSC/Metria notified ESA of this problem on May 15 2000. The problem was corrected by ESA at their receiving station software version 1.5.2 of August 23

3.1.6 Pitch correction error

During September, after that ESA receiving station software version 1.5.2 made the correction of Landsat-7 meaningful, the results from a number of scenes showed that the products still suffered from systematic errors. The analysis then showed that this was due to errors in the pitch compensation in the ESA products. This error varies from scene to scene and was not visible in the earlier test scenes. It could in some cases give systematic along-track scale errors of more than 100 m in a scene. These errors were impossible to compensate in any normal geometric correction. A detailed analysis is provided in Annex 2. SSC/Metria notified ESA of this problem on October 2, 2000. The problem was corrected by ESA at their receiving station software by October 18.
Most of these errors caused that orthocorrected products was not possible to produce with the required quality in relation to the standard set up in the Image2000/CLC2000 projects. Therefore the production of orthorectified images could start only those errors were fixed.

3.1.7 Gain problems

Another type of non systematic errors were problems in band 4, identified in six scenes.

Table 10 - Scenes presenting problems on band 4

Country	Scene id	Manually corrected	Data replaced
Germany	19723_ 000826	X	X
Germany	19622_ 000515	X	X
Austria	19027_ 000910	X	X
Finland	18815_ 000727	X	X
NL	19723_ 000826	X	X
Slovenia	19027_ 990915		Neighbouring scene

The band 4, near infra-red, provides essential information for image-interpretation or classification and so it was mandatory to correct the problem. When possible, meaning if other dates were available for the same frame, the scene was rejected and replaced with one from a new date. When no other data was available, the frame was corrected by SSC / Metria.
The shift in pixel values was due to gain shift, and correction was done by manual contrast stretch on raw data to make the shift less visible.

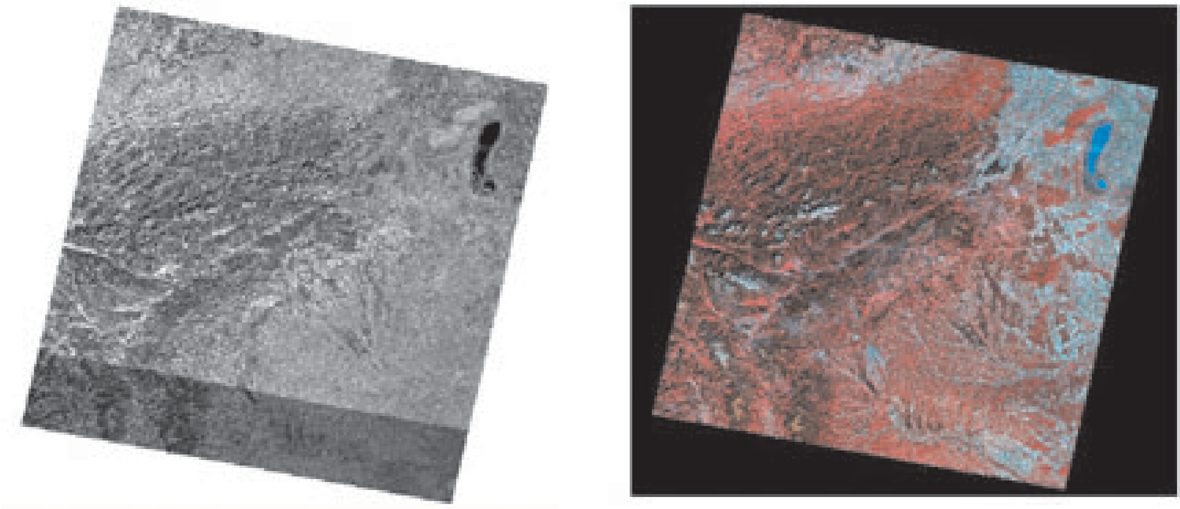


Figure 4 - Illustrates the gain problem on data before and after correction.

3.1.8 Errors in linear features

Errors in linear features were often found like in scene 201-32 (test scene) and 200-33. The errors are in general difficult to detect, but it appears within linear elements in part of the scenes (Figure 5). The problem detected in linear features is a problem of Landsat 7 sensor, with random shifts (1-2 pixels) present on raw data. Image provider was requested to replace the data, but no other images with appropriated date could be proposed.

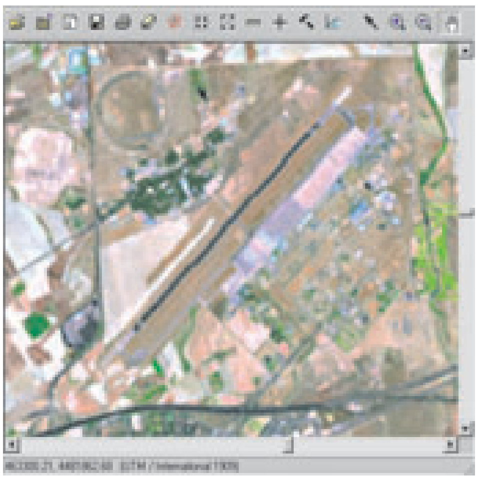


Figure 5- Errors in linear features

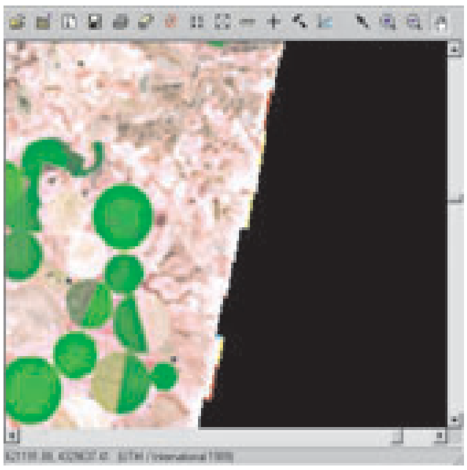


Figure 6- Border effects

3.1.9 Border effects

Some national teams notified the occurrence of bright pixels on border images, like the example of Figure 6. The bright border pixels are no errors in data, but the result of "edge effects from the calibration of the detectors". When realizing the mosaic a 50-100 metre buffer zone was applied to correct the problems.

3.2 Procedure and criteria for image selection

3.2.1 Acquisition windows

The year 2000 was targeted as reference year, with a deviation of maximum 1-year (1999 or 2001).
The National Administrations were responsible to define the acquisition window divided in two periods, according to the most suitable dates to identify land cover classes in its country:

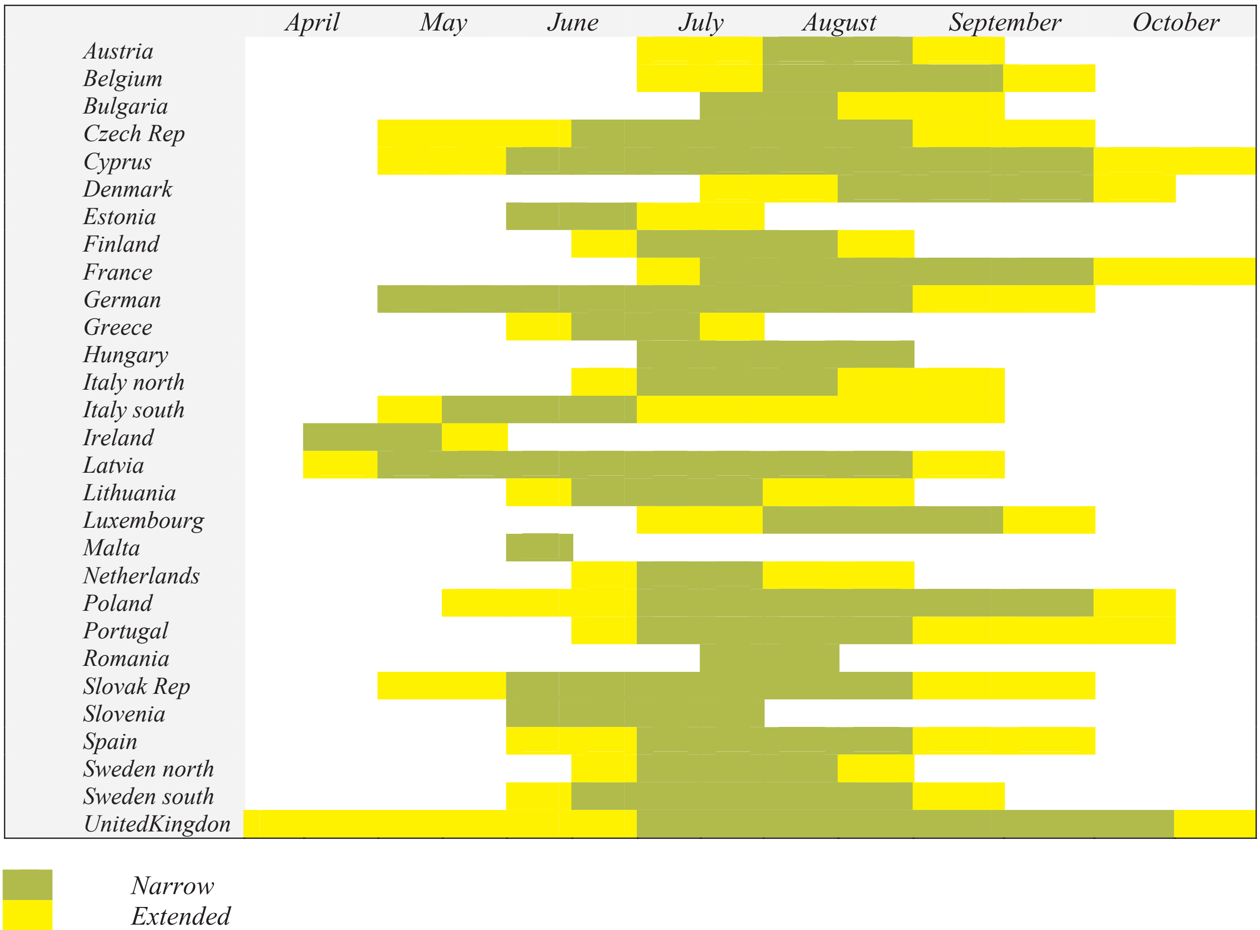
- A **narrow / restricted** acquisition window, corresponding to optimal acquisition dates,
- An **extended** time window, with an enlarged period of acquisition window (1 to several months beyond restricted window depending on the country).

Table 11- Acquisition windows defined by the National administrations

Country	**Narrow period**	**Extended**	**Comments**
Austria	**0801-**0831	**0701-**0915	-
Belgium	**0801-**0915	**0701-**0930	-
Bulgaria	**0715- **0815	**0715- **0915	
Czech Republic	**0615- **0830	**0501-**0930	
Cyprus	**0601- **0931	**0501- **1031	
Denmark	**0815-**1001	**0715-**1020	-
Estonia	**0601-**0620	**0601- **0801	
Finland	**0710-**0810	**0620-**0831	-
France	**0715-**0930	**0701-**1030	-
Germany	**0501-**0831	**0501-**0930	-
Greece	**0615-**0715	**0601-**0730	-
Hungary	**0710- **0820	**0701- **0830	
Italy	**0701-**0815 **0515-**0630	**0615-**0915 **0501-**0915	Northern Southern
Ireland	**0424-**0507	**0416-**0530	-
Latvia	**0501- **0901	**0415- **0915	
Lithuania	**0615- **0801	**0601- **0901	
Luxembourg	**0801-**0915	**0701-**0930	-
Malta	**		
Netherlands	**0701-**0731	**0615-**0831	-
Poland	**0701- **0930	**0515- **1015	
Portugal	**0701-**0831	**0615-**1015	-
Romania	**0715- **0815	**0715- **0815	
Slovak Republic	**0601-**0831	**0501- **0930	
Slovenia	**0601- **0730	**0601- **0730	
Spain	**0701-**0831	**0601-**0930	-
Sweden	**0701-**0815 **0615-**0831	**0615-**0831 **0601-**0915	Northern Southern
United Kingdom	**0701-**1015	**0401-**1030	-

Table 12 shows that the acquisition window was defined in a consistent period all over Europe.

Table 12- Representation of the acquisition windows as defined by the National administrations



3.2.2 Image selection criteria

The image selection should be determined by the following criteria and priorities (ref SC-VP/I02/1.1, 2001):

- Cloud free images (i.e. 0 % or, in difficult regions <5 % cloud coverage).
- Acquired within the year 2000.
- Acquired on an appropriate date (restricted window, if not available then extended window).

<u>First priority:</u> For the reference year 2000, cloud free images acquired within restricted time window should be selected as a first priority.

<u>Second priority:</u> When no cloud free images were available for this year / window, the selection search successively:

- In extended acquisition window for year 2000.
- In restricted acquisition window for year 1999.
- In extended acquisition window for year 1999.

<u>Third priority:</u> When no cloud free images were available on the campaigns 1999 and 2000, the search continued in 2001, in restricted, then in extended acquisition windows. The third priority could become second, depending upon the preference of the National authority.

Selection of non-cloud free images was avoided and could only be considered in specific cases, where no cloud free images were available within extended time window for defined acquisition years.

To improve the cloud free coverage, some cloudy scenes were bought, to use their cloud free area to replace the cloudy cover of an already existing scene acquired within the defined window and following the selection criteria (**nominal scenes**). Those extra scenes were called **equivalent scenes.**

The **border scenes** were the ones located on the frontier between neighbouring countries. They represent a specific case. The selection of those images was done in agreement between the concerned National Administrations and Image2000 team. Image2000 Team informed the 2nd National Administration of the selection made by the first, which was the country with a larger surface covered by the concerned scene. Without reaction or counterproposal within 2 weeks, the first selected image was confirmed. If no common agreement could be reached, the first cloud free image available within the restricted acquisition frame was selected.

3.2.3 Image catalogue

To cover the AC10, Eurimage made a first selection of scenes within the provided acquisition windows and the corresponding quick-looks were loaded in CIRCA site of EEA. Each national team should then look at the quick-looks proposed and accept or ask for another possible selection if the scene proposed was not good enough. The approved scenes were then used by the Consortium for the orthorectification.

In case of the EU15, a single contractor was in charge of to purchase and to orthorectify the scenes. This obliged us to implement a procedure for image selection and acceptation by the national authority and the JRC, after proposal by the contractor. The acquisition windows were transmitted by the JRC to the contractor SSC / Metria who should propose the best images to be selected, following the procedure agreed at the kick-off meeting and further detailed (ref SC-VP/I02/1.1, 2001).

A website was constructed to display the available imagery through quick-looks, which gave the National Administrations and JRC a tool not only for image selection but also for monitoring the production progress of ortho-images in a country basis. Each country's National Administration and the JRC were given access to the website by a username and a password. Figure 7 illustrates the main page of the website for image selection. All selected available scenes and their distribution through time were viewed on the main page. The legend at the left hand of the main page, described the status of each available frame by a corresponding colour. This main page gave as well an overview of the status of the project at a certain date. When clicking on the "*about*" link in the main page, a help box appeared with a simple description of how to navigate throughout the web pages.

When clicking on one of the items in the list of country names, a new web page appears. This web page gave more detailed information about the situation in one specific country, as exemplified by Figure 8. The colours of each visible frame show its current status. A more detailed legend appeared on the right hand. All available frames for each country were visible in the page. Neighbouring frames, not overlapping the current country, were visible in transparency.

When hovering above one node in the viewer, its track and frame appeared as a help in the viewer. When clicking on a node in the viewer, a new web page was opened. This web page had more detailed information about a frame in a country. One frame can belong to several countries. If several images were available for one single frame, it was possible to browse between the images to view the quick-look and the corresponding metadata for each registered image. The status of the image was available as text, and described whether an image was selected, processed or available. The corner co-ordinates of the image were also viewed in the web page. The co-ordinates were given in Lat. / Long. when the image was available or selected, while they were presented as x and y in the respective country's co-ordinate system once the image had been orthorectified.

Information about the maps used for the correction of the scenes and a description of the co-ordinate system for each country was also found for each country on the respective web page (Figure 9).

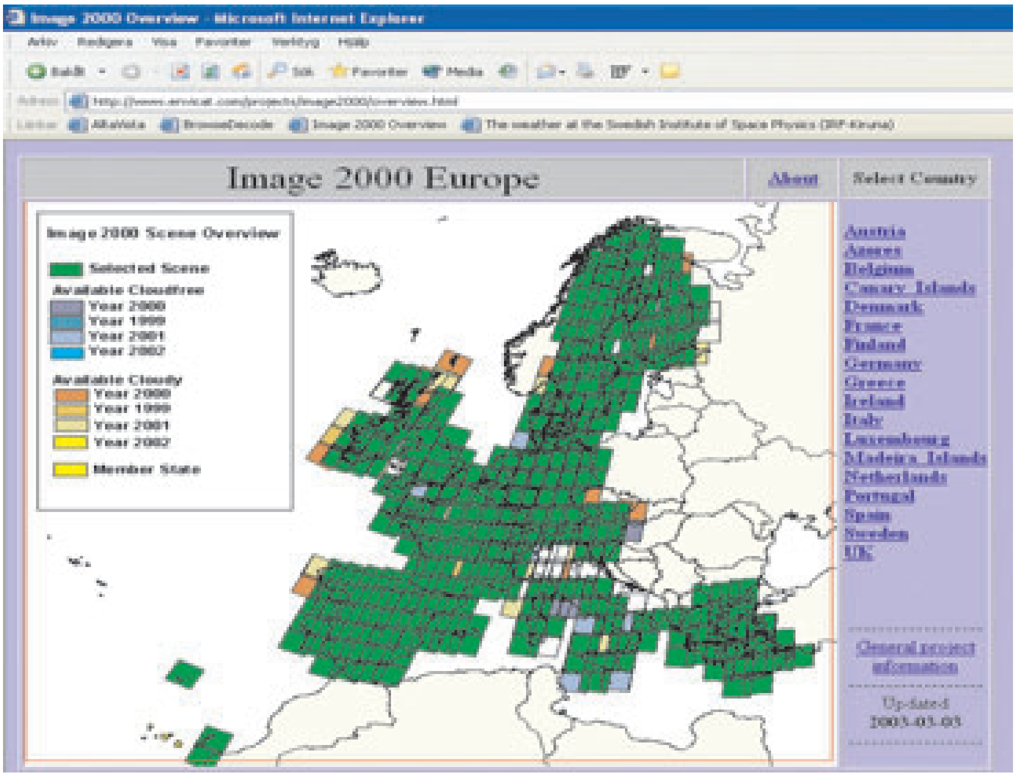


Figure 7- Main page of the web site for selecting the images

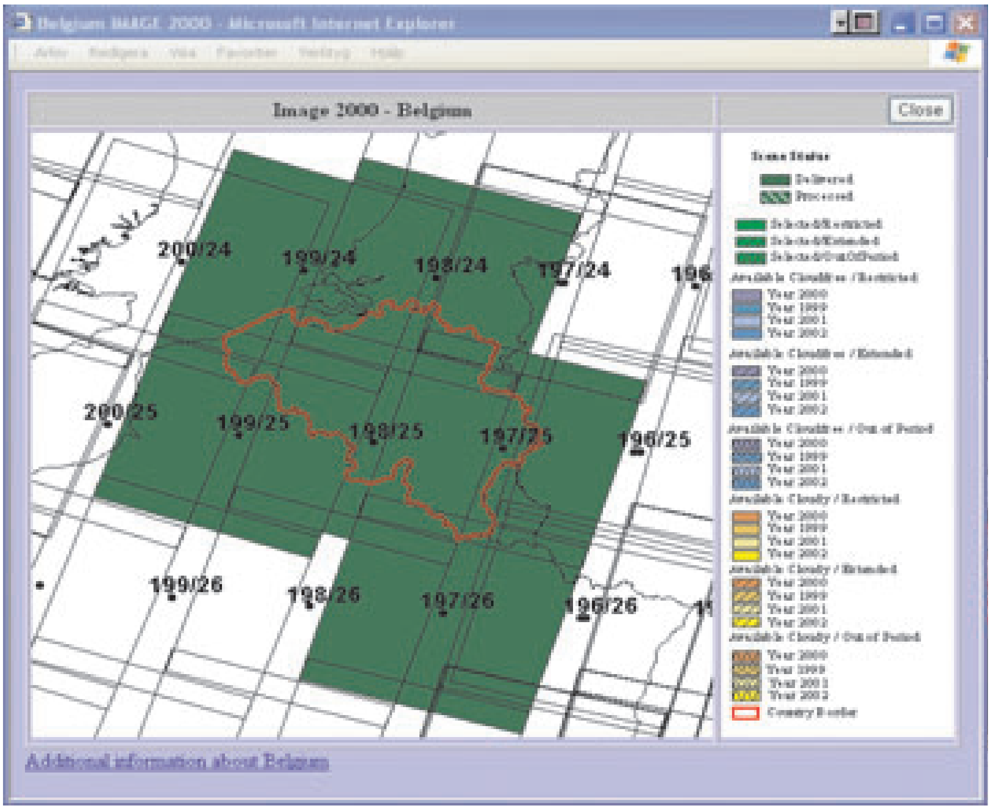


Figure 8- Status of available frames for a country

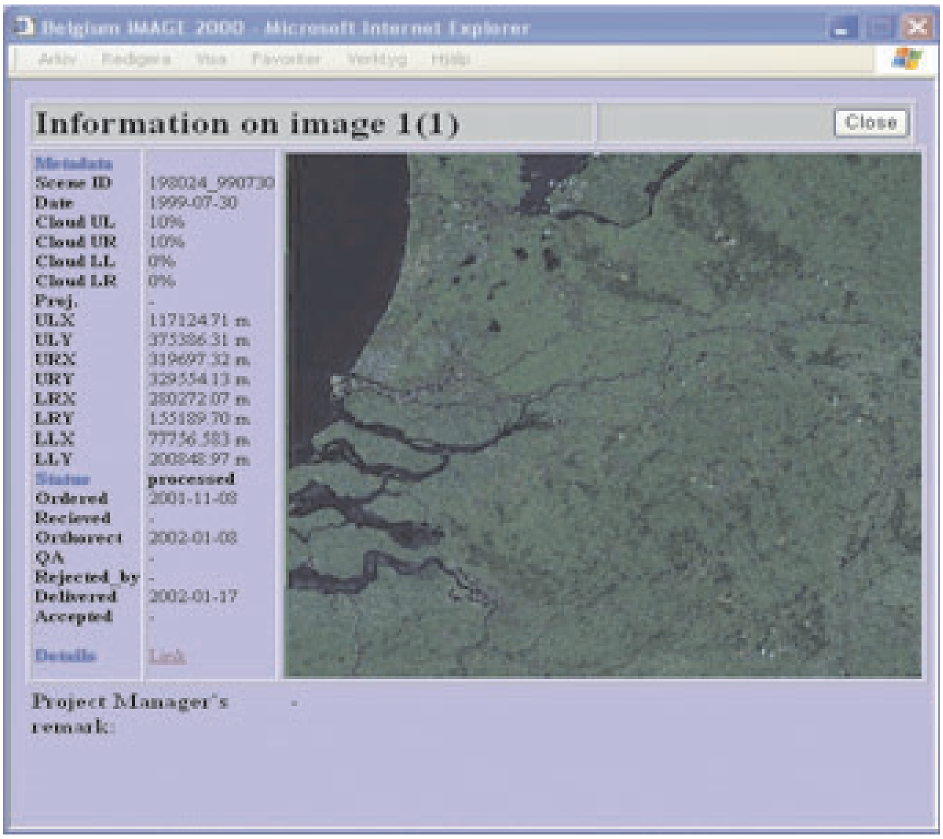


Figure 9- Web page with the information on a scene metadata and status

3.2.4 Selection Process

An operator at Metria browsed for available satellite images for a node where an image has not yet been selected on the search databases at Eurimage and USGS. Once a scene that had fulfilled the criteria for clouds and imaging periods was found, its metadata and quick-look were uploaded to the Image2000 Image Catalogue connected to the website for viewing. The National Administrations were notified by the Image2000 Team about the availability of quick look and regular updating of the web image catalogue. The National Administrations were responsible for:

- Selecting from the proposed images and send to Image2000 Team, within *2 weeks,* a list of ***selected images***.
- Informing the Image2000 Team, on the reasons for the non selection of image on a given frame (for instance, non availability, non optimal dates, cloud coverage, other preferences).
- Informing the Image2000 Team, if any priority for ortho-correction of the selected images, was to be taken into consideration.

Image2000 Team at the JRC verified the selection, giving a suggestion to which images should be best suited if several images were available and notified Metria and National team. The images selected by the National Administration had to be validated by the Contractor who had to check its conformity and the overlap with neighbouring image previously validated. Metria thereafter ordered the image from the supplier, set the status to "***selected***" on the IMAGE2000 Image Catalogue and notified the JRC and the National Administration by "Image Order Notification" (e-mail) of each order of images. Metria stopped then the Quick look updating for all the frames with a selected image, but continued the acquisition campaigns for the other cases.
At the end of the defined acquisition period (1999-2001), Metria analysed the best way to complete the missing area, on the basis of a pseudo-mosaic of images available, even if partially cloudy, and submitted it to Image2000 Team, who validate it in relationship with the National Administrations.

3.3 Overview of Time consistency

Table 13 shows for each country, the distribution of images within the years of acquisition. The images from 2002 were selected due to the impossibility to get cloud free images for the reference period or as equivalent scenes to improve the cloud coverage of the reference ones.

For equal conditions of acquisition window and cloud free frames, some countries preferred 1999 instead of 2001 to allow starting the national project first.

Table13- Distribution of images within the defined years of acquisition

	1999	2000	2001	2002	Total
Austria	4	5	2		11
Belgium	1	5			6
Bulgaria		10	1		11
Czech Rep	2	4	3		9
Cyprus		2			2
Denmark	1	6	2		9
Estonia	4	3	4		11
Finland	7	11*	11	3	33
France	5	29	12		46
Germany	10	17	5		32
Greece		17	9		26
Hungary		10			10
Italy	2	24	12	1	38
Ireland		2	7		9
Latvia	3	6	2		11
Lithuania	1	4	3		8
Luxembourg		1			1
Malta			1		1
Netherlands	3	3			6
Poland	4	18	6		28
Portugal	1	10	3	1**	15
Romania		18	2		20
Slovak Rep		4	1		5
Slovenia	1	3			4
Spain	3	41	2	1**	47
Sweden	8	17	8	4	37
United Kingdom	3	13	12	3	31
Total	63	283	108	13	467

* 2 images provided by the National Administration; ** Madeira island; *** Canary island

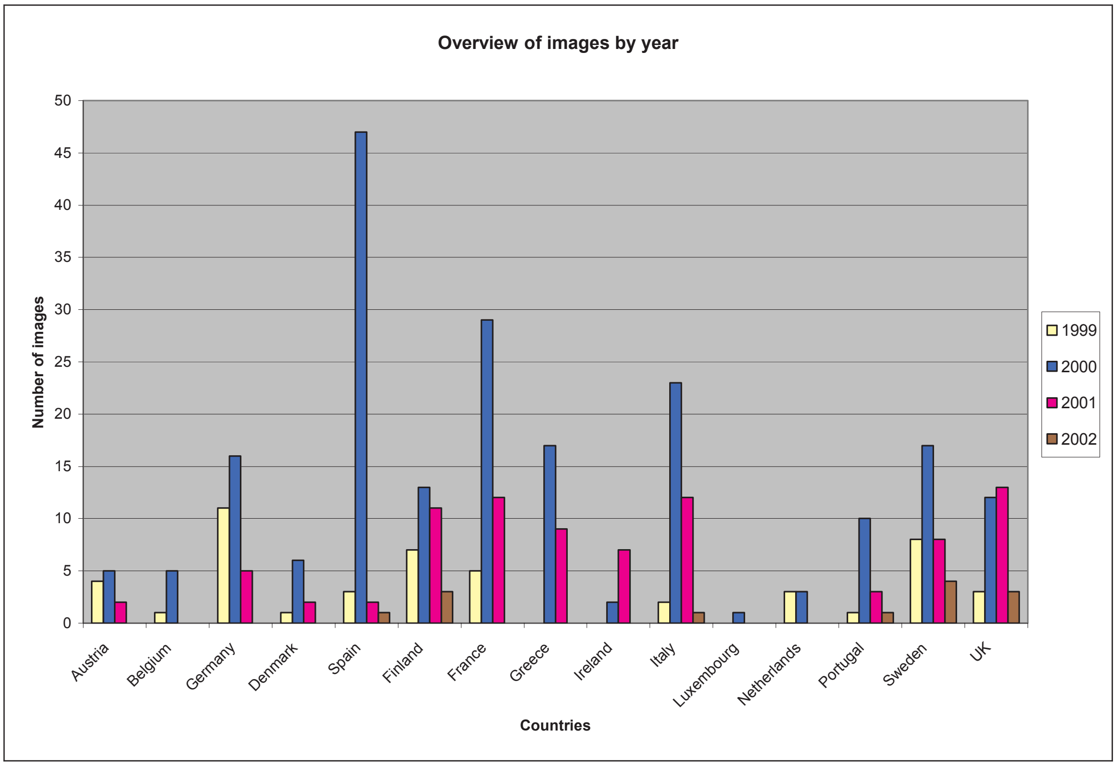


Figure 10 – Distribution of countries' images by year of acquisition

Figures 10 and 11 show for each country of the first group the distribution of scenes by year and by the window of acquisition respectively. Figure 12 gives for each country of the previous group AC10, the distribution of images per year of acquisition.

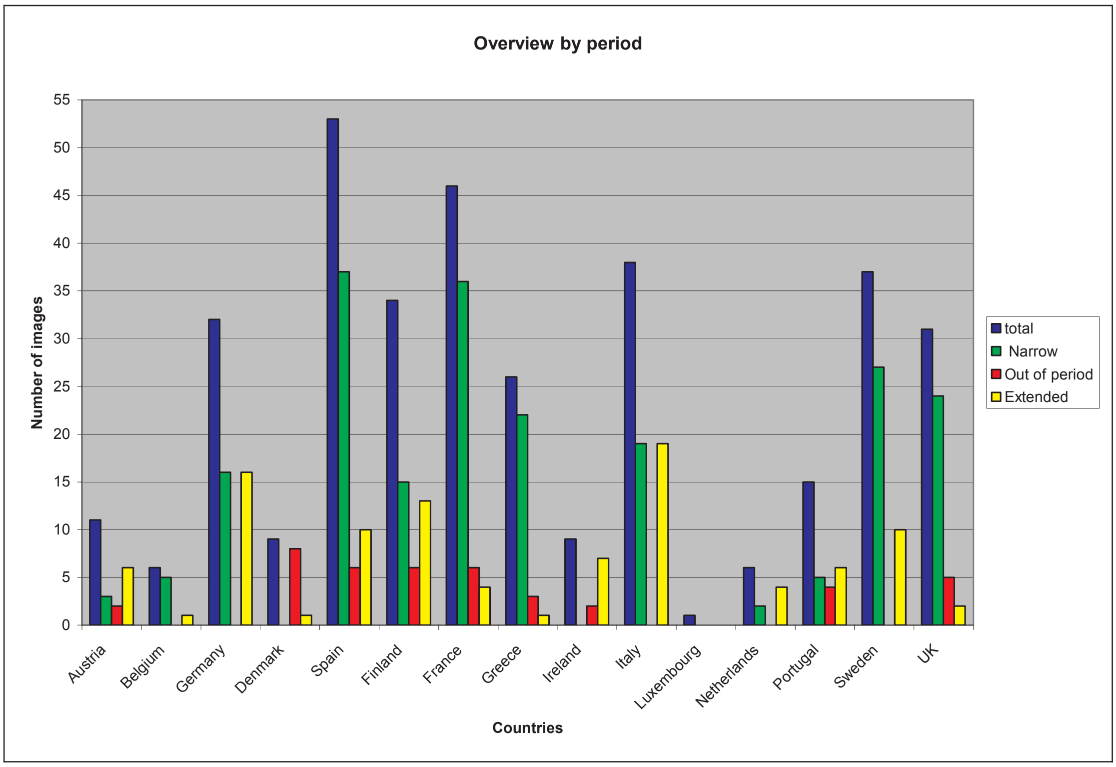


Figure 11 – Distribution of countries' images by window of acquisition

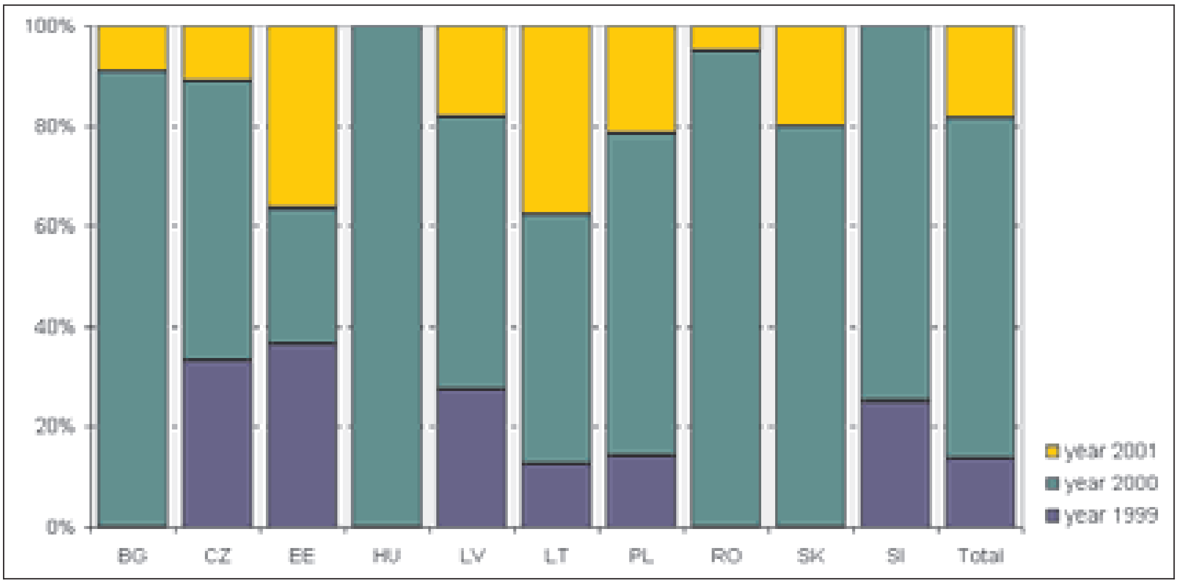


Figure 12- Acquisition year of scenes covering the previous AC10- overview per country

Figure 13 shows the distribution of scenes per year and acquisition window for the all IMAGE2000 coverage. It is clear that most of the scenes are from year 2000 and acquired within the narrow window of acquisition. Figure 14 indicates that, considering the totality of scenes, 79% of them were acquired within the defined most suitable window. The choice of frames out of period was due to the impossibility to get cloud free images within the most suitable period for the years defined or to improve the coverage as explained before Figure 15 gives an overview of the number of images within each acquisition window, by country. It shows somehow the difficulty to get cloud free images for certain geographic areas. As in the other figures, green represents the narrow period, yellow the extended and red out of period.

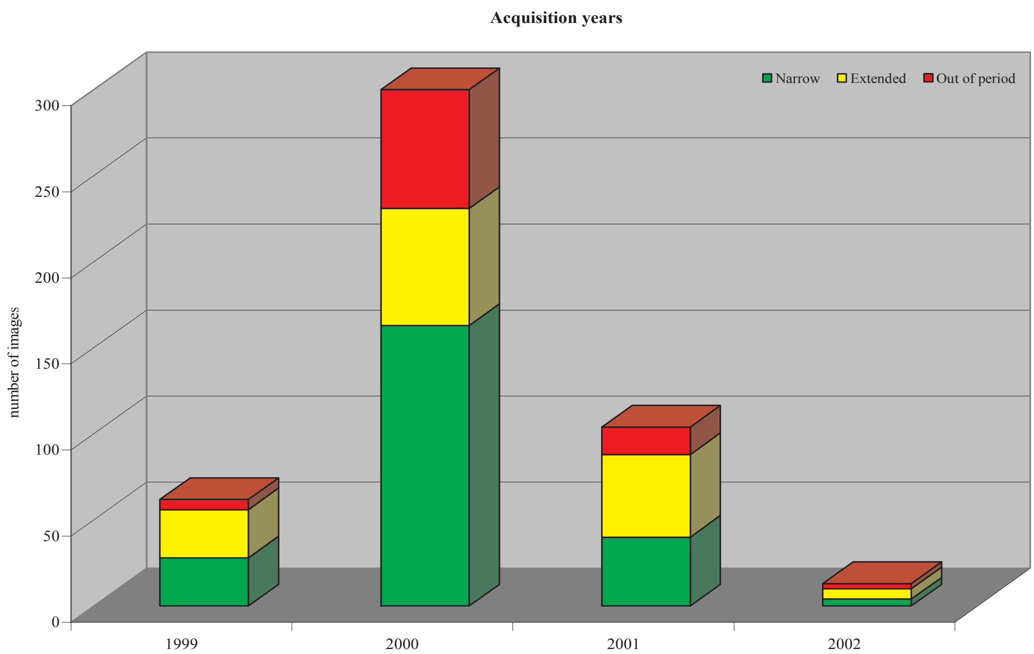


Figure 13- Distribution of scenes by year and window of acquisition

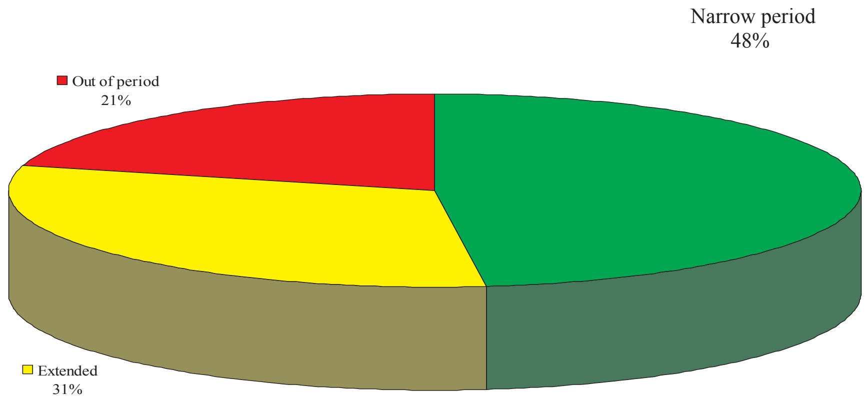


Figure 14- Percentage of scenes within each acquisition window

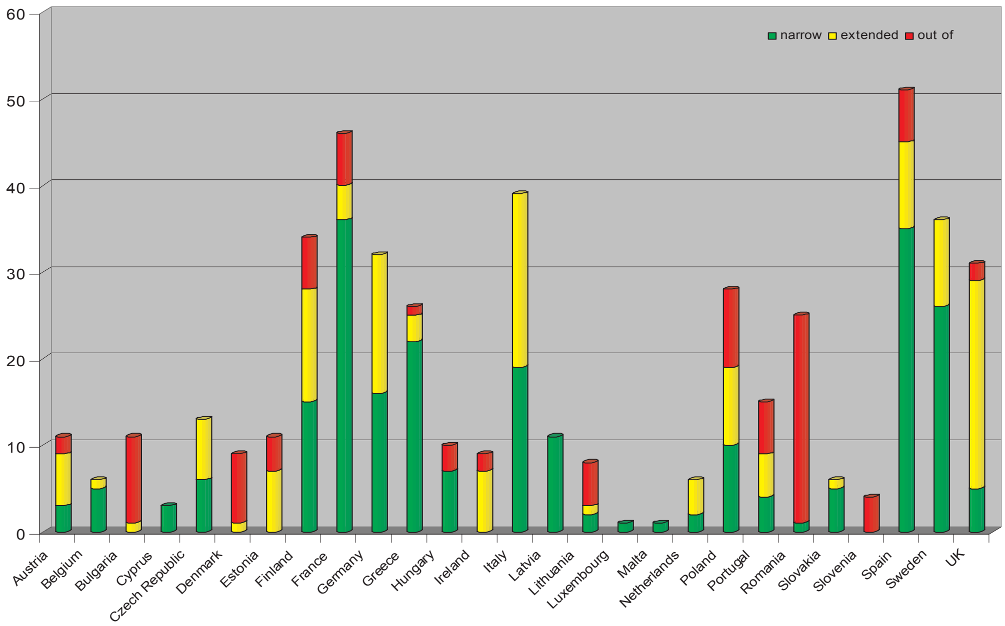


Figure 15- Overview of images distribution by country within the acquisition periods

The time consistency of IMAGE2000 is an important achievement, demonstrated by the 97% of the images acquired within the time period defined for the project (1999/2001), being 61% of the total acquired for the year 2000. It is also consistent regarding the window of acquisition with 79% of images acquired within the period of the year considered the most suitable for a certain region or country. To interpret these percentages, they correspond to images purchases and not to area coverage.

3.4 Distribution of images per participating country

The total number of selected scenes is 467, of which 6 are of Landsat 5. For those 6 cases, 3 scenes in Ireland and 3 in United Kingdom, no Landsat 7 images were available within the target period or not covered by its path/row. A little extract of IRS was used to cover a small surface of the Irish coast, not acquired by cloud free Landsat images. Two scenes were provided by the Finnish Administration to replace cloudy areas. With few exceptions the data was purchased from Eurimage.
Within the EU15, 41 scenes were processed for more than one country. Each of these "border scenes" was ortho-rectified for the area covering each country separately, using the corresponding projection system and leaving the area not concerned by the country without geometric correction. They are listed in the Table 14a. and 14b. Table 15 shows the number of nominal scenes used per country.

Table 14a- Border scenes, shared by more than one country

Scene Id	Countries				
191-28 990915	Austria	Italy			
192-14 010709	Finland	Sweden			
192-26 010826	Austria	Germany			
192-27 010826	Austria	Germany	Italy		
193-13 000729	Finland	Sweden			
193-21 990711	Denmark	Sweden			
193-22 000814	Denmark	Germany			
193-27 990913	Austria	Germany	Italy		
193-31 010801	France	Italy			
194-12 020811	Finland	Sweden			
194-27 000618	Austria	Germany			
195-12 000727	Finland	Sweden			
195-22 000609	Denmark	Germany			
195-26 010815	France	Germany			
195-27 010815	France	Germany			
195-28 010815	France	Italy			
195-29 000727	France	Italy			
195-30 000828	France	Italy			
196-22 000515	Denmark	Germany			
196-26 990902	France	Germany			
197-23 000826	Germany	Netherlands			
197-24 990909	Germany	Netherlands			
197-25 000911	Belgium	France	Germany	Luxembourg	Netherlands
197-26 000911	Belgium	France	Germany		
197-31 000810	France	Spain			
198-24 990730	Belgium	Netherlands			
198-25 000801	Belgium	France			
198-30 990916	France	Spain			
199-24 000824	Belgium	Netherlands			
199-25 000824	Belgium	France			
199-30 000909	France	Spain			
200-30 000730	France	Spain			
201-25 011012	France	UK			
202-25 010512	France	UK			
203-31 000905	Portugal	Spain			
203-32 000905	Portugal	Spain			
203-33 000719	Portugal	Spain			
203-34 000719	Portugal	Spain			
204-31 000624	Portugal	Spain			
206-22 010524	Ireland	UK			
207-22 010523	Ireland	Uk			

Table 15- Total number of images for each country

Austria 11	**Czech R 9**	**Estonia 11**	**Germany 32**	**Italy 38**	**Lithuania 8**	**Netherlands 6**	**Romania 20**	**Spain 47**
Belgium 6	**Cyprus 2**	**Finland 33**	**Greece 26**	**Ireland 9**	**Luxembourg 1**	**Poland 28**	**Slovakia 5**	**Sweden 37**
Bulgaria 11	**Denmark 9**	**France 46**	**Hungary 10**	**Latvia 11**	**Malta 1**	**Portugal 15**	**Slovenia 4**	**UK 31**

Table 14b- Border scenes, shared by more than one country

Path_Row	Countries		
181030	Bulgaria	Romania	
182031	Bulgaria	Greece	
183030	Bulgaria	Romania	
183031	Bulgaria	Greece	
182029	Bulgaria	Romania	
189026	Czech Republic	Slovakia	
184030	Bulgaria	Romania	
192026	Austria	Czech Republic	German
192027	Austria	Czech Republic	German
189025	Czech Republic	Poland	
189018	Estonia	Finland	
191028	Austria	Italy	Slovenia
187026	Hungary	Poland	Slovakia
186026	Hungary	Poland	Slovakia
190026	Austria	Czech Republic	
187022	Lithuania	Poland	
189021	Lithuania	Latvia	
189027	Austria	Hungary	
184031	Bulgaria	Greece	
190025	Czech Republic	Poland	
188035	Malta	Italy	
190027	Austria	Slovenia	
190028	Austria	Slovenia	
191025	Czech Republic	Poland	
191026	Austria	Czech Republic	
189028	Hungary	Slovenia	
192025	Czech Republic	German	
186021	Lithuania	Latvia	
185029	Bulgaria	Romania	
186027	Hungary	Romania	
186028	Hungary	Romania	
187018	Estonia	Finland	
187019	Estonia	Latvia	
187020	Estonia	Latvia	
189020	Estonia	Latvia	
186020	Estonia	Latvia	
185021	Lithuania	Latvia	
185020	Estonia	Latvia	
188020	Estonia	Latvia	
188021	Lithuania	Latvia	
188022	Lithuania	Poland	
188026	Poland	Slovakia	
188027	Hungary	Slovakia	
187021	Lithuania	Latvia	
192023	German	Poland	
192024	German	Poland	
193025	Czech Republic	German	

4 National topographic maps

Each participating country identified the national authority in conditions to provide the information on the national Coordinate Reference System (CRS) and the topographic maps to use for the orthorectification of the corresponding satellite images. The scale 1:25 000 was chosen whenever available.

Table 16 indicates the topographic maps used to georeferenced the national IMAGE2000 coverage.

Table 16- National maps approved by the national authorities and used to collect the Ground Control Points

Austria **Name**: Österreichische Karte 1:25 000 (ÖK 25V) **Description**: Enlarged from Österreichische Karte 1:50 000; Analogue maps **Published by:** Bundesamt für Eich- und Vermessungswesen (Landesaufnahme) Wien 1976- (rev continuously)	**Belgium** **Name:** Topografische kaart van Belgie 1:25 000 (old) Topografische kaart van Belgie 1: 20 000 (new) **Description:** Analogue maps **Published by:** Nationaal geografisch instituut 1997-1992 (1:25 000);1990- (1:20 000)
Denmark **Name:** Topografisk kort, Danmark 1:25 000 **Description:** Analogue maps **Published by**: Geodaetisk Institut 1957-1978 ;1978 – revised every 10-15 years	**German** **Name:** Digitale Topographische Karte 1:25 000 (DTK 25) **Description**: Digital form **Published by**: Bundesamt für Kartographie und Geodäsie 1999
Finland **Name:** Peruskartta (Grundkarta) / Topografinen kartta 1:20 000 **Description:** Peruskartta, a more detailed version, is published for southern and central Finland. Topografinen kartta is published for Lapland. Digital form **Published by:** Maanmittaushallitus (Lantmäteristyrelsen) 1950-1977 (Peruskartta is revised every 5 years)	**France** **Name:** TOP 25 / Série Bleue 1:25 000 **Description:** TOP25 "Les cartes touristic locales". Serie Bleue former "Carte topographique" Analogue maps **Published by**: Institut Géographique National (IGN) Paris 1977-1989 (revised continuously) Serie Bleue Paris & al.1988
Greece **Name:** Digital ortho-photos, with a resolution of 1 meter. Greece Re Linear, Digital vector data, showing coastline, rivers, roads etc. **Description:** Digital Form **Published by:** Ministry of Environment in Greece (orthophotos); ISTAR France (Digital vector data)	**Luxembourg** **Name**: Grand-Duche de Luxembourg - Carte Topographique 1:20 000 (old) Grand-Duche de Luxembourg - Carte Topographique 1:20 000 (TC) **Description:** Analogue maps **Published by**: Administration de Cadastre et de la Topographie - Luxembourg 1989 (old); 1998- (TC)
Ireland **Name:** Discovery series /Sraith Eolais 1:50 000 **Description:** Analogue maps **Published by:** Ordnance Survey Ireland Dublin 1993	**Italy** **Name:** Carta Topografica d'Italia 1:25 000 (new series) Carta d'Italia 1:25 000 (old series) **Description:** Analogue maps **Published by:** Instituto Geografico Militare 1872-1973 partly revised (old series) 1989- (new series)
Netherlands **Name:** Topografische kaart van Nederland 1:25 000. **Description**: Analogue maps **Published by:** Topografische Dienst, Emmen 1981-2000	**Portugal** **Name:** Carta Militar de Portugal 1:25 000 **Description:** Analogue maps **Published by:** Instituto Geográfico do Exército 1945-1950 (continuously revised since 1961, up to 4th edition)

Spain **Name**: Mapa Topográfico Nacional de España 1:25 000 **Description:** Analogue maps **Published by:** Instituto Geográfico Nacional Madrid 1975-	**Estonia** **Name:** Orthophotos, 1:10 000; topographic maps 1:10 000 **Description:** Digital orthophotos, resolution 0.8-1m; Analogue topomaps **Published by:**
United Kingdom **Name:** Explorer 1:25 000; Path finder 1:25 000 Discoverer Series 1.50 000 (Northern Ireland) **Description**: Analogue maps **Published by:** Ordnance Survey Great Britain 1965-1989 (revised continuously) Pathfinder 1994- Explorer; Ordnance Survey of Northern Ireland Belfast 1978-1985 (revised continuously) Discoverer series	**Sweden** **Name:** Gula kartan 1:20 000 Ekonomisk karta över Sverige 1:20000 / 1:10000 **Description:** Digital form **Published by:** Lantmäteriverket (LMV) Gävle 1935-1978 (partly revised) Ekonomisk karta 1983- (new editions every 5-10 years) Gula kartan
Czech Republic **Name:** Military topographic maps, 1:25 000 **Description:** Analogue maps **Published by:**	**Bulgaria** **Name:** topographic maps, 1: 25 000 **Description:** Analogue maps **Published by:**
Hungary **Name:** Military topographic maps, 1:25 000 **Description:** Analogue maps **Published by:**	**Latvia** **Name:** Vector basemap 1: 50 000 **Description:** Raster maps produced from the vector basemap, resolution 1 pixel=8.5m **Published by:** National Land Service
Lithuania **Name:** Topographic maps 1: 50 000; Orthophotos 1:10 000 **Description:** Analogue maps. Orthophotos were produced using aerial photos 1: 20 000- 1:30 000 acquisition 1995-1998 **Published by:**	**Estonia** **Name:** Orthophotos, 1:10 000; topographic maps 1:10 000 **Description:** Digital orthophotos, resolution 0.8-1m; Analogue topomaps **Published by:**
Romania **Name:** Military topographic maps, 1: 50 000 **Description:** Raster topomaps, resolution 1pixel= 6.4m **Published by:**	**Slovakia** **Name:** SAZP map archive, based on national military and civil maps, 1: 25 000 **Description:** Raster maps **Published by:**
Slovenia **Name:** topographic maps, 1: 25 000 **Description:** Analogue maps **Published by:**	**Malta** **Name:** national topographic maps 1:25 000 **Description:** analogue, scanned 300dpi **Published by:** Malta Environment
Cyprus **Name:** topographic maps, 1:50 000; orthophotos 1m resolution for part of coast line **Description**: Analogue maps,digital orthophotos **Published by:**	**Poland** **Name:** Military topographic maps, 1: 50 000, Serie M755 **Description:** Analogue maps **Published by:**

Table 17 resume the definition of the national coordinate reference system. For Greece, it was not possible to have suitable topographic maps. The orthophotos made available covered only parts of Greece. Therefore they were used in combination with vector data for the orthorectification, to give the geometric quality needed. Overall, the orthophotos gave a very good RMS, but the geometric coverage was not so good. For the areas not covered by orthophotos, the vector dataset was used as input data source. Table 18 shows the distribution of points derived from orthophotos and from the vector data.

Table 17- Summary of the national coordinate reference systems

Country code	Map projection	Spheroid	Datum	
			Name	Shifts to ETRS89
BG	Lambert Conformal Conic	Krassovsky 1940	N.A.	N.A.
CZ	Transverse Mercator	Krassovsky 1940	Pulkovo	7-term
EE	Lambert Conformal Conic	GRS-80	ETRS89	
HU	Oblique Mercator	GRS-67	HD72	7-term
LV	Transverse Mercator	GRS-80	ETRS89	
LT	Transverse Mercator	GRS-80	ETRS89	
MT	Universal Transverse Mercator	Hayford 1909	ED50	7-term
PL	Transverse Mercator	GRS-80	ETRS89	
RO	Transverse Mercator	Krassovsky 1940	Pulkovo	3-term
SK	Transverse Mercator	Krassovsky 1940	Pulkovo	3-term
SI	Transverse Mercator	Bessel 1841	D48	7-term
AT	Lambert Conformal Conic	Bessel 1841	MGI	7-term
BE	Lambert Conformal Conic	Hayford 1909	BD72	7-term
DE	Transverse Mercator	Bessel 1841	DHDN	7-term
DK	Universal Transverse Mercator	Hayford 1909	ED50	7-term
ES	Universal Transverse Mercator	Hayford 1909	ED50	3-term
FI	Transverse Mercator	Hayford 1909	KKJ	7-term
FR	Lambert Conformal Conic	Clarke 1880 IGN	NTF	3-term
GR	Transverse Mercator	GRS-80	GGRS87	7-term
IE	Transverse Mercator	Airy Modified	IRELAND65	7-term
IT	Universal Transverse Mercator	Hayford 1909	ETRS89	
LU	Transverse Mercator	Hayford 1909	LUREF	7-term
NL	Oblique Stereographic	Bessel 1841	Rijksdriehoeks	7-term
PT	Transverse Mercator	Hayford 1909	Lisbon	7-term
SE	Transverse Mercator	Bessel 1841	RT90	7-term
UK	Transverse Mercator	Airy	OSGB36	7-term

Table18 - Distribution of GCPs by orthophotos and vector cover for Greece

Scene	Acq.Date	Nr.Ortho	Nr.Vector	% Ortho	% Vector
179/035	000625	0	8	0	100
180/034	000702	0	16	0	100
180/035	000702	0	21	0	100
181/033	010626	0	11	0	100
181/034	000623	5	17	23	77
181/035	000623	6	16	27	73
181/036	000623	7	19	27	73
182/031	010601	0	18	0	100
182/032	010601	1	15	6	94
182/033	010617	2	14	12	88
182/034	010617	26	2	93	7
182/035	010617	11	11	50	50
182/036	010617	3	7	30	70
183/031	000621	1	6	14	86
183/032	010811	14	12	54	46
183/033	000707	11	21	34	66
183/034	000707	11	16	41	59
183/035	000707	16	0	100	0
184/031	000628	0	6	0	100
184/032	000628	8	9	47	53
184/033	000628	13	17	43	57
184/034	010615	21	8	72	28
185/032	000705	4	9	31	69
185/033	000705	7	15	32	68
185/034	000705	8	0	100	0
186/032	000728	2	4	33	67

5 Digital Elevation Model (DEM)

5.1 European DEM

The same European Digital Elevation Model (DEM) was used to orthorectify the images covering EU15, except for Ireland, Finland, Sweden, Austria, the Canary Islands and Madeira Islands. The DEM provided by the American company "Virtual World Developers Inc", Hawaii, USA covers most of Europe and its technical characteristics are compatible with the quality requirements of IMAGE2000:

Technical Characteristics:

Supplier is the Virtual World Developers Inc. Hawaii, USA. The DEM is based on DMA DTED Level 1 databases, re-sampled using MultiGen Pro software on Silicon Graphics W/S.

Grid size: approximately 90 metre grid. Quality: RMS (Root Mean Square) horizontal radial error relative WGS84 <= 25 meters. RMS vertical linear error relative height over mean sea level <= 15 m.

5.2 National DEM provided by the countries

For some countries the National administrations made available more detailed and precise DEM.

Technical Characteristics of the Swedish DEM- Supplier: Lantmäteriet (National Land Survey). Source: Based on the national topographic 1:50,000 scale maps. Height system: National system RH 70. Grid size: 50 m grid. Quality: RMS horizontal radial error relative <= 10 m. RMS vertical linear error relative height over mean sea level <= 5 m.

Technical Characteristics of the Finnish DEM- Supplier: National Land Survey of Finland. Source: 1:20 000 topographic maps. Grid size: 25 m grid. Quality: RMS horizontal radial error relative <= 5-20 m. RMS vertical linear error relative height over mean sea level <= 2 m.

Technical Characteristics of the Austrian DEM- Supplier: The Austrian National Administration. Grid size: 50 m grid. Quality unknown.

Technical Characteristics of the Estonian DEM- Source: DEM, digitized contour lines, height points. Grid size: 25 m.

Technical Characteristics of the **Lithuanian DEM-** Source: national DEM. Scale 1:50 000. Accuracy 0,5m.

Technical Characteristics of the Canary Islands- Supplier: "MDT200" from CNIG (Instituto Geográfico Nacional, Spain). Source: topographic maps 1:200.000. Grid size: 200 m grid. Quality: RMS horizontal radial error relative = 0 m (based on fixed grid). RMS vertical linear error relative height over mean sea level <= 30 m.

Technical Characteristics of the Madeira Islands- Supplier: Sector de Divulgação e Comercialização at IGEO. Source: topographic maps. Grid size: 100 m grid. Quality: RMS horizontal radial error relative <= 30-40 m. RMS vertical linear error relative height over mean sea level <=25-30 m.

5.3- Other DEMs

Ireland: Ireland was not covered by the European DEM used. The DEM used for Ireland was produced for military purpose in Russia from various sources of information and it met the technical characteristics required. Supplier: The National Administration. Source: combined sources. Grid size: 100 m grid. Quality: RMS horizontal radial error relative unknown. RMS vertical linear error relative height over mean sea level <= 15 m.

Table 19 summarize the main characteristics of the DEMs used for the ortho-rectification of each of the ten Accession Countries.

Table19 . List of DEM acquired for ortho-rectification purposes for each of the ten A.C.

Country	Provider	Source origin	Grid resolution used	Vertical accuracy	Accuracy relative to map
Bulgaria	Geosys (FR)	combined sources	100x100m	4-13m	1:100000
Czech Republic	GISAT (CZ)	combined sources	100x100m	10-20m	1:100000
Estonia	WorldSat Int (CA)	combined sources	100x100m	10-20m	1:100000
Hungary	FOMI (HU)	topographic maps	100x100m	10m	1:100000
Latvia	WorldSat Int (CA)	combined sources	100x100m	10-20m	1:100000
Lithuania	WorldSat Int (CA)	combined sources	100x100m	10-20m	1:100000
Poland	Geosys (FR)	combined sources	100x100m	4-13m	1:100000
Romania	Geosys (FR)	combined sources	100x100m	4-13m	1:100000
Slovakia	Geomodel (SK)	topographic maps	100x100m	5m	1:100000
Slovenia	Surveying and Mapping Authority (SI)	radar interferometry	100x100m	3-16m	1:100000

6 Product 1- Orthorectified images

6.1 Methodology

6.1.1 Orthorectification of Landsat scenes

The main methodology and criteria defined by the JRC as the technical specifications for IMAGE2000 were applied for the orthorectification of both group of countries and anytime a new country joined the project. Slight differences in execution are due to local conditions and they are not relevant regarding the standard products. The requirement was that the resulting ortho-image would have a Root Mean Square Error (RMS) of at the most 25 m in both X and Y. This was obtained with extremely good margin, approximately 12.5 m by country as average, in spite of problems with some Landsat 7 raw images and old or less accurate reference material (maps) for some countries.

Metria had developed a unique integrated processing system for the orthocorrection of optical data such the one from Landsat. The orthocorrection method used in the Project had consisted in use of a physical model of the satellite’s flight during the scene acquisition, which was then in one operation complemented with **Ground Control Points** (**GCP**) and DEM. Attached to the model was all required map projection information, so that the production of a final product was carried out by transforming raw data directly into the final product in a single step. This results in a final product quality that offers:

- Excellent accuracy between the spectral bands.
- Sub-pixel location accuracy throughout the image from quite few control points.
- Excellent preservation of radiometric characteristics through the single resampling step.
- Known orbital viewing geometry, so true ortho-images can be generated using DEMs.
- Possibility of creating extensive mosaics at a consistently high accuracy.

The satellite scene was ingested, and the scene metadata interpreted. This information was used to calculate an *a priori* acquisition model for the scene, including the six Keplerian orbital elements, and three attitude angle offsets. Control point observations were used to refine the *a priori* values of the orbit and attitude model parameters. A control point observation consists of a 3-dimensional geodetic coordinate for the ground space, and the corresponding 2-dimensional image coordinate. Corrections to the *a priori* model parameters were determined by a weighted least squares adjustment of the control point observations.

GCPs data were digitized from maps, provided by the participating countries, normally at the scale 1:25 000. From each map sheet, at least 16 well distributed points had been selected for the correction and normally 9 well distributed points for the internal quality control. The GCPs had been correlated to the panchromatic band.

In the orthocorrection, parallax errors in spatial positioning caused by oblique viewing were corrected. A DEM was used to determine the parallax size. The DEM was first resampled to the image output space, and the terrain displacement vector was then calculated for each output pixel.

In the **resampling** of the scene, the original image was transformed to the desired frame, pixel size and map projection, taking into account the acquisition model and parallax corrections. The resampling kernel used was *cubic convolution*. The resample had been performed in one single step from raw data to the final product. This preserves the original radiometry better than the two steps procedure normally used. The final pixel size is 12.5m for panchromatic, 25 m for multispectral bands and 60m for the thermal band. Figure 16 describes the process-flow in PKu-system. The input was a system-corrected satellite scene (aimg). Output were orthorectified image (pimg) and logfiles (aimg.res and aimg.ps).

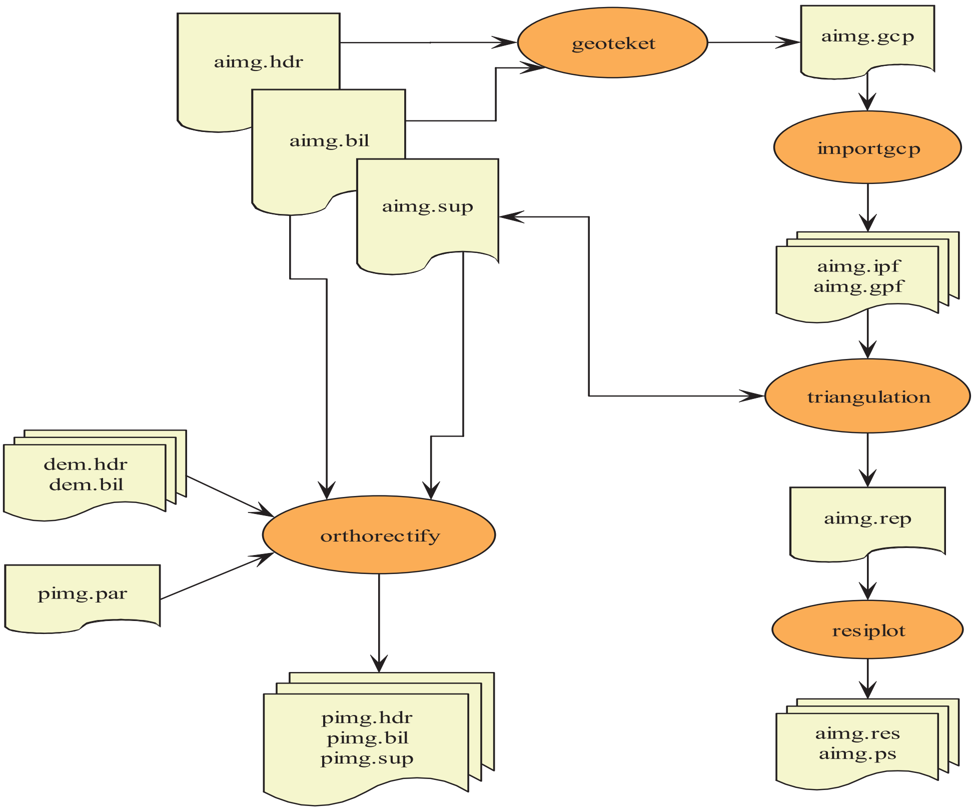


Figure 16- Orthorectification process flow in PKu-system

The orthorectification of all the Landsat 7 imagery covering the AC10 was done by GISAT s.r.o.. Geomatica software package developed by PCI Geomatics was used. It includes OrthoEngine Satellite Models package that uses ephemeris satellite data a ground control points in proven parametric model to describe acquisition geometry of each scene. Such a model, together with DEM (see Table 19) of the area, allowed correcting all type of geometric distortion, caused by satellite position, Earth curvature, Earth terrain and cartographic projection, inherent in each satellite scene. The block bundle adjustment method was used during orthocorrection. Single project for each country (or more in case of zone projections) was defined. A single geometric model considered all of the project images was calculated and identical GCPs were used in overlapping areas. It ensured maximum possible geometrical homogeneity in all orthorectified scenes of the project.

Regarding **radiometric correction**, the data were examined for coherent noise. If this was present, a convolution filter had been applied to reduce these artefacts.
The orthocorrection production environment is described in table 20.

Table 20 - Description of the production environment

	Metria			GISAT	
System name	Geoteket	PKu	Socet Set	PCI Geomatica/ PCI GCPWorks	PCI OrthoEngine
OS	MS Windows	Sun Solaris	Sun Solaris	MS Windows	MS Windows
Usage	Geodetic computations and ground control point measurements	Image orthorectification	Framework in which PKu functions are implemented	General IP environment, geodetic computations and ground control point measurements	Image orthorectification

6.1.2 Internal quality control

The internal quality controls and verifications were based on Joint Research Centre's (JRC) document "Guidelines for Quality Checking of Ortho Imagery" Issue 1.5. This resulted in the following internal quality control steps:

Checks of input data:
The selected images had been ordered as system corrected Level 1G images from Eurimage. When the data had arrived, the following checks had been made and recorded:

1. Check that the received data correspond to what was ordered. This was done by comparing the order with the documentation from Eurimage, including the quick-look.
2. Read and display the data to check the location (compared with maps); if there were clouds or haze in the image, readability of the product and that there were no other technical or visual problems with the input product.

Checks before orthocorrection:
Before starting the orthocorrection, the following checks had been done and recorded:

1. Check of the DEM to be used against maps. RMS_z was calculated using 9 checkpoints and checked that the RMS_z was less than 50 m.
2. Check that the maps to be used were available and corresponding to the map series given by the countries.
3. Check and document the ellipsoid and projection and that it corresponded to the information given by the countries.

Checks after orthocorrection:
When the orthocorrection had been performed, the following checks had been done and recorded:

1. Check that the GCPs are at least 16 and equally spread over the scene.
2. Check that the verification points are at least 9 and equally spread over the scene.
3. Check in the production report that RMS_x and RMS_y are < 25 m.
4. Check the maximum check-point accuracy.
5. Perform blunder check.
6. Perform visual accuracy check by using digital map data.
7. Check that all bands can be overlaid with < 1 pixel discrepancy.

Checks before delivery:
Before delivery, the output products and the metadata had been checked concerning content and readability. The internal quality control done right after ortho-rectification, consisted in an independent check of GCP elevation, combined with the accuracy verification specified in contract Terms of Reference. Verification of positional accuracy entailed comparisons of coordinates of orthorectified imagery to previously specified 9 well-distributed verification points (see above). When discrepancies in the verification points were found, 3 times larger than RMS residual error in the adjustment, the causes were investigated and the scene reprocessed (if the causes were not found in the verification points themselves). Results of this internal validation were summarized in internal quality reports included as metadata of each scene. Results of internal quality control show that achieved positional accuracy exceed the project specifications as illustrated in Figure 17. Table 21 summarize the results for 10 participating countries, showing the average RMS obtained for the panchromatic and for the multispectral bands, both the GCPs and the verification points. The mean residual errors, in meters, for each country EU15 are shown in the Table 22.

Table 21- Summary of the results on internal quality control (group of 10 AC)

	Average RMS [m]			
	PAN		MS	
	GCPs	verification points	GCPs	verification points
Bulgaria	16,98	19,42	17,12	19,82
Czech Republic	13,63	16,38	14,02	15,81
Estonia	8,34	11,51	11,46	12,46
Hungary	11,99	14,24	11,24	12,88
Latvia	17,64	20,57	16,58	19,18
Lithuania	12,56	14,86	15,03	17,38
Poland	15,86	18,62	15,35	17,54
Romania	19,97	21,86	20,64	22,93
Slovakia	17,18	18,23	17,35	18,07
Slovenia	15,87	20,86	17,33	21,78

Table 22- Summary of the results on internal quality control

Country	X res	Y res	Comments
Austria	12.7	13.5	
Belgium	7.6	8.8	
Denmark	9.6	8.7	
Finland	9.7	9.5	
France	12.2	13.0	
Germany	11.3	10.8	
Greece	14.5	14.3	
Italy	14.0	17.7	
Ireland	11.7	12.4	
Luxembourg	15.2	11.8	
Netherlands	8.6	8.7	
Portugal	12.0	11.4	Mainland
Portugal	16.7	18.1	Azores and Madeira
Spain	12.8	13.1	Mainland
Spain	9.8	10.4	Canary Islands
Sweden	7.9	7.5	
UK	10.7	10.9	

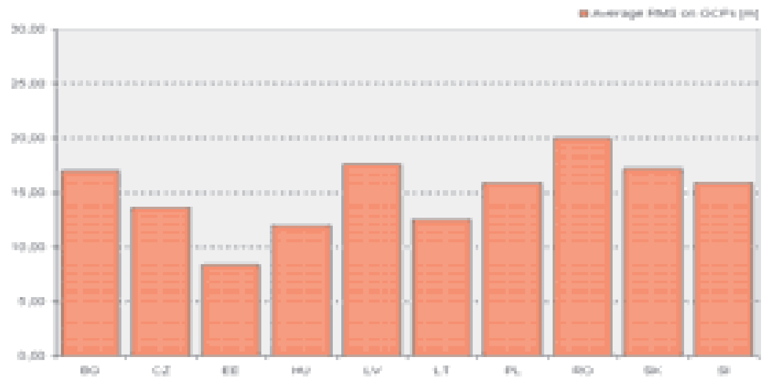


Figure 17- Accuracy verification - Average RMS on GCPs (in meters)

Figure 18 gives a visual distribution of the total RMS (X and Y) by scene covering EU15.

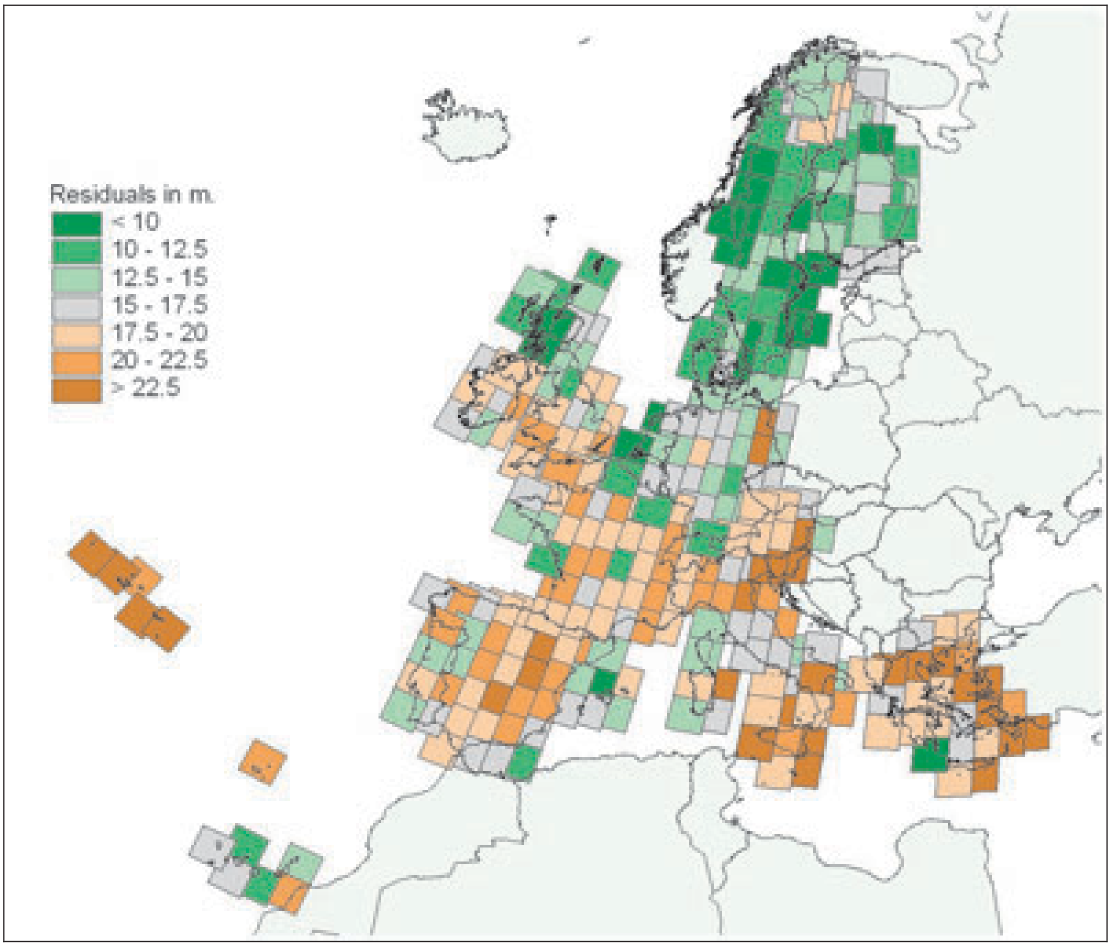


Figure 18- Total RMSE (X and Y) by scene covering EU15

6.2 The Test images

The validation of test images was introduced in order to detect geometric errors related to the image ortho-rectification to avoiding error propagation related to a wrong projection system, transformation or parameters used for the geometric correction of the images and to assure that the defined accuracy specification of Image2000 products was reached. Before launching the operational ortho-rectification of a country, one test image per country was selected and validated.

6.2.1 IMAGE2000 geometric quality requirements

The expected geometric quality of the final Image 2000 product was a RMS less than 25 m. In general, the ortho-image should be assessed in comparison with this specification, understood as a maximum value calculated both in RMSx and RMSy. Instead of a one dimension RMS (RMSxy), the recommendations of the JRC (reference: SK/I04/M1517/99) prefers to check independently the two dimensions (RMSx, RMSy), which allows identification of possible shifts and bias. The tolerable vertical accuracy (RMSz) was indicated to be twice the horizontal accuracy. The RMS in each dimension was calculated according to the formula:

$$\mathrm{rmse}_{\mathrm{x}} = \sqrt{\frac{1}{n}\sum_{\mathrm{i=1}}^{\mathrm{n}}(\mathrm{x}_{\mathrm{r}} - x_i)^2}$$

$$\mathrm{rmse}_{\mathrm{xy}} = \sqrt{rmse_x^2 + rmse_y^2}$$

$$\mathrm{rmse}_{\mathrm{y}} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_r - y_i)^2}$$

In case a delivered orthorectified images, verified by external quality control proved to be outside Image2000 project specifications, it should be rejected and returned back for a new orthorectification. The new delivered ortho-image was then subject to a second external quality control.

6.2.2 Methodology of Quality checking

The methodology of quality control used for validation of test images was based on the technical specifications of the Image2000 and CLC2000 project (refCST24/07/00), and in accordance with the JRC document “Guidelines for Quality Checking of Ortho Imagery”, defined by the MARS project of the JRC (reference: SK/I04/M1517/99).
For the geometric quality controls within Image2000 project, two different approaches were used:

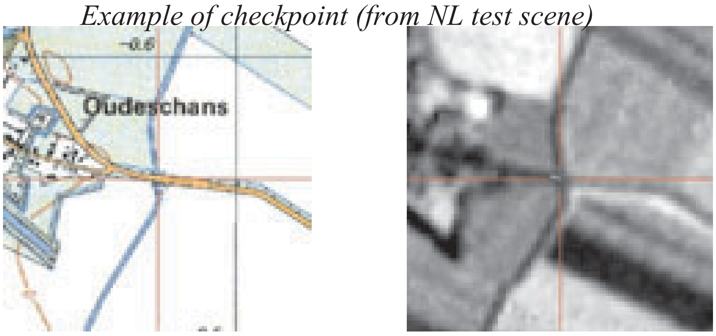
- Topographic maps-sheet.
- GPS measurements.

Geometric quality checks were performed on all test images using topographic maps-sheet, as this approach is relatively simple and cost effective. However, it may not give a clear and objective statement of the geometric quality of the final Image2000 products, because: (a) it is based on the same source of information used for ortho-rectification (even if different points are measured); (b) the maps are an indirect representation of the ground “truth”, including their own inaccuracy due to scale, generalisation or out-dating.

For these reasons, two studies using GPS measurements were carried out. The first study, conducted by the JRC (MARS project and Image2000 team), was directly based on GPS measurements. The second one was conducted by “Gael Consultant”and used GPS kinematic measurements more to assess the geometric inaccuracy of topographic maps than to estimate the quality of the ortho-images. The results of those two studies were used to validate the methodology proposed and to better understand the quality of the ortho-images.

The accuracy of ortho-image was obtained by measuring the distance between the position of a number of checkpoints observed on the satellite image and the real position of the corresponding terrestrial references. These terrestrial references were surveyed in the field (GPS measurements) or measured on topographic map, ortho-photos, or any other valid sources of information considered as the “terrestrial truth”. Figure 19 illustrates the selection of checkpoints from topographic maps (a), compared to satellite image (b).

Example of checkpoint (from NL test scene)



(a) topographic map (b), Satellite image

Figure 19 - Selection of checkpoints

The objective of the quality control was to check the absolute location of a number of selected image pixels, in order to obtain the overall accuracy of the orthorectified image. For each checkpoint a discrepancy was calculated in X and Y. For all the checkpoints of each scene controlled, an overall RMS was calculated. The results were compared to Image2000 project requirements (§6.2.1) and the image “pass” or “fail” the procedure of quality checking. For each scene controlled, the results of the quality control were documented in a quality control report, containing the list and location of Ground Control Points, their co-ordinates derived from terrestrial reference and RMS results.

For each Landsat 7 scene a minimum of 25 checkpoints should be selected on the ortho-rectified image. The checkpoints should be randomly distributed all over the site and located within areas of mean altitude varying as much as possible. Well-identified points like road intersections, the middle of a bridge or clear visible land-use features should be selected independently, as shown in Figure 20. Care should be taken not to choose features, which have a risk of being over generalised on the map.

Middle of a bridge *Land-use features* *Crossroad*

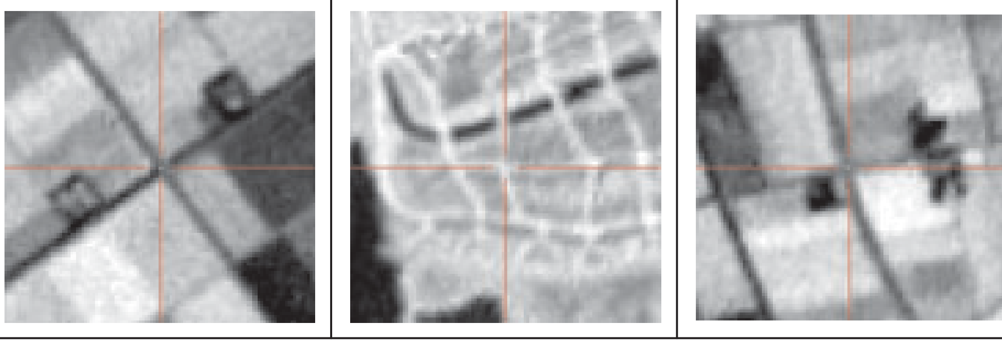
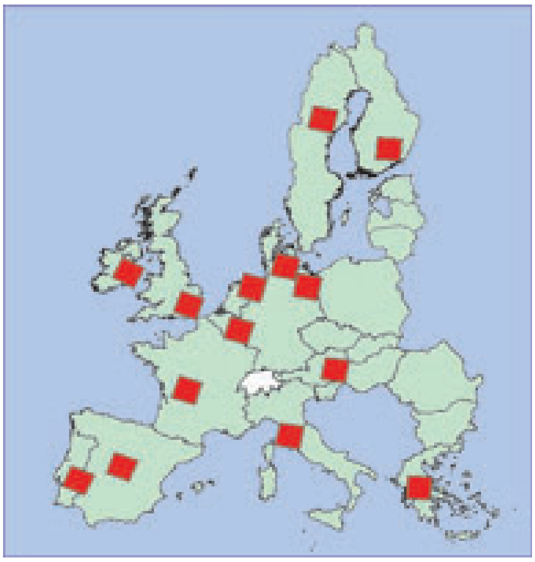


Figure 20- Examples of checkpoints

6.2.3- Selection of test images

One test image per country was selected. The selection was based on the first cloud-free image available and selected for the reference year 2000. The list of selected test images is illustrated in Figure 21 and Figure 22.



Country	Scene_date
Austria	190-27_000910
Belgium	197-25_000911
Denmark	195-22 _000609
Finland	188-17_000827
France	199-28_000909
Germany	193-23_000814
Greece	184-33_000628
Ireland	206_23_010524
Italy	192-30_000706
Luxembourg	197-25_000911
Netherlands	197-23_000826
Portugal	203-33_000719
Spain	201-32_000806
Sweden	195-15_000727
UK	201-24_00061

Figure 21- Test images for the EU15

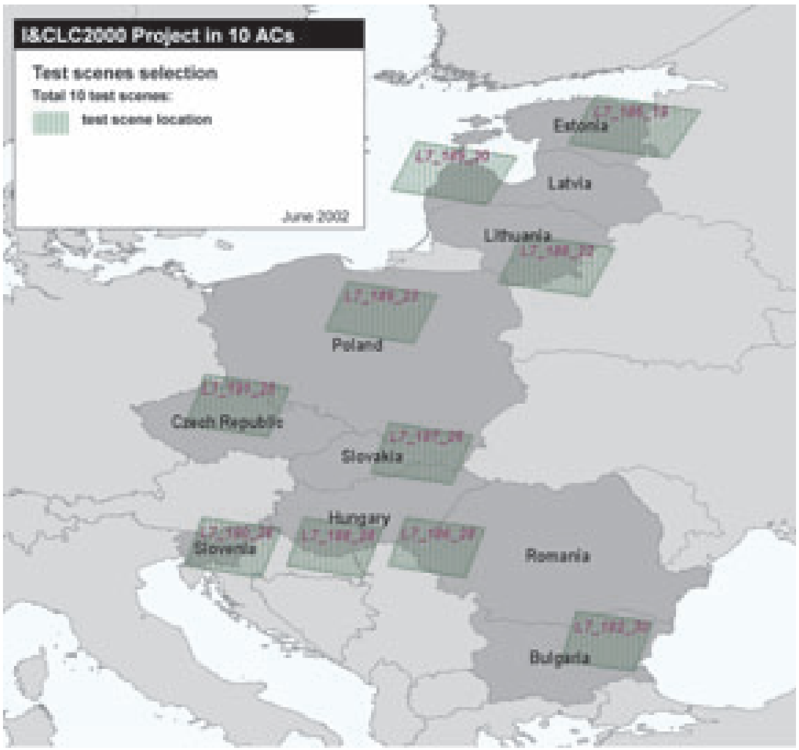


Figure 22- Location of the Test scenes in 10 AC

6.2.4 Geometric quality control using topographic maps

The analogue topographic maps were scanned and geo-referenced into national projection systems. The images were resampled to an absolute pixel-size of 2 m. Once geo-referenced, the maps were submitted to a quality assessment, to quantify errors due to paper variation and scanning. The results of this quality assessment performed on the coordinate-grid of the maps indicated a global error ranging between 2 and 5 meters RMS. An average of 36 -71 checkpoints were selected on the geo-coded maps, and randomly distributed all over the frame.

The coordinates of the checkpoints were measured both on the map and on the image, and the discrepancies in X and Y then the RMSE where computed according to § 6.2.1. The results are summarised in Table 23, indicating also the range of variation in elevation, derived from the Digital Terrain Model, which is one of the principal difficulties for the image ortho-correction.

Table 23- – Results of quality control of test images EU15

Country	Points	RMSE (X,Y)	RMSE_X	RMSE_Y	Hmin	Hmax	Hmean
FR	71	16.029	10.065	12.475	10	966	282
LUX	68	16.757	12.362	11.313	18	782	289.093
DE	73	15.018	11.994	9.038	1	171	47.084
ESP	36	16.496	11.223	12.089	323	2386	794.727
SWE	40	14.811	10.792	10.145	1	748	335.751
AUS	47		15.60	21.75	1	2366	628.686
DK	57	15.303	10.211	11.399	1	139	14.879
FIN	39	16.768	12.383	11.306	1	246	100.114
NL	39	15.390	13.278	7.782	1	106	8.032
POR	43	15.715	11.829	10.345	49	1080	342.883
BE	62	18.024	13.903	11.472	2	774	263.402
IRL	52	21.954	12.690	17.915	1	911	96.334
UK	37	13.669	8.899	10.375	2	260	48.479
IT	57	27.461	13.407	23.966		Not	Available
GR	27	15.89	12.10	10.30		Not	Available

6.2.5 GPS measurements for quality assessment

The absolute accuracy of topographic maps is often unknown, and is expected to vary from one country to another. Taken into consideration, the use of topographic maps for ortho-rectification and geometric quality control, it was considered of high importance to get a better understanding on geometric quality of maps used within the Image2000.

To realise this study, topographic maps from the French Geographic National Institute (IGN), scale 1/25 000 were chosen. For each map (total of 10), an average of 25 points were selected. GPS data network, using Kinematic on the fly and 5 seconds epoch, was collected, travelling by car along streets and roads, with special attention to crossroads. The data was post-processed (differential correction) to obtain an absolute accuracy smaller than1 m. The output "GPS network" of measurements, was compared to the geocoded topographic maps. A quality report together with error vector field was produced and statistics on the absolute geometry were obtained. The results indicate that errors within topographic maps may vary **between 5 and 11 meters.**

The errors are mainly attributed to generalisation, constraints due to scale and readability, problems of updating and errors of interpretations. Figure 23 illustrates some example of errors identified on maps. Despite the observed errors, the accuracy of topographic maps in scale 1/25 000, is fully adapted for quality control of high resolution satellite data like Landsat 7.

The Kinematic on the fly approach represents an interesting way to check the geometric quality of maps, but the “Kinematic method” is not considered adapted for geometric quality control of ortho-images, where measurements of well identified, individual points are necessary.

Location of intersection not precise Current street doesn’t correspond to map

Figure 23- Example of errors identified on topographic maps

According general rules for quality control as described in “Guidelines for Quality Checking of Ortho Imagery”, checkpoints should have a 3 time better accuracy than the expected RMS, which for 1/25000 maps should give 8 m RMS.

For the geometric quality assessment using GPS measurement, the test image of Italy was chosen. Located in the region of Toscana and Umbria, the image was characterised by important strong variations in elevation, which was important for the geometric validation. To check a full Landsat 7 scene, an average of 25 points was considered necessary. In the present case where the scene was comprised with 30 % ocean, the number of checkpoints was reduced to 14. Using a regular grid, the points were randomly selected over the frame. For each grid, a nearest visible point was selected, as seen in Figure 24. Points representing cross road, middle of a bridge, bridge and rivers, visible land-use features were preferably selected on the satellite image, then identified and measured in the field.

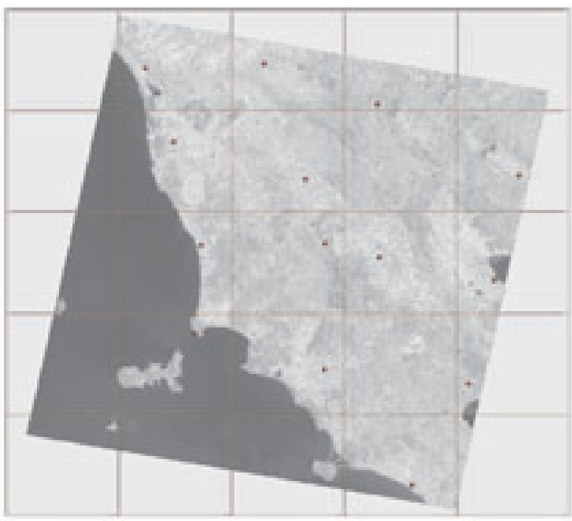


Figure 24- Distribution of checkpoints

Professional high accuracy GPS equipment was used: Ashtech Z-surveyor for measuring and Trimble Pathfinder to facilitate the navigation.
A total of 14 points were measured in differential mode, using a fix reference station. An evaluation of the accuracy was made without or with post-processing:

- GPS with post-processing. The accuracy reached with GPS (code signal), was better than 1 m in absolute position.
- GPS without post-processing. The accuracy reached was between 4 and 6 m, which in theory is sufficient for quality control of Image2000 products.

The coordinates of the ground control points measured by GPS were compared to the ones on the satellite image and the overall image accuracy was computed. The results are reported in Table 24.

Table 24– Results of quality control of test image with GPS

Country	Points	RMSE (X,Y)	RMSE_X	RMSE_Y
IT	14	35.79	19.37	**30.10**

The reported results were calculated with very accurate GPS measurements (post-processing). Taken into account the original pixel size of 30 m, resampled into 25 m, errors introduced from scanning (2-5 m), generalisation of topographic maps (5-10 m), we would expect a larger difference of RMS between image and real terrain. According to general guidelines for quality control, checkpoints should have a 3 times better accuracy than the expected accuracy. Considering the estimated accuracy of 5-11 m errors measured on topographic maps scale 1/25 000, maps of smaller scale are not likely to present a sufficient accuracy. Other uncertainties to consider are the pointing accuracy on maps during digitalisation, which generally is estimated to 3/10mm, with an RMS of 8 m.

6.3 Metadata

The orthocorrected Landsat scenes had been delivered to the National Administrations as well as to JRC as soon as they were ready. JRC and the National Administration had been informed about the delivery through a delivery notification form sent by Metria as an e-mail. The delivery notification form proved to be fundamental in the monitoring of production at national and at European levels.
Each orthocorrected Landsat image had been delivered in two CD-ROMs: one CD-ROM containing the panchromatic data and one containing the multispectral data. The associated metadata and the respective file name are as follows:

CD-ROM containing panchromatic data:

Image_name.bil	Band Interleaved by Line image data. Single band
Image_name.hdr	Image layout, data format, geo-reference, gain and bias.
Image_name.rs1	Information on imaging date and time, image outline co-ordinates.
Image_name.res	Description of the *a priori* image errors.
Image_name.map	Description of the co-ordinate system used.
Image_name.prj	Description of the co-ordinate system used in ESRI Arc/Info.
Image_name_check.xls	Description of the *a posteriori* image errors.

CD-ROM containing multispectral data:

Image_name.bil	Band Interleaved by Line image data. Seven bands
Image_name.hdr	Image layout, data format, geo-reference information, gain and bias.
Image_name.rs1	Imaging date and time, image outline co-ordinates.
Image_name.map	Description of the co-ordinate system used.
Image_name.prj	Description of the co-ordinate system used in ESRI Arc/Info.

Metadata on GCPs:
All GCPs used for the orthocorrection were stored as metadata. They were organised by country. An "imagette" of 42 x 42 pixels showing the surroundings of each GCP in the satellite image was also included. For the EU15, they were delivered on CD-ROM, each one containing the imagettes

corresponding to a country. Figure 25 gives an example of an imagette as prepared by Metria. Figure 26 shows an imagette as prepared by Gisat. The test images keep this attribute and the results of the external quality control associated.

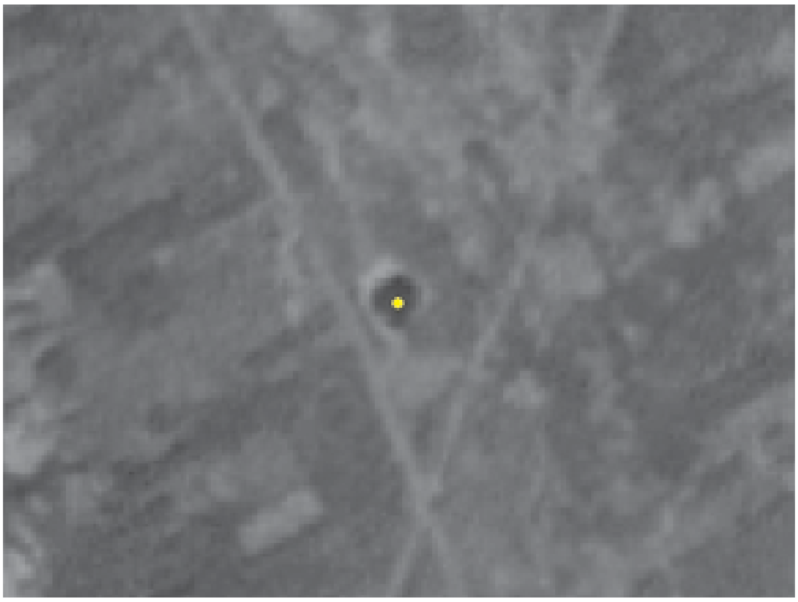


Figure 25- Example of an imagette representing a GCP, as prepared by Metria

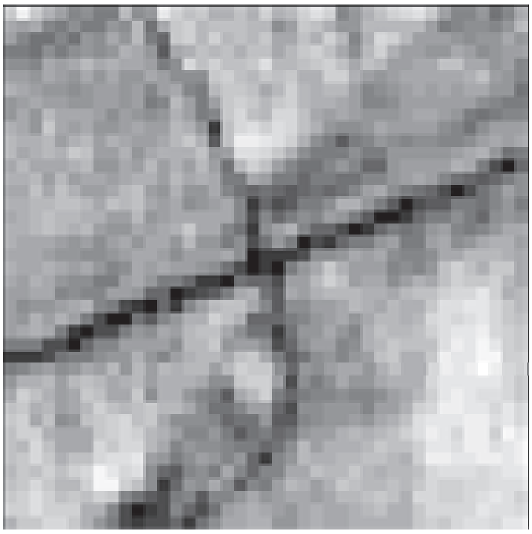


Figure 26- Example of an imagette representing a GCP, as prepared by Gisat

6.4 Pseudo-mosaic

The guidelines for the production of the stitch files (Nunes de Lima, V., Christensen, S., 2002) defined the criteria to take into account to produce the pseudo-mosaic. To assure the time consistency and the best cloud-free coverage at European level, a criterion need to define, with respect to the overlapping area/scenes, which part of each single scene is to be used for the creation of the European mosaic. This "scene grading" should be based on following criteria:

- cloud coverage (cloud-free) as **absolute priority**
- acquisition period (**date** and year)

This "grading" was based on the relationship between overlapping scenes, as illustrated in Figure 27, (scenes 198023 and 197023).

A cloud coverage per country, in arc-view shape file was produced, indicating the precise location of clouds, indicating also, which other image should be used to improve the cloud coverage by using the scene overlapping or images acquired for this purpose (e.g. Finland, Sweden, UK). A "fill in image gaps" in arc view shape file, per country was produced, indicating which image was acquired to fill in the gaps (e.g. Sweden, Finland, France, Austria).

Figure 27- Pseudo-mosaic of The Netherlands and the scenes information to attribute priorities

Scene	Date	Window	Clouds	Priority	Scene:	Date:	Window	Clouds	Priority
199024	000824	extended			197023	000824	extended		
198023	990730	optimal			197024	990909	extended		
198024	990730	optimal			198025	000911	extended		

A virtual mosaic, also known as stitch files, was prepared for each country of the EU15. The stitch files indicated which part of each scene will be part of the final mosaic. Each delivery was a zip-file containing a catalogue structure of files:

- Clouds
- Scenes
- Substitutes

The "**Clouds**" directory contains cloud masks for each scene in Esri ArcView shape format. The "**Scenes**" directory contains frames for each scene, in Esri ArcView shape format, describing how the processed image should be cut to avoid border effects in the orthorectified image. The "**Substitute**" directory contains shape files showing from which other scene(s), image data covering the clouds in

Figure 28- The stitch file for Austria

the current scene shall be taken from. Figure 28 represents the "scenes" directory for Austria, meaning how the scenes should be used to cover the country.

6.5 Analysis of production

6.5.1. Production of scenes by country and year

The project started with an estimated number of 300 scenes to cover the EU15. This number was adjusted during the execution of the project, when the real overlapping and gaps between scenes were visible after the orthocorrection. A distinction was made between the **nominal scenes**, meaning the scenes necessary to cover the EU15, considering the existing path and row coverage, and the **extra scenes** as the ones acquired to improve the clouds and haze cover, by replacing the cloudy zone of a nominal scene with the cloud free area of the selected extra scene. As it represents an additional cost (imagery and labour), the extra scenes allowed by country were carefully managed by the IMAGE2000 team, giving the possibility to all countries to improve the national coverage and having in mind that the European coverage should be cloud free- less than 5% clouds. In fact, the EU15 mosaic reach 0,3% of clouds and 1,5% of haze cover, as seen in §.8.5.3 Therefore, extra scenes were concentrated in countries where clouds persist. It can be seen comparing the numbers Total and Nominal in Table 25.This facility was not available for AC10 due to the budget foreseen.

The production of such a large number of ortho-images should follow a criterion of priority that allowed the national teams to start the national CLC2000. It was oriented by two rules:

- To start the selection of scenes and production of ortho-images with the countries ready to initiate first the national CLC2000 project.
- To work with several countries at the same time, allowing most countries to launch immediately the national project.

To keep these principles, an intense networking between the national teams, the JRC and the contractor was established, following precise rules defined for communication regarding image selection (§ 3.2), reporting of progress, image delivery and quality control of deliveries.

The state of progress on image acquisition and orthorectification was monitored through the web page and catalogue and by the Quarterly Reports prepared by Metria for acceptance by the JRC. When necessary, progress meetings were held to discuss the status of progress and eventual actions to undertake in case of problem.

The delivery of the ortho-images was monitored by a delivery note, sent by Metria via e-mail to the national team and to the JRC, identifying the ortho-images delivered and the respective date of posting. The quality control of the deliveries was done by the JRC and obviously by the national team, normally when using the images (§ 6.6). When a problem was found, Metria was notified by the JRC, the error was corrected and two copies of the corrected version was sent, one to the national team and one to the JRC for the archive. In any case, the JRC was the interface between the national team and Metria.

Table 25- Number of ortho-images produced by year and country (Metria)

Country	2000	2001	2002	2003	Total	Nominal	Comment
Austria	-	3	8	-	11	9	-
Belgium	1	4	1	-	6	6	-
Denmark	-	9	-	-	9	7	-
Finland	-	10	23	-	33	29	-
France	1	21	23	1	46	42	-
Germany	1	24	7	-	32	32	-
Greece	-	-	-	26	26	24	-
Italy	1	1	35	1	38	32	-
Ireland	-	3	6	-	10	11	9 Landsat+1IRS -
Luxembourg	1	-	-	-	1	1	-
Netherlands	-	5	1	0	6	5	-
Portugal	-	4	4	0	8	8	Mainland
Portugal	-	-	7	-	7	7	Azores and Madeira
Spain	-	38	3	-	41	40	Mainland
Spain	-	-	6	-	6	6	Canary Islands
Sweden	1	22	12	2	37	30	-
UK	-	3	28	0	31	22	-
TOTAL	**6**	**147**	**164**	**30**	**348**	**311**	-

The evolution of production was reported to the Steering Committee meetings. The poor production during 2000 was mainly due to the problems described above on Landsat 7 scenes produced at ESA stations. Furthermore there were quite few countries that had established by that time National Administrations responsible for the national CORINE Land Cover update.

The production during 2003 was manly the orthorectification of the scenes covering Greece. After a long process, it turns out impossible to get the appropriate topographic maps of Greece to do the ortho-correction of IMAGE2000. The ortho-photos for part of Greece were then made available in 2003 by the Ministry of Agriculture, Topographic Service. They were used in combination with vectordata (§ 4) for the areas not covered by the ortho-photos.

The maximum number of IMAGE2000 scenes produced during one day was **7** (020627). The estimated average production had been **2-3 scenes/day** (Metria).

The Consortium leaded by Gisat followed the same principles to define priorities regarding the production of ortho-images to cover the AC10. The production was concentrated into a shorter period. The delivery of the ortho-images was carried in two steps. First, the test images were delivered to the National Authority for approval of CRS, format and quality assessment prior to full national coverage delivery. Having the test scene accepted, comments and request from national team were reflected and full coverage shipped to the country. After the all project finalised, a complete set of ortho-images for all countries was sent to the EEA. Table 26 summarize for each country, the number of nominal scenes, the number of ortho-images, the date of delivery of the test scenes and of the full coverage. The total number of scenes to handle was reduced comparing to Metria and the selection of scenes was already carried out. Therefore the implemented two steps procedure for deliver was enough and efficient.

Table 26- Number of scenes, of ortho-images and delivery dates

Country	Number of nominal scenes	Number of Ortho-images [a)]	Test scene delivery 2002	Full coverage delivery 2002
Bulgaria	11	19	June 04	June 28
Czech Republic	9	12	March 27	June 28
Estonia	11	11	March 27	May 21
Hungary	10	10	June 11	July 11
Latvia	11	11	May 22	May 30
Lithuania	8	8	May 22	June 20
Poland	28	28	June 07	June 28/July 11 [c)]
Romania	20	25	March 27	June 28
Slovakia	5 [b)]	6	March 27	June 28
Slovenia	4	4	March 27	May 21
Total	117	134		

Notes: a) number of Ortho-images is higher then number of nominal scenes when multiple zones are present in CRS definition, b) one scene for Slovakia is floating, c) full coverage for Poland was shipped in two parts

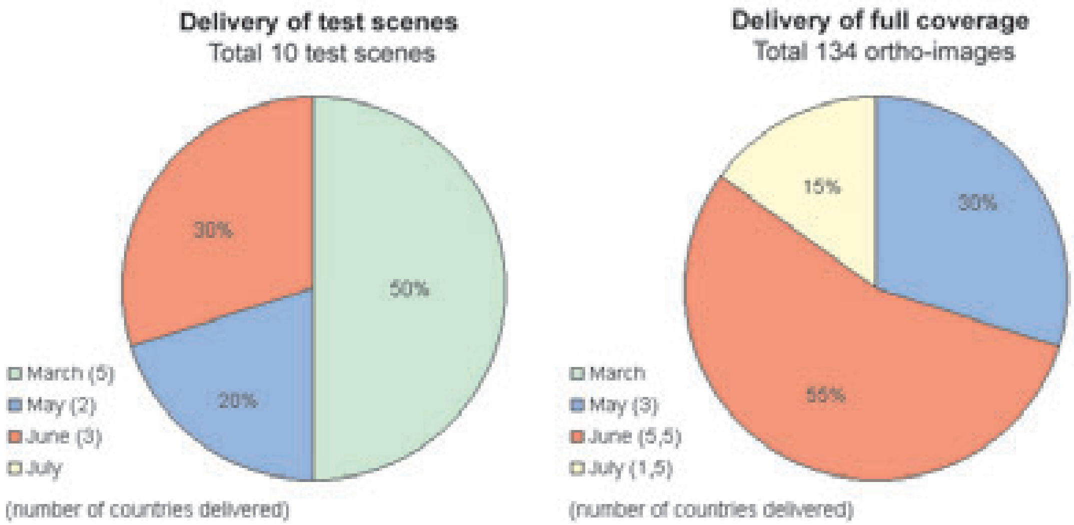


Figure 29- Delivery to countries – test scene and full coverage (Gisat)

6.5.2 Problems in production

Radiometric problems:

As indicated above a number of scenes with radiometric problems occurred during processing of the data. All radiometric anomalies were due to gain shift in the system-corrected data delivered by Eurimage. The anomalies were clearly visible as a shift in the image, where the southern part of the image was considerably darker than the northern part. It is mathematically possible to correct these gain shifts, since they are known in advance. These shifts were made to use a larger part of the available pixel values in the registered image, and in that way it makes the image more readable. The drawback is that these shifts can occur in the middle of one registered scene, which is not desirable.

The correction procedure used by Metria was to manually correct gain shifts as follows:

The system-corrected image data were copied to a hard drive, to make it editable. The band where the gain shift occurs was identified and a working copy of the band was made. The single band was imported as a raw image file into ERDAS Imagine format (*.img). It must be stressed that these operations were performed in the system-corrected data where the original rows and columns in the image are oriented in a perpendicular system. If the data would be rectified or orthorectified before the correction of the gain shift, the gain shift would not occur as a straight line, but in a way depending on the chosen coordinate system. The line in where the gain shift occurs was manually identified in the image file. A subset of the image was created, where the first line in the new image was the first line where the gain shift occurred in the original image. The physical gain shifts are known, since they occur in a fixed pattern, depending on track and frame. A list of all gain shifts is available at
http://ltpwww.gsfc.nasa.gov/IAS/handbook/ascii/defgains_12.14.00.lst
The value of each pixel in the subset of the image was then recalculated, depending on whether it was a shift from high to low gain or the other way around, according to the following formulae:

Low gain to high gain for band 4:
*New Pixel Value = Pixel Value In Image * 225(low gain) / 149.6(high gain) – Bias*

High gain to low gain for band 4:
*New Pixel Value = Pixel Value In Image * 149.6(high gain) / 225(low gain) – Bias*

Band 4 was used as example since the gain shifts usually occur in this band. The output was an image with new pixel values, in accordance with the neighbouring part of the scene. This new image was merged with the original image to replace the part where the gain shift occurred. The new image was converted to a generic binary format compatible with the Landsat Fast Format and replaced the original data on disk. This data was then ready to be imported as raw data into the system where the correction was taken place.

Geometric problems:
For three scenes, the RMS was outside the limits of 25m, one scene in Sweden and two scenes covering Spain. The Spanish scenes, 200035-000714 and 201035-000822 had large areas of water and small parts of land in the northern part of Africa. These small parts of Africa comprised Ceuta and Melilla, which were not taken under consideration during the collection of GCPs, which resulted in large residual errors in these scenes. These errors were corrected with a set of GCP:s that the Spanish Administration provided to Metria. The scenes were orthorectified again with satisfying result. The Swedish scene 197012-000725, indicated high residual errors in parts of the scene close to the Norwegian border. The problem was solved in the same way as mentioned above. Additional points were collected on the Norwegian side of the scene. These new GCPs were used as a supplement to the already collected GCPs and a new orthorectification was performed with good accuracy.

6.6 Quality assurance of deliveries

Taking into account the importance of the orthorectified images as the basis for derived products as European spatial reference and the CLC2000, the large amount of data and the cost, it becomes mandatory to assure that all data delivered to the National Administrations in participating countries and to the JRC, were in accordance with project requirements and with the technical specifications of the I&CLC2000 project. The fact that the National projects did not all start at the same time- sometimes much later than production of Product 1 for EU15, therefore with no possibility to verify the ortho-images by using them- it became fundamental that the JRC guaranteed that the products delivered were of good quality and without errors.

The results of quality verification were summarised periodically in a report during production to assure the follow up on image delivery and data quality control. The Report of IMAGE2000 on Quality assurance of delivered images contains the results from quality control performed by the JRC, and it was updated regularly. The last update was in July 2003 to include the check of Greek ortho-images.

As part of the quality assessment of Image2000, a systematic quality check on all delivered image data had been defined by the JRC (ref; procedure for quality control 25.07.01) and performed internally. It was initiated in July 2001 and done following the data delivery. The quality checking was performed in several steps, with the objective of verifying the content of each CD for:

- Verify existence of all image data multi-spectral: bands 1 to band 7 and panchromatic band 8.
- Verify existence of all metadata as defined in technical specifications (e.g. file: map, rs1, res, rs1, prj, excel).
- Assure that all date can be read by importing and visualising the data sets.
- Assure in-existence of errors in data by data errors detection: visualisation of bands 1 to 8, and their histogram (ex. gain problem).
- Verify that the date of acquisition is identical to the date selected by MS.
- Assure consistency in file names.
- Assure consistency on CD labels and coverage.

Based on procedure for quality control each image was verified and integrated into the database. All CDs were attributed an identifier code "CD_ID", composed of the official country id and a serial number: e.g. IT01, IT02, IT03, etc. for Italy, and FR01, FR02, for France etc. Once the CD was verified, the data was automatically archived into the Image2000 database. If an error was found, Metria was notified and fixed it. The corrected version was sent to the National Administration and to the JRC. The results and problems occurred are summarised in 5 main categories:

Problems with image data: During the quality assessment a certain number of bands could not be read or the data was missing. These errors were principally due to the copy on CDs, where data can be lost during coping.

Problems with metadata files: For some scenes not all metadata files were included. The missing files were often the map file, with information on projection systems.

Quality problems of data: For four scenes, radiometric problems in band 4 were identified. The problem was related to shift in pixel values in the raw data due to gain shift. When possible the data were rejected and replaced with a new date. When no other data was available, the data were corrected by SSC / Metria.

Problems reported by National Teams: In the case of problems with delivered products, the JRC was contacted by National Administration. The few problems reported concern principally: missing data, geometric and radiometric problems as reported under problems in the production (geometry) or gain shifts. In most cases the data were re-processed and the countries provided with a new version of the data. Scenes 201-32 and 200-33 (Spain) presented errors on linear features on the raw data which can not be corrected. In some scenes the Finish administration observed very low gain-values in orho-rectified header files. In delivered Image2000 data (ex 188-14_20000726), the gain value for band 1 is 0.0426 while standards gain values for high and low gain for band 1 are 0.7787 and 1.1807. Values differ from standards also in scenes 186-17; 195-12; 186-15; 187-16 and 193-13. This specific problem could have affected scenes produced between Sep/Oct 2001 (23 scenes) and partly January 2002 (15 scenes).

Information on sun elevation and azimuth which normally appear in .rs1 files were missing until middle of January 2002. To solve the problems SSC / Metria delivered an internal dimap-file or original FAST format file from Eurimage.

Only the close network with the national teams and standard procedures of quality control, allowed to solve all the problems faced within the production of such large amount of data.

6.7 External Quality Control

6.7.1 Approach for External Quality Control

The expected geometric quality of the final IMAGE2000 product is described in §6.2.1. The external quality control of the orthorectified images was carried out in two steps. The first one was done for the EU15 coverage, and the second for the AC10 coverage. This was due to the different timing and budget lines used for each group of scenes. In both groups of countries, it was done by the same team, using the same technical specifications and criteria. This quality control was based on a **10% sample of the totality of scenes**, divided by 4 strata defined according the relief (Figure 30) and under the condition that:

- Each country should have at least one scene included in the European sample;
- The test scene can not be part of the European sample.

The sampling population was defined as the set of all TM frames intersecting the region of interest.
A low resolution DTM with 1km grid available in GISCO (Geographic Information System of the European Commission), was considered sufficient to classify TM frames into four topographic roughness classes:

- Stratum 1: standard deviation of the elevation <100m
- Stratum 2: standard deviation of the elevation 100m-200m
- Stratum 3: standard deviation of the elevation 200-300m
- Stratum 4: standard deviation of the elevation >300m

For each theoretical scene, a roughness indicator was computed as the standard deviation of the elevation (Figure 31). It is a simple indicator that does not take into account the changes between contiguous points, but it is easy to compute and it avoids the unstable results that could come considering the range maximum-minimum altitude, which could be too dependent on the presence of a single mountain in the area. Sea area is excluded from the computation, but land area outside the EU is included to compute the roughness.

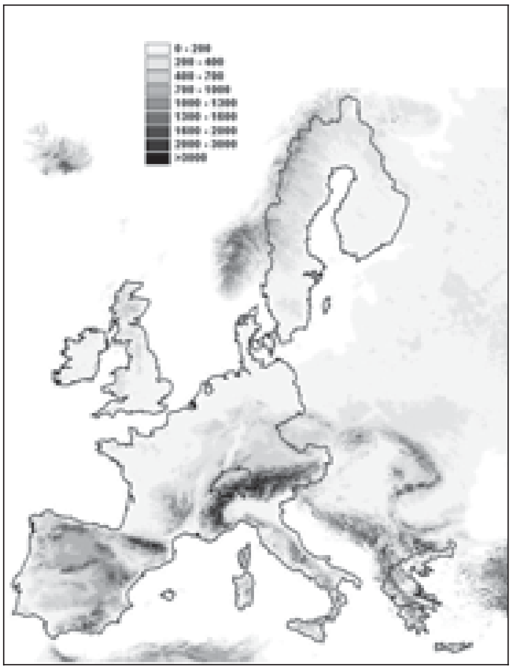


Figure 30- Elevation model with 1 km resolution

A sampling rule was defined, giving to each scene a sampling probability within a certain stratum. A total of 41 samples (scenes) were obtained.

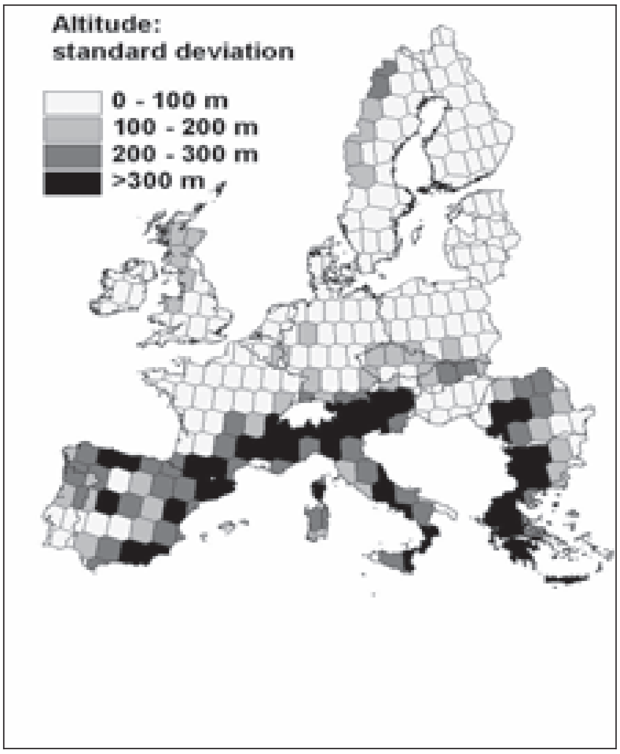


Figure 31- –Altitude Standard Deviation for each scene

We estimate the average value per pixel of a variable y (mislocation). The sampling units can be seen as clusters of pixels. We assume first that we have perfectly measured y in all the pixels j of a selected unit i, i.e. we have a single stage cluster sampling. Let M be the total number of pixels (M_i in unit i and m in the sample) and N the total number of clusters (n in the sample). An unbiased estimator for the mean of y is:

$$\hat{y}_h = \frac{1}{M_h}\sum_{i\in h}\frac{\bar{y}_i M_i}{\pi_i} = \frac{1}{n_h}\sum_{i=1}^{n}\bar{y}_i$$

Since, in each stratum, the probability is proportional to size (pps): $\pi_i = \dfrac{nM_i}{M}$

Therefore a non-weighted average of the means per unit is an unbiased estimator of the mean per pixel. The estimated variance also looks as the simple random sampling formula:

$$v_1(\hat{y}_h) = \left(1 - \frac{n_h}{N_h}\right)\frac{1}{n_h(n_h - 1)}\sum_{i\in h}(\bar{y}_i - \hat{y})^2$$

However we do not have an exhaustive measurement of the M_i values of y in each selected unit, only an estimation from a sample of m_i pixels. The estimate of the mean remains unbiased, but we need to add a term to the variance estimator corresponding to the second sampling stage (Cochran, 1977):

$$v(\hat{y}_h) = \left(1 - \frac{n_h}{N_h}\right)\frac{1}{n_h(n_h - 1)}\sum_{i\in h}(\bar{y}_i - \hat{y}_h)^2 + \frac{1}{n_h^2}\sum_{i\in h}\frac{1}{m_i(m_i - 1)}\sum_{j\in i}(y_j - \bar{y}_i)^2$$

The global mislocation average was computed by weighted average of the mislocation per stratum:

$$\hat{y} = \frac{\sum_h M_h \hat{y}_h}{M}$$

with variance:

$$v(\hat{y}) = \frac{1}{M^2}\sum_h M_h^2\, v(\hat{y}_h)$$

The flowchart of Figure 32 illustrates the methodology used for the external quality control. For each Landsat 7 ETM+ scene, a minimum of 25 checkpoints were selected on the ortho-rectified image. In most cases the number of checkpoints was 27, giving 3 points per map sheet. The operator had identified the location of each checkpoint on the image (X and Y input co-ordinates) and on the scanned topographic map, vector overlay or using the digitiser (X and Y reference co-ordinates) as appropriate. Where the image and map projections differ, or where map sheets corresponding to an image cover more than one UTM zone, the map co-ordinates were converted into the image projection co-ordinates after collection of all control points. The image co-ordinates and 'true' terrestrial co-ordinates were compared, to establish the discrepancy between the two for each point. The overall RMSE for each image was computed in X and Y directions independently in accordance with the specifications. Each image was categorised as "Pass" or "Fail" depending on whether the RMSE in either X or Y exceeds the 25 m tolerance. Furthermore, each panchromatic and multispectral image was treated independently.

To minimise error, due to operator error or selection of points that may have changed with time, a checkpoint blunder check was made for each image. The RMSE for each individual point was checked to ensure that no value exceeded 3 times the overall RMSE requirement. Any point outside this tolerance was revisited and / or replaced as necessary. Also, over 10% of checkpoints were re-input by an independent operator, to assess their accuracy as part of the internal QA procedures. For each image, 3 checkpoints were selected at random and a second operator reselected the point on the panchromatic image. The average difference between the original and new co-ordinates was reported and the overall RMSE was recalculated using the new co-ordinates and compared to the original RMSE.

It had been intended that the same checkpoints would be used for the **control of elevation** as in the control of the images. Unfortunately for a majority of points it has not been possible to measure the elevation with any degree of accuracy from the topographic maps. This was because there were either very few spot heights or it would have been too inaccurate to interpolate the elevation from the contours [2]. As a result the control of the DEM has been somewhat restricted as it was considered better to restrict this to those points where the elevation could be measured with some confidence.

Details of every checkpoint were also stored in Microsoft Excel and this was used to compute all the necessary statistics. Maps showing the image and map locations, the check point locations and the error vectors were all created using ArcView. The error vectors were plotted automatically in ArcView from the input and reference co-ordinates. A scale factor was applied to the errors so that a 25 m error was represented by a 5 millimetre error bar on the maps. The image and map extracts showing the locations of each checkpoint were generated. All extracts are 5 centimetres square, which is equivalent to 1.25 kilometres at 1:25,000 (i.e. 100 pixels for panchromatic and 50 pixels for multispectral images).

[2] For countries with digital vector data there were no elevation data supplied.

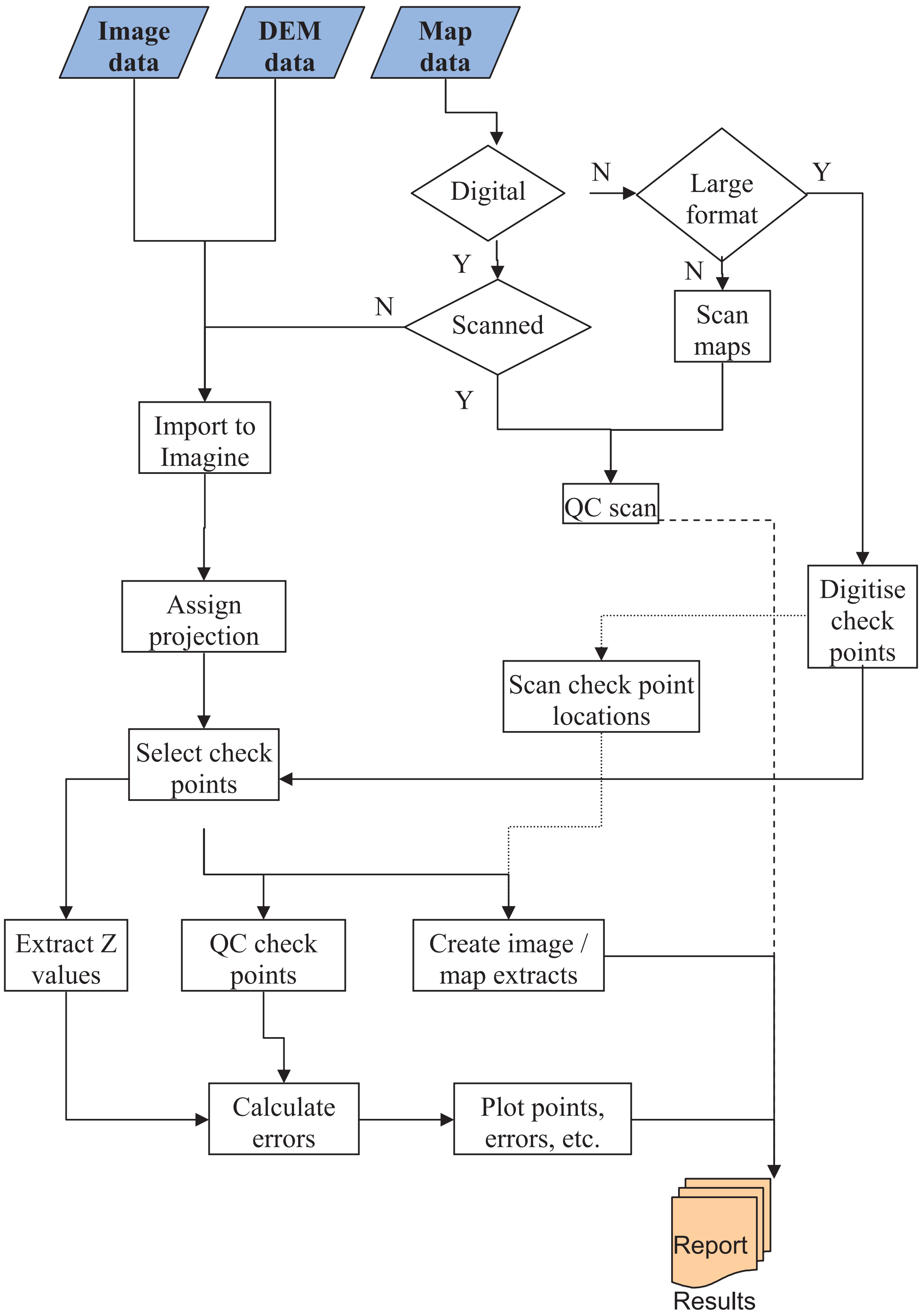


Figure 32- Flowchart of the methodology for external quality control

6.7.2- Results of EQC for EU15

The sample to control was 30 scenes. The topographic data used were those available in each country and kindly made available by Metria: 183 paper maps to cover 20 images over Austria, Belgium, Spain, Denmark, France, The Netherlands and Portugal; 72 digital maps to cover 8 images of Finland, Germany and Sweden. For Finland and Germany these were rasterised versions of vector maps (in tiff format), which therefore do not contain any grid marks; for Sweden these were vector maps in shapefile format. A vector shapefile was also supplied for 1 Greek scene. This covered the whole Greek territory within the scene and so does not comprise map sheets; Ortho-photograph tiles (17) were used for 1 Greek scene. In only two cases less than 25 points were used as checkpoints:

- For one French image only 3 map sheets were used due to the fact that only a small part of the scene is actually within France. In this instance 15 checkpoints were used as this was considered to be more than sufficient for the control;
- For one Greek image which has only vector data and where only a part of the scene is within Greece. In this case 15 checkpoints were used.

Results were reported for each scene used for the external quality control. Summary results were also reported for each country in a standard form.

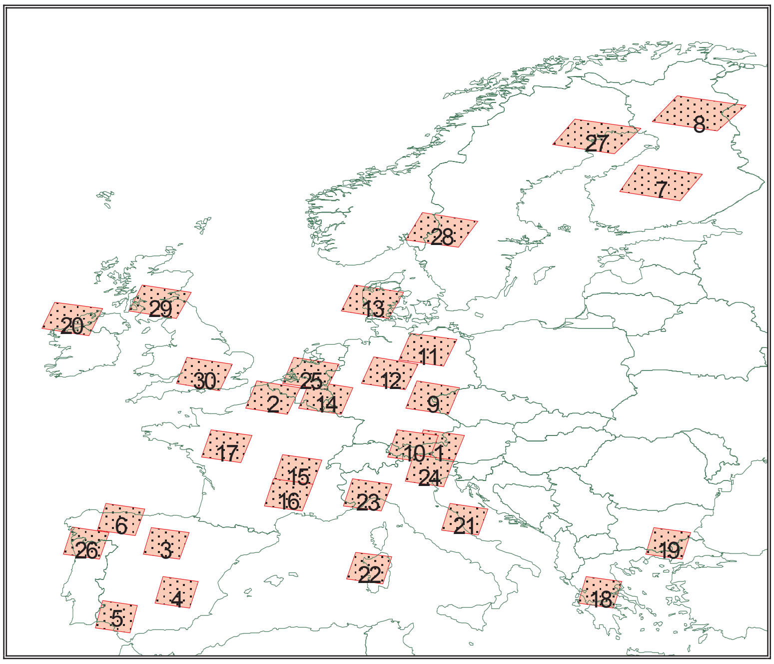


Figure 33- Location Diagram of Image Samples

Map Scan errors during EQC:

All the 165 scanned map sheets were subjected to a control of the quality of the scanning based on the rectilinear map co-ordinate grid, as shown in Table 27. The mean difference in the X dimension between the Number of sheets top and bottom edge of the sheet is 0.04%. The maximum difference for any one sheet is 0.19%. The mean difference in the Y dimension between the left and right edge of the sheet is 0.06%. The maximum difference for any one sheet is 0.27%.

Table 27- Map Scanning Global Statistics

Number of sheets	165
Mean dx (%)	0.04
Max dx (%)	0.19
Mean dy (%)	0.06
Max dy (%)	0.27

where dx and dy are calculated as follows:

a

$$dx = 100*(a-c)/a$$

d $\qquad$ $$dy = 100*(b-d)/b$$ $\qquad$ b

c

Ortho-images:

The global results for all 30 images controlled are presented in Table 28. For both the panchromatic and multispectral images, all scenes have RMSE errors within the required tolerance and therefore "pass" the external quality control. A total of 756 checkpoints were used. The number of points per image was 25 or more with the exception of one French and one Greek image where the majority of the image area was actually outside the country concerned; in both these cases 15 points were used.

For all panchromatic images the average RMSE in X and Y is 13.8 and 13.7 m respectively; the maximum RMSE in either X or Y for any single image is 22.6 m.

For all multispectral images the average RMSE in X and Y is 14.3 and 14.1 m respectively; the maximum RMSE in either X or Y for any single image is 21.5 m. All checkpoints are within the recommended tolerance of 3 times the required RMSE, i.e. the maximum offset in X and Y is 69.7 and 72.3 m for panchromatic images and 55.0 and 66.3 for multispectral images. The average offset between image and reference co-ordinates is close to zero indicating the errors are generally random.

Table 28- Satellite Imagery Quality Control Global Status

	Panchromatic	Multispectral
Mean Check Point RMSEx m	13.81	14.31
Mean Check Point RMSEy *m*	13.72	14.12
QC Status	**Pass**	**Pass**

Table 29- Satellite Imagery Quality Control Global Statistics (m)

	Panchromatic	Multispectral
Total check points	756	756
Mean check points	25.2	25.2
Mean RMSEx (all points)	13.81	14.31
Mean RMSEy (all points)	13.72	14.12
Mean RMSExy (all points)	19.60	20.26
Max dx	69.65	55.04
Max dy	72.25	66.32
Max dx+dy	89.00	69.26
Mean dx	1.27	1.24
Mean dy	-1.86	0.64
Mean dx+dy	17.16	17.82
Mean standard deviation dx	13.36	13.89
Mean standard deviation dy	13.17	13.68
Mean standard deviation dx+dy	9.47	9.73

The results of the internal quality audit are very similar to the main control results, as shown in Table 30. The average difference between the original RMSE and the recalculated QA RMSE is very low at -0.05 in X and -0.04 in Y. This indicates that the checkpoints have been selected with a high degree of accuracy and the results of the control can be treated with confidence.

Table 30-Satellite Imagery Quality Audit Statistics (m)

QA 3 point RMSEx	6.49
QA 3 point RMSEy	6.47
QA recalculated RMSEx	13.87
QA recalculated RMSEy	13.76
QA recalculated RMSExy	19.65
RMSEx - QA RMSEx	-0.05
RMSEy - QA RMSEy	-0.04
RMSExy - QA RMSExy	-0.06

Digital Elevation Models:
The global results for the DEM are presented in Table 31.A total of 212 checkpoints were used for 24 images. No control of the DEM was possible in Finland, Greece or Sweden as the digital map data did not include elevations. Furthermore in many cases it was extremely difficult to select checkpoints for which an elevation could be determined; in many areas it was difficult to find suitable points for the image control irrespective of measuring the elevation. For 7 images [3] there were only 4 or less points used which is hardly sufficient for a statistical analysis. In other instances check points were known to be located in areas of rapidly changing elevation in which case there is the possibility of a large error in Z given the pixel size of the DEM.

Overall the results are within tolerance with an average RMSE in Z of 26.7 m. However the maximum RMSE is 155.4 m and the maximum offset in Z is 200.0 m for one of the Italian images[4]. On the other hand the average offset between DEM elevation and map elevation is only -0.86 m.

Table 31- DEM Quality Control Global Statistics

Total elevation check points	212
Mean elevation check points	8.8
Mean RMSEz (elevation points)	26.70
Max dz	200.00
Mean dz	-0.86
Mean standard deviation dz	12.25

Figure 34 shows the scene 192027 of Austria as an example of the Check Point Location on a map extract and on both panchromatic and multi-spectral images. Figure 35 shows a panchromatic image and the location of map sheets used for the control. For each map sheet, there is the distribution of the original check points and the distribution of the check points used for the external quality control.

[3] Austria, Germany (2), Italy (3) and Netherlands.

[4] This image had only 2 elevation check points and particularly steep slopes.

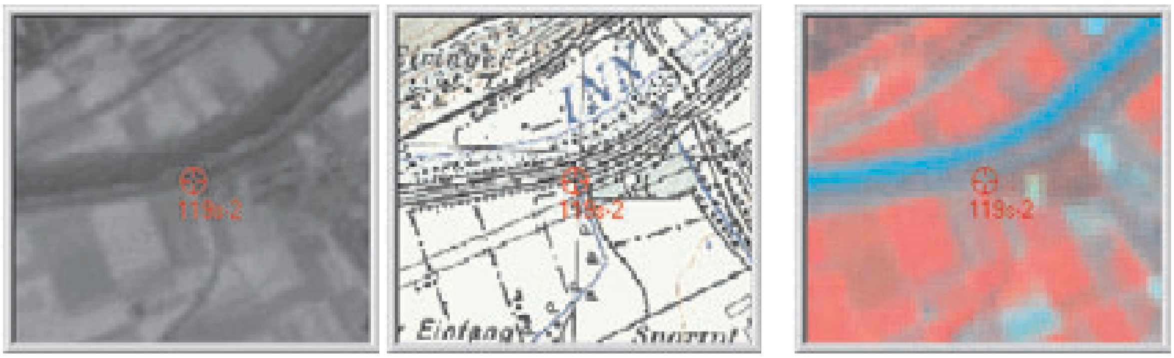
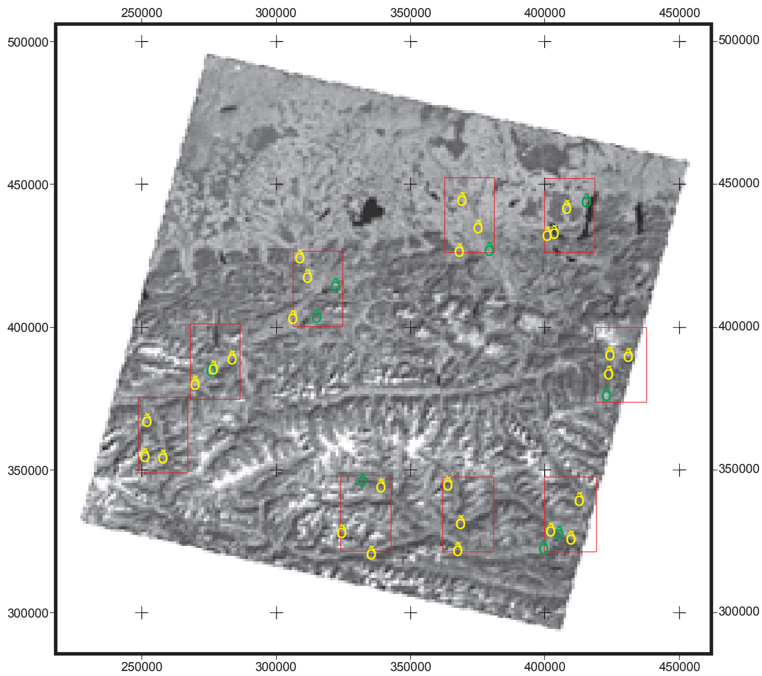


Figure 34- Check Point images and map extracts (Austria 192027)



& External QC check points
& Original check points
Map sheet locations

Figure 35- Image Overview with location of map sheets and of the Check Points (Austria 192027)

Overall Accuracy of EU15 Product 1:
The overall accuracy of Product 1 was calculated by J. Gallego, 2003, taking into account the 4 stratum defined in the sampling approach and using the adequate weighting (see §6.7.1). The results obtained are given in the Table 32.

It should be noticed that all the means along one direction, X, Y, or Z, (lines Mnd* in the table) are averages of positive and negative values. Therefore the average is an indicator of mislocation bias, not of the mislocation itself. As expected, the bias is very low. Interesting to see that the RMSE increases with the complexity of the relief, according to what was expected. The average RMSX and RMSY for the panchromatic band is 13.5m whether the average RMSX and average RMSY for the multispectral bands is respectively 14.2m and 14.1m.

Table 32- Overall accuracy of EU15 Product 1

Stratum	1	2	3	4	Average	Standard error
N scenes (Z)	8	4	5	7	24	
N scenes (XY)	10	6	6	8	30	
Area of stratum	1313475	694555	524483	686306	3218819	
Area of sampled units	118891	101184	84172	118254	422500	
RMSXPan	11.90	12.56	14.40	16.72	**13.48**	0.64
RMSYPan	12.56	12.10	12.98	16.93	**13.46**	0.47
RMSXYPan	17.42	17.53	19.62	23.85	19.17	0.63
RMSZP	8.95	11.24	30.65	53.01	22.37	9.28
MxdXP	27.12	26.52	34.57	42.42	31.47	1.65
MxdYP	29.38	28.06	29.95	44.48	32.41	1.53
MxdXYP	34.46	32.76	42.44	56.25	40.04	2.04
MxdZP	20.63	25.00	62.20	80.43	41.09	12.00
MndXP	1.13	1.13	2.33	0.77	1.25	0.98
MndYP	-1.27	-3.05	-1.23	-2.19	-1.84	0.87
MndXYP	15.62	15.66	17.42	20.00	16.86	0.66
MndZP	-0.68	-0.31	-0.46	-1.67	-0.78	1.58
RMSxMult	13.48	13.15	14.70	16.46	**14.24**	0.64
RMSyM	14.12	11.55	13.71	16.96	**14.10**	0.51
RMSxyM	19.65	17.66	20.29	23.72	20.19	0.61
MXDXM	32.87	29.23	32.53	40.28	33.61	1.58
MXDYM	31.80	28.82	34.14	45.53	34.47	1.71
MXDXYM	38.88	34.91	41.57	53.29	41.54	1.42
MNDXM	1.25	1.82	2.24	0.66	1.41	1.04
MNDYM	2.22	-0.19	0.89	-1.65	0.66	0.96
MNDXYM	17.52	15.76	18.07	20.27	17.82	0.65

6.7.3- Results of EQC for AC10

The same method, with some adaptations on the strata thresholds and sampling rate, was applied for 10 countries of central Europe, resulting in a sample of 11 scenes distributed across 7 Accession Countries as shown in Figure 36.

The topographic data for the 11 scenes was used in a variety of formats, as follows:-

- 55 paper maps were supplied for 8 images, comprising Bulgaria, Poland (part of one image), Estonia and Romania. The sheets for Poland and Estonia were all scanned and were checked for scanning accuracy based on the map grid. For Bulgaria and Romania the sheets were scanned in situ and were not supplied in digital format. Thus no control of the scanning accuracy could be made for these maps;
- 32 sheets were supplied as scanned digital maps, comprising Poland (part of one image), Lithuania, Slovenia and Czech Republic. The Czech maps did not have a map grid so it was not possible to check the scanning accuracy.

Paper maps were scanned at a resolution of approximately 1 metre, using a Colortrac 360Gx Plus sheet-feed scanner [5]. All scanned maps were subjected to a quality check wherever possible, using the rectilinear map grid to determine the errors due to paper distortion and/or scanning.

[5] Scan resolution of 600dpi, equivalent to 1.06 metres at 1:25,000 scale.

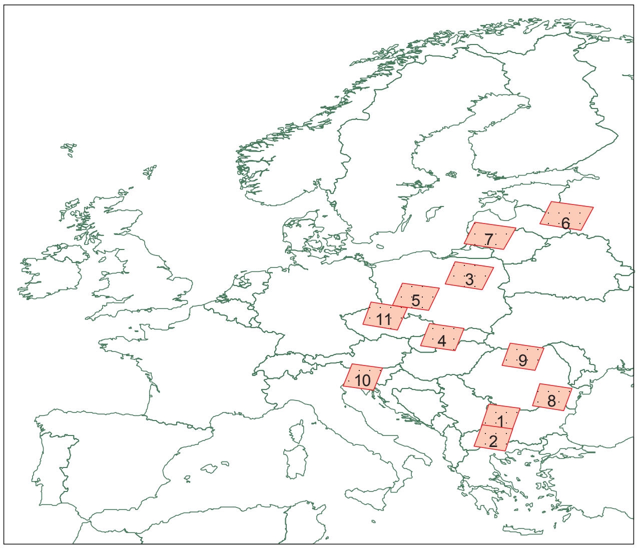


Figure 36- Image Location Diagram for AC10

For each Landsat 7 ETM+ scene, a minimum of 25 checkpoints were selected on the ortho-rectified image. In most cases the number of checkpoints was 27 giving 3 points per map sheet. In only three cases were less than 27 points used:

- For a Polish and Estonian image only 3 map sheets were used as only a small part of the scene is actually within the country concerned. In this instance 15 checkpoints were used as this was considered to be more than sufficient for the control.
- For one Bulgarian image only 26 points were used as it proved impossible to locate another point due to the topography.

Map Scan Errors:
A total of 42 scanned map sheets were subjected to a control of the quality of the scanning based on the rectilinear map co-ordinate grid. The results are shown in Table 33, where dx and dy are calculated as for EU15. The mean difference in the X dimension between the top and bottom edge of the sheet is 0.05%. The maximum difference for any sheet is 0.24%. The mean difference in the Y dimension between left and right edges of the sheet is 0.04%. The maximum difference for any sheet is 0.20%.

Table 33- Map Scanning Global Statistics

Scanned map sheets	42
Mean dx (%)	0.05
Max dx (%)	0.24
Mean dy (%)	0.04
Max dy (%)	0.20

Ortho-images:
A total of 272 checkpoints were used. The number of points per image was 25 or more except for one Polish and Estonian images where the majority of the image area was actually outside the country concerned; in both cases 15 points were used. For all panchromatic images the average RMSE in X and Y is 16.5 and 16.2 m respectively. The maximum RMSE in either X or Y for any image is 21.5 m. For all multispectral images the average RMSE in X and Y is 19.4 and 19.1 m respectively. The maximum RMSE in either X or Y for any image is 24.4 m. All checkpoints are within the recommended tolerance of 3 times the required RMSE, i.e. maximum offset in X and Y is 57.2 and 46.0 m for panchromatic images and 61.5 and 52.4 m for multispectral images. The average offset between image and reference co-ordinates is close to zero, indicating the errors are generally random.

The global results for all 11 images controlled are presented in Tables 34 and 35. For both panchromatic and multispectral images, all scenes have RMSE within the required tolerance and therefore "pass" the external quality control.

Table 34- Satellite Imagery Quality Control Global Status

	Panchromatic	Multispectral
Mean Check Point RMSEx	16.46	19.38
Mean Check Point RMSEy	16.19	19.06
QC Status	**Pass**	**Pass**

The results of the internal quality audit are very similar to the main control results, as shown in Table 36. The average difference between the original RMSE and the recalculated QA RMSE is very low: -0.41 in X and -0.11 in Y. This indicates that the checkpoints have been selected with a high degree of accuracy and the results of the control can be treated with confidence.

Table 35 -Satellite Imagery Quality Control Global Statistics

	Panchromatic	Multispectral
Total check points	272	272
Mean check points	24.7	24.7
Mean RMSEx (all points)	16.46	19.38
Mean RMSEy (all points)	16.19	19.06
Mean RMSExy (all points)	23.17	27.31
Max dx	57.20	61.47
Max dy	45.97	52.36
Max dx+dy	64.91	71.82
Mean dx	8.18	10.81
Mean dy	-6.75	-8.44
Mean dx+dy	20.92	24.78
Mean standard deviation dx	13.19	15.26
Mean standard deviation dy	12.79	15.47
Mean standard deviation dx+dy	9.90	11.49

Table 36- Satellite Imagery Quality Audit Statistics

QA 3 point RMSEx	8.23
QA 3 point RMSEy	8.87
QA recalculated RMSEx	16.87
QA recalculated RMSEy	16.30
QA recalculated RMSExy	23.57
RMSEx - QA RMSEx	-0.41
RMSEy - QA RMSEy	-0.11
RMSExy - QA RMSExy	-0.40

Table 37- Overall accuracy of AC10 Product 1

	Panchromatic		Multispectral	
	Weighted average	Std error of the weighted average	Weighted average	Std error of the weighted average
RMSEx	17.7	1.2	20.6	1.2
RMSEy	16.7	1.5	19.7	1.5
RMSExy	24.4	1.3	28.6	1.2
Max dx	38.9	2.5	45.8	4.4
Max dy	35.4	4.0	39.7	3.5
Max dx+dy	46.0	3.3	54.0	3.4
Mean dx	9.3	2.5	12.3	2.2
Mean dy	-6.6	6.3	-9.1	6.3
Mean dx+dy	21.9	1.3	26.1	1.2

6.7.4- Overall Accuracy Results of the European Product 1

The overall accuracy of Product 1, considering the 25 countries is represented in Table 38.

Table 38-European Overall Accuracy of Product 1

	Panchromatic		Multispectral	
	Weighted average	Std error of the weighted average	Weighted average	Std error of the weighted average
RMSEx	14.5	0.6	15.8	0.6
RMSEy	14.3	0.6	15.5	0.6
RMSExy	20.5	0.6	22.3	0.6
Max dx	33.3	1.0	36.7	1.1
Max dy	33.2	1.0	35.8	1.0
Max dx+dy	41.5	1.1	44.7	1.0
Mean dx	3.3	0.8	4.1	0.8
Mean dy	-3.0	1.1	-1.8	1.1
Mean dx+dy	18.1	0.6	19.9	0.6

The weighted average RMSEx of 14.5 m for the panchromatic and 15.8 m for the multispectral bands and the weighted average RMSEy of 14.3 ms and 15.5 m for the panchromatic and multispectral bands are fare from the initial 25 m defined within the project Technical Specifications. This is an important achievement on geometric accuracy, considering the high number of ortho-images involved, the significant differences on national CRS and of the DEMs available.

7 Product 2- National Mosaic

7.1 Verification of Internal Geometry

Based on Product 1, a national mosaic was obtained with the corresponding national Coordinate Reference System, named as Product 2 in the list of the project deliveries. For that purpose, the stitch files were used when available (EU15) to select the image in the areas overlapped by more than one scene and to get ready of clouds. The first step to produce the mosaic was the verification of the internal geometry within each country.

To cover all overlaps between adjacent scenes (in east-west and south-north direction) it was decided to apply the concept of reference scenes. Reference scenes were panchromatic data selected for each country based on “chessboard” scheme. For every reference scene, overlaps with 4 adjacent scenes (eastern, western, northern and southern scene – if all applicable) were checked. It assures that homogeneity of geometry for all scenes in each country was verified. Figure 37 illustrates the case of Poland.

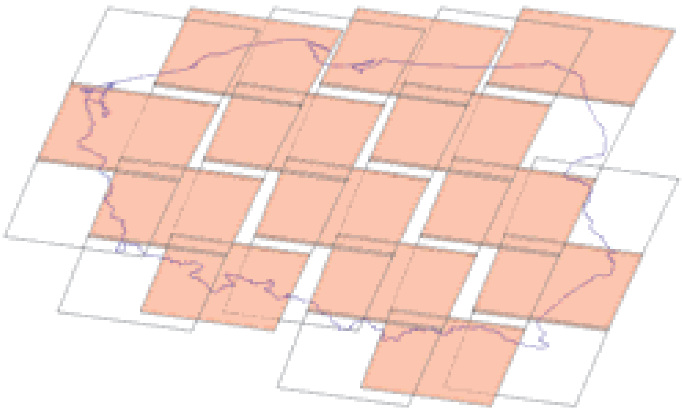


Figure 37- Reference scenes (in red) for Poland

The results of the geometry check were reported for three verification points for east-west overlaps and for two verification points in south-north overlaps. If displacement above 2 pixels have been found, the error amplitude and direction was recorded. The points were selected in the middle of each overlap because this is the area where mosaicking lines are preferably defined and larger displacement can make troubles during mosaicking.

The verification of internal geometry was done on country basis. One country can be divided into several parts if more projection zones are used. The verification results are presented in several forms:

- Summary statistics for the country (number of reference scenes, number of verification points, average displacements, minimum and maximum displacements, standard deviation).
- Summary statistics for each reference scene (IDs of all adjacent scenes, maximum displacement found).
- Graphical error report for each reference scene (error amplitude and direction are presented for all verification points).
- Vector data (point layer with associated attribute table for each reference scene as ArcInfo Shape file).

The results of internal geometry verification are summarized per country in the Table 39. The overall results are good having in mind the accuracy requirements defined for single orthorectified Image2000 scenes (RMS_{xy}< 25m, max. residual on verification points < 3xRMS) and the tolerance of two pixels displacement. Often the larger errors were found close to the country boundary. Normally the problem was local and the displacements for neighbouring verification points were lower. The preferred solution was to eliminate problem areas during mosaicking. Especially in northern countries the overlaps between adjacent scenes are large and this solution was feasible.
Figure 38 illustrates the graphical error report for a reference scene.

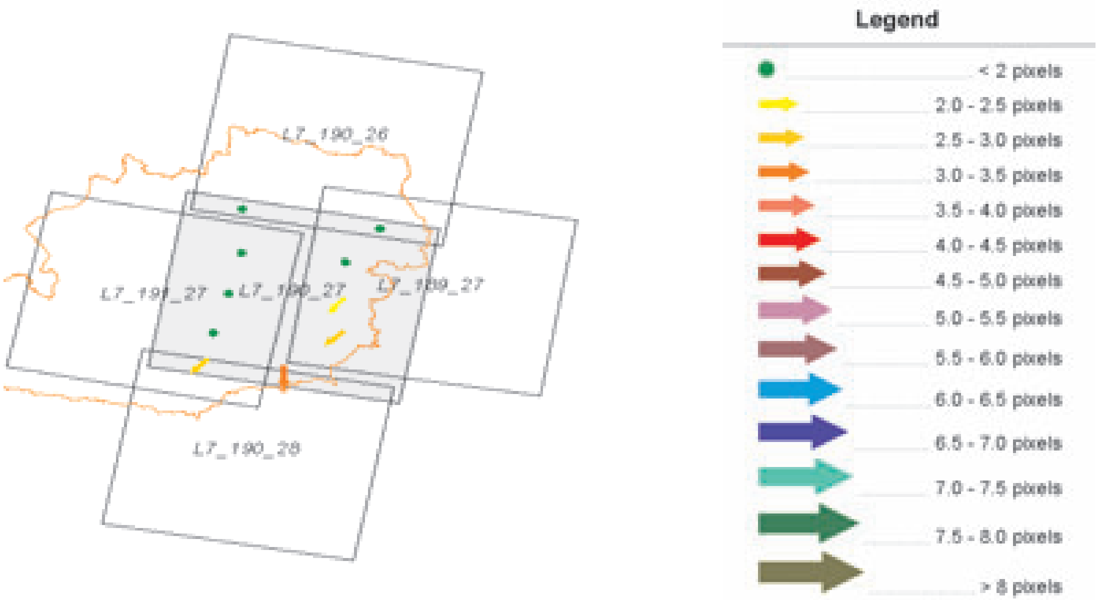


Figure 38- Example of graphical error report for the scene 190/21 (Austria)

Table39- Summary statistics on internal geometry for each country

Country / Zone	Total n° reference scenes	Total n° verification points	Average displacement (pixels)	Country / Zone	Total n° reference scenes	Total n° verification points	Average displacement (pixels)
BG3	2	6	1.0	FI	15	102	0.9
BG5	3	12	1.1	FR	23	152	1.2
BG7	1	8	0.8	DE2	2	5	1.2
BG9	2	12	1.2	DE3	5	29	0.9
CZ3	4	24	0.1	DE4	6	31	1.0
CZ4	1	2	0.5	DE5	2	4	1.3
HU	5	25	0.5	UK	13	73	0.9
PL	13	99	0.4	GR	12	54	1.5
EE	4	21	0.3	IE	3	16	1.2
LV	5	24	0.9	IT	19	87	0.9
RO4	5	25	1.0	PT	4	20	0.9
RO5	7	44	1.0	PT26	2	3	1.7
SK4	2	11	0.7	SE	16	115	1.0
SI	1	5	0.8	NL	3	13	1.0
LT	3	22	0.6	ES29	7	24	1.1
AT	5	26	1.3	ES30	11	74	1.5
BE	3	11	0.2	ES31	5	14	1.4
DK32	3	17	0.7	ES28	3	6	1.7
DK33	1	2	0.5				

7.2- Preparation of the National mosaic

The National mosaics were made using the mosaicking lines defined for the European mosaic and look-up-tables (LUT) as explained in Chapter 8 for the European mosaic. Figure 39 shows the National mosaic of Hungary.

Figure 39- Overview of country mosaic for Hungary (band combination 7-5-3), overlaid with mosaicking lines, with 5km buffer along country boundary.

8 European Mosaic

The European mosaic is a multi-purpose and multi-scale product. To achieve this, technical specifications were defined to allow implementation of different t mosaic types, based on specific user requirements. All bands were re-projected from the national projection systems to a European representation, in full resolution. A pan-sharpened European mosaic was also produced. Geomatica Prime and OrthoEngine software (version 9.1.3.) was used for all image processing tasks. Specific routines were written to automate many processing steps and run the computation in batch mode.

8.1 Ortho-Image Re-projection

Before re-projecting Product 1, GISAT made a comprehensive study to validate coordinate reference system (CRS) definition for each country. National Mapping Authorities and national CLC2000 teams were contacted to verify map projection, spheroid and datum definition parameters for each country. Especially for the datum definitions, the analysis of data source and expected accuracy was always done. Also, an independent test of the re-projection accuracy was done where reliable test data were available.

The image re-projection is based on three sets of parameters: Map projection, Spheroid and Datum (7 term Bursa-Wolf or 3 term Molodensky transformation according to the datum definition available for each country). The projection and spheroid definition is unique and the parameters, if properly applied, do not introduce any geometric errors during re-projection. However, the datum definition is not so straightforward. It is often the case that more sets of parameters for one datum are available. Use of incorrect parameters may affect the absolute geometric accuracy of re-projected scene.

As the projection and datum parameters for Bulgaria are not available, local transformation had to be applied. Regular grid of identical points and Thin Plate Spline transformation was used instead of re-projection and the accuracy reached is high enough for the purposes. Spain and Portugal represent countries with specific CRS related to islands and archipelago. All necessary parameters were acquired using the same way as for other countries. In the case of Azores Islands, two different datum were reported for Central and Occidental Islands. As simple geocentric translation intended only for low resolution applications was available for Occidental Islands, it was decided to use accurate datum definition acquired for Central Islands.

All the parameters (map projection, spheroid and datum definition) as applied during image re-projection were listed in comprehensive tables country by country. They are part of the metadada and presented in Annex 3. Table 40 summarize the CRS definition for each country. Figure 40 illustrates graphically the different CRS for each country, being clear that there are no European countries with the same CRS.

Table 40- Updating of CRS definition

Country code	Map projection	Spheroid	Datum		Update of delivered parameters
			Name	Shifts to ETRS89	
BG	Lambert Conformal Conic	Krassovsky 1940	N.A.	N.A.	N.A.
CZ	Transverse Mercator	Krassovsky 1940	Pulkovo	7-term	N.A.
EE	Lambert Conformal Conic	GRS-80	ETRS89		N.A.
HU	Oblique Mercator	GRS-67	HD72	7-term	N.A.
LV	Transverse Mercator	GRS-80	ETRS89		N.A.
LT	Transverse Mercator	GRS-80	ETRS89		N.A.
MT	Universal Transverse Mercator	Hayford 1909	ED50	7-term	N.A.
PL	Transverse Mercator	GRS-80	ETRS89		N.A.
RO	Transverse Mercator	Krassovsky 1940	Pulkovo	3-term	N.A.
SK	Transverse Mercator	Krassovsky 1940	Pulkovo	3-term	N.A.
SI	Transverse Mercator	Bessel 1841	D48	7-term	N.A.
AT	Lambert Conformal Conic	Bessel 1841	MGI	7-term	NO
BE	Lambert Conformal Conic	Hayford 1909	BD72	7-term	NO
DE	Transverse Mercator	Bessel 1841	DHDN	7-term	YES
DK	Universal Transverse Mercator	Hayford 1909	ED50	7-term	YES
ES	Universal Transverse Mercator	Hayford 1909	ED50	3-term	YES
FI	Transverse Mercator	Hayford 1909	KKJ	7-term	NO
FR	Lambert Conformal Conic	Clarke 1880 IGN	NTF	3-term	NO
GR	Transverse Mercator	GRS-80	GGRS87	7-term	NO
IE	Transverse Mercator	Airy Modified	IRELAND65	7-term	YES
IT	Universal Transverse Mercator	Hayford 1909	ETRS89		NO
LU	Transverse Mercator	Hayford 1909	LUREF	7-term	YES
NL	Oblique Stereographic	Bessel 1841	Rijksdriehoeks	7-term	YES
PT	Transverse Mercator	Hayford 1909	Lisbon	7-term	YES
SE	Transverse Mercator	Bessel 1841	RT90	7-term	YES
UK	Transverse Mercator	Airy	OSGB36	7-term	YES

Full Resolution Mosaic:
All scenes orthorectified into national projection system were re-projected into geographic coordinates according to the ETRS89 specification. The re-projected pixel size is **0.0001150 deg for panchromatic** and **0.0002300 deg for the multispectral** bands. Re-projection of raster data to geographic coordinates implicates non-square image pixel with variable pixel size, when projected into plain and expressed in meters. In particular, for the European mosaic, the panchromatic pixel size (0.0001150 deg) varies approximately from 3.9m x 12.8m (northern edge of mosaic), to 11.7 x 12.8 m (southern edge of mosaic). Cubic convolution was used for resampling. Figure 41 shows an extract of image re-projected into geographic coordinates.

Small scale mosaic:
All scenes orthorectified into national projection system were re-projected into ETRS89 Lambert Conformal Conic Coordinate Reference System (Figure 42). The pixel size for the ETRS89 LCC

mosaic is defined as 125 m for panchromatic band and 250 m for multispectral bands. The re-projection results in strong resampling during the processing (1 pixel of small scale mosaic corresponds to 100 pixels in original orthorectified data). The standard Cubic Convolution resampling approach determines the gray level from the weighted average of the only 16 closest pixels to the specified input coordinates. Therefore two resampling options have been evaluated:

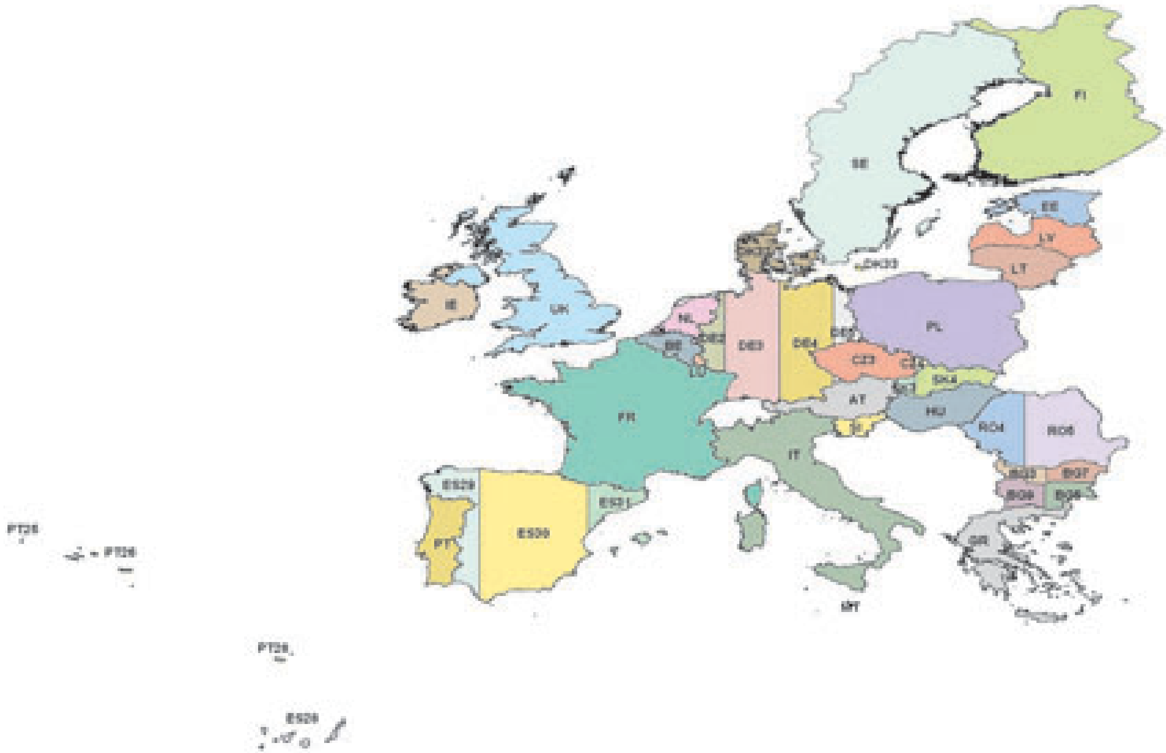


Figure 40- Graphical presentation of differences between various CRS in individual countries

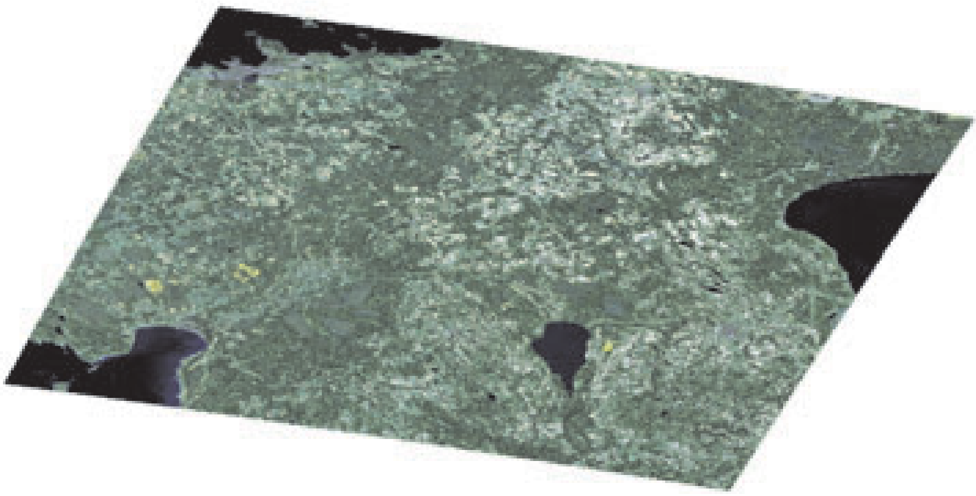


Figure 41- Landsat 7 scene 187/19 (bands combination 7-5-3) re-projected to geographic coordinates (ETRS89)

- Image averaging: all input pixel values falling into output pixel are averaged when calculating output pixel value.
- 16 Pt SinX/X: this resampling option determines the output pixel value from the weighted average of the 256 closest pixels.

Based on the evaluation results the image averaging was selected. The 16 Pt SinX/X resampling has a sharpening effect which can be appreciated when displaying data in full resolution. As soon as we further zoom in, the image seems noisy and it is not nice to look at. On the contrary, image averaging makes data smoother, as shown in Figure 42.

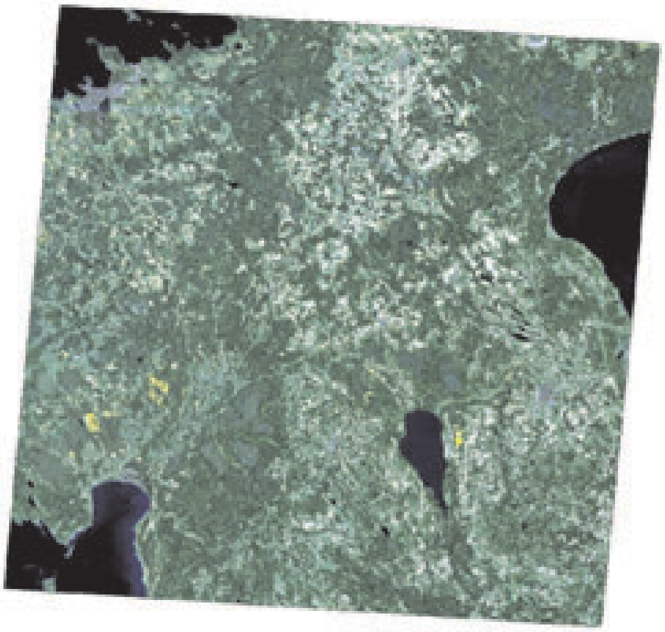


Figure 42- Landsat 7 scene 187/19 (bands combination 7-5-3) re-projected to ETRS-LCC

8.2 Mosaicking and Colour Harmonization

After image re-projection, separate mosaics for each country (or several mosaics if the country is divided into projection zones) were produced. Two mosaic versions were prepared: ETRS89 geographical coordinates for the full resolution mosaic and ETRS89-LCC coordinate system for the small scale mosaic.
A few times Landsat 5 or IRS 1C data were used due to the unavailability of Landsat 7 scenes. With panchromatic mosaic it was necessary to deal with empty areas as only multispectral data were available in this case. It was decided to replace the missing part using one multispectral band. After visual inspection band 4 was selected, having the closest radiometry to panchromatic Landsat 7 data. Cubic convolution was used to resample multispectral data to the panchromatic resolution.

A similar problem happened when using one IRS 1C scene for multispectral mosaic in Ireland. As IRS data do not contain the same spectral bands as Landsat data, there is no data available equivalent to band 1 and 7 of Landsat 7 and the following relation was set up:

- Landsat spectral band 2 = IRS spectral band 1
- Landsat spectral band 3 = IRS spectral band 2
- Landsat spectral band 4 = IRS spectral band 3
- Landsat spectral band 5 = IRS spectral band 4

The mosaicking had been done in three steps.

8.2.1 Definition of Mosaicking-Lines

Mosaicking lines, sometimes called also “cut line” or “seam line”, were selected for each scene to be mosaicked. They define the part of each scene that is put into the mosaic. There are some rules that should be followed during the definition of mosaicking lines. If possible, areas with higher probability of misregistration such as mountainous areas, areas with big terrain variations or areas close to the scene edge, shall be avoided. Also, areas with varying radiometry on overlapping scenes are not suitable. Usually, linear features such as roads or rivers make very suitable objects from which to trace mosaicking lines, since they are low to the ground, generally uniform in appearance, display clear boundaries, and tend to be conspicuous on imagery. Two more criteria were always applied:

- Mosaicking line is defined to get cloud-free mosaic whenever possible.
- Preferably images acquired in similar date with similar radiometry are mosaicked.

The same mosaicking lines were used for full resolution and small scale mosaic. One pixel buffer width was defined to allow simple image blending on all mosaicking lines. The mosaicking lines were delivered as a separate vector layer for each country.

8.2.2 Colour Harmonization (Colour Balancing)

Technical Specifications defined the usage of linear stretching to harmonise the radiometry of all scenes for simplicity and time saving. When working with linear stretching lookup table (LUT) the parameter which trims the low and high ends of the histogram by specified percentages can be specified. This parameter is useful for eliminating outliers or noise, but it can also affect the radiometric resolution of areas with extreme radiometry, close to histogram minimum and maximum.

To select proper linear stretch, three LUT options had been evaluated: (a) No trimming; (b) 1% trimming; (c) 2% trimming. Based on the results, 1% trimming option was selected. No trimming was unsuitable and 2% trimming gave better general contrast but suppresses radiometric differences for some areas when displaying in full resolution. Nevertheless, linear LUT generated using 1% trimming for each scene had been visually inspected and refined if this default solution gave unsatisfactory result. Usually this happened for cloudy and coastal scenes, where the image bands histograms are significantly affected. All such cases were recorded and reported. Linear LUT stretching with 1% trimming was used as well but the “problematic” areas of the scene were excluded from the histogram. Table 41 shows the number of scenes where the generated LUT had to be refined. In total 30% of panchromatic scenes and 45% of multispectral scenes needed this correction. All applied linear stretching look-up-tables were delivered as separate text files.

8.2.3 Replacement of Cloudy areas

As described above, the cloudy areas issue had been taken into account during tracing of mosaicking lines. Most of cloudy areas in overlapping parts of the neighbouring scenes could be removed when mosaicking line was properly defined. However, if the clouds and shadows were situated close to the scene edges or in the area with poor geometry or radiometry coherence, it was preferred not to trace mosaicking line here. Such cases were solved after composition of the country mosaic.

The stitch files were available for EU15 scenes and used to verify on the country mosaic which cloudy areas had been replaced during mosaicking. All remaining clouds and shadows, described as individual polygons in stitch files, were then replaced by adjacent scenes. All equivalent scenes available for individual country were also used during that step. The automatic procedure was used to replace cloudy areas left after mosaicking. All such stitch polygons were manually corrected.

Neither stitch files nor equivalent scenes were available for AC10. Country mosaics were visually inspected and all remaining cloudy areas verified. If replacement using adjacent scene was possible, the polygon enclosing detected clouds and shadows was constructed and the replacement done. All clouds and shadows polygons used for image data replacement were delivered as vectors.

Table 41- Summary of standard and refined LUTs

Country / Country zone	Total no. of scenes	Standard LUT		Refined LUT	
		PAN	MS	PAN	MS
BG3	4	4	4	0	0
BG5	6	4	2	2	4
BG7	4	2	0	2	4
BG9	5	5	5	0	0
CZ3	9	7	7	2	2
CZ4	2	2	2	0	0
HU	10	9	9	1	1
PL	28	26	23	2	5
EE	11	11	7	0	4
LV	11	10	5	1	6
MT	1	0	0	1	1
RO4	10	7	8	3	2
RO5	15	13	10	2	5
SK3	1	1	1	0	0
SK4	5	4	4	1	1
SI	4	3	3	1	1
LT	8	8	5	0	3
AT	11	5	5	6	6
BE	6	4	0	2	6
DK32	7	7	7	0	0
DK33	2	2	2	0	0
FI	34	18	5	16	29
FR	46	25	22	21	24
DE2	5	3	4	2	1
DE3	11	10	9	1	2
DE4	12	8	12	4	0
DE5	4	1	2	3	2
UK	31	14	0	14	31
GR	26	15	21	11	5
IE	10	4	3	2	7
IT	39	29	26	10	13
LU	1	1	1	0	0
PT	8	5	4	3	4
PT25	1	0	0	1	1
PT26	4	0	0	4	4
PT28	2	0	0	2	2
SE	36	21	8	15	28
NL	6	6	3	0	3
ES29	12	12	12	0	0
ES30	23	21	21	2	2
ES31	10	3	5	7	5
ES28	6	0	0	6	6
Total	487	330	267	150	220

8.3 Inter-Country Verification

Inter-country verification was done similarly as for internal geometry. Full resolution panchromatic country mosaics were checked to find possible misalignments on country borders and projection zone borders inside the country. The results of the geometry check are reported for verification points that are defined on all shared country borders with 50 km density, i.e. these points are located every 50 km on all common boundary lines. If displacement above 2 pixels was found, the error amplitude and direction are recorded. The verification results are presented in several forms:

- Summary statistics (number of countries, number of verification points, average displacement, minimum and maximum displacements, standard deviation).
- Graphical error report (error amplitude and direction are presented for all verification points).
- Vector data (vector point layer with associated attribute table as ArcInfo Shape file).

The results of inter-country verification are summarized in Table 42. The overall results are satisfactory with respect to accuracy requirements defined for single orthorectified Image2000 scenes. A graphical presentation of individual error vectors for each verification point is shown in Figure 43.

Table 42- Summary statistics of inter-country verification

Total number of countries	Total number of verification points	Displacement			
		Average [pixels]	Minimum [pixels]	Maximum [pixels]	Std Dev [pixels]
26	230	1,1	0,0	6,0	1,1

Displacements are expressed in panchromatic pixels. It should be noted that full resolution mosaic is defined with non-square image pixel with variable pixel size, when projected into plain and expressed in meters. This explains large error values (5-6 pixels) found on the border between Sweden and Finland, where pixel size reaches up to 3.9x12.8 m. Based on this fact, the geometrical misalignments found on this northern boundary are in the same rank as the displacements encountered between other countries.

In about 70% of points the displacement found is below 2 pixels limit. Displacement between 2-3 pixels is generally found in mountainous areas which are most sensitive to absolute geometric accuracy. As for internal geometry, slightly better results among accession countries can be explained by the fact that GCPs from neighbouring countries were used for orthocorrecting border images.

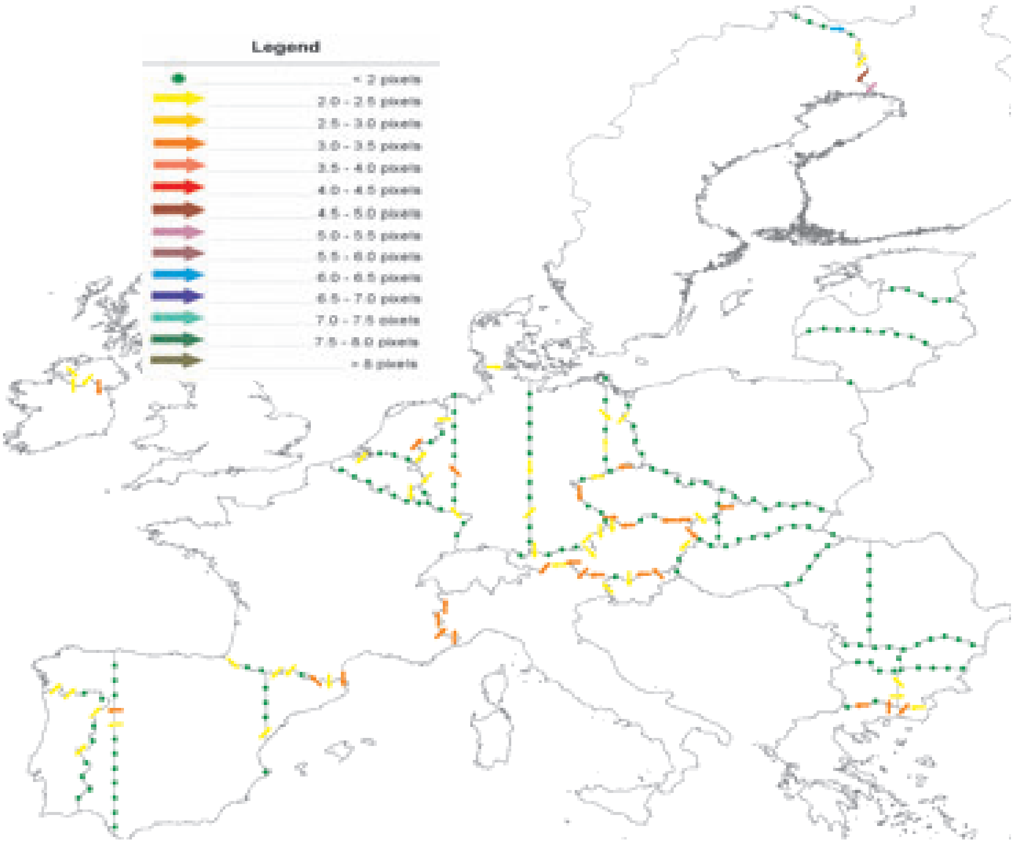


Figure 43- Graphical error report for inter-country verification

8.4 Small Scale Mosaic

Small scale mosaic was compiled in ETRS89-LCC, based on country mosaics prepared in previous step and country boundaries (and projection zone boundaries if applicable) used as mosaicking lines. The Eurostat GISCO country boundaries dataset was used. Two countries boundaries– Bulgaria and Romania - were missing in the dataset. The national versions were made available through NFPs of both countries and used as for the CLC2000 data integration. The final mosaic is delivered in one file.
Two versions covering the AC10 were prepared, differing in the approach applied to harmonise the radiometry of input scenes:

- **"Standard" small scale mosaic:** It was based on linear stretching look-up-tables as described in paragraph 8.2.2. The mosaic was prepared in panchromatic and multispectral version. The multispectral mosaic comprises of 6 Landsat 7 spectral bands (all bands except for thermal ones) and it was delivered in one file.
- **"Advanced" small scale mosaic:** Linear stretching method does not allow harmonizing the radiometry of all scenes acquired in different years and different time of the year. To prepare a real seamless mosaic it was decided to generate the advanced version. The focus was on scenes where linear stretching did not properly balance the radiometry. Histogram matching techniques were used here instead. The mosaic was prepared for 4-5-3 Landsat 7 band colour combination and it was delivered in one file.

The small scale mosaic covering the EU15 countries was done before by another contractor and the "advanced" version was not considered. Therefore, a completely colour harmonized single coverage is very difficult to be obtained when produced by a different team.

8.5 Full Resolution Mosaic

8.5.1 Definition of Tiles

Full resolution mosaic was compiled based on country mosaics, in ETRS89 geographical coordinates and country boundaries (and projection zone boundaries if applicable) used as mosaicking lines as explained before. The final mosaic was divided in tiles, defined according to a grid with the size of 1.725 deg. Thus the tiles have size of 7500 x 7500 pixels for multispectral bands and 15000 x 15000 pixels for panchromatic band. Panchromatic and multispectral (all bands except for thermal one) data, were delivered separately. It means that all bands combinations are possible to mosaic. In all, to cover participating countries there are **351 tiles** as seen in Figure 44.

Extent of mosaic: The extent of the current mosaic has been defined Longitude: 20.7° W - 34.5° E; Latitude: 24.15° N - 72.45° N. Azores Islands are to be covered as well. Hence, the western limit of the mosaic was extended up to 32.775° W.

Naming of tiles: A simple matrix was created to define rules for tile naming. Sequential alphabet letters were used for ROW_ID, starting from northern edge of the mosaic; sequential numbering, starting from west edge of the mosaic defines COUMN_ID. The tile name is constructed as follows:

TILE_ID = ROW_ID&COLUMN_ID

Figure 45 shows a tile for the band combination of 3-2-1.

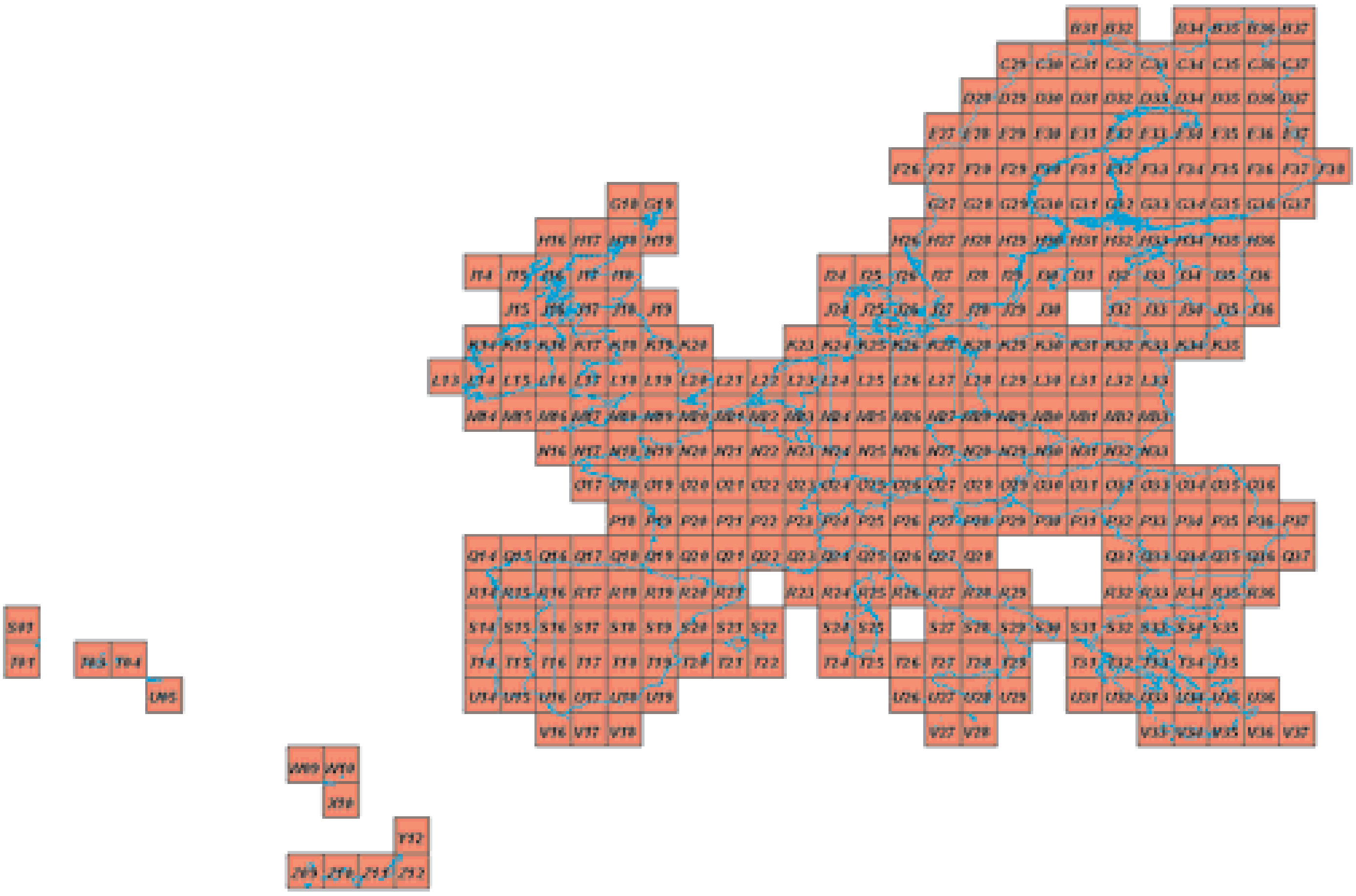


Figure 44- Tile definition for full resolution mosaic

8.5.2Evaluation of remaining clouds and haze areas

Once the full resolution mosaics had been made the evaluation of remaining clouds and haze areas was carried out. The results are reported separately for accession countries and member states in Table 43, as well as the overall result.

Table 43- Results of remaining clouds and haze areas evaluation

Region	Total area	Clouds		Haze	
	[km2]	[km2]	[%]	[km2]	[%]
AC	1 012 000		0,0	21 500	2,1
MS	3 099 500	9 500	0,3	47 500	1,5
EU25	4 111 500	9 500	0,2	69 000	1,7

Note: The designation of MS and AC in this context means the 2 lots of orthorectified images. The cloudy area statistics for MS is based on remaining cloud polygons as delivered with the stitch files. Separate assessment was done for AC based on the full resolution mosaic. All remaining cloudy areas were digitized as polygons and total area calculated.

The final result of **0.2% of clouds** for the European mosaic is excellent, as it is the 1.7% of haze affected areas, especially considering the high time consistency and the extent of the coverage. The haze evaluation is based on band combination 3-2-1 which is most sensitive to the atmospheric problems. When working with other band combinations, the affected area is much smaller. The objective of cloud free mosaic was achieved.

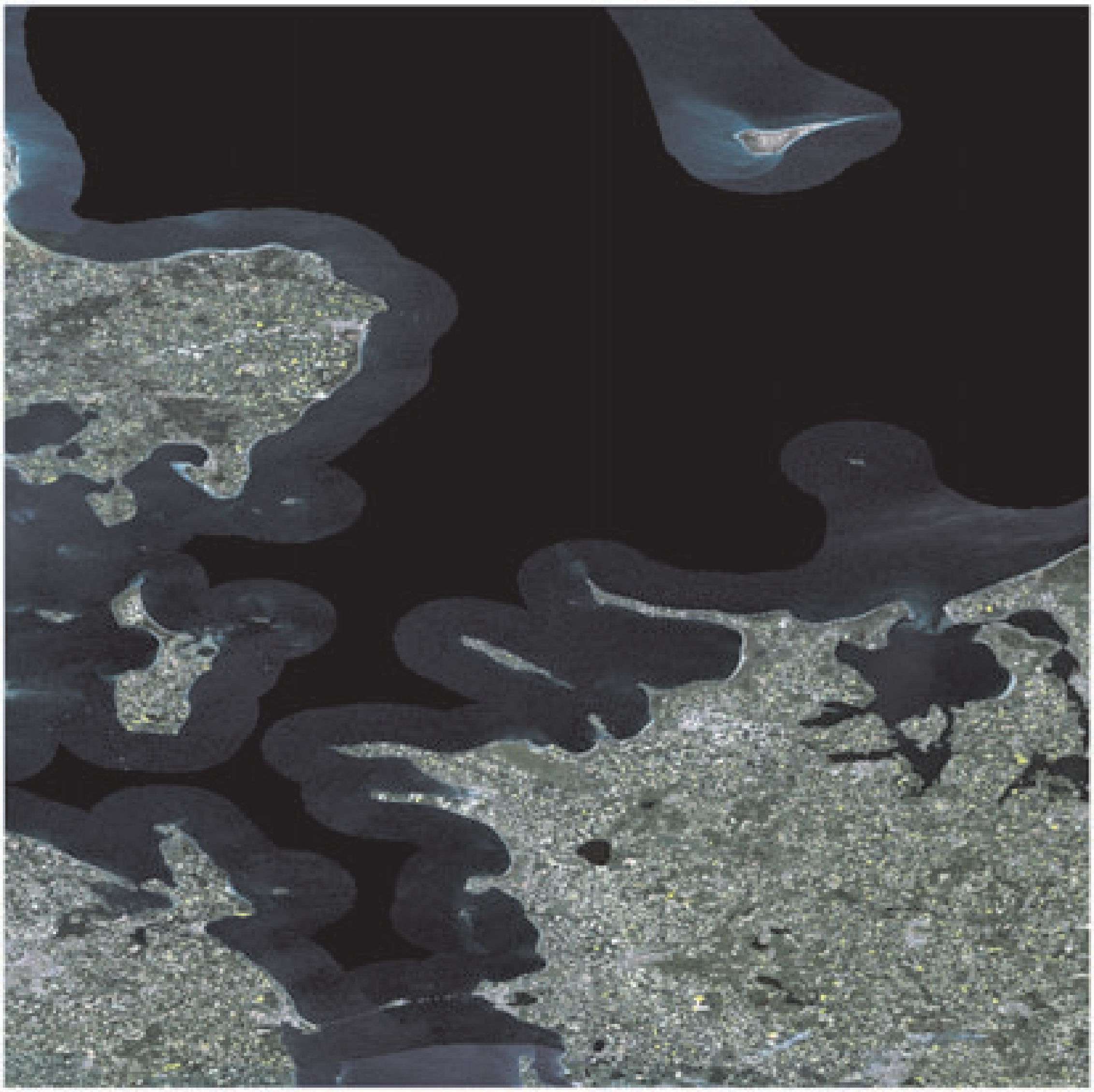


Figure 45- Tile J26_MS (multispectral data, bands combination 3-2-1

8.5.3 Pan-Sharpened mosaic

Pan-sharpening is an image processing technique that fuses high resolution panchromatic data with multispectral data, creating a high resolution colour image. This procedure has been used for years to prepare an image product that would combine information content of both input images. The radiometric distortions in resulting image were the main drawback of most techniques. However, advanced algorithms released recently can preserve the spectral characteristics of the original multispectral data in the resulting high resolution colour image. The technique, developed by Professor Yun Zhang of the University of New Brunswick, is ranked to be one of the best and gives superior results comparing to standard procedures (e.g. IHS or Brovey transformation). His technique, as implemented inside Geomatica Prime software was applied.

The Yun Zhang approach solved two major problems- colour distortion and operator / data dependency. A least squares technique was developed to approximate best the grey value relationship between the original multispectral, panchromatic and fused images, for the best colour representation. Statistical approaches were developed to realize a standardized and automated fusion process.

Although the image fusion technique implemented in PANSHARP diminishes greatly those deficiencies, no algorithm is known to produce "perfect" results. The pan-sharpened multispectral images will inherit the level of spatial details from the panchromatic image data but won't benefit from sufficient colour information to guarantee "true" high resolution multispectral images. Thus, spatial features of sizes smaller than the multispectral sensor resolution may be assigned "fake" colour, although visually the image quality appears to be excellent.

Another very important aspect of image fusion algorithms is ensuring very good co-registration of the input panchromatic and multispectral image data. A single pixel offset between the high resolution panchromatic image data and the low resolution multispectral image data results in colour shifts clearly visible in the pan-sharpened imagery. This was avoided due to the orthorectification previously done and the simultaneous acquisition of the panchromatic image and the multispectral image data offered by Landsat 7. Due to the lack of sufficient colour information in low resolution multispectral imagery compared to the panchromatic image, it is recommended that the ratio of resolutions between the images do not exceed 5:1. PANSHARP produces best results for multispectral image channels whose wavelengths lie within the frequency range of the panchromatic image channel. Multispectral channels outside the wavelength range of the high resolution panchromatic image channel will still look good but may have reduced physical meaning.

The PANSHARP algorithm attempts to preserve spectral characteristics, i.e. image colour. Mean, standard deviation and histogram shape for each channel are approximately preserved. Significant deviations from the original histogram shape can occur, however, if the resolutions of the multispectral and panchromatic imagery differ greatly or if data from different sensors are used together.

The pan-sharpened full resolution mosaic consists of the same tiles as panchromatic mosaic (15000x15 000 pixels). The tiles are delivered in 6 multispectral bands (thermal bands excluded).

Figure 46- Comparison of multispectral (top) and pan-sharpened (bottom) full resolution mosaic (bands combination 4-5-3)

IV- CLC2000

1 Introduction

The aim of the CLC database is to provide an inventory of the Earth surface features for managing the environment (Heymann et al., 1994). Only features that are relatively stable in time are mapped. CLC is not interested in diurnal changes (e.g. tide), seasonal changes (e.g. vegetation cycle) or short-term changes (e.g. flooding). The approach of computer aided visual interpretation of satellite images have been chosen as mapping methodology. The basic choices of scale 1:100.000, minimum mapping unit (MMU) of 25 hectares and minimum width of linear elements 100 metres represent a trade-off between cost and detail of land cover information. These basic parameters are the same for CLC90 and CLC2000. However, in CLC90 some of the countries had not kept the 25 ha limit, which made comparison among countries difficult. This limitation was removed with the CLC2000.

The standard CLC nomenclature includes 44 land cover classes. These are grouped in a three level hierarchy, having five level-one categories (see §2). All national teams had to adapt the nomenclature according to their landscape conditions, following standard criteria. For national purposes it is allowed to further subdivide any of level-3 elements of the nomenclature. For example, two different types of inland marshes (411) and peat bogs (412) were defined in Estonia (EEIC, 2003). The European database however includes only level-3 classes. The 44 classes have not changed since the implementation of the first CLC inventory (1986-1998). However, the definition of each nomenclature element was significantly improved (Bossard et al., 2000), to facilitate comparable results in time and space. A special feature of the nomenclature is class “Heterogeneous agricultural areas”. It is formed by objects, (e.g. plots of arable land, areas of natural vegetation, etc.) which themselves would be smaller than the minimum mapping unit (25 hectares). E.g. class 242 has been introduced to characterise mixed agricultural areas: mixtures of small plots of any of two or more of the following cover types: arable land, pastures, vineyards, fruit trees and berry plantations and olives. Class 243 has the aim to characterise agricultural areas with significant amount of natural formations (e.g. patches of forests, areas of shrub, grasslands, wetlands or water bodies). These are very useful tools to characterise heterogeneous landscapes at scale 1:100 000.

Raw satellite images first have to be pre-processed and enhanced to yield a geometrically correct document (satellite image map) in national projection. For CLC2000, IMAGE2000 provided accurate ortho-images (see § III). But for CLC90, usually only a polynomial correction was applied to the Landsat 5 images and GCPs were usually selected from 1:100.000 scale maps. No DEM was used, except for Slovenia. The accuracy of those image-maps was significantly poorer than that of IMAGE2000.

During the first CLC inventory a “traditional” image-interpretation method was used: a transparent overlay was fixed on top of a satellite image hardcopy printed at scale of 1:100 000 and the image-interpreter drew polygons on it. Later the overlay was digitised, topology was created and the CLC code entered (Heymann, et al., 1994). This procedure often resulted in several types of errors:

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

When comparing CLC90 with IMAGE2000 as the basic geometric reference, sometimes geometric errors larger than 200 m were observed. In some of the countries, the thematic accuracy of CLC90 hardly achieved the target 85% value.

In CLC2000 the method of drawing on transparencies was rejected, and the use of computer-aided image-interpretation (CAPI) was required (Perdigão, V. and A. Annoni, 1997). As expected, the improved technology and implementation scheme provided better thematic and positional accuracy.

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

2 CLC Nomenclature

The CORINE Land Cover (CLC) nomenclature is based upon land cover classes, discriminated mainly by physiognomic attributes (shape, size, colour and pattern) of landscape objects (natural, modified – cultivated and artificial), as recorded on satellite images. Artificial surfaces and agricultural areas are also discerned by functional attributes and are related to land use (LU). LC represents the biophysical state of the landscape (Feranec and Otahel 2001) or Barnsley et al. (2001) refer to land cover as "the physical materials on the surface of a given parcel of land (e.g. grass, concrete, tarmac, water)". The biophysical essence of LC means that it comprises not just natural but also modified (cultivated) and artificial objects. Man perceives landscape as a combination of physical objects of natural character and objects (re)created by himself (agricultural land, artificial urban objects). For instance, urbanized objects (artificial surfaces) or intensively used agricultural objects (arable land, permanent crops) also indicate their LU, their societal function. On the other side, the nature and appearance of the natural or semi-natural objects does not mean that they are not used or that function is absent. For example, coniferous forest can be used for timber, recreation and nature conservation or military purposes (Feranec and Otahel 2003). The CLC nomenclature does not consistently discern LC from LU. However, the mentioned functions do not have to be, and often are not visually identifiable, in particular from remote sensing data. Satellite images are sources of information on physiognomic attributes (Table 44) of landscape objects by means of which CLC classes are identifiable.

Table 44- Physiognomic attributes relevant for identification of CLC classes

Urban fabric areas	Size, shape and density of the buildings, share of supplementing parts of the class (e.g. square, width of the streets, gardens, urban greenery parking lots), character of transport network, size and character of neighbouring water areas, arrangement of infrastructure, size of quays, character of the runway surfaces, state of the dumps and arrangement and share of playgrounds and sport halls
Agricultural areas	Share of dispersed greenery within agricultural land, arrangement and share of areas of permanent crops, relationships grasslands with urban fabric, occurrence of dispersed houses (cottages), arrangement and share of agricultural land (arable land), grasslands, permanent crops and natural vegetation (mainly trees and bushes), irrigation channel network
Forest and semi-natural areas	Character (composition), developmental stage and arrangement of vegetation (mainly trees and bushes), share of grass and dispersed greenery (composition density)
Wetlands	Character of substrate, water and vegetation,
Water bodies	Character (shape) of water bodies

The CLC nomenclature (Table 45) comprises three levels:

- The first level with 5 items, indicates the major land cover classes on the planet,
- The second level with 15 items is for use on scales 1:500 000 and 1:000 000,
- The third level, 44 items, is for use on scale 1:100 000 (Heymann et al. 1994).

A fourth level could be added at this and larger scale to respond to a specific need and national request.

The smallest unit identified in CLC is 25 hectares (MMU) and the minimum width of linear feature (e.g. water course, road, etc.) is 100 m.

Table 45- The CLC nomenclature contains 44 classes (Heymann et al. 1994, Bossard et al. 2000)

LEVEL 1	LEVEL 2	LEVEL 3
1. ARTIFICIAL SURFACES	1.1. Urban fabric	1.1.1. Continuous urban fabric 1.1.2. Discontinuous urban fabric
	1.2. Industrial, commercial and transport units	1.2.1. Industrial or commercial units 1.2.2. Road and rail networks and associated land 1.2.3. Port areas 1.2.4. Airports
	1.3. Mine, dump and construction sites	1.3.1. Mineral extraction sites 1.3.2. Dump sites 1.3.3. Construction sites
	1.4. Artificial, non-agricultural vegetated areas	1.4.1. Green urban areas 1.4.2. Port and leisure facilities
2. AGRICULTURAL AREAS	2.1. Arable land	2.1.1. Non-irrigated arable land 2.1.2. Permanently irrigated land 2.1.3. Rice fields
	2.2. Permanent crops	2.2.1. Vineyards 2.2.2. Fruit trees and berry plantations 2.2.3. Olive groves
	2.3.Pastures	2.3.1. Pastures
	2.4. Heterogeneous agricultural areas	2.4.1. Annual crops associated with permanent crops 2.4.2. Complex cultivation patterns 2.4.3. Land principally occupied by agriculture, with significant areas of natural vegetation 2.4.4. Agro-forestry areas
3. FOREST AND SEMI-NATURAL AREAS	3.1. Forests	3.1.1. Broad-leaved forest 3.1.2. Coniferous forest 3.1.3. Mixed forest
	3.2. Scrub and/or herbaceous associations	3.2.1. Natural grassland 3.2.2. Moors and heathland 3.2.3. Sclerophyllous vegetation 3.2.4. Transitional woodland-scrub
	3.3. Open spaces with little or no vegetation	3.3.1. Beaches, dunes, sands 3.3.2. Bare rocks 3.3.3. Sparsely vegetated areas 3.3.4. Burnt areas 3.3.5. Glaciers and perpetual snow
4. WETLANDS	4.1. Inland wetlands	4.1.1. Inland marshes 4.1.2. Peat bogs
	4.2. Marine wetlands	4.2.1. Salt marshes 4.2.2. Salines 4.2.3. Intertidal flats
5. WATER BODIES	5.1. Inland waters	5.1.1. Water courses 5.1.2. Water bodies
	5.2. Marine waters	5.2.1. Coastal lagoons 5.2.2. Estuaries 5.2.3. Sea and ocean

3 Training of National Teams

3.1 Objectives and Specifications

The training of the CLC2000 national teams was one of the important tasks of the CLC2000 Technical Team (TT). The main objective of the training was to provide the members of national teams with the most comprehensive and harmonised information concerning the whole CLC2000 Project, giving special emphasis to the updating rules and nomenclature and the possibility to discuss all technical problems specific to a national environment. This is the basic prerequisite for generating results of desirable quality, high mutual compatibility of the individual CLC classes and of the identified land cover changes through all the Europe. A systematic and consistent training was dedicated to each national team separately and before to start the production, to be sure that national specific thematic aspects could be discussed if needed. This procedure allowed to reaching a harmonised and consistent interpretation and application of the nomenclature and of the methodological rules in all participating countries, many of them with more than one team and significant variety of landscapes.

The training process consisted of four parts (Feranec, J.):

- Lectures by the TT members about the individual steps of the CLC 2000 Project.
- Characteristics of the implementation procedures in the context of the participating country, presented by the representative/s of the national team.
- Assessment of results obtained at the date of the training.
- Final discussion of the TT members with the national team members.

A **core of lectures** was prepared by the TT, to present at each national training session and distributed to the national teams on CD Rom, as lecture notes. The lectures are:

- *Overview of the European CLC2000 Project,* to review the characteristics and structure of the I&CLC2000 in terms of specialised and organisational aspects and its significance in the light of the European requirements.
- *Systemic CLC90 corrections* - characteristics and documented examples: samples and ways to remove the geometric and thematic errors identified in the CLC90 data layer.
- *CLC nomenclature* - detailed explanation of the contents of CLC classes according to the *CORINE Land Cover Technical Guide – Addendum 2000,* with emphasis on the characteristics of classes occurring in the landscape where the training was held.
- *Updating methodology and practical examples* - explanation of theoretical and methodological aspects of land cover change identification, characteristics of the land cover change types defined by the CLC2000 Project, demonstration of examples of such changes.
- *Field checking* - explanation of the meaning, ways of ensuring, realisation and use of results obtained in the field in the framework of the CLC2000.
- *Quality assessment / quality control* meaning, characteristics and approaches to the quality assessment and validation.
- *Support of TT to national teams* - explanations of the tasks of the TT, its readiness to assist by e-mail or phone communications, to solve the emerged / identified problems associated to the different phases of the Project.

Presentations from the representative(s) of the national team included the characteristics of the working plan, ensuring of solutions to the Project and introducing potential specific problems of interpretation regarding a particular landscape.

The practical part of the training consisted of assessment of results obtained by the national team as to the date of training. The TT members minutely checked the geometrical and thematic aspects of the CLC2000 and CLC90/2000 data layers (CLC-changes), aiming to identify the existence of potential systemic or incidental errors.

During the final discussion, the TT characterised the errors identified by the checks of CLC90 and CLC2000 data layers, presenting proposals for its correction, commenting on the way to ensuring the success of CLC2000 Project in the country and answering to the questions asked by the national team. In more than half of the countries and according to their request, there was a presentation on the capabilities of the InterChange photointerpretation (image-interpretation) tool - an ArcView macro programme developed by FÖMI, and offered free for any interested national teams. The presentation was followed by a short technical session demonstrating the use of the software in solving practical problems.

After each training session, the TT prepared a detailed written report, describing the context of national project, training agenda and participants, discussions, assessment and recommendations from the TT. The report was distributed to the national team-coordinator, the EEA, JRC and uploaded in the project's web site.

3.2 Overall Planning

Table 46- Date and place of national trainings

Country	Date	Place
Germany	05 - 08 February 2002	DLR/DFD, Oberfaffenhofen, Munich
Netherlands	12 - 13 February 2002	Alterra-Centre for Geoinformation, Wageningen
Ireland	19 – 21 February 2002	ERA Maptec, Dublin
Spain	26 – 28 February 2002	IGN-CNIG, Barcelona
Belgium	13 -15 March 2002	IGN – NGI, Brussels
Austria	09 -11 April 2002	Federal Environment Agency-UBA, Vienna
Finland	21-23 October 2002	Finish Environment Institute SYKE, Helsinki
Sweden	24-25 October 2002	Metria GIS-Centrum, Stockholm
Portugal	27-29 November 2002	Istituto Superiore de Estatistica e Gestão da Informação-ISEGI, Lisbon
Bulgaria	03-05 December 2002	Space Research Institute, Sofia
U.K.	10-11 December 2002	Centre for Ecology and Hydrology- CEH, Monks Wood
Estonia	17-19 December 2002	Estonian Mapping Centre, Tallinn
Denmark	19-21 December 2002	National Environmental Research Institute-NERI, Silkeborg
Poland	13-15 January 2003	Institute for Geodesy and Cartography-IGIK, Warsaw
Czech Republic	15-17 January 2003	Help Service Remote Sensing Ltd., Praha
Hungary	23 January 2003	Institute of Geodesy Cartography and Remote Sensing, FÖMI, Budapest
Slovakia	24 January 2003	The Slovak Environmental Agency-SAZP, Banska Bystrica
Latvia	04-06 February 2003	Envirotech, Riga
Romania	11-13 February 2003	Danube Delta National Institute, Tulcea
France	19-20 February 2003	Geosys, Toulouse
Slovenia	25-27 February 2003	GISDATA d.o.o., Ljubljana
Italy	04-06 March 2003	University of Rome La Sapienza, Rome
Lithuania	01-03 April 2003	University of Vilnius, Institute of Ecology, Vilnius
Croatia	15-16 October 2003	Ministry of Environmental Protection and Physical Planning, Zagreb
Greece- Cyprus	28-30 January 2004	Hellenic Mapping and Cadastral Organisation Ktimatologio, Athens

Remark: no formal training has been conducted in Liechtenstein, Luxembourg and Malta

4 Methodology

The CLC2000 was done by mapping the changes occurred between theCLC90 and the date of updating. The change detection process and the mapping of the CLC-Changes were carried out by means of image comparison, using computer aided visual interpretation tools. The CLC90 is used as reference data set. The methodology was developed by the JRC in collaboration with the ETC Land Cover (Perdigão, Vanda and A. Annoni, 1997). The method was successfully applied within the LACOAST Project (Perdigão, V. and S. Christensen, 2000) and by the Phare Topic Link on Land Cover Project (Feranec et al., 2000). Figure 47 illustrates the general work flow.

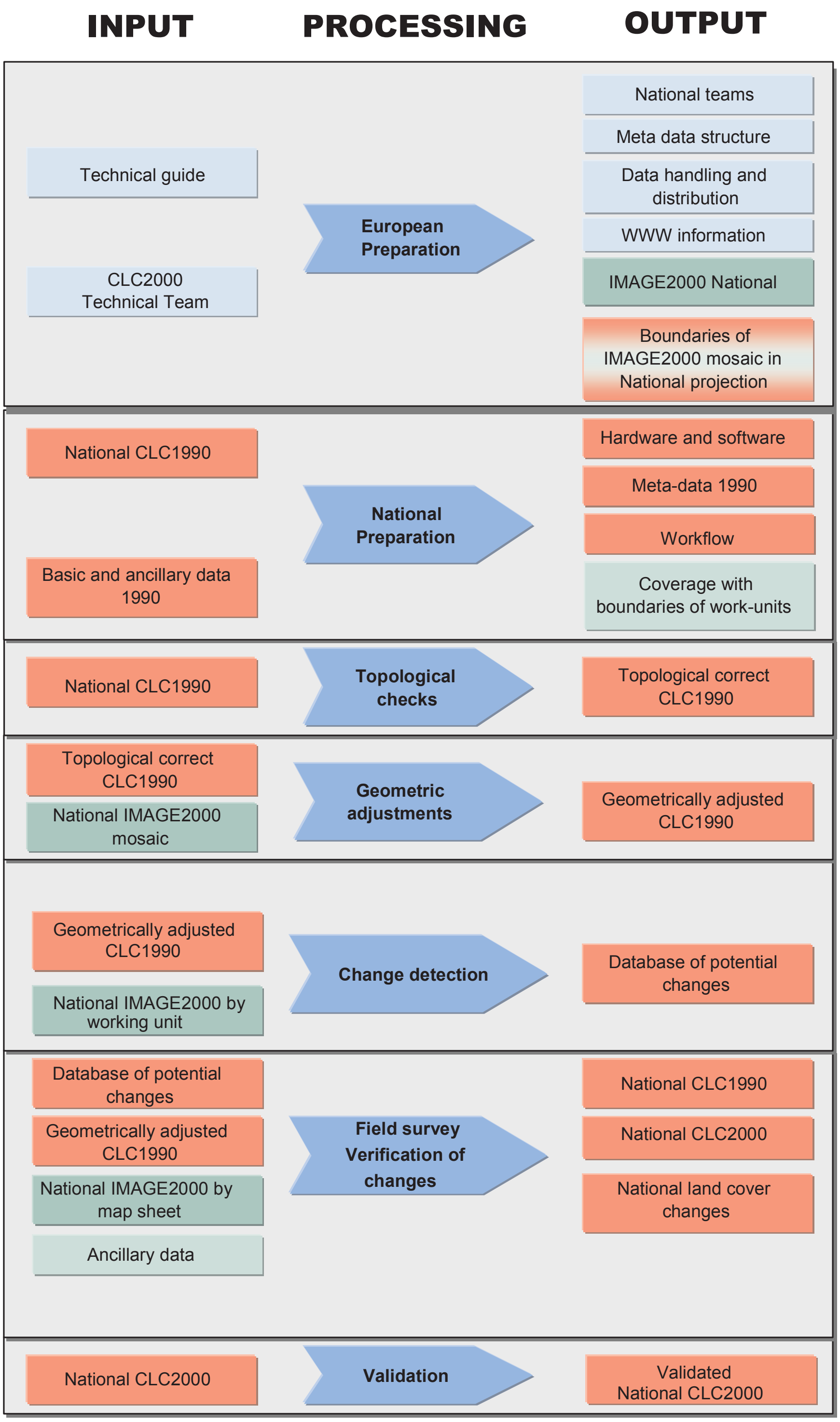


Figure 47- Production flow (I&CLC2000 Technical Specifications, 2000)

4.1 Geometric adaptation of satellite images from 1990s

The Landsat TM images used to derive CLC90 database were necessary, to verify and eventually to correct thematic errors of CLC90, fundamental to avoid the identification of false changes. The satellite data used in the first edition of CLC was geometrically corrected in a decentralised way, without standard procedures for quality control and, for most countries, without the use of a DEM. In many countries they were used in analogue format. Therefore significant inconsistencies in geometry existed and should be corrected against the reference (IMAGE2000) before starting the identification of land cover changes.

The geometry of the images used in 1990s and IMAGE2000 data were compared by image processing. If a systematic deviation larger than 50 m was observed, the old image data had to be corrected to have similar geometry of the IMAGE2000. First order transformation and cubic convolution resampling was recommended. After the geometric adjustment, the ortho- image obtained is called **IMAGE90**.

4.2 Geometric and Thematic Corrections of CLC90

CLC90 might have had different types of errors. The severity of these errors varies from country to country (Büttner, G. et al., 2004):

- Systematic or non-systematic geometric shift (compared to IMAGE90),
- Topology problems,
- Holes, like not interpreted areas, etc.

4.2.1 Geometric corrections of CLC90

The geometric distortions of CLC90 were the result of four effects.

- The type of geometric correction and ortho-rectification process of the satellite images (number of GCP selected, reference data used. etc).
- Distortion of printed image hardcopy (film-writing, optical enlargement).
- The geometric instability of image hardcopy and plastic overlay during the image interpretation phase (sometime the shift error could be more than 0,5 mm at scale 1:100 000).
- Geometrical distortions generated by scanning.

Each step gave different distortions and the main goal was to decrease the cumulative distortion of CLC90. CLC90 data and the geometrically correct IMAGE90 were compared using an IP/GIS system. If a systematic deviation larger than 50 m was observed between CLC90 and IMAGE90 on any part of the working unit, CLC90 data had to be corrected. A rubber-sheeting technology proved to be superior to linear transformation, as distortions were usually systematic only locally. Interactive adjustment of control features of CLC90 (small image windows on forest-arable land boundary, lake, etc.) on IMAGE90 had been used to define the transformation (normally realised in ArcInfo). The local or residual geometrical error when existing was corrected manually.

4.2.2 Thematic corrections

The CLC90 was produced by visual interpretation of the colour hardcopy of satellite images at scale 1:100 000. This methodology justified by the time when the first Terms of Reference of CLC were prepared, has limitations regarding the computer aided visual interpretation of satellite images applied to generate the CLC2000 database. The assets of the last method are (Feranec, J.):

- Better resolution of satellite imagery on the computer screen than the hardcopy images at a constant scale of 1:100 000 overlaid by transparency.
- The possibility of an operative enlargement and comparison with ancillary data on digital or analogical format (mainly aerial photographs, images, topographic and thematic maps).
- The possibility of more precise delineation of the CLC mapping units.

These differences in technology are the principal reason for the errors identified in CLC90, during the implementation of CLC2000:

- Imprecise area(s) shape of the CLC90 class(es), (digitization on transparencies, distortion introduced by scanning).
- Erroneous CLC class designations.
- Not identified area(s) of the CLC class(es).

The topology of the coverage was checked and topological errors (dangles, more than one label, unnecessary boundaries, etc.) were corrected. These corrections include removing random geometrical errors and thematic errors. The polygons of CLC90 were examined for the validity of CLC codes and the size of the MMU. All polygons smaller than 25 ha were generalised. This was a difficult task in some countries, where MMU < 25 ha was applied as a rule in CLC90 (e.g. 10 ha in Belgium). Any random geometric error was corrected, if the inaccuracy of the delineation was larger than 100 m, as seen on the IMAGE2000 or on the IMAGE90 data.

If a thematic error was discovered, the CLC code was corrected. Thematic and geometric improvements occurred frequently together: e.g. subdivision of a polygon into two parts. This required drawing of a new boundary and changing the code. Only after the removal of errors from the CLC90, it was possible to do a correct identification of the LC changes. In some countries correcting CLC90 needed significantly more efforts than the subsequent updating (Büttner, G. et al., 2004).

4.3 Land cover changes

In the framework of CLC2000, land cover change is interpreted as a categorical change i.e. conversion of the area of an LC class or its part(s) to another LC class(es) (Coppin et al., 2004). The basic condition for identification of categorical land cover changes using satellite images is the presence of changes in spectral reflectance, detectable by the satellite detector. Such changes are manifest in images by changes in characteristics of the interpretation elements. From the methodological point of view it means that images from two or more time horizons (temporal series) may be used in identification of land cover changes. Two basic sets of methods exist to detect land cover changes from images:

- Visual and computer aided visual interpretation (CAPI).
- Digital methods of change identification (Jensen 1986, Rogan and Chen 2004).

The computer aided visual interpretation of satellite images is the one proposed and the most used for the CLC. This method makes use of the corrected CLC90 as reference layer and the IMAGE 2000 (Steenmans, C. and V. Perdigão, 2001). According to the Technical Guide, all needed modifications (LCC) are performed on this initial data layer, which is altered only locally in areas of the identified land cover changes. All unchanged polygons are maintained and the common boundaries of areas from two or more time horizons are not burdened by any discrepancies. Coppin et al. 2004, refers this method as the bi-temporal change detection methodology - comparing the same area at two points in time. The generation of the CLC2000 is the *updating* approach, instead of the creation of a new database from scratch. The primary purpose of this approach is to minimise the chance of introducing inaccuracies into the database of changes, which are common when the independent generation of the compared databases, and to reduce the cost by drawing less polygons.
The basic principle of this approach is shown in the Figure 48 (Feranec et al., in print).

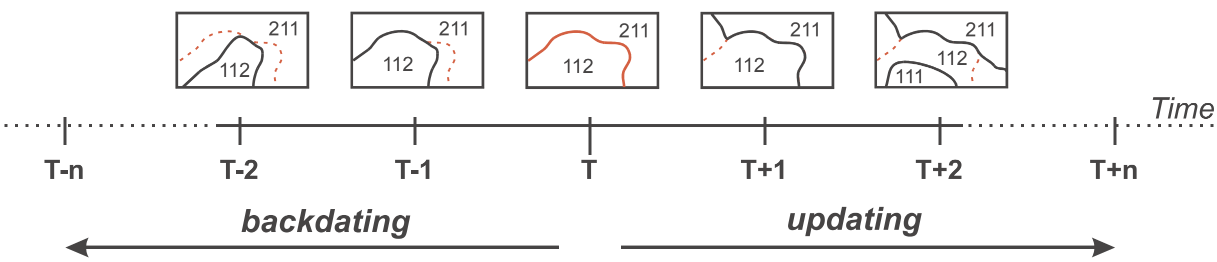


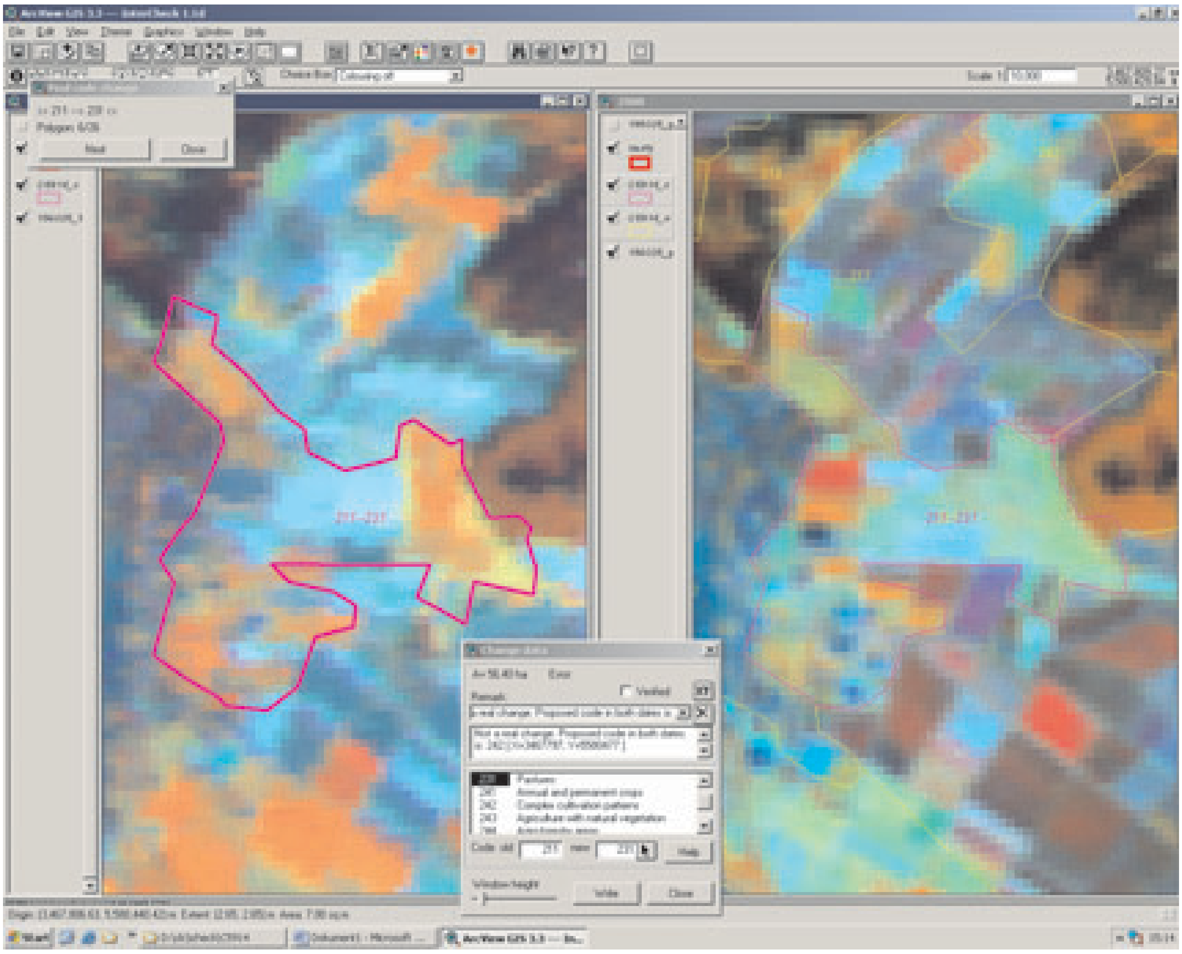
Figure 48- Basic principle of updating

As discussed in 4.3.2, two other variant approaches were also used for the updating.

4.3.1 Definition of Land Cover Change

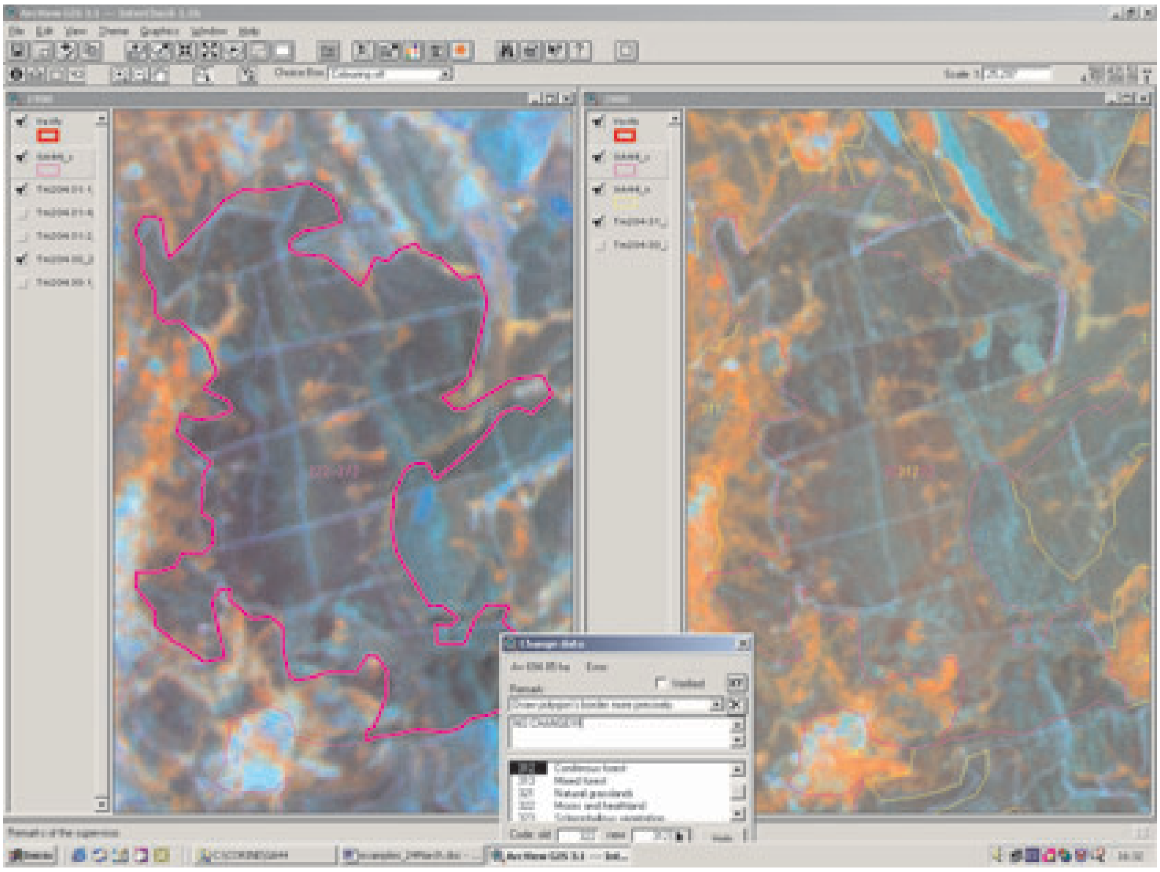
CLC2000 respects the spatial characteristics of the CLC methodology (Heymann et al. 1994), i.e., the new database comply with the criteria of minimum area of 25 ha and the minimum width of 100m. According to Technical Guidelines (EEA-ETC/TE, 2002), Land Cover Changes are mapped if the area of the change is larger than 5 ha and the width of change is ≥ 100 m (See Figures 51, 52, 53).

This means that, in order to produce results for Europe within the available time and budget, not all detected (visible) changes had to be interpreted. As an additional requirement, changes should be valid, reflecting real land cover evolutions (e.g. increase of settlements, forest clear-cutting, etc.) and not seasonal changes of the same land cover class. Figures 49 and 50 give two examples of seasonal effects, not considered as LCC. The first shows the same unit of complex cultivation in two different time periods; the second the same coniferous forest in the process of regeneration after a cut.



Left: IMAGE90 and CLC-changes, right: IMAGE2000 and CLC-Changes & CLC2000

Figure 49- Example of seasonal effects in complex cultivation land cover class, not considered as land cover changes



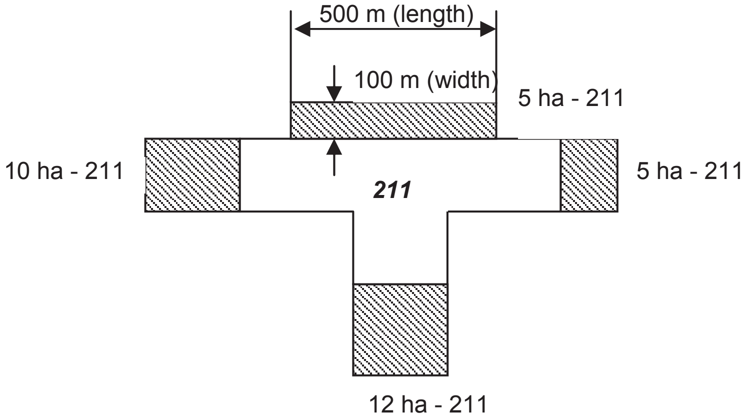
Left: IMAGE90 and CLC-changes. Right: IMAGE2000 and CLC-Changes & CLC2000

Figure 50- Example of seasonal effects in coniferous forest, not considered as land cover changes

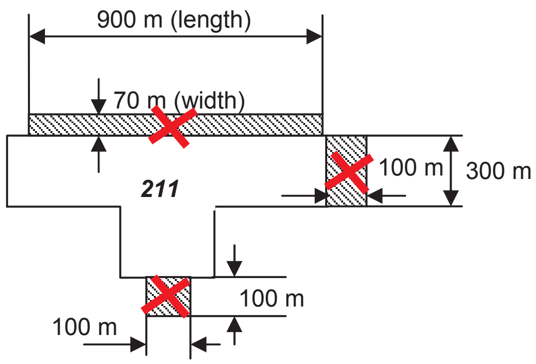
Figure 51 illustrates the basic criteria to map the minimal land cover change unit. The land cover change is considered if it represents a polygon of at least 5 ha (annexed to an existing polygon with the same code) and if the width of LCC polygon is at least 100 m. The first draw shows an increase of a polygon with code 211 by three new units, each of one fulfilling the criteria of surface and width. The resulting updated polygon must always be at least 25 ha. The second example shows cases of LCC that can not be mapped because the width of the LCC field is smaller than 100 m or because the area is less than 5 ha. The third example presents a LCC that can be partially mapped: although the area is 7 ha, the left side of the field is 40 m width; therefore the new boundary can not be mapped.

Figure 52 gives four simple examples of LCC. In the first case, only the land cover class changed and not the area of the polygon. In the second one, there is an area exchange between two polygons, increasing one (112) by the same surface (> 5ha) as the other (211) decrease. The third example shows a polygon that disappear in CLC2000 since the increasing of polygon 311 results in a reduction of area 324, which became < 25ha. Finally in the fourth case it appears a new isolated polygon 311 inside the existing 243, since the area of LCC is >25ha.

Figure 53 illustrates two examples of more complex LCC. In the first one, polygon with code 112 increases more than 5ha due to the reduction of other adjacent polygons (211; 243; 311). Two of these reductions were too small to be mapped individually but, being adjacent, together they are 7 ha. The second example illustrates the case of the total decrease of a polygon's area, composed by several contiguous LCC, some of them smaller than 5 ha but making more than 5ha of change in total.

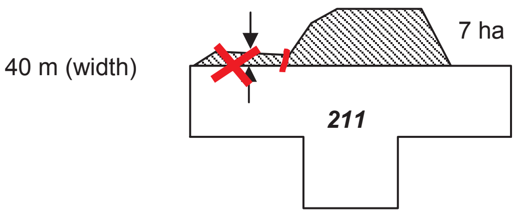


Changes to be considered (width of change must be ≥ 100 m, at scale 1:100 000 it is ≥ 1 mm; area of change must be ≥ 5 ha)



Changes not to be considered (if area is smaller than 5 ha)

- width of change is ≤ 100 m (≤ 1 mm at scale 1:100 000)
- area of change ≤ 5 ha



Part of the change is not considered (as width is ≤ 100 m)

Figure 51- Criteria for the detection of the smallest land cover change at scale 1:100 000(EEA-ETC/TE, 2002)

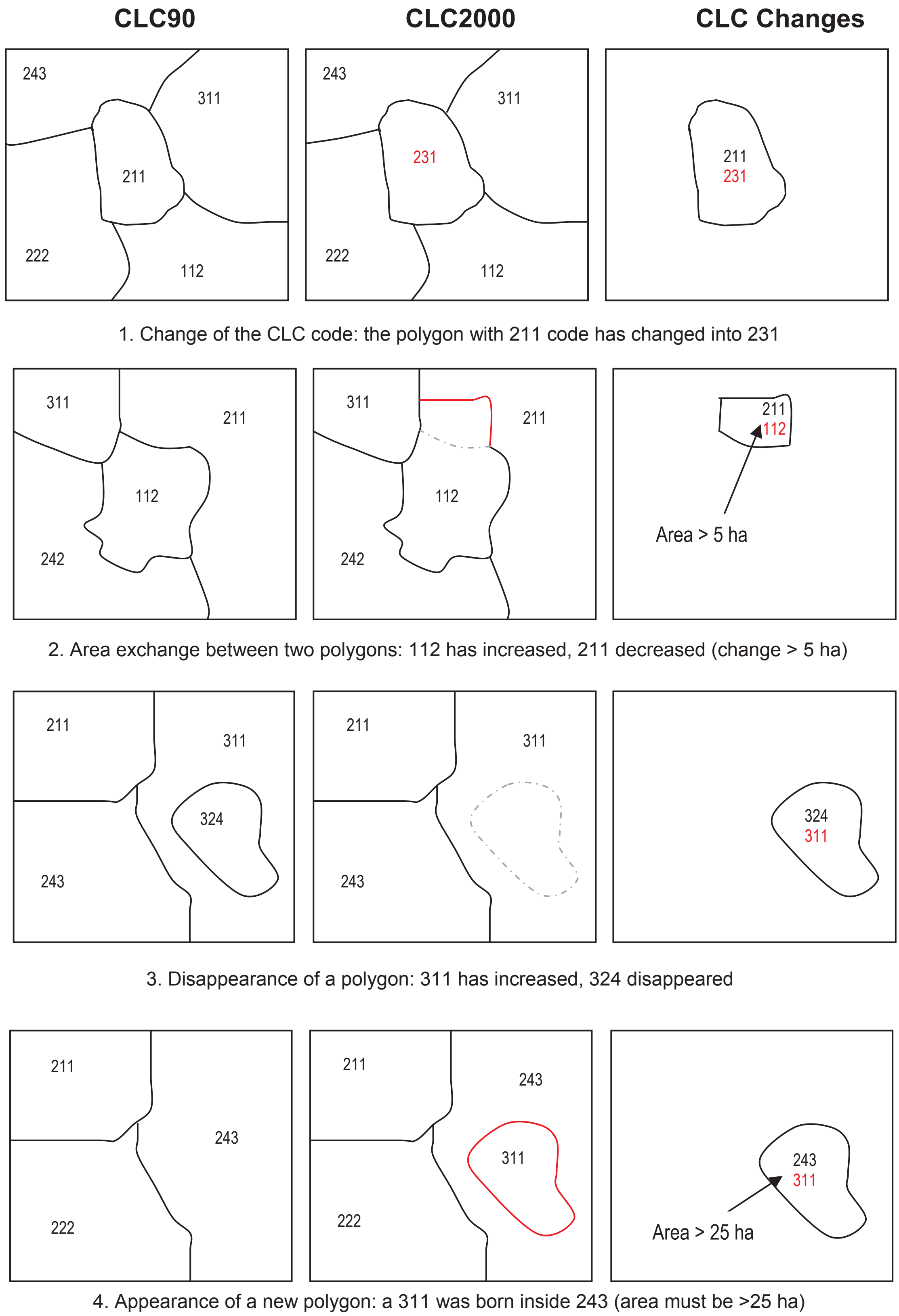
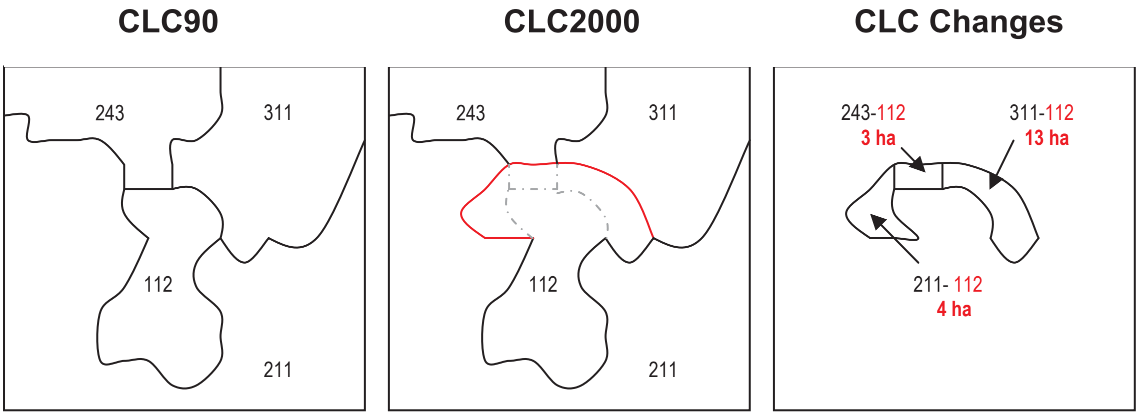
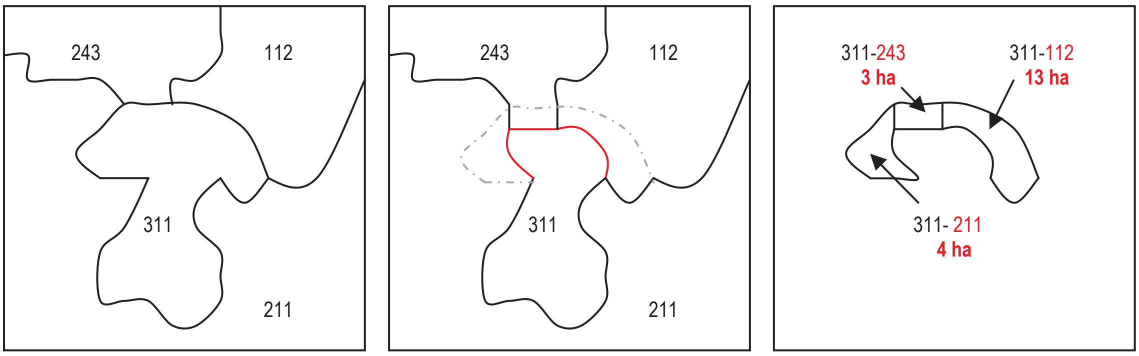


Figure 52- Examples of simple LC changes(EEA-ETC/TE, 2002)



Example 1:
Total increase of a polygon (> 5 ha) can include several contiguous elementary changes, some of them smaller than 5 ha. The example illustrates the growing of a settlement.



Example 2:
Total decrease of a polygon (> 5 ha) can include several contiguous elementary changes, some of them smaller than 5 ha. The example illustrates the shrinking of a forest.

Figure 53- Examples of complex LC changes (EEA-ETC/TE, 2002)

The most typical types of change are (EEA-ETC/TE, 2002):

- Change of the CLC code of the entire polygon: e.g. arable land (211) has changed into pasture (231);
- Area exchange between two polygons: e.g. settlement (112) has increased, arable land (211) has decreased;
- Emergence of a new polygon: e.g. a forest (311) was established inside an agricultural area with significant amount of natural vegetation (243)
- Disappearance of a polygon: e.g. a transitional woodland-shrub (324) inside the forest (311) disappeared;

4.3.2- Generalization

In the course of revising CLC90 and in generating the CLC2000 by identifying the LCC, the polygons smaller than 25 ha had to be removed, it means added to the neighbouring polygons. This operation is called generalization and it was done by applying rules established in the priority table (Table 47)

Table 47- Priority table

		codes of neighbouring polygon > 25 ha																																																
		111	112	121	122	123	124	131	132	133	141	142	211	212	213	221	222	223	231	241	242	243	244	**311**	**312**	313	321	322	323	324	331	332	333	334	335	411	412	421	422	423	511	512	521	522	523
unit<25ha	111		1	1	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	2	2	3	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5
	112	1		1	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	2	2	3	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5
	121	3	3		1	1	1	2	2	2	4	4	6	6	6	6	6	6	6	5	5	6	7	7	7	7	7	7	7	7	7	7	7	7	7	8	8	8	8	8	8	8	8	8	8
	122	2	2	1		1	1	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5
	123	3	3	1	1		1	2	2	2	4	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	6	6	6	6	6	6	6	6	6	6
	124	3	3	1	1	1		4	4	4	2	2	6	6	6	6	6	6	5	6	5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	7	7	7	7	7	7	7	7	7
	131	3	3	2	2	3	3		1	1	4	4	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	6	6	8	8	8	8	5	8	8	8
	132	3	3	2	2	3	3	3		1	4	4	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	6	6	8	8	8	8	5	8	8	8
	133	1	1	1	1	1	1	2	2		2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4
	141	3	2	3	3	3	3	3	3	3		1	7	7	7	7	7	7	7	7	7	5	5	4	4	4	4	4	4	4	7	7	7	7	7	7	7	7	7	7	7	6	6	7	7
	142	3	2	3	3	3	3	3	3	3	1		5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	4	5	5
	211	5	5	5	5	5	5	5	5	5	5	5		1	1	4	4	4	3	2	2	2	2	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	7	7	7	7
	212	5	5	5	5	5	5	5	5	5	5	5	1		1	4	4	4	3	2	2	2	2	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	7	7	7	7
	213	5	5	5	5	5	5	5	5	5	5	5	1	1		4	4	4	3	2	2	2	2	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	7	7	7	7
	221	4	4	5	5	5	5	5	5	5	5	5	3	3	3		1	1	3	2	2	2	2	5	5	5	4	4	4	4	4	4	4	4	6	6	6	6	6	6	7	7	7	7	7
	222	5	5	6	6	6	6	6	6	6	6	6	3	3	3	1		1	3	2	2	2	2	4	4	4	6	5	5	5	6	6	6	6	7	7	7	7	7	7	8	8	8	8	8
	223	5	5	6	6	6	6	6	6	6	6	6	3	3	3	1	1		3	2	2	2	2	4	4	4	6	5	5	5	6	6	6	6	7	7	7	7	7	7	8	8	8	8	8
	231	6	5	6	6	6	5	6	6	6	4	4	2	2	2	3	3	3		1	1	1	1	7	7	7	4	6	6	6	5	5	5	5	8	4	4	4	7	7	8	8	8	8	8
	241	3	2	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1		1	1	1	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	5	5	5	5	5
	242	3	2	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1		1	1	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	5	5	5	5	5
	243	4	3	4	4	4	4	4	4	4	4	4	2	2	2	2	2	2	2	1	1		1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	3	4	4	4
	244	4	3	4	4	4	4	4	4	4	4	4	2	2	2	2	2	2	2	1	1	1		3	3	3	4	4	4	4	4	4	4	4	5	5	5	5	5	5	8	6	6	6	8
	311	7	7	7	7	7	7	7	7	7	3	3	7	7	7	7	6	6	7	6	6	3	3		2	1	5	4	4	4	5	5	5	5	8	6	6	6	8	8	8	8	8	8	8
	312	7	7	7	7	7	7	7	7	7	3	3	7	7	7	7	6	6	7	6	6	3	3	2		1	5	4	4	4	5	5	5	5	8	6	6	6	8	8	8	8	8	8	8
	313	7	7	7	7	7	7	7	7	7	3	3	7	7	7	7	6	6	7	6	6	2	3	1	1		5	4	4	4	5	5	5	5	8	6	6	6	8	8	8	8	8	8	8
	321	8	8	8	8	8	8	8	8	8	3	3	7	7	7	7	7	7	5	6	6	2	6	4	4	4		1	1	1	3	3	3	3	8	4	4	4	9	4	8	8	8	8	8
	322	6	6	6	6	6	6	6	6	6	3	3	5	5	5	4	4	4	5	5	5	2	4	3	3	3	2		1	1	3	3	3	3	8	2	2	4	7	4	8	8	8	8	8
	323	6	6	6	6	6	6	6	6	6	3	3	5	5	5	4	4	4	5	5	5	2	4	3	3	3	2	1		1	3	3	3	3	8	2	2	4	7	4	8	8	8	8	8
	324	6	6	6	6	6	6	6	6	6	3	3	5	5	5	4	4	4	5	5	5	2	4	1	1	1	1	1	1		2	2	2	2	8	3	3	4	7	4	8	8	8	8	8
	331	6	6	6	6	6	6	6	6	6	3	3	5	5	5	5	5	5	5	5	5	2	5	4	4	4	2	2	3	3		1	1	1	1	4	4	2	4	2	2	2	3	3	3
	332	5	5	5	5	5	5	3	3	3	4	4	4	4	4	3	4	4	4	4	4	2	4	3	3	3	2	2	2	2	1		1	1	1	4	4	4	4	4	6	6	6	6	6
	333	6	6	6	6	6	6	6	6	6	3	3	5	5	5	5	5	5	4	5	5	2	5	3	3	3	2	2	2	2	1	1		1	1	4	4	4	4	4	7	7	7	7	7
	334	7	7	7	7	7	7	7	7	7	4	4	5	6	6	5	4	4	5	5	5	3	3	2	2	2	2	2	2	2	1	1	1		8	6	2	6	6	6	8	8	8	8	8
	335	8	8	8	8	8	8	8	8	8	8	5	8	8	8	8	8	8	8	8	8	8	8	6	6	6	4	5	7	6	1	1	1	7		4	4	5	5	5	3	2	5	5	5
	411	7	7	7	7	7	7	7	7	7	7	7	6	6	6	6	6	6	5	6	6	2	6	4	4	4	4	4	4	4	4	4	4	5	3		1	2	2	2	3	3	3	3	3
	412	7	7	7	7	7	7	7	7	7	7	7	6	6	6	6	6	6	5	6	6	2	6	4	4	4	4	4	4	4	4	4	4	5	3	1		2	2	2	3	3	3	3	3
	421	8	8	8	8	8	8	8	8	8	8	8	7	7	7	7	7	7	4	7	7	4	7	7	7	7	4	6	6	6	5	5	5	8	8	3	3		1	1	2	2	1	1	1
	422	6	6	5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	7	2	3	1		1	4	4	3	3	3
	423	6	6	6	6	5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	7	4	4	1	1		3	3	2	2	2
	511	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	5	5	5	5	5	5	5	5	2	5	5	6	6	4	4	3	3	3		1	2	2	2
	512	5	5	5	5	5	5	2	5	5	4	4	5	5	5	5	5	5	5	5	5	3	5	5	5	5	5	5	5	5	3	5	5	6	6	3	3	3	3	3	1		2	2	2
	521	5	5	5	5	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	3	5	5	5	5	5	5	5	5	5	5	5	6	6	4	4	3	3	3	2	2		1	1
	522	6	6	6	6	5	6	6	6	6	5	5	6	6	6	6	6	6	6	6	6	3	6	6	6	6	6	6	6	6	6	6	6	7	7	4	4	3	3	3	2	2	2		1
	523	6	6	6	6	5	6	6	6	6	5	5	6	6	6	6	6	6	6	6	6	3	6	6	6	6	6	6	6	6	6	6	6	7	7	4	4	3	3	3	2	2	1	1	

Remark: 1 is the highest priority. Larger numbers indicate lower priority

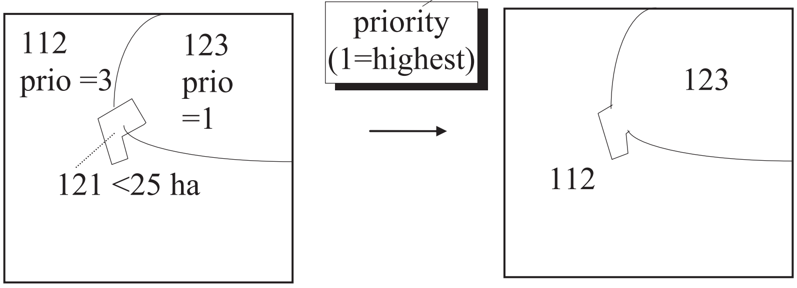
The priority table should be used as follows (EEA-ETC/TE, 2002, Annex 1 Generalization rules):

Example row 3: The small individual unit 121 (<25 ha) should be aggregated to the unit with the highest priority.

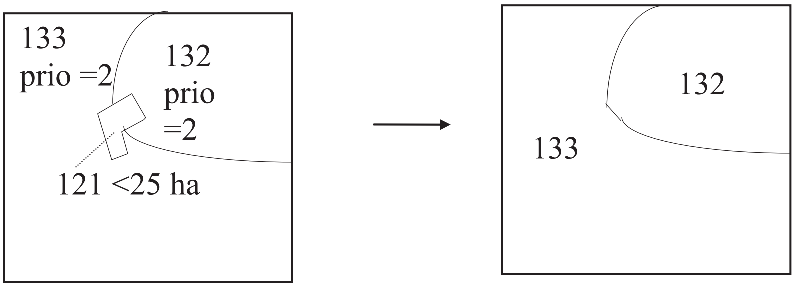
unit <25 ha

	111	112	121	122	123	124	131	132	133	141	...
121	3	3		1	1	1	2	2	2	4	...

priority (1=highest)

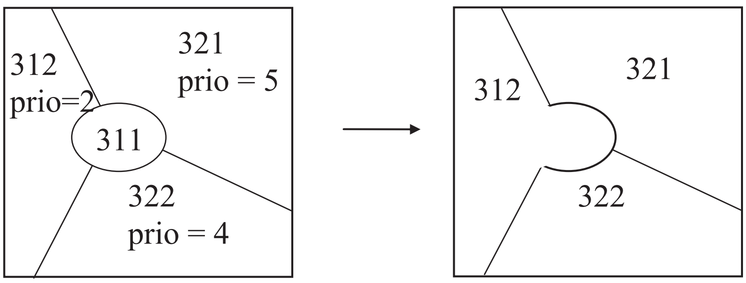


If the unit 121 is surrounded by two units with equal priority, the area of the smallest unit should be cut into two equal pieces and each part is allocated to the neighbouring unit.

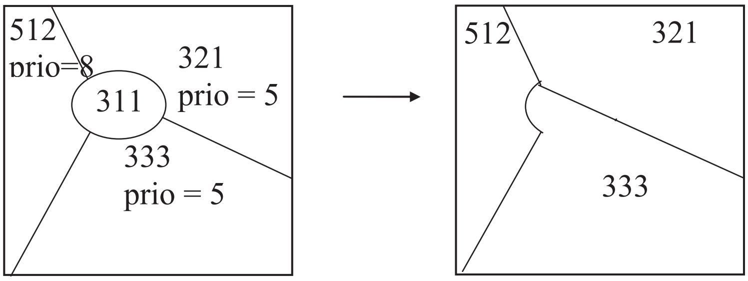


This aggregation procedure is sometimes more complex in real situations with complex geographical structures. The split of the small unit in two or more equal parts should be done according to the structure of the landscape; it will not always be possible to maintain equal areas after subdivision of the unit.
Very often, the unit is connected to more than two larger units, with different priorities.

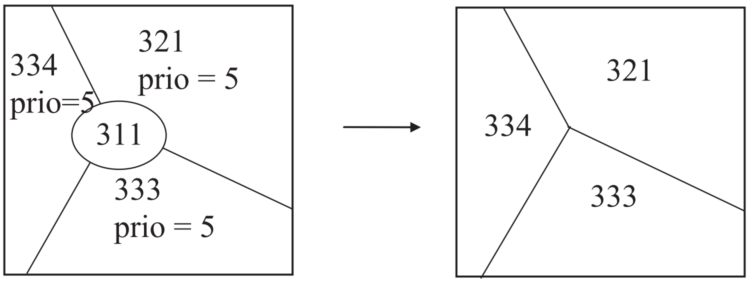
Case 1: If one unit has the highest priority, the unit is entirely aggregated to that class.



Case 2: If the priority of two units is equal, the area is split and distributed over the two classes, according to the most 'logical' subdivision. In this context, 'logical' means that the structure of the landscape and the geographical context should be taken into consideration.



Case 3: If all priorities are equal, the unit is split up and aggregated to all the different surrounding units.



This, however, also leads to generation of "unreal changes".

4.3.3 Updating approaches

The methodological procedure of updating initially proposed in the Technical Guide has the following steps (EEA-ETC/TE, 2002):

- Preparation of the Image 2000 for identification of CLC classes.
- Creation of the initial CLC2000 data layer by copying the revised CLC90.
- Identification of CLC-Change polygons on Image2000 and modification of the initial CLC90 data layer.
- Identification of CLC2000/90 changes by overlay of the CLC2000, CLC90 data layers, being the minimal area of polygon change 5 ha.

When implementing the national projects, three different approaches of updating CLC database were established using computer added image interpretation, generally called CAPI (Maucha et al, 2003).

According to **approach (a)** on Figure 54, first CLC90 is revised and corrected using IMAGE90 data, and then the interpreter modifies the database according to the new status seen on IMAGE2000 imagery. This yields the CLC2000 database. CLC-Changes is computed accordingly (Büttner, G. et al., 2004):

CLC-Changes = CLC2000 (|) CLC90 (a)

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

Benefits of approach (a) are:

- Focuses directly on producing CLC2000.
- Checking of minimum mapping unit in CLC2000 is easy, as well as amalgamation of the residual parts of polygons <25 ha with neighbouring polygons, using the priority table.

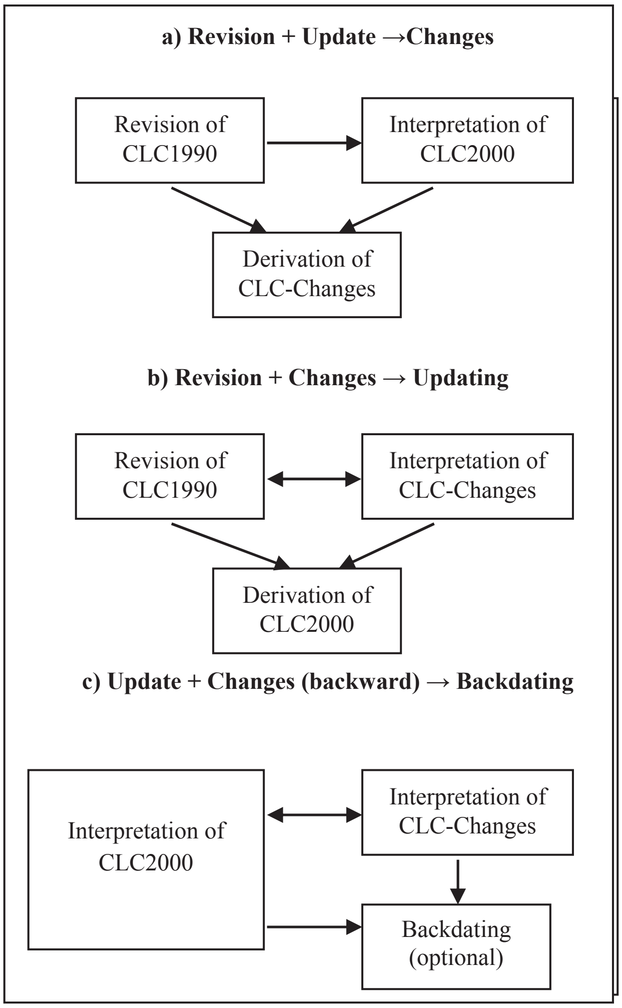


Figure 54-: Approaches of CLC2000 implementation

- Overlaying the CLC90 and CLC2000 layers enables to derive CLC-changes. This approach is open for using other CLC layers.

Weaknesses of approach (a) are:

- Improving CLC90 should be stopped before starting updating.
- Additional CLC90 improvements introduce sliver polygons in CLC-Changes.
- Does not require or enforce full thematic improvement of CLC90.
- After deriving CLC-Changes according to (a) eliminating small and false changes is needed.
- Observations showed that the revision and the updating are difficult to organise sequentially. If during the updating process a new mistake is discovered in CLC90 (e.g. missing LC polygon), it has to be drawn into the CLC2000 database as well. Since the lines in the two databases will differ to some extent, slivers will be produced in the CLC-Changes database, which are difficult to eliminate automatically (Büttner, G. et al., 2004).

According to **approach (b)** in Figure 54, after the basic revision of CLC90, CLC-Changes are first delineated on IMAGE2000. This means that revision and correction of CLC90 can be accomplished in parallel, not necessarily in sequential order. This method is implemented in the InterChange software, developed by FÖMI (Büttner et al., 2003) and offered free for any interested CLC2000 national teams. The CLC2000 database is computed accordingly:

CLC2000 = CLC1990 (+) CLC-Changes (b)

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

Benefits of approach (b) are:

- Focuses on directly producing CLC-Changes.
- Requires and forces full thematic improvement of CLC90.
- Modification of CLC90 is possible at any time.
- Checking of parameters of change polygon (5 ha area, 100 meter width) is easy.

Weaknesses of approach (b) are:

- Complex changes, composed of more than a single part, are interpreted in parts.
- Following derivation of CLC2000 according to (b), additional editing is needed for polygons shrunk below 25 ha.
- Changes derived by overlaying CLC90 and CLC2000 are not the same as changes identified by the interpreter.
- CLC2000 includes max. 5 ha inaccuracies because of not considered changes under 5 ha.

According to **approach (c)** in Figure 54, first the CLC2000 database is interpreted (e.g. because of no CLC90 is available – like in Croatia - or of the existence of recent higher resolution CLC compatible database – like in Luxembourg and Hungary. CLC-Changes are then interpreted using CLC2000 and IMAGE90 data. This means, a reverse process compared to approach (b). The revised CLC90 database is computed accordingly:

CLC1990 = CLC2000 (+) CLC-Changes (c)

Although approach (b) and (c) are similar concerning benefits and weaknesses, an important difference is that in approach (c) both primary deliverables (CLC2000 and CLC-Change) are produced directly.

4.3.4 Implementation by country

The Technical Guidelines (EEA-ETC/TE, 2002) describes and propose approach (a) (Figure 54). Other solutions were also allowed, if discussed and agreed on with the CLC2000 TT. Three countries of the 29 participants (Finland, Sweden and UK) do not apply computer added image interpretation. They preferred a digital image processing (DIP) based technology. It starts with an automated classification of the Landsat 7 ETM+ imagery, which is further processed by various GIS procedures, using several existing national databases to yield a high resolution (2 ha, 5 ha) national LC database. The last and most difficult step is to produce CLC2000 by means of generalisation. These methodologies are rather country specific (Swedish Space Corporation, 1994, Smith et al., 2002, Finnish Environment Institute, 2003).

Table 48 summarize the approach followed to create CLC2000. CAPI-a, -b and -c refers to the variant of computer assisted image interpretation methodology, as shown in Figure 54 (Büttner, G. et al., 2004).

4.3.5- Consequences of the two different Minimal Mapping Units

The minimal mapping unit (MMU) in CLC90 and CLC2000 is 25 ha. But the minimal mapping change unit is 5 ha (CLC-Changes). Understandably, decision makers are interested in changes smaller than the 25 ha limit of CLC. However, the change mapping rule saying: “a change inside a polygon having area between 5 and 25 ha will not be recorded as change” (EEA-ETC/TE, 2002) results in a biased change database in the size range of 5-25 ha. Changes between 5 and 25 ha were mapped only if they were increments or decrements of an existing polygon (Maucha et al., 2003). Isolated changes were mapped only if larger than 25 ha. E.g.: a new industry of 20 ha was mapped as a change if it was an increment of an existing industry polygon in CLC90, but it was not mapped as a change if it was built isolated inside an arable land polygon. The severity of this bias depends on the typical size and distribution of changes in the country and it differs with the land cover class.

Table 48- Approaches and tools used to realise CLC2000

Country	Approach	Base sw	Application sw
Austria and Liechtenstein	CAPI-b	ArcView	Geomatica InterChange
Belgium	CAPI-b	ArcInfo	Arc Map
Bulgaria	CAPI-b	ArcView	InterChange
Croatia	CAPI-c	ArcView	InterChange
Cyprus	CAPI (only CLC2000)	PCI; ArcView	Geomatica;InterChange
Czech Repub	CAPI-a	Topol (self development)	
Denmark	CAPI-b	ArcView	Self-customized
Estonia	CAPI-b	ArcView	InterChange
Finland	DIP/GIS (only CLC2000)	na	na
France	CAPI-a	ArcView	Self-customized
Germany	CAPI-b	ERDAS; ArcView	IMAGINE; Self-customized
Greece	CAPI-a; CAPI-b	Intergraph; ArcView	Geomedia; InterChange
Hungary	CAPI-c	ArcView	InterChange
Ireland	CAPI-b	ArcView	InterChange
Italy	CAPI-a	ArcView	
Latvia	CAPI-a	ArcGIS	Self-customised
Lithuania	CAPI-b	ArcView	InterChange
Luxembourg	CAPI-c	ArcInfo	ArcEdit
Malta	CAPI (only CLC2000)	na	na
Netherlands	CAPI-b	ArcInfo	ArcEdit
Poland	CAPI-b	ArcView	InterChange
Portugal	CAPI-b	ArcView	InterChange
Romania	CAPI-b	ArcView	InterChange
Slovak Rep.	CAPI-a	ArcView	---
Slovenia	CAPI-b	ArcView	InterChange
Spain	CAPI-a	ArcGIS	
Sweden	DIP/GIS;(only CLC2000)	na	na
UK	DIP/GIS	na	na

Another consequence is that the “trivial” relation (a) between the three databases is not entirely fulfilled regarding the final databases. The reasons are as follows (Büttner et al., 2004):

- In countries applying approach a), the result of intersecting the revised CLC90 and CLC2000 databases have to be considered a “difference” database. The “difference” database had to be checked and non-real changes, due to generalisation, forgotten polygon revision of CLC90, should be deleted from the CLC-Changes database. Its identification was supported by image-interpretation and logics, like considering what changes are not possible in a country or in a region.
- In countries applying approach (b), the result of adding together CLC-Changes and revised CLC90 has to be considered as a “raw” CLC2000 database. The “raw” CLC2000 database had to be checked and polygons smaller than 25 ha had to be “intelligently” generalised to yield a final CLC2000.
- The same situation exists with applying approach (c), when the backdated CLC90 needs generalisation.

5 Quality Assurance / Quality Control

For the I&CLC2000 project with several organisations working towards a common output, the assurance of a quality product was very important during the entire life cycle of the project. The quality control validates the different steps of the update process, which serve as input to a subsequent work step. The objective was that the European requirements for the CLC were met by the countries, to creating an integrated, harmonised and well documented European database from the national contributions.

Each processing step of the update, i.e. topological correction, geometric adjustment, thematic correction and change detection, was followed by a number of checks to assure consistency in the LC database. The checks had to be recorded as part of the meta-information produced. The CLC2000 Technical Team organised regular visits to the national teams to verify the thematic and geometric consistency of the final products. The overall responsibility of QA/QC relies with the national project leader. According to the Technical Specifications of I&CLC2000, the national teams have to assess thematic and geometrical quality control all along the project:

- Thematic QA/QC- CLC90 and CLC2000: target thematic accuracy (reliability) at least 85%.
- Geometric QA/QC- CLC90 and CLC2000: target geometrical accuracy better than 100m.

The national teams collected the necessary metadata to document the different steps and products of the project. The CLC2000 Technical Team managed the metadata for the European products, organising the centralised European metadata, adding information on the used procedures and persons responsible for the development of the European products and raster databases. The European metadata also includes information on data dissemination. The CLC2000 metadata was collected at the working unit and country level, using standard tables as described in Annex 2 of the I&CLC2000 Technical Guide.

6 Verification Sessions

6.1 Objectives and Technical Specifications

The verification sessions carried out by the Technical Team in each participating country were a particular way of quality assurance, having at the same time the role of controlling the quality, correcting for errors, discussing specific interpretation problems as on-the-job training and harmonising national problem-solving at the European level by using the same criteria and approach. The verification sessions had three main objectives (Büttner et al., 2004):

- To assist the national teams in producing CLC2000 database and to assure a homogenous implementation across Europe.
- Corrective goal: discussing specific problems occurring during the production, correcting databases if necessary and thereby assuring a harmonised European CLC database.
- Provide the EEA with information on overall quality of work performed by the countries.

In each country, about 8% of its total area was verified, usually in two sessions. Verification was carried out on a sample of verification units selected by the TT. From a regular grid of 10x10 km, a minimum of 1 verification unit per working unit (map sheet) was systematically checked, allowing verification in most working units. Figure 55 shows as an example, the sampling scheme for Lot 1 in German. Large green rectangles represent working units; small red rectangles are verification units (10×10 km). Black means areas that have been interpreted as changes. Verification units were selected before the session, using both CLC2000 and CLC- Changes data, based on the following criteria (EEA-ETC/TE, 2002):

- To check all dominant classes with a density proportional to their occurrence, as given by the level-1 CLC statistics of the region.
- To control areas with many changes as well as areas with no or few changes.

The software tool InterCheck (an ArcView 3.x application, developed by FÖMI) was used as a support for verification. InterCheck provides a linked dual window environment: the left window includes IMAGE90 data and CLC-Changes, while the right window displays IMAGE2000, CLC2000 and CLC-Changes. Naturally, any additional digital databases in a suitable format could be added (e.g. digitised topographic maps, orthophotos, vineyard cadastre maps, etc.). Statistical queries and some technical error detection possibilities were included in the tool. The expert could enter remarks into the polygon (with coordinates). The checking process was usually as follows:

1. Checking validity of codes and neighbouring polygons with the same code (merge errors) in CLC2000.
2. Checking size errors in CLC2000.
3. Checking CLC2000 statistics to reveal non-relevant codes.
4. Checking validity of codes and neighbouring polygons with the same code (merge errors) in CLC-Changes.
5. Checking size errors in CLC-Changes.
6. Checking change statistics, to reveal invalid changes.
7. Visual evaluation inside verification units.

The first six steps were performed for the entire working units, to highlight technical mistakes. Visual evaluation was usually made for areas outlined by the verification units. If a systematic error was suspected or present, areas outside the verification unit were also controlled. Verification comments, included in the ArcView project file, were provided to the national team in order to start the corrections immediately.

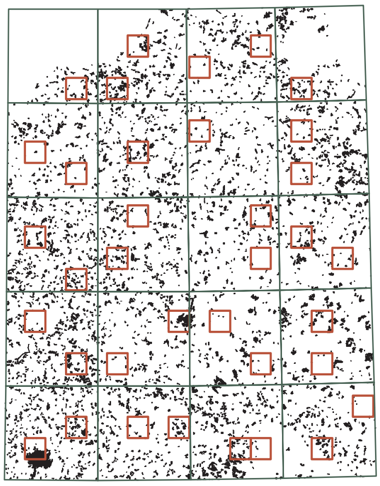


Figure 55- Verification sampling for Lot 1 in German

Final technical quality control: After the last thematic verification, the national team finalised the seamless databases and delivered to the CLC2000 TT (GISAT) for final technical control. The aim of this procedure was to assure uniform technical quality and compatibility of CLC2000 results from all participating countries. Obviously, all deliverables (either partial of full) have to conform to the CLC2000 output specification in the Technical Guidelines (EEA-ETC/TE, 2002), and they had to be checked by the national team prior to delivery for integration. Nevertheless, in order to harmonise this effort and support national teams to easily fulfil this task, a new specific document was prepared (ETC/TE, 2003). It covers technical specifications and standards for data and metadata, standard checks required, as well as data delivery flows. All required formal and technical criteria had been specified in a simple checklist manner, both for data and metadata, to simplify inter-communication in case of problems or inconsistencies and to accelerate their solution in an iterative and collaborative manner. After the integration of last recommendations, final versions of the CLC2000 products were uploaded to the EEA Common Data Repository (CDR) or national equivalents. The CDR is the common structure that allows the EEA to keep track of the country’s data flows.

6.2- Overall Organization

The Table 49 gives the information about the number and date of verification session for each country. In total, 58 verification sessions were held. Each of these sessions produced a report, summarizing the discussion of problem solving, illustrating the difficulties, detailed list of errors found (with coordinates) and proposals for corrections.

Table 49- Verification Sessions per country

Country	1st Verification	2nd Verification	3rd Verification
Austria	18/19-08-2003	13/14-05-2004	
Belgium	17/18-07-2003	17/18-05-2004	
Bulgaria	20/22-10-2003	12/15-07-2004	
Croatia	24/25-05-2004	06/07-12-2004	
Cyprus	17/18-01-2005	03/11-03-2005 off-site	
Czech Republic	02/03-06-2003	17/18-11-2003	
Denmark	26/27-05-2003	16/17-06-2004	
Estonia	26/27-08-2003	10/11-11-2003	
Finland	28/29-08-2003	24/28-05-2004	
France	24/27-06-2003	21/25-06-2004	04/08-10-2004
German	29/31-10-2002	19/21-11-2003	11/15-10-2004
Greece	26/28-07-2004	24/26-11-2004	
Hungary	10-12-2003	03/04-06-2004	
Ireland	05/06-11-2002	13/14-03-2003	
Italy	07/11-07-2003	13/16-04-2004	
Latvia	24/25-04-2003	02/04-07-2003	
Lithuania	16/18-09-2003	25/26-02-2004	
Luxembourg	31-01-2003	Not applicable	
Malta	19-08-2003	Not applicable	
Netherlands	06/08-11-2002	28/30-01-2003	
Poland	13/17-10-2003	01/05-03-2004	
Portugal	24/26-09/2003	04/06-05-2004	
Romania	08/12-09-2003	29-06/02-07-2004	
Slovakia	09/10-10-2003	07-06-2004	
Slovenia	20/21-08-2003	27/28-11-2003	
Spain	29-08/07-10-2003	22/26-03-2004	
Sweden	19/23-05-2003	29-03/02-04-2004	
U.K.	16/19-06-2003	05/09-07-2004	02/05-11-2004 *

* In U.K., a fourth off-site verification was carried out in 24-02-2005. “Off-site” means that verification was done remotely, without visiting the national team.

6.3- Most Frequent Problems

The problems that most frequently occur when making the CLC2000, were identified during the verification sessions in 29 participating countries. They can be considered the most difficult land cover discrimination cases in Europe. To know them it is very important for future updating of the database and for a good understanding of the CLC content. The most common inaccuracies found in identification, classification and delineation of CLC classes are summarised in Table 50 prepared by Jan Feranec and further discussed in Chapter 10.2.

Table 50- Most difficult CLC classes discrimination cases (Feranec, J. , 2005)

CLC classes	Problems
Continuous urban fabric (111)	Overestimation; occurrence >20% of urban greens
Discontinuous urban fabric (112)	Missing some areas of this class; reasons: 300m distance between houses; rural settlements with area around 25 ha (+/- 1-3 ha) missing
Green urban area (141)	Misinterpretation with classes 31x or 324
Non-irrigated arable land (211)	Distinguishing from the class 231 (or abandoned land and old fallow land) – serious problem because both classes have very similar spectral characteristics
Pastures (231)	Frequent confusion with natural grasslands (321); not considering the human impact and specific natural conditions (e. g. steep slopes, high mountains, etc.)
Complex cultivation patterns (242)	Overestimation caused by inaccurate discerning the class 243 (presence of small areas of tree, shrub vegetation, swamps); areas of annual or permanent crops larger than 25ha
Land principally occupied by agriculture with significant areas of natural vegetation (243)	Overestimation caused by a presence of spots (e. g. arable land, natural vegetation, etc.) larger than 25 ha
Moors and heathlands (322), sclerophyllous vegetation (323), transitional woodland/shrub (324)	Confusion or erroneous determination of these classes represented by bushy vegetation; separation of the climax stage of bushy vegetation (e. g. Atlantic and Alpine heaths, sub-Alpin bushes – 322; Mediterranean and sub-Mediterranean evergreen sclerophyllous bushy and scrub vegetation – maquis, garrig, mattoral. – 323) and vegetation representing either woodland regeneration or degradation, e. g. clear-cuts, forest calamities by air pollution, etc. – 324 is problematic
Transitional woodland shrub (324)	Underestimation in some countries, mainly in CLC90
Inland marshes (411) and peat bogs (412)	Ambiguities in distinguishing of these classes, they are very similar in terms of spectral characteristics

In many cases, it was advised to the national team to check the natural vegetation classes such as 321, 322, 411, and 412 with specific thematic maps, particularly botanic information, or to organize field checking. Indeed satellite images do not allow per se, to delineate any natural vegetation peat bogs, marshes, swamps, or moors and Atlantic heathlands, which are particular ecosystems composed by specific plants.

7- Analysis of National Production

Table 51 gives the time spent by the national projects to execute the national CLC2000. Here we consider the date of the national training as the starting date for the image-interpretation, although the national project implementation started before, with the organisation and putting in place the national team. At the date of the last verification, the national CLC2000 was usually completed at the level of working units. After producing the seamless databases (CLC2000 and CLC-Changes), it must be accepted by the TT.

Table 51- Analysis of time needed for production (Data provided by G. Buttner)

Country	**Area (km²)**	**Date of training**	**Date last verification**	***Date final data delivery 1st version***	**Date of DBTA Report**	**Days to finish after last verific.**	**Project Duration Days**	**Day/ km²**
Netherlands	35398	2002-02-13	2003-01-30	2003-04-09	2003-06-04	125	476	0.010
Latvia	63700	2003-02-06	2003-07-04	2003-07-30	2003-08-26	53	201	0.002
Malta	316		2003-08-19	2003-09-18	2003-10-03	45		
Ireland	70283	2002-11-06	2003-03-14	2003-04-09	2003-12-03	264	392	0.002
Luxembourg	2590		2003-01-31	2003-12-03	2003-12-05	308		
Slovenia	20273	2003-02-27	2003-08-21	2004-01-06	2004-01-09	141	316	0.009
Estonia	45226	2002-12-19	2003-11-11	2003-12-10	2004-02-12	93	420	0.007
Lithuania	65200	2003-04-03	2004-02-26	2004-03-30	2004-05-14	78	407	0.005
Czech Repub.	78864	2003-01-17	2003-11-18	2004-06-09	2004-06-28	223	528	0.004
Sweden	449960	2002-10-25	2004-04-02	2004-06-28	2004-06-30	89	614	0.001
Poland	312685	2003-01-15	2004-03-01	2004-06-23	2004-07-29	150	561	0.001
Slovakia	49035	2003-01-23	2004-06-07	2004-07-02	2004-07-23	46	547	0.010
Italy	301270	2003-03-06	2004-04-16	2004-06-30	2004-08-20	126	533	0.001
Romania	237500	2003-02-13	2004-07-02	2004-08-02	2004-09-03	63	568	0.002
Hungary	93030	2003-01-21	2004-06-04	2004-09-17	2004-10-15	133	633	0.005
Belgium	30520	2002-03-15	2004-05-18	2004-07-22	2004-11-04	170	965	0.026
Germany	356910	2002-02-08	2004-10-15	2004-12-15	2005-01-03	80	1060	0.003
Finland	338130	2002-10-23	2004-05-28	2004-11-01	2005-01-17	234	817	0.002
Liechtenstein	160	2002-04-11	2004-05-14	2004-10-29	2005-01-17	248	1012	4.8
Austria	83850	2002-04-11	2004-05-14	2005-01-07	2005-03-22	312	1077	0.013
Bulgaria	110993	2002-12-05	2004-07-15	2004-09-20	2005-02-17	217	805	0.005
Denmark	43090	2002-12-20	2004-06-18	2004-10-28	2005-03-25	280	827	0.019
Portugal	92390	2002-11-29	2004-05-06	2004-11-08	2005-06-10	371*	905	0.006
Spain	504780	2002-02-28	2004-03-26	2004-11-02	Metadata			
Croatia	56542	2003-10-17	2004-12-07		2005-06-21	196	634	0.008
Cyprus	9251	2004-01-30	2005-03-11	2005-04-02	2005-04-20	40*	446	0.044
France	551500	2003-02-20	2004-10-08	2005-01-21	2005-03-11	154	750	0.001
Greece	131990	2004-01-30	2004-11-26	2005-03-03	2005-05-17	172	498	0.002
UK	244880	2002-12-11	2005-02-24	2005-01-05	2005-06-16	112	930	0.003
Average						163		
Average*						159		

Average*= average, excluding the fastest and the slowest.

Total area CLC2000 km² *4380316*

Total countries CLC2000 *29*

The Data-Base Technical Acceptance Report (DBTAR) was prepared and issued at the dates reported here. Only at that stage is the project considered completed. The number of days between the last verification and the DBTAR can be significantly reduced, depending on how big the TT is and how long a national team takes to produce the corrected seamless database. So, it is a circumstantial and not technical value. The date of final data delivery (1st version) was the starting of an interaction process. After the data control by the TT, eventual corrections are introduced and the interaction between national team and TT ends with the acceptance of the final version. Only after that the DBTAR is issued. The figures in column “Days to finish after last verification” show how much this step influences project duration. Average is 159 days (excluding the fastest and slowest counties). The column day / km² gives an indicator of time per km². It is calculated “Project duration”- “days to finish after last verification”/ country’s area. Significant differences are visible, to be interpreted according to specific realities related to the national project implementation, not to interpretation and production.

Other factors that influence the total duration of the project and that influenced its total duration of more than 3 years (from the decision to implement it to the end of the project) are the delays in setting up the funding mechanism, the long setting up of national project in most of the countries (e.g. tendering) and the increased number of countries along the way. The average project duration per

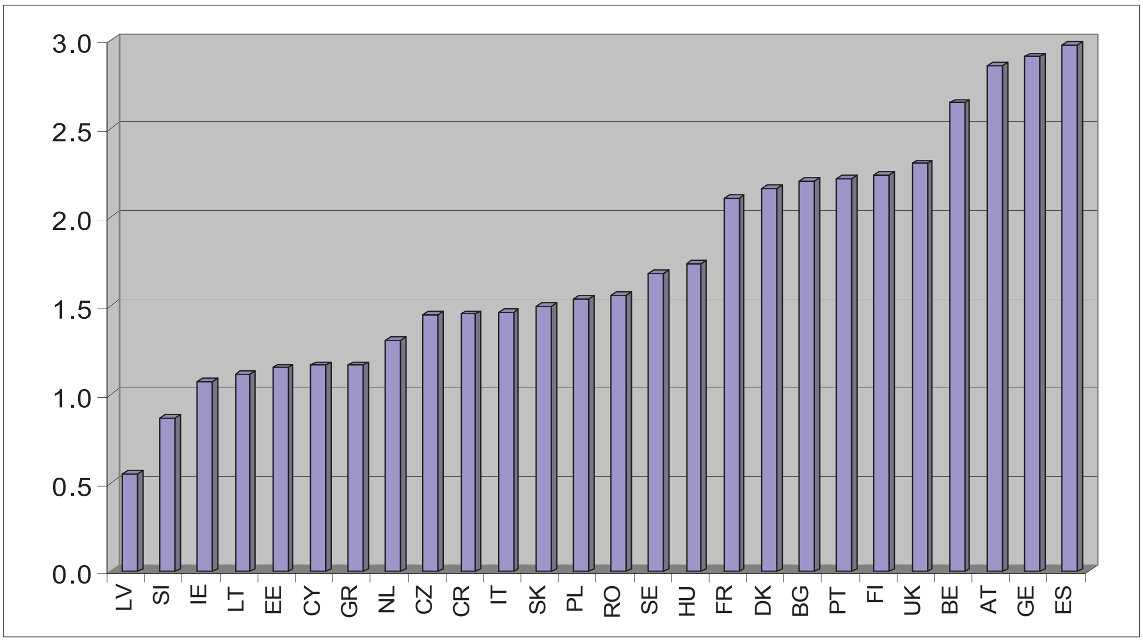


Figure 56- Indicative Project duration by country

8 Data integration

European data integration starts when national CLC2000 deliveries have been accepted. Delivered national data were produced in national systems of all participating countries and following the standard formats described. Each national Coordinate Reference System (CRS) definition must be known precisely, together with its geometric relationship to a standard system, in order to accurately transfer all national data into a standard coordinate reference. As explained in §II IMAGE2000, in particular the preparation of the European mosaic, ETRS89 Ellipsoidal Coordinate Reference System (ETRS89) represents this standard coordinate reference for European wide geographic data. European CLC2000 datasets also follow this specification.

The process itself was carried out by global equation-based transformation to ETRS89 (e.g. seven-parameters Bursa-Wolf method). A particular transformation's accuracy ranges from centimetres to metres depending on method, quality and number of control points available to define transformation parameters. In any case, the accuracy is far above the actual CLC2000 data resolution (Büttner, G. et al., 2004). National data, when transformed to the common European reference, were introduced into tiled pan-European CLC2000 DB structure, following IMAGE2000 tiling definition (Soukup, T., 2005). To produce the real seamless European database, the integration step included also harmonization of the database along country borders. It consists of edge-matching of land cover polygons from the national databases across national borders, and verification / re-interpretation with the IMAGE2000 European mosaic in the border regions, within a 2 km wide strip along borders. Two layers of the CLC2000 database were used, but the order of priority was as following (Soukup, T., 2005):

- CLC2000, both geometric and thematic adaptations of all polygons in a 2 km strip along national boundary lines.
- Change database, to ensure that changes in CLC2000 are consistent with the change database.

This integrated seamless European-wide georeferenced database can then be used to generate other standard CLC2000 products. The corrected CLC90 was not harmonised, so the available European CLC90 is not the same version as the (corrected) one used to produce CLC2000 and CLC-Changes.

9 Validation of the European CLC2000

The aim of the validation was to assess the overall thematic accuracy of CLC2000 database, (not the change database and not the corrected CLC90 data) by means of a statistical method.

Some countries performed a national validation of the database, using different approaches. In most cases more spatially and thematically detailed data were used for that purpose (see Dutch final report). Although a heterogeneous national approach was followed, a common European approach for the validation of the European database was necessary. The LUCAS data *(Land Use and land Cover Area frame Sampling)* was used for the validation of CLC2000. LUCAS is a project managed by Eurostat. It was collected during 2001-2003 and it covers only 18 E.U. countries. This "EU-18" database contains about 10.500 primary sampling units (PSU) and about 8.500 locations with landscape photographs (mostly with 4 photos each). These 18 countries represent 3,4 M km^2, i.e. 75% of the total area of the 29 countries participating in CLC2000.

9.1 The validation data

The LUCAS data fulfil some important criteria for the selection of reference data:

- They have been collected independently from the CLC data.
- They are available at a higher resolution than the CLC data.
- They represent a similar seasonal time window, although 1-2 years difference in data acquisition compared to IMAGE2000 may exist.
- They are available without an additional expenditure.

LUCAS Survey, has the main purpose of providing harmonised information on agri-environment for Europe. LUCAS records land use and land cover (and other environmental and agricultural) information in a two-level regular grid. The grid size is 18 x 18 km (primary sampling units, PSU). Each PSU includes 10 secondary sampling units (SSU). SSUs are placed in two parallel rows, with five points in each row. The distance between SSU points is 300 m (Figure 57). The field surveyor locates the point with high accuracy (specification is 1-3 m), and registers LC and LU information related to this point, according to strict guidelines (LUCAS Technical Document No1: Sampling plan). The area of observation is usually a circle with of 1.5-m radius, in exceptional cases an area with 20 m radius should be considered. In special cases LUCAS might include two land use and / or land cover categories for a single point. (LUCAS Technical Document No2: The Nomenclature). In each central SSU point of the first row (SSU13), landscape photographs are taken in East, West, North and South directions. These photographs are available in digital format.

The LUCAS LC nomenclature in 2001 included 57 categories in 7 major groups, while LUCAS LU codification applied 14 land use classes. The first LUCAS surveys have been implemented in 13 EU Member States in 2001. UK and Ireland were left out because of the foot and mouth disease. These were surveyed in 2002 together with three Accession Countries (Estonia, Hungary, and Slovenia). The survey for EU 15 was repeated in 2003.

9.2- Methodology used

The methodology for validation was proposed by the Technical Team, following a 2-tier approach, taking into consideration the availability of the data and the need for a method that can be employed within a limited timeframe for a maximum area (ETC/TE, 06-09-2004). It includes (1) Data quality assessment using SSUs and (2) Data quality assessment using landscape photographs.

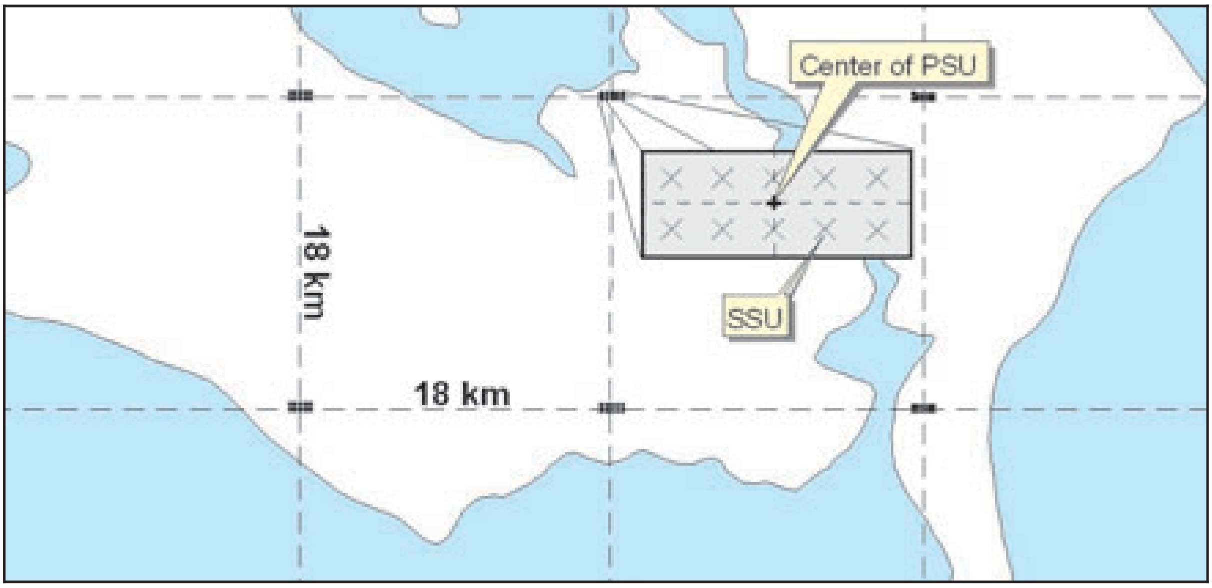


Figure 57- The LUCAS 2-stage sampling (LUCAS Technical Document No1: Sampling plan)

9.2.1 Data quality assessment using SSUs

The proposed methodology was based on the pilot study executed by the ETC/TE (FÖMI) in 2003. It comprises 3 steps:

(a) Creating correspondence table between CLC and LUCAS (land use LLU, land cover LLC codes).
A correspondence table was computed for CLC and LLC / LLU classes. In this table only basic constituents of each CLC class were considered and not those additional elements, that might be present in a given polygons because of the generalisation. Some of the elements of the correspondence table are explained in Table 52.

The two land cover nomenclatures (CLC and LUCAS) are, although similar, not directly compatible. As the CLC is not a pure land cover nomenclature – especially considering the 1st group of classes (artificial surfaces) – the LUCAS LU classes should also be considered during comparison with LUCAS. Comparison is further complicated by the much different geometry specification of the two databases and especially the generalisation process used in deriving CLC databases.

Table 52- Examples of correspondence between CLC and LUCAS based on LC/LU definitions

CLC code	Class name	Main constituents	Corresponding LLC codes	Corresponding LLU codes
112	Discontinuous urban fabric	Houses (irrespective of the number of floors), urban greenery, roads, parking lots	A11, A12, A21, A22, B43, E	U31, U34, U35, U37
242	Complex cultivation patterns	Arable land, pastures, vineyards, fruit trees, olives, smaller houses	A11, A13, all A2, all B, except B17; E	U11, U37
324	Transitional woodland, shrub	Clear cuts, young forests, diseased or damaged forest, forest nurseries	D, B83, all C1, C30	U12, U40
512	Water bodies	Water, wetland	G01	U13, U31, U21, U36, U40

(b) GIS overlay of all secondary sampling units (SSU) (10 per PSU) on CLC2000.

(c) Comparison of codes using the correspondence table and calculation of the degree of agreement between the 2 databases.

For each SSU, it was checked whether the CLC code corresponds to (one of) the LLC categorie(s) in the correspondence table. If yes, the value of the "lc_ok" variable is set to "1", otherwise the value of "lc_ok" remains "0". Land use was handled in a similar way: "lu_ok" is set to "1", if the CLC code corresponds to (one of) the LLU code(s) in the correspondence table, otherwise the value of "lu_ok" remains "0". The value of agreement ("SSU_ok") is considered OK, if both the value of "lc_ok" and the value of "lu_ok" is equal to "1". This means that both LUCAS codes, LLC and LLU value, should correspond to the CLC data.

This measure is expected to provide a pessimistic assessment of the data quality, as the inherent differences between CLC and LUCAS (minimum mapping unit, difference of scale, point versus area sampling) are not considered.

9.2.2- Data quality assessment using landscape photographs

The second method for quality assessment of the CLC2000 database was based on landscape photos from the field survey. These were used to re-interpret the context of the sampling point (ETC/TE, 06-09-2004). Landscape photos (at least one) are available for about 8,500 locations of the about 10,500 PSUs observed for 18 EU countries. The main advantages of this second method over the first one are:

- CLC generalisation and complex classes of CLC can be considered.
- Visual interpretation of the location using ancillary data: LUCAS LU/LC/Photos, IMAGE2000.
- More transparency, higher reliability.

The methodology was based on a visual re-interpretation of the context situation of the sampling point, made by an experienced CLC expert, in combination with the increased amount of reference information. The re-interpretation includes the following steps (G. Büttner):

1-Providing a CLC code by visual interpretation of the landscape around the LUCAS sampling point based on IMAGE2000 data, LUCAS LU/LC data and landscape photographs. No information from the CLC database shown at this moment. The interpreter / operator should respect all the interpretation rules (MMU, class definitions, generalisation, etc).

2- Display of CLC polygons on top of IMAGE2000 and LUCAS point, but still without class information. Assignment of 2nd CLC code. The availability of CLC polygons can influence the interpretation of the CLC code since for border cases it will be important to know to which polygon the original photo interpreter has attributed the location of the sampling point.

3- Display of CLC code (stored in the CLC2000 database).

4- Comparison of assigned CLC code with actual code in the CLC2000 database. There are four possibilities:

- **Clear agreement:** this is used when there is agreement without any doubt between the control interpretation and the CLC2000. (Mostly cases when the two control interpretations are the same as theCLC2000 code).
- **Another interpretation is possible:** this is used when the interpretation is still acceptable, although the control codes are not fully agree with the CLC2000 code. (Mostly the cases when only one of the control interpretation is equal to the CLC2000 code.) The interpreter / operator should select the explanation whether: another delineation is possible, another code is possible, or LC boundary.
- **Wrong interpretation:** this is used when the CLC2000 interpretation is not acceptable. (Mostly cases when none of the control interpretations is the same as the CLC2000 code). The

interpreter / operator should select the explanation whether: wrong code, wrong generalisation, not enough details or inaccurate delineation.

- **Not enough information:** this is used for those rare cases, when there is insufficient information for the validation (e.g. cloudy IMAGE2000, bad quality LUCAS photos, etc.).

This measure should give a more optimistic evaluation of database quality as it considers the landscape context in which the CLC2000 database was created. Disagreements in reinterpretation can also be weighted differently – an error 211 / 512 is more crucial than 211 / 231). Specific cases where the assigned CLC code is different, but the difference could be explained by the comments provided by the interpreter, could be considered or omitted to provide different accuracy measures. Figures 58 and 59 were prepared by G. Büttner, illustrating some examples of clear agreement and disagreement between LUCAS and CLC2000.

10 Conclusions

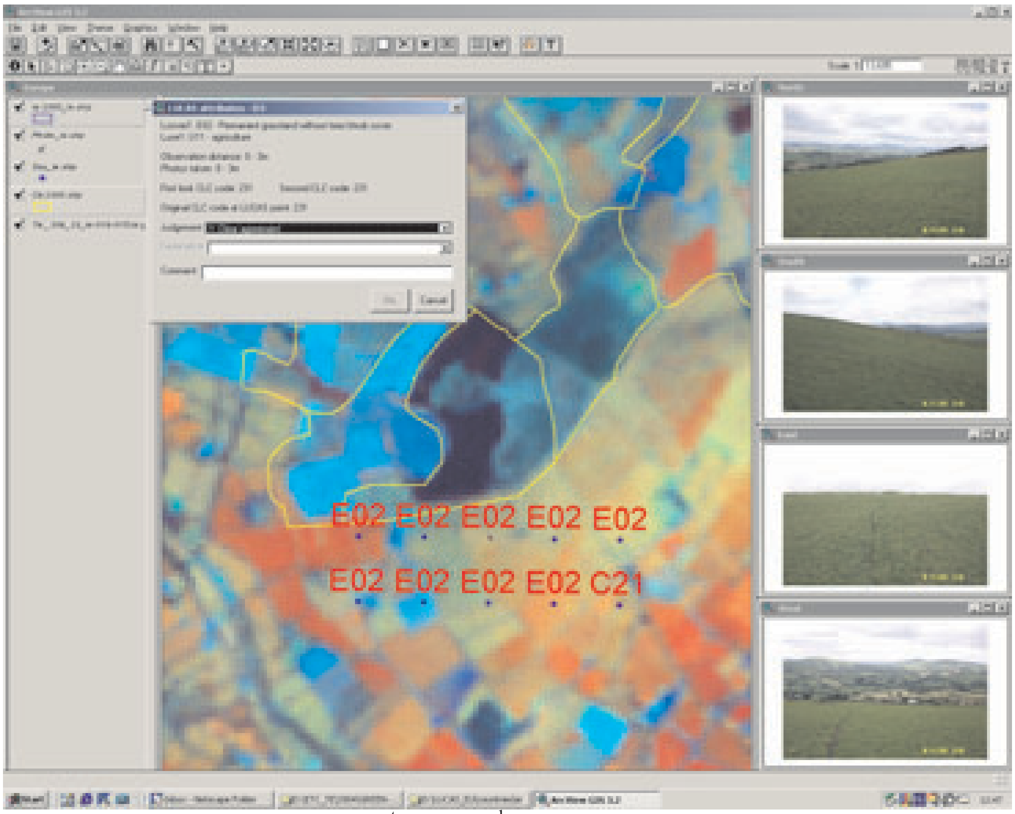
Compared to the original CLC90, the geometrical accuracy of the corrected CLC90 and consequently the updated CLC2000 has improved significantly and the specification "better than 100 m positional error" is fully met (Büttner, G. et al., 2004). Heterogeneity concerning the MMU had been eliminated so datasets produced by different countries are comparable. Topological errors, unclassified areas, invalid codes, which occurred in original CLC90 had been eliminated due to the national QC/QA and the technical control of the CLC2000 TT.

10.1 Thematic improvements of CLC2000 regarding CLC90

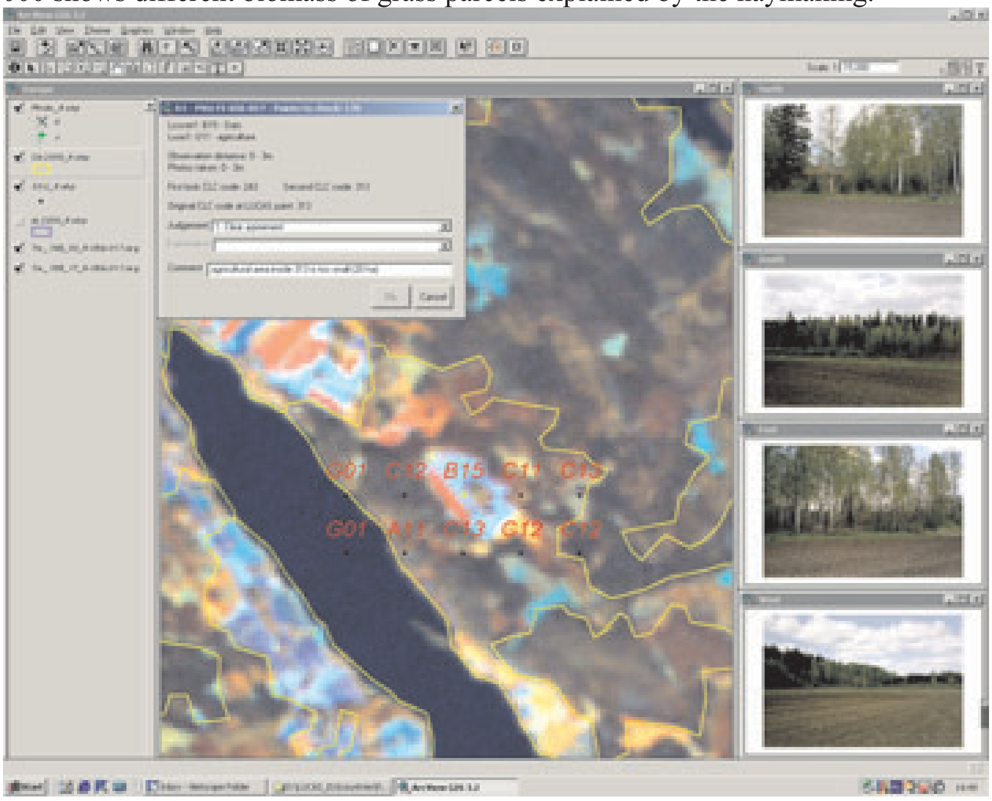
Identification, classification and delineation of land cover using the CLC nomenclature at scale 1:100.000 are mainly based on physiognomic attributes manifested on satellite images. The use of ancillary data (e.g. topographic maps, thematic maps, aerial photographs, etc.) cannot be neglected (Feranec and Otahel, 2001). Based on experiences of 58 verification missions, the CLC2000 TT can conclude that the thematic quality of CLC2000 has improved significantly and the European harmonisation of national datasets is also better. Main factors of improvements are as follows:

- Better technology (interpretation on screen not on hardcopy).
- More precise definition of nomenclature elements (Bossard et al., 2000).
- Easier and frequent use of ancillary data (digitized topographic maps, orthophotos, other thematic data).
- Properly organised support by the CLC2000 TT.

CLC90 data had not been improved in the same way in all countries, because of the lack of appropriate ancillary data, or simply the reluctance of interpreters to change a code given by the former interpreter during the 1st inventory. Intersection of a good quality CLC2000 and a CLC90 with thematic errors yielded false changes in some countries. Comparing IMAGE90 and IMAGE2000 and logic interpretation could help to solve these problems and keep only real changes (Büttner, G. et al., 2004).

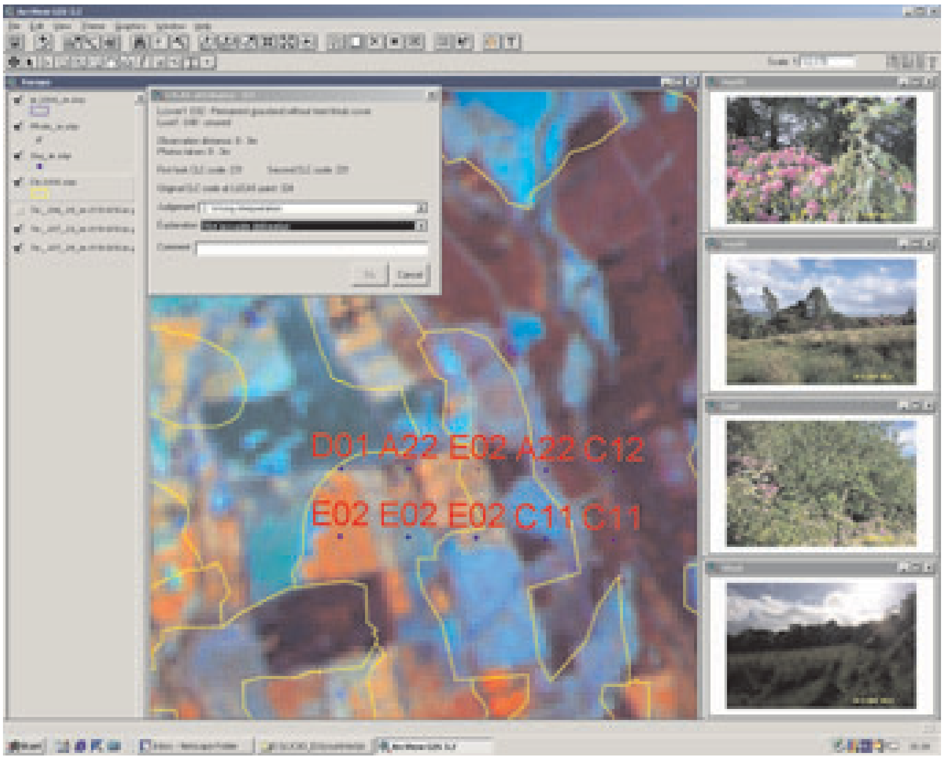


Validating interpretation: 231 (both 1st and 2nd); *CLC2000 database:* 231; *LUCAS land cove*r: permanent grassland with tree/shrub cover; *LUCAS land use*: agriculture; *Result*: Clear Agreement. IMAGE2000 shows different biomass of grass parcels explained by the haymaking.

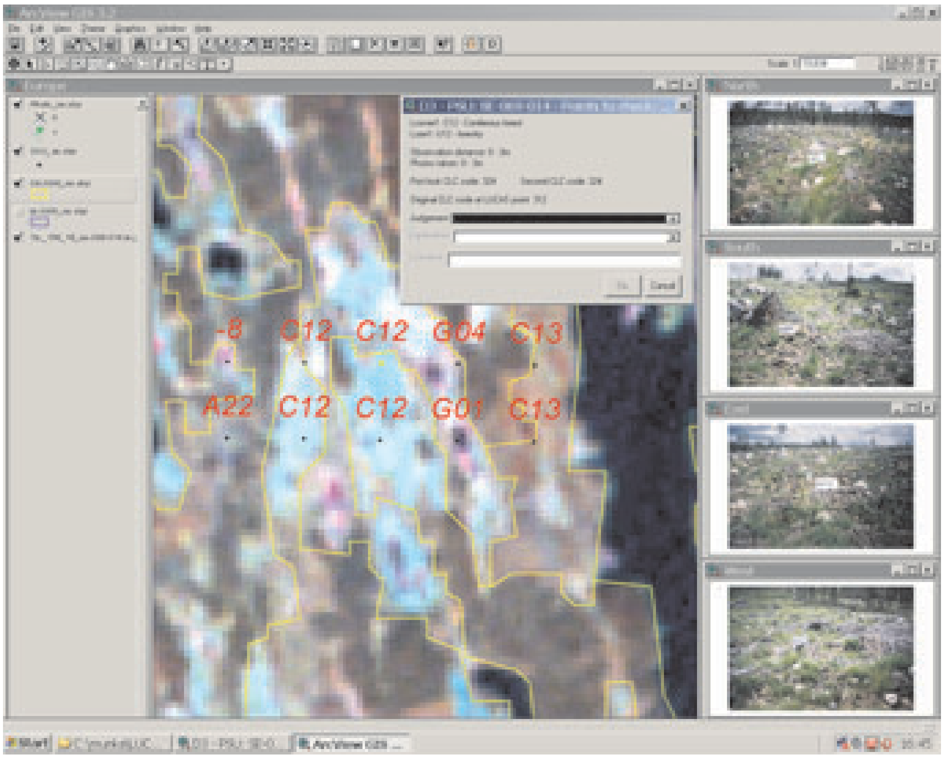


1st validating interpretation: 243; *2nd validating interpretation*: 313; *CLC2000 database*: 313; *LUCAS land cover:* Oats; *LUCAS land use*: agriculture; *Result*: Clear Agreement. Agricultural area inside the forest is too small (around 20ha) to interpret in CLC as a separate polygon.

Figure 58- Validation of CLC2000: two examples of Clear Agreement



Validating interpretation: 231 (1st and 2nd); *CLC2000*: 324; *LUCAS land cover*: permanent grassland without tree/shrub cover; *LUCAS land use*: unused; *Result*: Disagreement, wrong interpretation. Compared with IMAGE2000, CLC2000 lines are shifted by more than 100 m
Explanation: not accurate delineation



Validating interpretation: 324 (both 1st and 2nd); *CLC2000*: 312; *LUCAS land cover*: coniferous forest (no category in LUCAS for transitional woodland); *LUCAS land use*: forestry; *Result*: Disagreement, wrong interpretation. LUCAS photos show clear-cut and IMAGE2000 supports that. Treeless area exceeds 25 ha. Explanation: wrong generalisation

Figure 59- Validation of CLC2000: two examples of Disagreement

The most remarkable thematic improvements are (Büttner, G. et al., 2004):

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

10.2 Thematic highlights

The main difficulties in identification, classification and delimitation of CLC classes (based on Feranec, J., G. Jaffrain, 2005) are important to report, to take into account when updating the CLC2000 database or when CLC down-dating is necessary for the analysis of land cover time series.

Regarding artificial surfaces (mainly CLC classes 111 and 112), to mapping the alternation of urban fabric, urban greenery and gardens, the density of urban fabric (300 m distance between villages, at least 50% covered by artificial structure) must be taken into account. As a consequence of ignoring these criteria, the class continuous urban fabric (111) can be overestimated and the identification of rural settlements (class 112 – discontinuous urban fabric) underestimated or missing.

Classification of areas such as woods, shrubs and grass formations within urban fabric (112) is not frequent, but it did occur. Such areas are typical examples of the green urban areas (class 141) and not those of classes 31x or 324.

A frequently occurring problem is to distinguishing class 211 (annual crops or recently abandoned land) from class 231, as they are very similar in spectral characteristics. To distinguishing arable land abandoned for more than three years is a specific problem, as this time component is not identifiable by satellite images. To solve the problem, the use of aerial photographs and in particular the knowledge gathered from field checking is necessary. Other solution not always feasible is to compare several satellite images from different dates of the same season, in order to understand the agricultural practice and the trends of landscape evolution. It would allow distinguishing old abandoned land (more than 3 years which could be classify on 231), young abandoned land (less than 3 years which could be classify into 211) and arable land (211).

Confusion of pastures (class 231) with natural grassland (class 321) is a similar problem. Grass associations free from human impact must be classified under natural grasslands. If they are under human impact, mostly focused on increased biomass production (e.g. fertilising, mowing, etc.), such grass associations must be classified as pastures, class 231. Occurrence of grass areas in high mountains, on steep slopes with difficult access, or in military space, predetermines their classification to natural grassland (321). Globally the class 321 should be classified only for the herbaceous climax stage, when the biotope condition is not sufficient in the long term to obtain another series of vegetation.

Neglecting the natural vegetation in heterogeneous agricultural area, generates further problems of correctly discerning between class 242 – complex cultivation patterns and class 243 (land principally occupied by agriculture with significant areas of natural vegetation). Presence of enclaves smaller than 25 ha with tree and shrub vegetation, swamps, etc. is typical for class 243.

Care should be taken to not confuse classes representing the bushy vegetation – moors and heathlands (322), sclerophyllous vegetation (323) and transitional woodland/shrubs (324). The correct identification of these classes requires interpreter's knowledge of the occurrence of bushy vegetation in the climax stage of development: class 322 in Atlantic and Alpine heaths, sub-Alpine bushes, etc.; class 323 in Mediterranean and sub-Mediterranean evergreen sclerophyllous bushy and scrub like maquis, garrig, mattoral, etc. and vegetation representing either woodland degradation, (e.g. clear-cuts, forest calamities by polluted air..), or forest degradation/afforestation. In some countries, revising the CLC90 data, it was necessary the reclassification of the clear-cut areas, classified as forests (31x), into the transition woodland/shrubs (324). Figure 60 shows the separation between forests and Sclerophyllous vegetation.

Ambiguities may occur in distinguishing the class inland marshes (411) and peatbogs (412), as some of their phenol-phases are very similar in terms of spectral characteristics. The use of aerial photographs, field checking or precise botanical information helps to eliminate this problem.

Regarding the CLC-Changes database, the most typical problems found are mentioned here (based on CLC2000 Technical Team, 2005, Lessons learned on thematic quality control):

1) Overestimation (meaning that "no change" is indicated as change): Main reasons for that is an omitted revision in CLC90 or to consider a transient / short term change. Figure 62 shows two examples of this type of mistake. In the first example, the change reported was from mineral extraction sites (131) to natural grassland (321). The verification showed that there was a mistake since the land cover was natural grassland in both dates. The visible differences are purely seasonal effects. The same illustration demonstrates that the correction of the CLC90 before identification of changes is of fundament importance. It's visible that CLC90 land cover mapping units are missing. The second example shows a mistake in the identification of the change- complex cultivation patterns (242) to transitional woodland-scrub (324). In fact it was land principally occupied by agriculture, with significant areas of natural vegetation (243). In Figure 63, No change is indicated as change 312-311. What is seen are difference in sensors (SPOT XS vs. Landsat TM), seasons and image enhancement. On the other hand, this type of change would mean changes in forest practice (coniferous to deciduous) and usually is very rare.

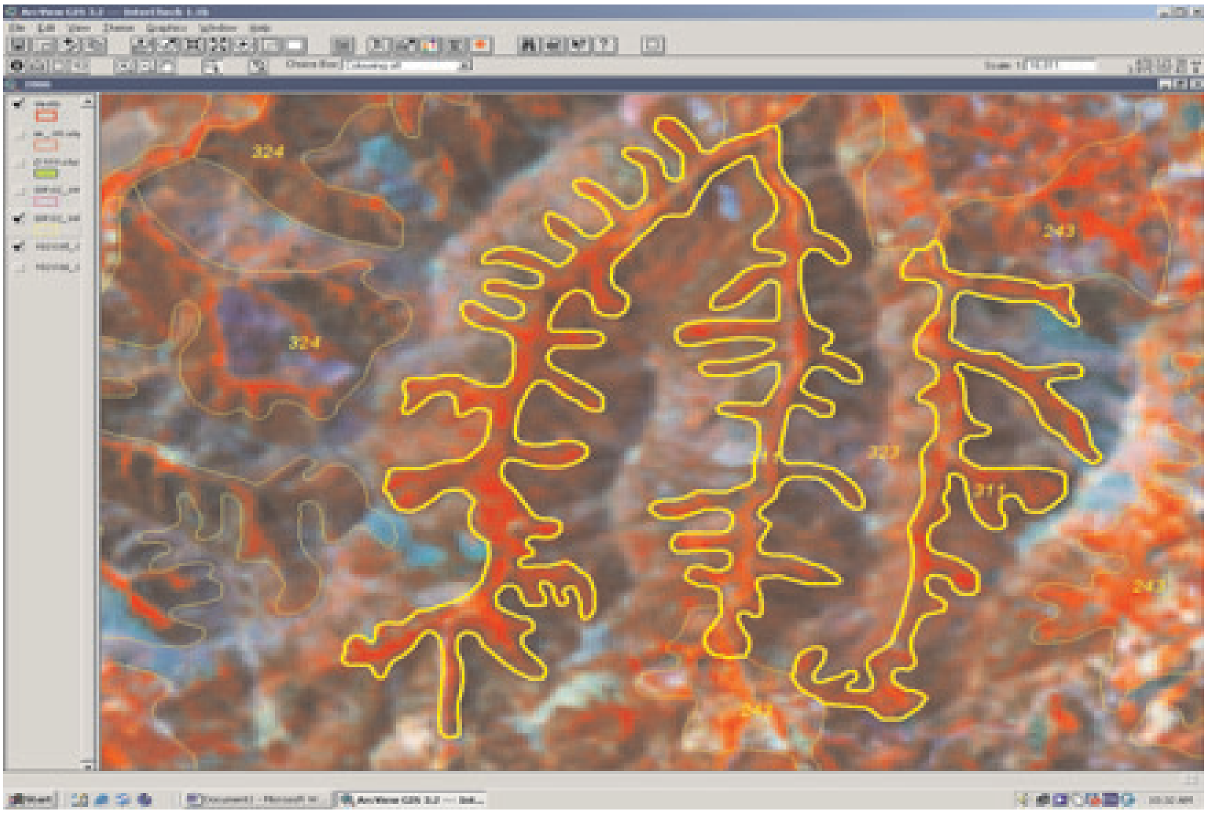


Figure 60- Separation of forests and Sclerophyllous vegetation (GR)

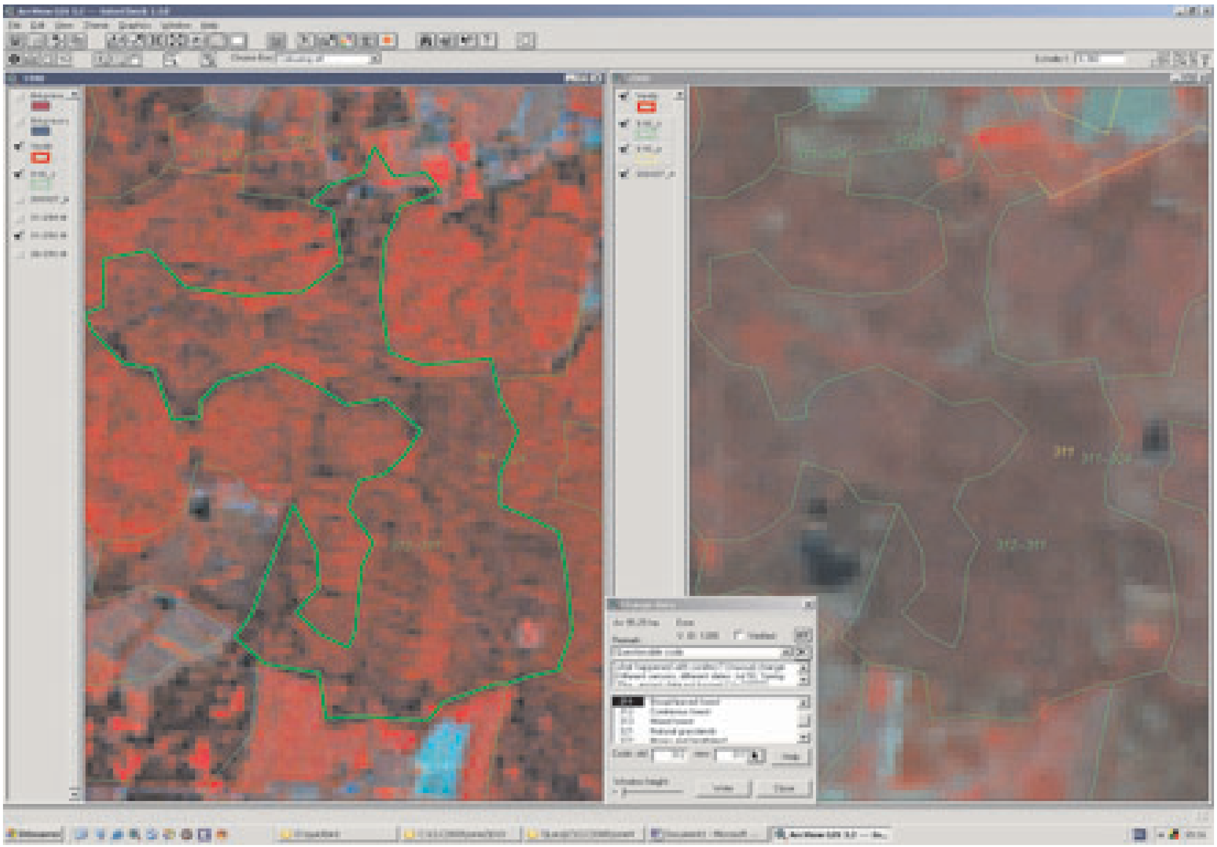


Figure 61- Example of CLC-Changes correction with the verification (1)

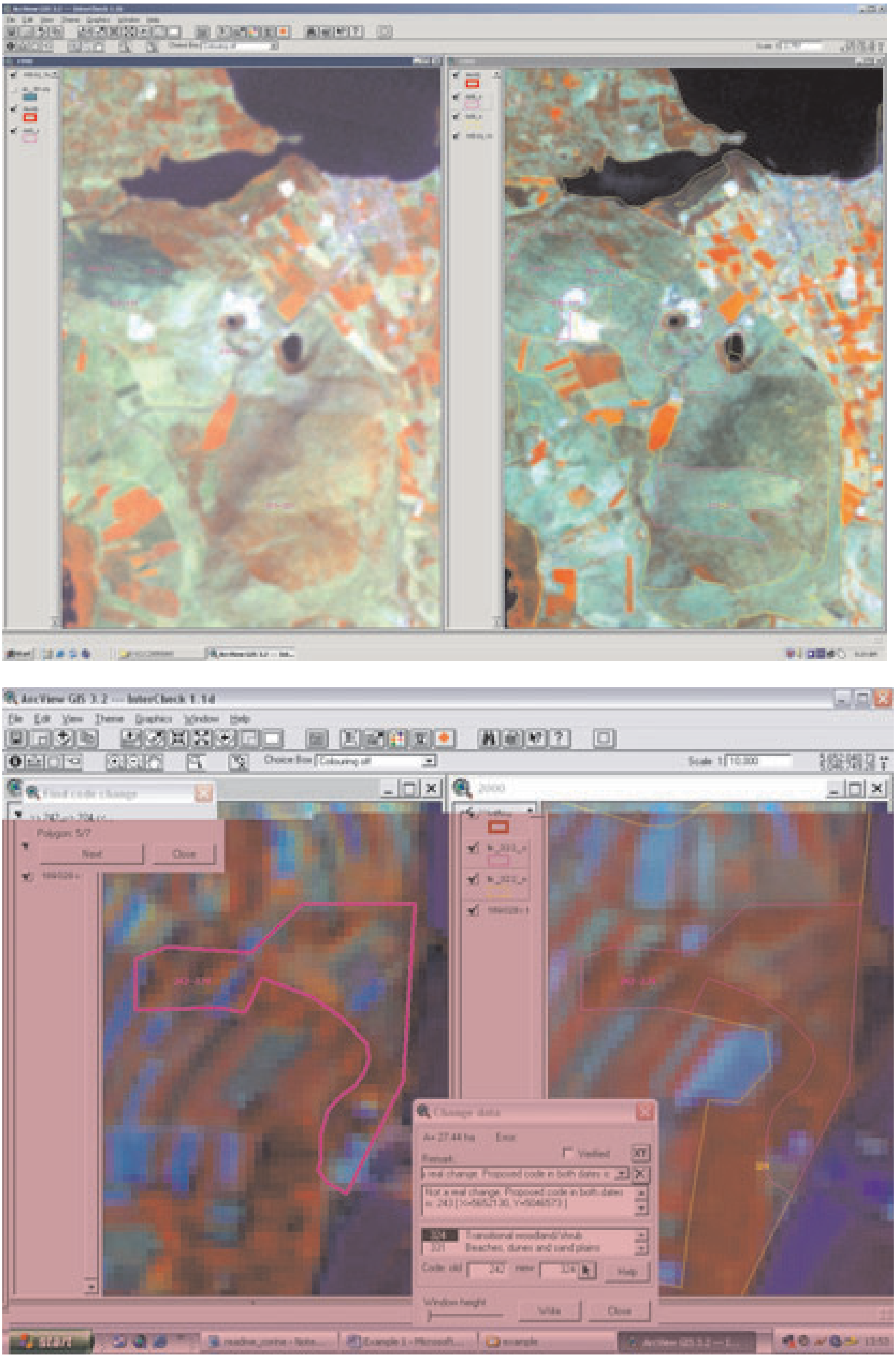


Figure 62- Example of CLC-Changes correction with the verification (2)

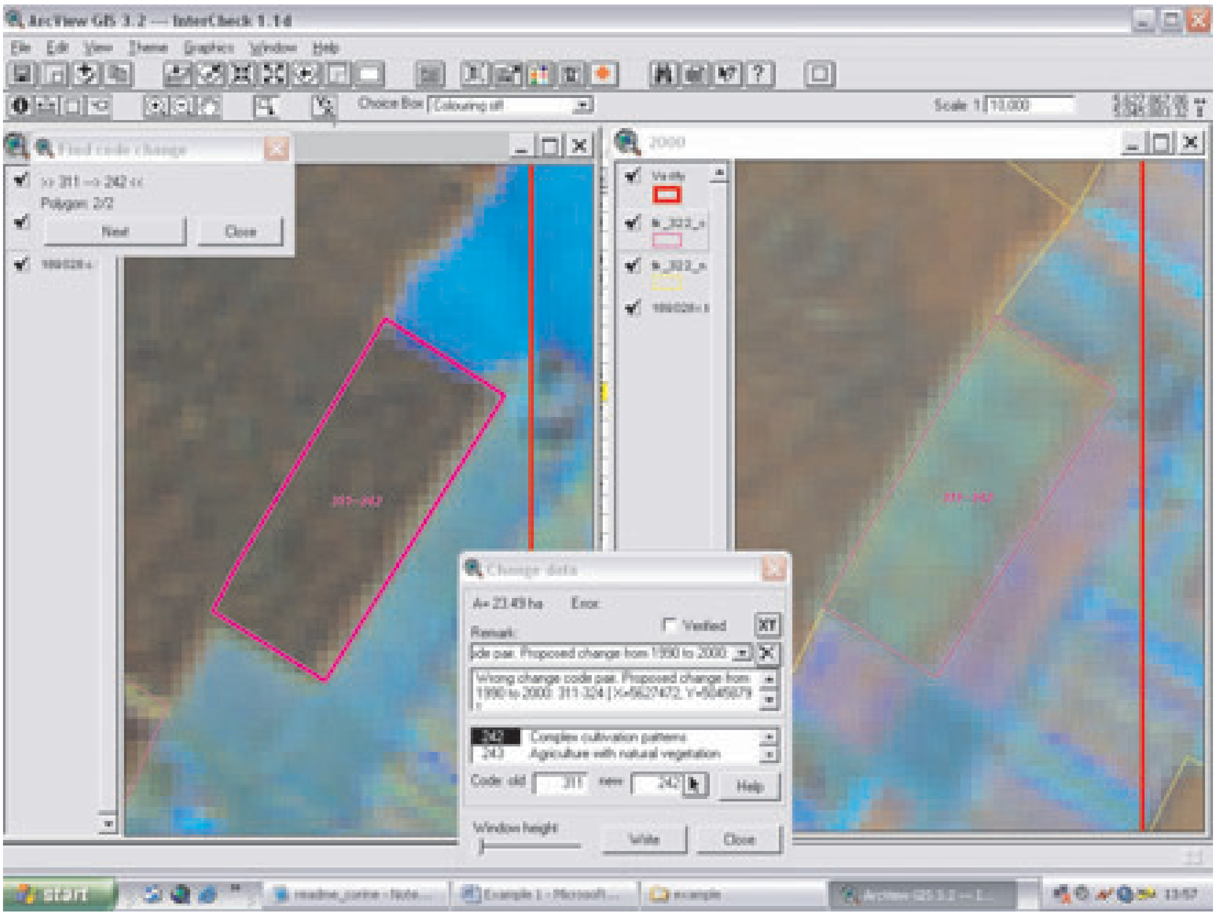
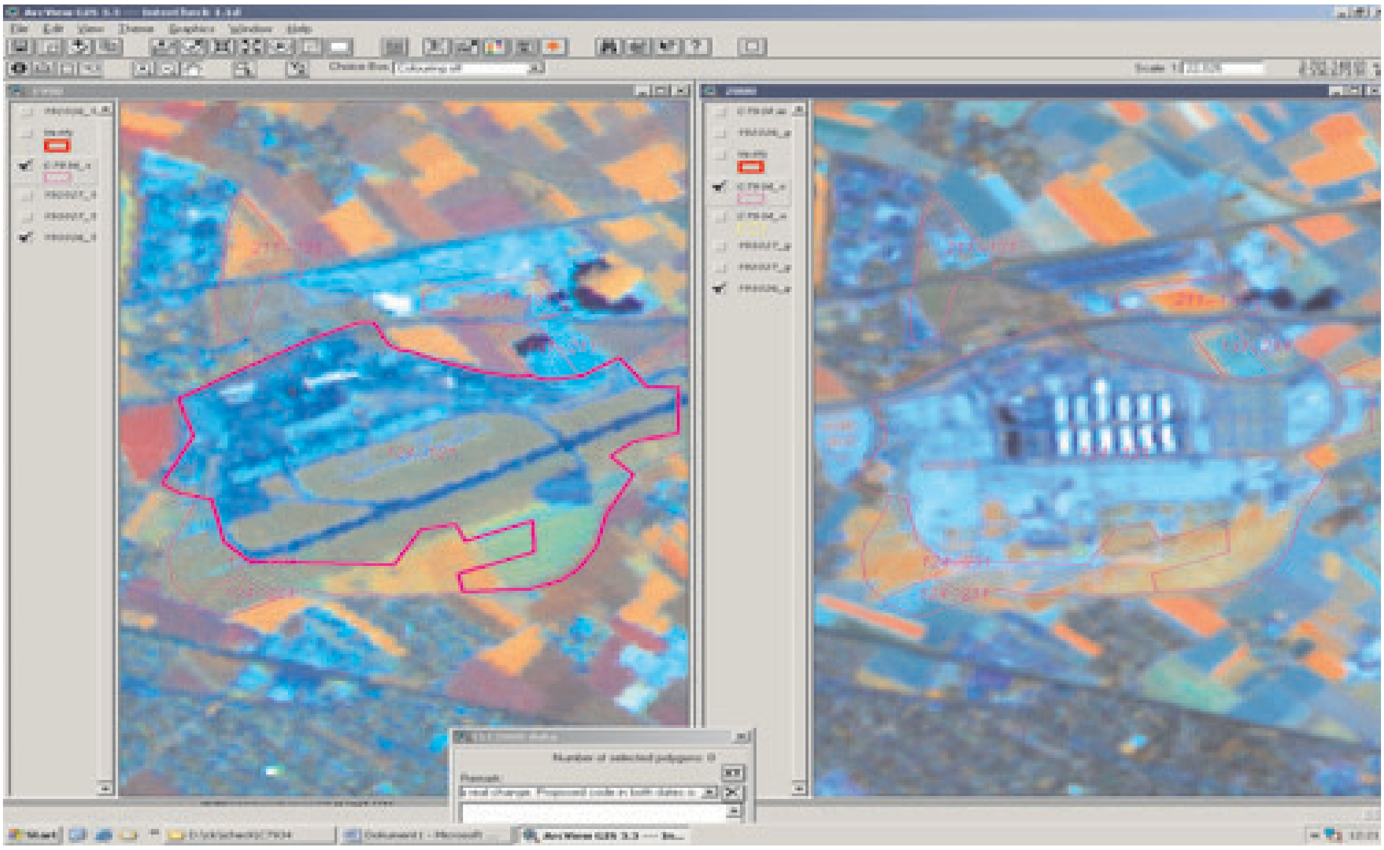


Figure 63- Example of wrong identification of the change process

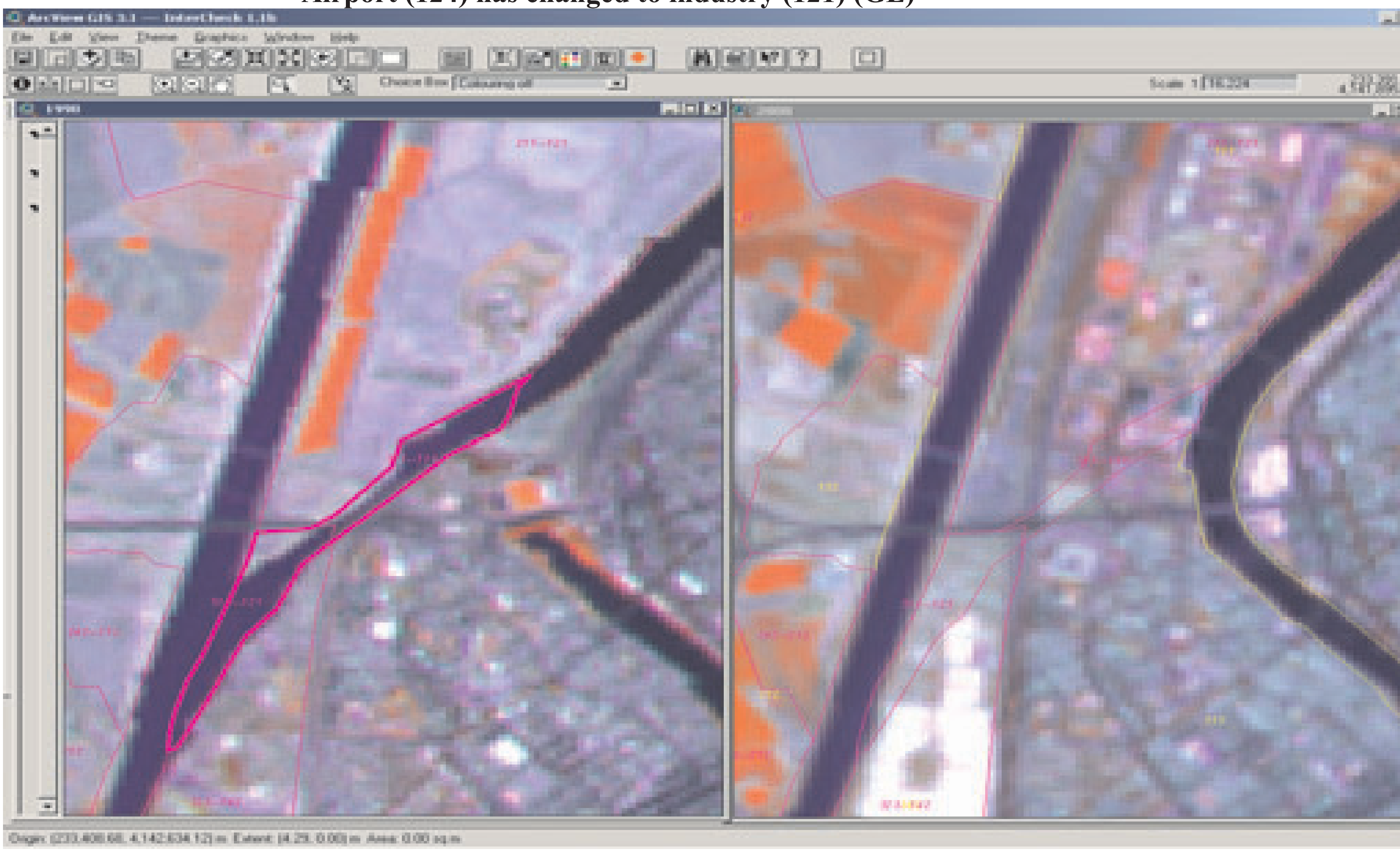
2) Wrong change code pair when there is a true change: The improper code could be either in CLC90 or CLC2000 and identified during the verification procedure. It can occur due to omitted revision in CLC90 or not enough consideration regarding the evolution process. Figure 63 illustrates a case where broad-leaved forest (311) was identified changing to complex cultivation patterns (242). The real change proved to be to transitional woodland-scrub (324). However, according to the area of the polygon (23.49ha), it shouldn't be considered as a change but included inside the polygon 311.

3) Impossible change (meaning that no change occurs or identification of a wrong change: It may be a consequence of the difference in MMU in CLC and CLC-change (technical change). But it also can be that the interpreter didn't consider the evolution process. Another aspect to take care is that unlike or rare type of changes can occur and they do not necessarely mean that there is an error. Figure 64 gives a examples of such cases.

4) Underestimation: This happens when there is an omitted change and in particular in cases of isolated changes, which means changes affecting a surface within 5 ha and 25 ha. According to the Technical Guidelines (Aug 2002), "a change inside a polygon having area between 5 and 25 ha will not be recorded as change". As a consequence, the delineation of changes in the size 5-25 ha is depending on their position. These changes will be mapped only if increase / decrease of an existing polygon, resulting in underestimating real changes that are isolated polygons within this range of surface. It is still unknown how large this effect is for the all database. What is important is that the limitations of the change mapping methodology are known and understood. Figure 65 illustrates this effect in the case of Hungary. If we compare the distribution of CLC2000 polygons' size in Hungary (where all changes larger than 5 ha have been mapped) and, say, Belgium, mapped according to the Guidelines (Figure 66), we see an abrupt break on the graph at the 25 ha polygon size. This is because, due to the change mapping rules, only part of the 5-25 ha changes have been mapped, and so the total change area is underestimated.



Airport (124) has changed to industry (121) (GE)



River (511) has became industry (121) (ES)

Figure 64- Examples of rare land cover changes

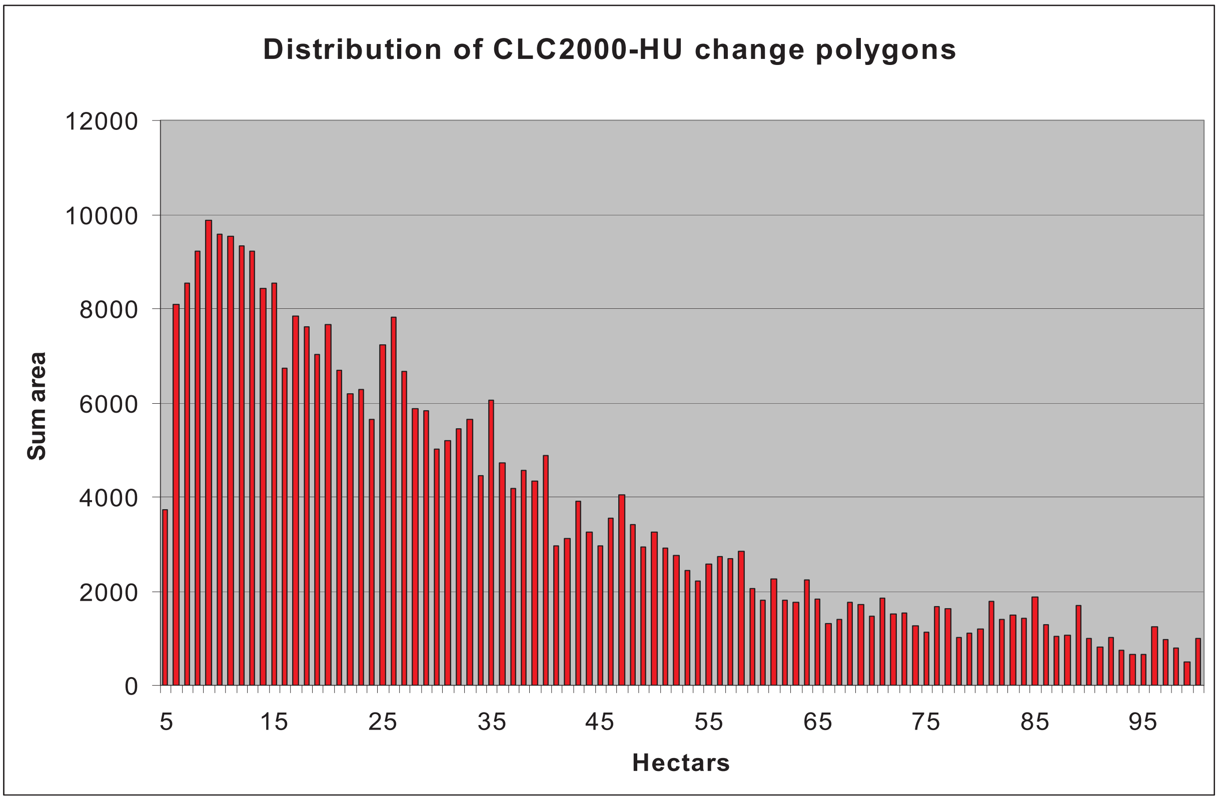


Figure 65- Size Distribution of CLC2000 Change polygons in Hungary

Area of all changes: 100%. Area of all change polygons under 25 ha: 37 %.
Area of isolated changes: **17%** (45% of the changes under 25 ha).

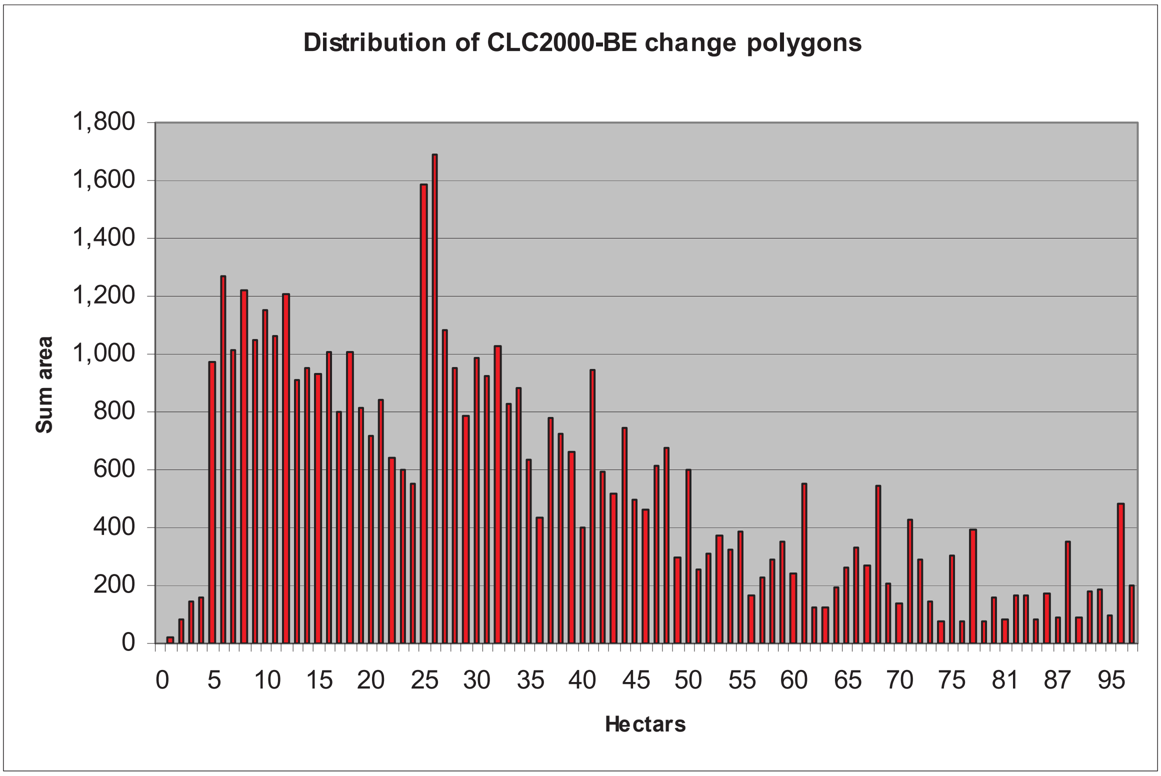


Figure 66- Size Distribution of CLC2000 Change polygons in Belgium

10.3 Most significant changes in terms of surface

Reliable information on Land cover changes is always related to a time frame and to a certain land cover class or group of classes. Therefore there are many different ways to present the results and to make partial or global analysis of changes. The date of CLC90 is depending upon when the first CLC inventory was done, in some countries with images acquired along several years. In that case an average date was estimated. The period of changes is so ranging from 15 to 5 year interval. The time interval the changes are related is indicated in the Table 53.

Table 53- Overview of IMAGE90 /CLC90 reference dates (acquisition period)

Country	Start date	End date	Comments
Albania	1995	1996	considered as CLC2000
Austria	1985	1986	
Belgium	1989	1990	
Bosnia and Herzegovina	1998	1998	considered as CLC2000
Bulgaria	1989	1992	
Croatia	1990	x	by downdating CLC2000
Cyprus	x	x	no CLC90 available
Czech Republic	1989	1992	
Denmark	1989	1990	
Estonia	1993	1995	
Finland	1986	1994	Withdrew CLC90 due bad quality
France	1987	1994	
Germany	1989	1992	
Greece	1987	1991	
Hungary	1990	1992	
Ireland	1989	1990	
Italy	1990	1993	
Latvia	1994	1995	
Liechtenstein	x	x	no CLC90 available
Lithuania	1994	1995	
Luxembourg	1991	1991	
Malta	x	x	no CLC90 available
Macedonia	1995	1996	considered as CLC2000
The Netherlands	1986	1988	
Poland	1989	1992	
Portugal	1985	1987	
Romania	1989	1992	
Slovak Republic	1989	1992	
Slovenia	1995	1996	
Spain	1984	1990	
Sweden	x	x	no CLC90 available
United Kingdom	1989	1990	

Table 54 presents some statistics per country: the four largest level-3 changes in each of the level-1 groups, the total surface changed in % of the total area of the country, the time interval, an indicative rate of change per year and the 4 largest changes in each country.

Looking at the results presented, in most of the countries (21) the dominant changes occur within the level-1 class forest and semi-natural areas, having 8 of them the 3 dominant changes within this class and 3 countries with the four dominant changes there. Only in The Netherlands and Croatia forest area is not involved in the dominant changes. In the first one, the largest LC-Change results in increasing non-irrigated arable land from previous pasture land and the next three largest in surface due to the increase of discontinuous urban fabric respectively from previous pasture land, non-irrigated arable land and complex cultivation patterns.

Table 54- The four largest land cover changes per country and the four largest level-3 CLC-Changes in each level-1 (Technical Team, 2005)

Country	Artificial surfaces	Agricultural areas	Forest and semi-natural areas	Wetlands and water bodies	Changes (% of total area)	Time difference (CLC2000 - CLC90, years)	Yearly changes (% of total area)
Austria	211-112	211-112	335-332	511-243	0.43	15	0.03
	211-142	211-142	312-324	411-142			
	231-142	231-142	324-312	411-211			
	211-131	211-131	313-324	511-242			
Belgium	211-121	211-121	324-312	211-512	1.76	10	0.18
	242-112	242-112	312-324	312-412			
	242-121	242-121	324-313	242-512			
	211-112	231-242	324-311	131-512			
Bulgaria	211-131	213-211	324-311	512-411	1.11	10	0.11
	132-211	222-211	311-324	243-512			
	231-131	231-211	324-313	512-211			
	311-131	211-231	312-324	211-411			
Croatia	242-112	211-243	311-324	512-411	1.93	10	0.20
	311-133	242-231	324-311	511-311			
	242-121	324-231	324-231	242-512			
	242-133	243-231	243-324	411-324			
Czech Republic	211-112	211-231	324-312	243-512	6.65	8	0.83
	132-324	231-211	312-324	211-512			
	131-132	211-243	324-313	131-512			
	211-121	211-222	313-324	512-411			
Denmark	211-112	211-324	312-324	523-331	1.32	10	0.13
	211-142	211-112	313-324	523-123			
	211-121	211-142	311-324	523-423			
	211-131	211-121	324-322	412-512			
Estonia	243-112	231-211	313-324	324-412	2.68	6	0.45
	324-131	211-231	312-324	312-412			
	131-333	231-242	311-324	412-324			
	242-112	211-242	324-311	411-412			
Spain	211-121	211-212	312-324	523-123	4.72	14	0.34
	211-112	211-242	324-312	511-512			
	242-112	211-223	323-324	421-422			
	211-133	211-321	324-311	523-331			
France	242-112	231-211	324-312	131-512	2.06	10	0.21
	211-121	211-231	312-324	231-512			
	211-112	242-112	324-311	211-512			
	242-121	211-121	311-324	311-512			
Germany	211-112	211-231	312-324	523-423	2.47	10	0.25
	211-121	211-112	321-324	131-512			
	211-131	211-242	324-313	211-512			
	131-333	231-211	131-333	423-523			
Greece	211-131	211-212	312-324	512-211	2.16	10	0.22
	242-112	213-212	311-324	512-331			
	242-121	212-213	324-311	512-411			
	323-133	211-131	323-321	511-512			
Hungary	211-121	231-211	324-311	411-512	4.48	8	0.56
	211-131	211-231	311-324	211-512			

	211-122	211-324	211-324	231-512			
	211-112	231-324	324-313	231-411			
Ireland	231-112	231-211	412-324	412-324	8.03	10	0.80
	231-142	211-231	312-324	412-312			
	211-112	231-242	324-312	512-321			
	231-133	231-112	412-312	412-243			
Italy	211-112	243-323	324-311	211-512	1.31	10	0.13
	242-112	211-112	243-323	411-512			
	211-121	242-112	321-324	512-331			
	243-112	211-121	324-312	211-411			
Lithuania	133-112	231-211	313-324	243-512	2.54	5	0.51
	211-131	211-242	312-324	242-512			
	133-121	231-242	311-324	512-231			
	242-112	211-231	324-311	231-512			
Luxembourg	242-112	242-112	312-324	--	1.60	11	0.15
	231-112	231-112	311-324				
	243-112	243-112	313-324				
	243-142	243-142	311-142				
Latvia	312-131	231-211	313-324	412-512	4.01	5	0.80
	311-131	211-231	312-324	--			
	313-131	222-231	311-324				
	324-131	222-211	312-131				
Netherlands	231-112	231-211	211-311	231-411	4.16	14	0.30
	211-112	231-112	211-321	331-423			
	242-112	211-112	231-311	231-512			
	231-121	242-112	331-423	523-423			
Poland	211-131	231-211	312-324	231-512	0.83	8	0.10
	133-112	211-231	324-312	411-324			
	211-133	211-131	324-313	411-512			
	211-112	222-211	313-324	411-231			
Portugal	241-112	211-212	312-324	512-321	10.65	14	0.76
	242-112	243-324	324-311	511-331			
	243-112	231-212	324-312	421-422			
	211-112	241-242	311-324	512-211			
Romania	211-112	213-211	324-311	411-211	1.67	8	0.21
	211-121	231-211	312-324	512-411			
	243-131	211-231	311-324	411-512			
	311-131	211-243	324-313	131-411			
Slovenia	133-122	411-231	334-324	512-411	0.12	5	0.02
	311-122	311-243	311-324	411-231			
	312-133	243-312	311-243	311-512			
	243-133	313-231	311-122	131-512			
Slovakia	133-512	211-242	312-324	133-512	4.24	8	0.53
	211-112	231-324	324-311	133-511			
	133-511	231-211	311-324	411-512			
	133-324	231-243	324-313	243-512			
UK	211-142	211-142	324-312	412-312	1.51	10	0.151
	211-112	211-112	322-312	412-324			
	231-112	231-112	312-324	211-512			
	211-131	231-312	321-312	423-123			

Key: Red: 1st most frequent change; Yellow: 2nd most frequent change; Green: 3rd most frequent change; Blue: 4th most frequent change.

Another country where the second dominant LC-Change occurs within artificial surfaces is Germany with increase in discontinuous urban fabric from the reduction of non-irrigated arable land, Denmark and Austria where it represents the third dominant surface change. In Luxembourg and Belgium, the increase of discontinuous urban fabric from previous agricultural land represents the fourth dominant land cover change.
In Table 54, total changes might include areas outside national boundary. Consequently the percentage of changes can be slightly overestimated. The time difference is just indicative, therefore "yearly percentage change" have to be used with care. Figure 67 presents the rate of change per year, giving the relative land cover changes dynamic of each country.

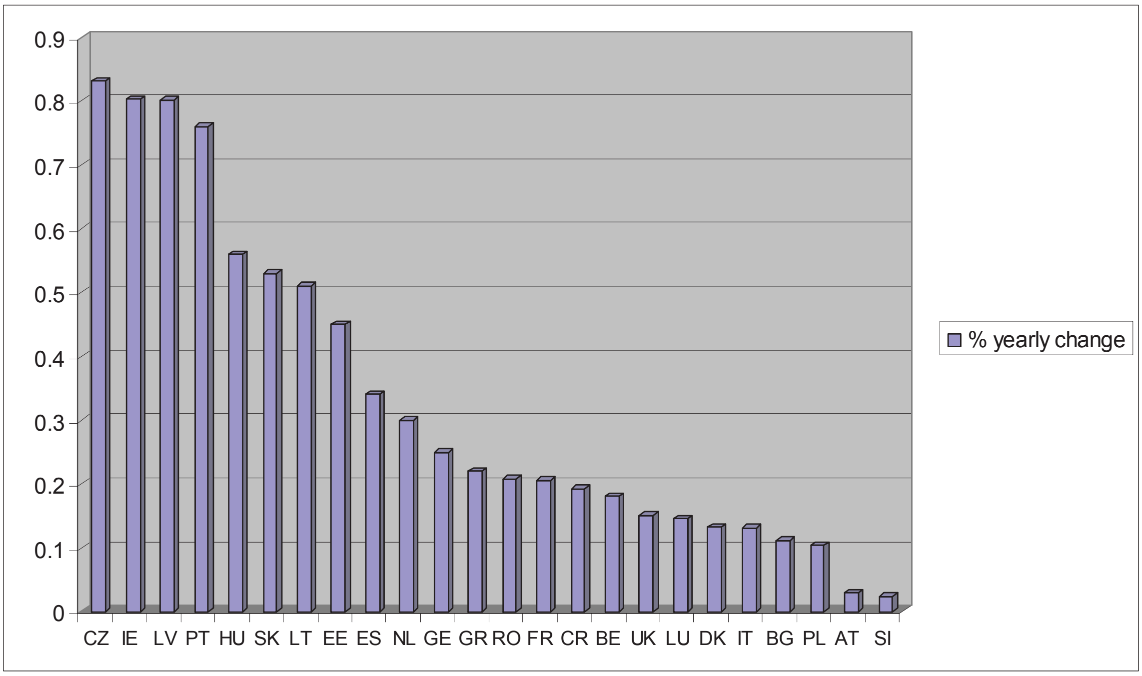


Figure 67- Annual rate of Land Cover Change in each country (Technical Team, June 2005)

Czech Republic is the country with highest rate of land cover changes per year (0.83%), represented in percentage of the total country's surface (survey period of 8 years). The dominant land cover change in terms of surface (3.6% of the national surface) is the increase of pasture land from previously non-irrigated arable land. The four next largest changes representing 2.3% of the national surface, occurred within the forest and semi-natural areas, especially with the increasing of the coniferous forest (42 400 ha) and of the mixed forest. The largest change within the artificial surfaces was the increasing of discontinuous urban fabric on former non-irrigated arable land. The contrary occurs in Ireland, also with 0.8% of land cover change per year, being the first surface CLC-Change the increase of non-irrigated arable land from pasture (3% of the country's surface). However, the second largest land cover change is the reduction of peat bogs (representing 1.1% of the country's surface), in a process of afforestation. Latvia also with a rate of 0.8% of CLC-Change (period of 5 years only), has as the first contribute the transformation of the mixed forest and coniferous to transitional woodland-scrub. In this country, the most significant change within the artificial surface was the increase of mineral extraction sites.

On the other side of the curve with the lower rate of land cover change (0.02%), is Slovenia (survey period of 5 years) and Austria with 0.03% of land cover change per year for the survey period of 15 years (Table 54). In Slovenia, the two largest changes lead with an increase of transitional woodland from burnt forest area and broad-leaved forest; the third largest land cover change was the construction sites that became 1.2.2 road and rail networks. Curiously in Austria, the largest land cover change is represented by the class 3.3.5 (glaciers and perpetual snow) that became bare rocks, which is 0.12% of the country's surface.

Figure 68 illustrates Table 54 regarding the total land cover change in each country, as a percentage of the country's area. Portugal is where land cover changes represent a higher % of the territory (10.7%), within a period of 14 years (Portugal was the first country to create the CLC90, using satellite images acquired in 1985). The land cover changes that affect the ten largest surfaces are in forest and semi-natural areas, as a result of the enormous forest fires occurring during the last years, except for the change from non-irrigated to permanently irrigated land which affect 0.44% of the area

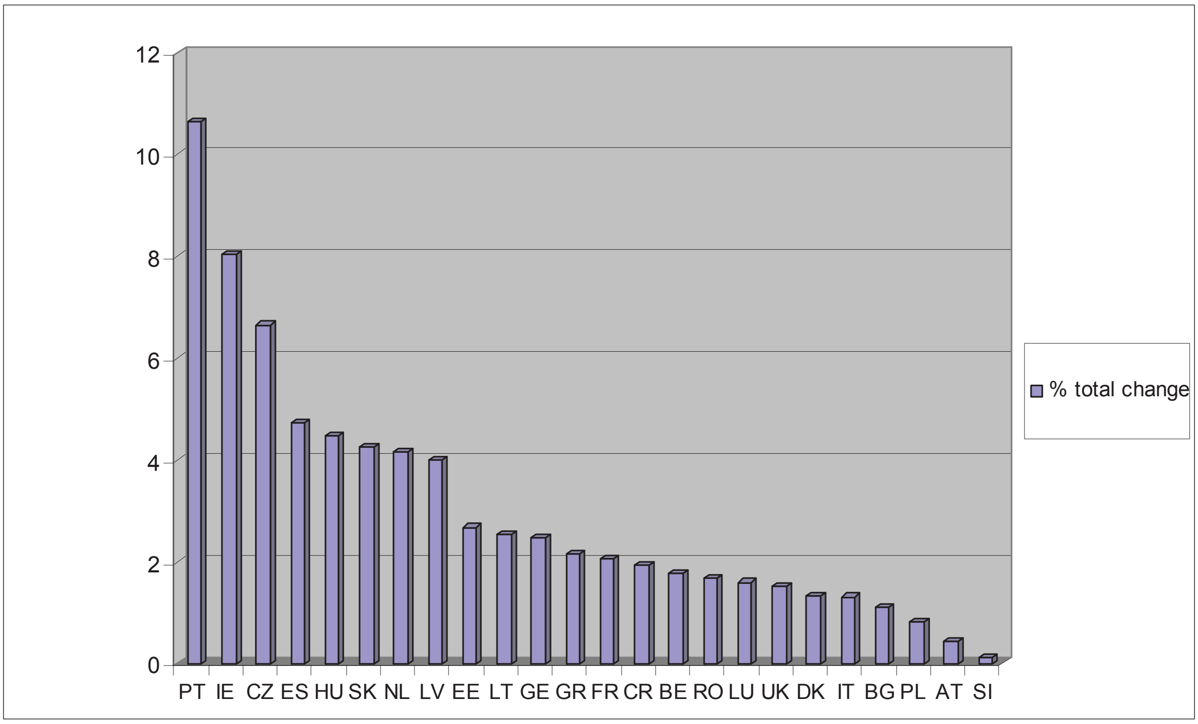


Figure 68- Distribution of countries regarding the total Land Cover Change in the period between the two CLC, in percentage of the total area of the country

Analysing the CLC-changes matrix in each country we realise which processes are dominant for the time interval between CLC90 and CLC2000. As an example, for some countries there are here the dominant changes, listed in descending importance (Büttner, G. et all, 2004):

Ireland (EPA, 2003): Changing pasture (231) to arable land (211) and arable land to pasture, as a traditional practice in Ireland, with a net increase of arable land; Peat bogs are afforested (412-324); Coniferous forests are clear-felled (312-324); Coniferous plantations mature (324-312).

Latvia (Baranovs, 2003): Felling of forest (313-324); Changing pasture (231) to arable land (211) and arable land to pasture almost balanced.

Lithuania (Vaitkus, 2003): Intensification in agriculture (231-211); Felling of forest (31x-324); Diversification of agriculture (211-242).

Estonia (EEIC, 2003): Changing pasture (231) to arable land (211) and arable to pasture, with a net increase of arable land; Felling in forests (31x-324); Diversification of agriculture (231-242).

The Netherlands (Hazeau, 2003): Urbanisation (urban growth, new sport and leisure areas) on former agricultural land; Internal changes in agriculture (e.g. new green house areas); Industrialisation with loss of agricultural land; Agricultural areas converted to semi-natural areas (211-311, 211-321); New wetlands (231-411); New water bodies (231-512)

The importance of land cover change is not only according to the affected surface. There are many relevant changes that involve small areas with a high environmental impact. The land cover changes in the class wetlands are an example. The way to bring those changes to light is to analyse the LC-Changes by level-1 class and reporting the changes as % of the total area of the relevant level-1 class.

V Overall Conclusions

I&CLC2000 was a complex multi-annual and multi-partners project, facing with success the challenges and the evolving users' requirements. Planned as a three years project, it was able to deliver most of the products before that date, supporting many policies as a tool for monitoring Europe's changing landscape, and to visualise phenomena with a spatial representation as an integrative effect of human and nature activities.

I&CLC2000 was launched in 1999 with 15 participating countries. The Technical Guide in 2002 included already 26 countries. During 2003-04, three additional countries joined the project (Croatia, Cyprus and Malta), and five more countries are starting the project in 2005 (CH, IS, NO, SCG, TR). The Seamless European CLC2000 will in the end include 37 countries, representing a significant increase since the start of the project.

Table 55- Extension of CLC in time

CLC1990	23 countries	3.86 M km2
CLC2000 in 2004/05	29 countries	4.38 M km2
CLC2000 in 2006/07	37 countries	5.74 M km2

I&CLC2000 was the first user for Landsat 7 ETM+ data requiring a significant amount of data, when technical problems were still present at the receiving station. IMAGE2000 detect those problems in the row satellite data and it contributes to fix them for the satellite data user community, being still always in time to allow the national CLC2000 to start at the date foreseen.

The estimated cost of I&CLC2000 was 10 MEURO, considering 15 Member States in 1999, which should be reached with annual budget of the E.C. and of the participating countries. With the increasing number of participating countries, the number of financing parties and Programmes also grew, with only marginal increase in the total cost of the project. This implies a project organisation and management able to cope with the administrative and technical deadlines, not always easily compatible. A multi-annual project implemented with yearly approved budgets creates uncertainties in the implementation and it increases the real cost and timing of some tasks by launching more than one market consultation and derived contracts. The situation of having a multi-annual and multi-institutional initiative relying on annual budgets derives from the fact that at that time, there is no regulated obligation on updating the European land cover database. The recognition of the CLC database as a thematic European reference data and of ortho-images as European reference data, as included in the proposed INSPIRE directive may contribute to improve this aspect, when it is possible to regulate a dedicated budget for future updates.

The significant number of partners involved, European and national authorities, commercial and non-commercial organizations, were able to define and to deliver consistent and reliable products based on a co-ownership principle and respecting all rights involved. The agreed and implemented data policy accepts the multi-purpose and multi-users characteristics of the databases created, fully in line with the INSPIRE principles, although those were approved when I&CLC2000 was already in place. On the other hand and from the technical aspect, only an efficient communication established between all the national teams, the Technical Team and the national and European management made it possible to reach the consistency on quality, harmonization of standards and compatibility achieved between the

National and European results. What was a network and communication challenge turned out to be the key factor of success for the project.

The co-management done by EEA and JRC, making the best use of competences specific to each organization proved to be of high quality by looking at the achievements, in particular:

- The creation of European reference data: image based spatial reference (IMAGE2000), reference land cover (CLC2000) and reliable information on land cover changes for Europe, as a first example of INSPIRE implementation and as a first step for a land cover and land use monitoring in Europe, relying in a cost-effective, high quality, coherent and possibly frequent information on land cover.
- The agreement on data policy and consequent dissemination tools.
- The data documentation through the data quality control and quality assurance, and standardised national and European metadata.
- The significant uses and users of the products and the recognised need for their frequent updating.

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Annex 1: Participants in I&CLC2000 Project

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

Annex 2: Technical note on errors observed by IMAGE2000 team on system corrected Landsat 7 scenes, during the period April to November 2000

Torbjörn Westin

1- Along-scan shifts in Landsat-7 scenes from ESA (15-06-2000)

Background
Both ESA and USGS process Landsat-7 ETM+ to system corrected products (level 1G). The differences in the respective products could be compared by the acquisition of 195/018 on 1999-09-11. This scene was processed at both facilities, which allowed for the comparison. The resampling method was cubic convolution in both cases. The ESA scene was produced on the date 2000-05-09.

Along-scan shift measurements
In the visual inspection of band-to-band registration quality, it was evident that the ESA scene suffered from scan-related mis-matches between band 8 (Pan) and the rest of the reflective bands. No such problems could be seen in the USGS scene.
To be able to quantify the problems, a test area was selected at the upper left corner of the scene. An area of 2000 columns and 1000 lines was selected in the Pan band (band 8). The corresponding area was selected in band 4, which was resampled to 15 m pixelsize to correspond exactly to the selected area in band 8. The registration between band 4 and band 8 was then measured by correlation in a 5 x 5 pixel grid. Finally, the measured along-line shifts were averaged for all nodes on the same line in the grid. This results in average along-scan shifts between bands for 5 lines intervals in the test area. Exactly the same measurements were made in the USGS scene for reference.

Results
The measured average along-scan mis-matches between band 4 and 8 in the ESA scene are displayed graphically in figure 1. The mis-matches occurs in bands approximately 64 lines wide (pan-lines), and have amplitudes of +/- 30 m. The corresponding results for the USGS scene are shown in figure 2. The mis-matches have magnitudes of +/- 3 m. This corresponds well with the results obtained by USGS in their own on-orbit calibrations [Storey et al, 1999].

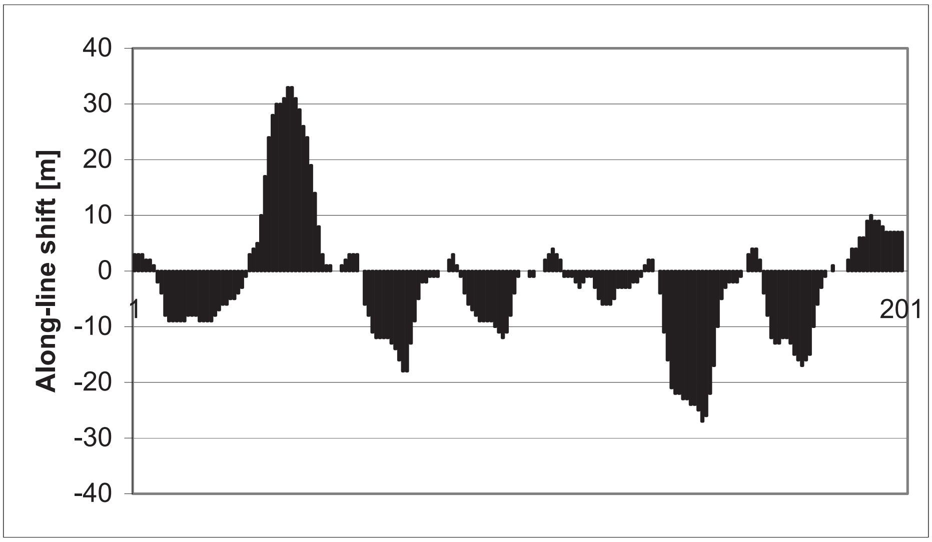

Figure 1. Along-.scan mis-registration between band 4 and band 8 in the ESA scene, measured in 5-line intervals for the first 1000 lines in the band 8 (Pan) band

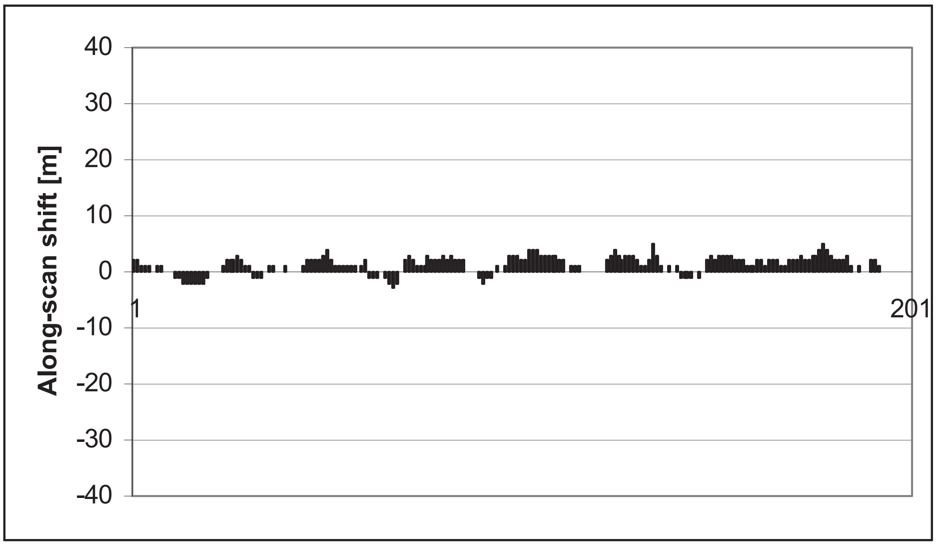

Figure 2. Along-.scan mis-registration between band 4 and band 8 in the USGS scene, measured in 5-line intervals for the first 1000 lines in the band 8 (Pan) band.

Conclusion

The result shows clearly that there is a problem in the processing of the ESA scene which causes scan-related shifts in the scene. The measurements are, however, unable to resolve if the mis-match is caused by errors in band 4 or band 8, or a combination of both. In any case, the errors are of such a magnitude that they introduce significant errors in value-added follow-on products. It will degrade the geometric accuracy in orthorectification, and introduce artefacts and blurriness in pan-sharpened colour products.

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2- Pitch anomalies in system corrected Landsat 7 ETM+ (02-10-2000)

During the processing of three Landsat ETM+ scenes from ESA, problems were encountered with abnormal residuals in the along track direction. The scenes are the following, all produced as system corrected full scenes:

- 195/014 2000-07-27
- 195/015 2000-07-27
- 195/016 2000-07-27

In all three scenes there are very large non-linear scale variations in the along track (pitch) direction. In the cross track (roll) direction, the residual error variation is normal, with no detectable anomalies. Figures 3 and 4 show these effects for the scene 195/015.

The fact that the errors are exactly in the along-track direction, and nothing in the across-track, makes us believe that there is a problem with the pitch compensation in the system corrected scene.

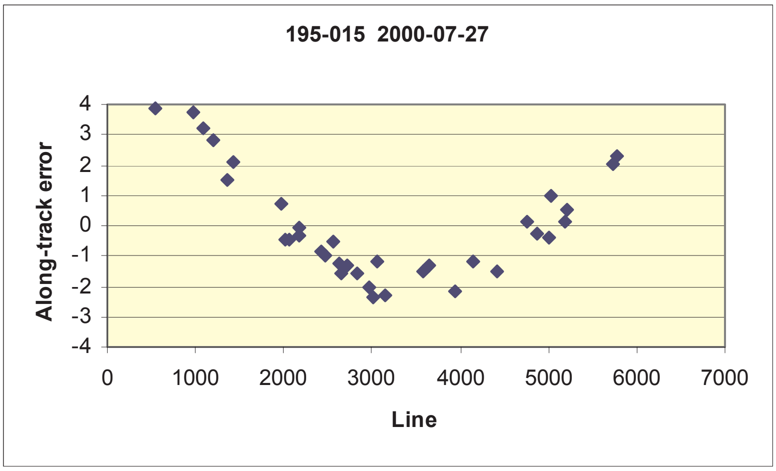

Figure 3. Along-track residual errors (unit = 30m lines)

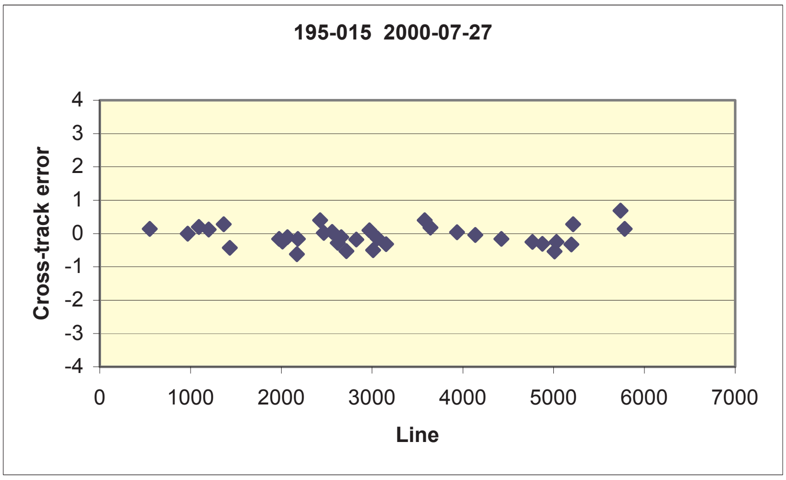

Figure 4 Across track residual errors (unit = 30m)

We also made a comparison between the USGS and ESA products for 195/018 1999-09-11, which have been used for previous tests. Also here we can see a difference, although not as large as above (see fig 5 and 6). In the USGS scene no trend is visible, the residuals are perfectly random. In the ESA scene, there is a clear trend. This trend is almost linear, amounting to about 60 m over the scene height.

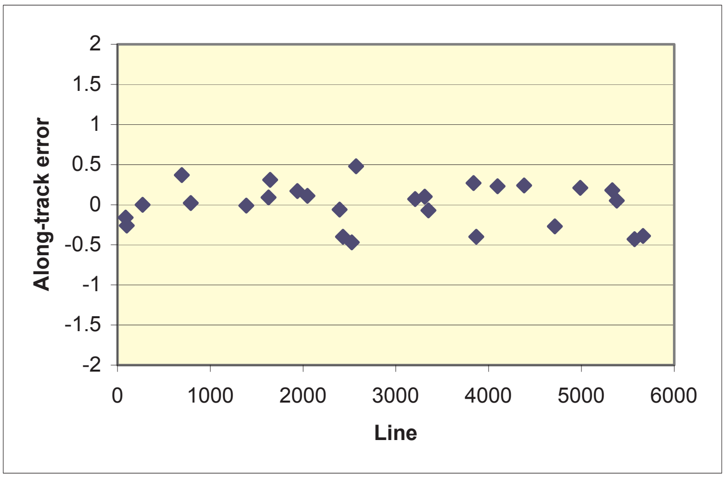

Figure 5- USGS 195/018 Along-track residual errors (unit = 30m lines)

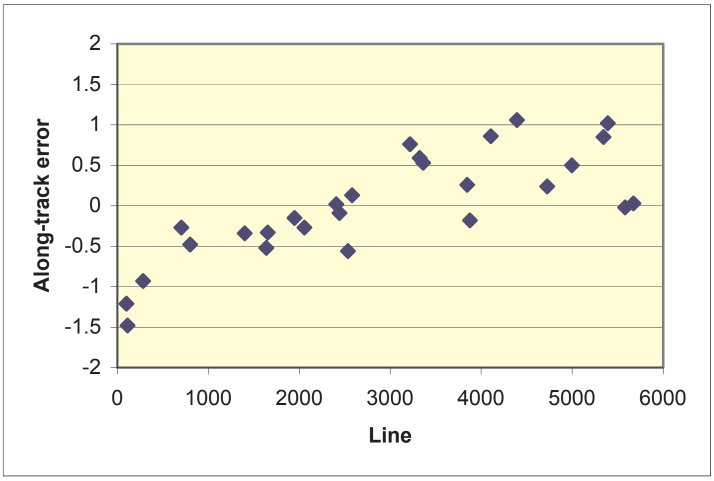

Figure 6- ESA 195/018 Along-track residual errors (unit = 30m lines)

Conclusion

The observed scale variations indicate that there is a problem with the pitch compensation in the system corrected scenes produced by ESA. The reason this was not observed during the testing last spring is that for the scene 195/018 the effect was not so strong. If the hypothesis is correct, the error will vary depending on the actual pitch variations, and the new scenes may be cases were the satellite is experiencing larger pitch variations.

Annex 3: Coordinate Reference Systems

CRS Definition - European Reference		Europe
	Geographic (ETRS89)	**Lambert Conformal Conic (ETRS-LCC)**
CRS name:	ETRS89 with ellipsoidal (geodetic) coordinates	ETRS89 with projected coordinates
CRS remark:		
Projection	Geographic	Lambert Conformal Conic Projection
Projection remark		
parameters		
lower parallel	not applicable	35 0 0
upper parallel	not applicable	65 0 0
longitude of origin	not applicable	10 0 0
latitude of origin	not applicable	52 0 0
False Easting:	not applicable	4000000 m
False Nothing:	not applicable	2800000 m
Ellipsoid/Spheroid:	GRS-80 (New international)	GRS-80 (New international)
parameters		
Ellipsoid semi major axis	6 378 137 m	6 378 137 m
Ellipsoid inverse flattening	298.257222101	298.257222101
Datum name:	ETRS89	ETRS89
Datum shifts to ETRS89	ETRS89	ETRS89
x-translation	0 m	0 m
y-translation	0 m	0 m
z-translation	0 m	0 m
x-rotation	0	0
y-rotation	0	0
z-rotation	0	0
scale	0 ppm	0 ppm
source	EUREF 2001	EUREF 2001
Remarks:	*This system is called ETRS89: European Terrestrial Reference System. ETRS89 was identical to IERS and EUREF, and transformations from one to the other are possible for the most part to an accuracy of 1 cm. There was consensus amongst the experts that this is the system to adopt at European level and several countries have already done so. ETRS89 is now available due to the creation of the EUREF permanent GPS station network and validated EUREF observations. In November 2000 COGI adopted ETRS89, with the underlying GRS80 ellipsoid, as the geodetic datum for the geo-referenced coordinates of its own data. The coordinates to express and store positions related to ETRS89 datum should normally be ellipsoidal (geodetic latitude, geodetic longitude and, if appropriate, ellipsoidal height). COGI-JRC, 2001*	

CRS Definition	Bulgaria – Zone K3; K5; K7; K9
CRS name:	National military reference system 1970
CRS remarks	4 overlapping zones- K3, K5, K7, K9
Projection:	4 Lambert Conformal Conic projections[6]
Scale at central meridian	secret
Longitude of origin	secret
Latitude of origin	secret
False Easting	secret
False Northing	secret
Ellipsoid / Spheroid:	Krassovsky 1940
Ellipsoid semi major axis	6378245 m
Ellipsoid inverse flattening	298.3
Datum name:	
Datum Shifts to ETRS89	secret
x-translation	
y-translation	
z-translation	
x-rotation	
y-rotation	
z-rotation	
Scale	
Source	
Remarks	Parameters remain secret, therefore the plane coordinates are used as local grids.[7]
CRS Definition	**Czech Republic – Zone 3; Zone 4**
CRS name:	S42
Projection:	Transverse Mercator (Gauss-Kruger)
Scale at central meridian	1
Longitude of origin	15 0 0 (zone 3); 21 0 0 (Zone 4)
Latitude of origin	0 00 00
False Easting	3500000 m(Zone 3); 4500000 m(Zone 4)
False Northing	0 m
Ellipsoid / Spheroid:	Krasovsky 1940
Ellipsoid semi major axis	6378245 m
Ellipsoid inverse flattening	298.3
Datum name:	Pulkovo
Datum Shifts to ETRS89*	BursaWolf (Coordinate Frame orientation) (method)
x-translation	-40.2640605120m
y-translation	-11.6984840000 m
z-translation	-54.5953790489 m
x-rotation	-0.0000152998 (-3,15581’’)
y-rotation	-0.0000112188 (-2,31404’’)
z-rotation	0.0000092839 (1,914942’’)
Scale	-0.0000063923 (-6,3923ppm)
Source	CVUT,2001
Remarks	* Datum shifts to ETRS89 and WGS84 are considered to be equal for CLC data purposes.
CRS Definition	**Estonia**
CRS name:	Estonia national projection, Lambert-Est – EE_L-EST97 / EST_LAMB
Projection:	Lambert Conformal Conic Projection with 2 standard paralleis
Scale at central meridian	
Longitude of origin	
Latitude of origin	
False Easting	500 000 m
False Northing	6 375 000 m
Ellipsoid section parallels	Lower parallel: 58°00’ N; Upper parallel: 59°20’ N
Latitude grid origin/zero par	57°31’103.19415’’ N
Longitude grid origin	24°00’ E
Ellipsoid / Spheroid	GRS-80 (New international)
Ellipsoid semi major axis	6 378 137 m

[6] Each zone is defined with a latitude of origin and a scale factor at origin and each zone has a different initial azimuth of the central meridian in order to rotate(and obfuscate) the grid.

[7] Mugnier, Grids & Datums- Republic of Bulgaria, PE&RS, January 2002

Ellipsoid inverse flattening	298.257 222101
Datum name:	ETRS89
Datum Shifts to ETRS89*	L-EST97 is realised through EUREF BAL92. It is entirely consistent with EUREF-89, therefore the transformation parameters to ETRS89 are zero.
x-translation	0m
y-translation	0m
z-translation	0m
x-rotation	0m
y-rotation	0m
z-rotation	0m
Scale	0 ppm
Source	EUREF 2001
Remarks	ETRS89 coordinates are derived from the final solution of EUREF-ESTONIA97 in ITRF96, Epoch 1997.56 by transformation.[8]
CRS Definition	**Hungary**
CRS name:	EOV- Egységes Országos Vetületi renszer (Uniform National Projection System)
Projection:	Oblique-axis reduced mercator projection
Latitude of projecti. centre	47°08'39.817392''
Longitude of project. centre	19°02'54.858408''
Azimuth of initial line	90°00'00''
Angle from rectified to skew grid	90°00'00''
Scale factor on initial line	0.99993
False Easting	650000 m
False Northing	200000 m
Source	Description directory of Hungarian Geodetic Reference, FOMI 1995; European Professional Surveyors Group (EPSG) 1999
Ellipsoid / Spheroid:	IUGG GRS (International 1967)
Ellipsoid semi major axis	6 378 160.000 m
Ellipsoid semi minor axis	6 356 774.516 m
Ellipsoid inverse flattening	298.2471674
Datum name:	HD72
Datum Shifts to ETRS89*	BursaWolf (Coordinate Frame orientation) (method)
x-translation	+52.684 m
y-translation	-71.194 m
z-translation	-13.975 m
x-rotation	+1.51261869 x 10-6 radian (+0.312'')
y-rotation	+5.15356943 x 10-7 radian (+0.1063'')
z-rotation	+1.8078702 x 10-6 radian (+0.3729'')
Correction of Scale	-1.0191 x 10-6
Source	FOMI
Remarks	* Datum shifts to ETRS89 and WGS84 are considered to be equal for CLC data purposes
CRS Definition	**Latvia**
CRS name:	Latvian Coordinate System 92 – LV_LKS92/LV_TM
Projection:	Transverse Mercator
Scale at central meridian	0.9996
Latitude of origin	0 0 0
Longitude of origin	24 0 0
False Easting	500000
False Northing	-6000000
Ellipsoid / Spheroid:	GRS-80 (New International)
Ellipsoid semi major axis	6 378 137 m
Ellipsoid inverse flattening	298.257222101
Datum name:	LKS92
Datum Shifts to ETRS89*	There is no geodetic transformation between ETRS89 and LKS92 datums (geographic and geodetic coordinates), because LV_LKS92 consistent withETRS89
x-translation	0 m
y-translation	0 m
z-translation	0 m

[8] Rüdja, A. 1999. A new ETRS89 realisation for Estonia.In Gubler, E., Torres, J.A.,Hornik,H.(eds): Report on the Symposium of the IAG Subcomission for European Reference Frame (EUREF) held in Prague, June 1999, Veroff. Der Bayer. Komm.für Intern. 1999.

x-rotation	0
y-rotation	0
z-rotation	0
Correction of Scale	0ppm
Source	VDC 2001
Remarks	According to Latvian legislation LKS-92coordinates can be assumed equal to ETRS89 and equal to WGS84 (with differences not >1m).
CRS Definition	**Lithuania**
CRS name:	Lithuania Coordinate System 1994 – LT_LKS94 / LT_TM
Projection:	Transverse Mercator
Scale at central meridian	0.9998
Latitude of origin	0 0 0
Longitude of origin	24 0 0
False Easting	500000 m
False Northing	0 m
Ellipsoid / Spheroid:	GRS-80 (New International)
Ellipsoid semi major axis	6 378 137 m
Ellipsoid inverse flattening	298.257222101
Datum name:	LKS94
Datum Shifts to ETRS89*	There is no geodetic transformation between ETRS89 and LKS94 datums (geographic and geodetic coordinates), because LT_LKS94 consistent withETRS89
x-translation	0 m
y-translation	0 m
z-translation	0 m
x-rotation	0
y-rotation	0
z-rotation	0
Correction of Scale	0 ppm
Source	EUREF 2001
Remarks	*Datum shifts to ETRS89 and WGS84 are considered to be equal for CLC data purposes
CRS Definition	**Malta**
CRS name:	MT- ED50/UTM
Projection:	Universal Transverse Mercator (UTM)- Zone 33
Scale at central meridian	0.9998
Latitude of origin	00 00 00 N
Longitude of origin	15 00 00E
False Easting	500000 m
False Northing	0 m
Ellipsoid / Spheroid:	Hayford 1909 (International 1924)
Ellipsoid semi major axis	6 378 388 m
Ellipsoid inverse flattening	297
Datum name:	European Datum 1950 (ED50)
Datum Shifts to ETRS89*	BursaWolf (Position Vector orientation) (method)
x-translation	-407.7190 m
y-translation	-44.0800 m
z-translation	72.1900 m
x-rotation	0.5366990’’
y-rotation	-11.3248820’’
z-rotation	3.0418360’’
Correction of Scale	-0.9999797334
Source	MT TT 2003
Remarks	
CRS Definition	**Poland**
CRS name:	National Coordinate System 1992
Projection:	Transverse Mercator (Gauss Kruger)
Scale at central meridian	0.9993
Latitude of origin	0 00 00
Longitude of origin	19 00 00
False Easting	500000 m
False Northing	-5300000 m
Ellipsoid / Spheroid:	GRS-80 (New International)
Ellipsoid semi major axis	6 378 137 m
Ellipsoid inverse flattening	298.257222101
Datum name:	PL_EUREF89

Datum Shifts to ETRS89*	Refers to ETRS89: not necessary because PL_EUREF89 consistent with ETRS89
x-translation	0 m
y-translation	0 m
z-translation	0 m
x-rotation	0
y-rotation	0
z-rotation	0
Correction of Scale	0 ppm
Source	EUREF 2001
Remarks	Agreement for publishing transformation parameters for an accuracy of coordinates of 1.0m
CRS Definition	**Romania- Zone 4, Zone 5**
CRS name:	S42
Projection:	Transverse Mercator (Gauss Kruger)
Scale at central meridian	1
Latitude of origin	0 00 00
Longitude of origin	21 0 0 (Zone 4); 27 0 0 (Zone 5)
False Easting	4500000 m (Zone 4); 5500000 m (Zone 5)
False Northing	0 m
Ellipsoid / Spheroid:	Krasovsky 1940
Ellipsoid semi major axis	6378245 m
Ellipsoid inverse flattening	298.3
Datum name:	Pulkovo
Datum Shifts to ETRS89*	Geometric translation (method)
x-translation	+28 m
y-translation	-121 m
z-translation	-77 m
x-rotation	
y-rotation	
z-rotation	
Correction of Scale	
Source	NIMA,1997
Remarks	NIMA lists transformation from System 42 in Romania to WGS84 Datum as DX= 28m±3m, DY= -121m±3m. This is based on four collocated points computed in 1997.[9]
CRS Definition	**Slovakia- Zone 3, Zone 4**
CRS name:	S42
Projection:	Transverse Mercator (Gauss Kruger)
Scale at central meridian	1
Latitude of origin	0 00 00
Longitude of origin	15 0 0 (Zone 3); 21 0 0 (Zone 4)
False Easting	3500000 m (Zone 3); 4500000 m (Zone4);
False Northing	0 m
Ellipsoid / Spheroid:	Krasovsky 1940
Ellipsoid semi major axis	6378245 m
Ellipsoid inverse flattening	298.3
Datum name:	Pulkovo
Datum Shifts to ETRS89*	Geometric translation (method)
x-translation	25 m
y-translation	-120 m
z-translation	-80 m
x-rotation	
y-rotation	
z-rotation	
Correction of Scale	
Source	
Remarks	S42<>WGS84 dX, dY, dZ=25 m,-120m,-80m rotation and scale is not considered, according Hefty, Frohman STU Bratislava referred in Mojzes, Kalafut, Bansky: Geocentrick suradnicovy system a GIS. Proceed 11 Kartograficka Konferencia, Bratislava 1995
CRS Definition	**Slovenia**
CRS name:	State Coordinate System D48 – SI_D48/SI_TM
Projection:	Transverse Mercator (Gauss Kruger)
Scale at central meridian	0.9999

[9] Mugnier, Grids&Datums- Romania, PE&RS, May 2001.

Latitude of origin	0 00 00
Longitude of origin	15 0 0
False Easting	500000
False Northing	-5000000
Ellipsoid / Spheroid:	Bessel 1841
Ellipsoid semi major axis	6 377 397.155 m
Ellipsoid inverse flattening	299.15281285
Datum name:	D48
Datum Shifts to ETRS89*	BursaWolf (Position Vector orientation) (method)
x-translation	+426.9 m
y-translation	+142.6 m
z-translation	+460.1 m
x-rotation	+4.91''
y-rotation	+4.49''
z-rotation	-12.42''
Correction of Scale	+17.1ppm
Source	EUREF 2001
Remarks	Agreement for publishing transformation parameters- tested with 11 identical points, accuracy is verified about 1 m horizontal position and height (with ellip. Heights only).
CRS Definition	**Austria**
CRS name:	LCC_MGI datum
Projection:	Lambert Conformal Conic
Longitude of grid origin	13 20 00 E
Latitude of grid origin	47 30 00 N
1st standard parallel	46 00 00 N
2nd standard parallel	49 00 00 N
False Easting	400000 m
False Northing	400000 m
Ellipsoid / Spheroid:	Bessel 1841
Ellipsoid semi major axis	6 377 397.155 m
Ellipsoid inverse flattening	299.15281285
Datum name:	Militargeographiches Institut (MGI) Datum reference point Austria, Hermannskogel, Habsburgwarte, Lat=48°16'15.2900'' N, Lon=16°17'41.0600''E (wrt. Greenwich).
Datum Shifts to ETRS89*	BursaWolf (Position Vector orientation) (method)
x-translation	577.326
y-translation	90.129
z-translation	463.919
x-rotation	+5.137''
y-rotation	+1.474''
z-rotation	+5.297''
Correction of Scale	+2.42 ppm
Source	BKG 2003
Remarks	Agreement to publish transformation parameters for an accuracy of coordinates about 1.5m
CRS Definition	**Belgium**
CRS name:	BE_BD72 / LAMB7 2
Projection:	Lambert Conformal Conic with 2 standard parallels
Longitude of grid origin	4 22 2.952 E
Latitude of grid origin	90 00 00 N
1st standard parallel	49 500.00204 N
2nd standard parallel	51 100.00204 N
False Easting	150 000.01256 m
False Northing	5400088.438
Ellipsoid / Spheroid:	Hayford 1909 (International 1924)
Ellipsoid semi major axis	6 378 388 m
Ellipsoid inverse flattening	297
Datum name:	Belgium Datum 72(BD/2). Anchor point: Belgium, Brüssel,Royal Observatory, Ukkel, Lat= 50°47' 57.704'' N; Lon= 04° 21' 24.983'' E
Datum Shifts to ETRS89*	Method Bursa-Worlf (Position Vector)
x-translation	-99.059 m
y-translation	+53.322 m
z-translation	-112.486 m
x-rotation	0.419''
y-rotation	-0.830''
z-rotation	1.885''

Correction of Scale	-1.00 ppm
Source	BKG, 2003
Remarks	Agreement for publishing the transformation parameters for an accuracy of coordinates of about 0.3 m
CRS Definition	**Germany**
CRS name:	DE_DHDN / GK_3-Datum DHDN
Projection:	Transverse Mercator (Gauss-Krüger)
Scale at central meridian	1
Latitude of origin	00 00 00 N
Central meridian	06 00 00 E (Zone 2); 09 00 00 E (Zone 3); 12 00 00 E(Zone 4); 15 00 00 E(Zone 5)
False Easting	2500000 m (Zone 2); 3500000 m(Zone 3); 4500000 m(Zone 4); 5500000 m(Zone 5)
False Northing	0 m
Ellipsoid / Spheroid:	Bessel 1841
Ellipsoid semi major axis	6 377 397.155 m
Ellipsoid inverse flattening	299.15281285
Datum name:	Deutsches Hauptdreiecksnetz (DHDN) alias Rauenberg Datum or Potsdam Datum anchor point: Germany, Rauenberg, Lat=52°27'12.021'' N; Lon=13°22'04.928'' E
Datum Shifts to ETRS89*	Method Bursa-Worlf (Position Vector)
x-translation	+598.1 m
y-translation	+73.7 m
z-translation	+418.2 m
x-rotation	+0.202''
y-rotation	+0.045''
z-rotation	-2.455''
Correction of Scale	+6.70 ppm
Source	BKG 2003
Remarks	Agreement for publishing transformation parameters for accuracy of coordinates of 3 m.
CRS Definition	**Denmark**
CRS name:	DK_ED50 / UTM – Datum ED50 with UTM Projection (one zone extended)
Projection:	Universal Transverse Mercator (UTM)- Zone 32 and Zone 33
Scale at central meridian	0.9996
Latitude of origin	00 00 00 N
Central meridian	09 00 00 E (Zone 32); 15 00 00 E (Zone 33)
False Easting	500000
False Northing	0
Ellipsoid / Spheroid:	Hayford 1909 (International 1924)
Ellipsoid semi major axis	6 378 388 m
Ellipsoid inverse flattening	297
Datum name:	European Datum 1959 (ED50), anchor point: ED50 – Germany, Potsdam, Helmert-Tower, Lat=52°22'51.4456'' N, Lon=13°03'58.9283'' E
Datum Shifts to ETRS89*	Method Bursa-Worlf (Position Vector)
x-translation	-81.1 m
y-translation	-89.4 m
z-translation	-115.8 m
x-rotation	+0.485''
y-rotation	+0.024''
z-rotation	+0.413''
Correction of Scale	-0.54 ppm
Source	BKG 2001
Remarks	Agreement for publishing transformation parameters for accuracy of coordinates of 1 m.
CRS Definition	**Spain**
CRS name:	ES_ED50 / UTM- Datum ED50 with UTM Projection
Projection:	Universal Transverse Mercator (UTM)- Zone 28, Zone 29, Zone 30, Zone 31
Scale at central meridian	0.9996
Latitude of origin	00 00 00 N
Central meridian	-15 00 00 E (15 00 00W) Zone 28; -09 00 00 E (09 00 00W) Zone 29; -03 00 00 E (03 00 00W)Zone 30; 03 00 00 E Zone 31
False Easting	500000 m
False Northing	0 m
Ellipsoid / Spheroid:	Hayford 1909 (International 1924)
Ellipsoid semi major axis	6 378 388 m
Ellipsoid inverse flattening	297
Datum name:	European Datum 1950 (ED50) anchor point:ED50- German, Potsdam, Helmert-Tower, Lat=52°22'51.4456'' N, Lon=13°03'58.9283'' E

Datum Shifts to ETRS89*	Method Bursa-Wolf (Rotation are positive counterclockwise-Coordinate Frame)
x-translation	-131.032 m
y-translation	-100.251 m
z-translation	-163.354 m
x-rotation	+1.2438’’
y-rotation	+0.0195’’
z-rotation	+1.1436’’
Correction of Scale	9.39 ppm
Source	National Geographic Institute- Spain (Geodesic Department), 2004
Remarks	Agreement for publishing transformation parameters for accuracy of coordinates of 1 m.
CRS Definition	**Finland**
CRS name:	FI_KKJ / _TM- Datum KKJ in Transverse Mercator Projection with Finnish parameters
Projection:	Transverse Mercator
Scale at central meridian	1.000
Latitude of origin	00 00 00 N
Central meridian	27 00 00 E
False Easting	3500000 m
False Northing	0 m
Ellipsoid / Spheroid:	Hayford 1909 (International 1924)
Ellipsoid semi major axis	6 378 388 m
Ellipsoid inverse flattening	297
Datum name:	Kartastokoordinaattijarjestelma (KKJ)
Datum Shifts to ETRS89*	Method Bursa-Worlf (Position Vector)
x-translation	-90.7 m
y-translation	-106.1 m
z-translation	-119.2 m
x-rotation	+4.090’’
y-rotation	+0.218’’
z-rotation	-1.050’’
Correction of Scale	+1.37 ppm
Source	BKG 2001
Remarks	Agreement for publishing transformation parameters for accuracy of coordinates of 1 m. (mean unit weight, max. residuals 2m).
CRS Definition	**France**
CRS name:	FR_NTF / FR_LAMB- Datum NTF in Lambert Projection with French parameters.
Projection:	Lambert Conformal Conic
Central meridian	2 20 14.025 E
Latitude of origin	46 48 00.00 N
1st standard parallel	45 53 56.108 N
2nd standard parallel	47 41 45.652 N
False Easting	600000 m
False Northing	2200000 m
Ellipsoid / Spheroid:	Clarke 1880 IGN
Ellipsoid semi major axis	6 378 249.2 m
Ellipsoid inverse flattening	293.4660213
Datum name:	Nouvelle Triangulation de la France (NTF) anchor point: France, Paris, Pantheon, Lat=48°50’46.52’’ N, Lon=02°20’48.67’’ E
Datum Shifts to ETRS89*	Geocentric translation
x-translation	-168 m
y-translation	-60 m
z-translation	+320 m
x-rotation	0.0
y-rotation	0.0
z-rotation	0.0
Correction of Scale	0.0
Source	BKG 2001
Remarks	Agreement for publishing transformation parameters for accuracy of coordinates of 2 m
CRS Definition	**Greece**
CRS name:	GR_GGRS87 / GR_TM- Datum GGRS87 in TM Projection with Greek parameters
Projection:	Transverse Mercator (Gauss Krüger)
Scale at central meridian	0.9996
Latitude of origin	00 00 00 N
Central meridian	24 00 00 E
False Easting	500000 m

False Northing	0 m
Ellipsoid / Spheroid:	GRS80 (New International)
Ellipsoid semi major axis	6 378 137 m
Ellipsoid inverse flattening	298.257222101
Datum name:	Greek Geodetic Reference System 1987 (GGRS87) anchor point: Greece, Dionysos Lat=38°04'33.8107'' N, Lon=23°55'51.0095'' E
Datum Shifts to ETRS89*	Method Bursa-Worlf (Coordinate Frame)
x-translation	-199.799
y-translation	74.281
z-translation	246.545
x-rotation	+4.97212e-06
y-rotation	-1.38884e-07
z-rotation	-1.860967e-06
Correction of Scale	-1.7e-08 (-0.017ppm)
Source	GREECENT 2004
Remarks	The accuracy in the determination of coordinates is below 1 m.
CRS Definition	**Ireland**
CRS name:	IE_IRELAND65 / IRELAND75_IRISHGRID- Datum Ireland65 in TM with Irish parameters
Projection:	Transverse Mercator
Scale at central meridian	1.000035
Latitude of origin	53 30 00 N
Central meridian	-08 00 00 E (08 00 00 W)
False Easting	200000 m
False Northing	250000 m
Ellipsoid / Spheroid:	Airy Modified
Ellipsoid semi major axis	6 377 340.189 m
Ellipsoid inverse flattening	299.32496460
Datum name:	IRELAND65
Datum Shifts to ETRS89*	Method Bursa-Worlf (Position Vector)
x-translation	+482.5 m
y-translation	-130.6 m
z-translation	+564.6 m
x-rotation	-1.042''
y-rotation	-0.214''
z-rotation	-0.631''
Correction of Scale	+8.15 ppm
Source	BKG 2001
Remarks	Agreement for publishing transformation parameters tested with 4 identical points without heights, accuracy is reached of about 1 m for horizon position.
CRS Definition	**Italy**
CRS name:	WGS84 / UTM
Projection:	Universal Transverse Mercator
Scale at central meridian	0.9996
Latitude of origin	00 00 00
Central meridian	09 00 00 E
False Easting	500000 m
False Northing	0 m
Ellipsoid / Spheroid:	WGS84
Ellipsoid semi major axis	6 378 137.0
Ellipsoid inverse flattening	298.257223563
Datum name:	WGS84
Datum Shifts to ETRS89*	
x-translation	0
y-translation	0
z-translation	0
x-rotation	0
y-rotation	0
z-rotation	0
Correction of Scale	0
Source	geoLAB- Laboratorio gi Geomatica, 2003
Remarks	
CRS Definition	**Luxembourg**
CRS name:	LU_LUREF / LU_TM- Datum LUREF in TM with Luxembourgian parameters
Projection:	Transverse Mercator (Luxembourg Gauss)

Scale at central meridian	1
Latitude of origin	49 50 00.0 N
Central meridian	06 10 00.0 E
False Easting	80000 m
False Northing	100000 m
Ellipsoid / Spheroid:	Hayford 1909 (International 1924)
Ellipsoid semi major axis	6 378 388 m
Ellipsoid inverse flattening	297
Datum name:	LUREF anchor point: Belgium, Northern Station of the baseline near Habay-la-Neuve. Lat=49°43'24.408'' N; Lon=5°38'22.470'' E
Datum Shifts to ETRS89*	Method Bursa-Worlf (Position Vector)
x-translation	-193.0 m
y-translation	+13.7 m
z-translation	-39.3 m
x-rotation	-0.410''
y-rotation	-2.933''
z-rotation	+2.688''
Correction of Scale	+0.43 ppm
Source	BKG 2001
Remarks	Transformation parameters are verified only for horizontal position with accuracy of <1 m
CRS Definition	**Netherlands**
CRS name:	NL_RD / DUTCH_ST- Datum RD with Dutch Stereographic Projection
Projection:	Oblique Stereographic
Scale at central meridian	0.9999079
Latitude of origin	52 09 22.17 N
Central meridian	05 23 15.5 E
False Easting	155000 m
False Northing	463000 m
Ellipsoid / Spheroid:	Bessel 1841
Ellipsoid semi major axis	6 377 397.155 m
Ellipsoid inverse flattening	299.15281285
Datum name:	Rijksdriehoeks Datum, anchor point: Netherlands, Onze Lieve Vrouwetoren, Amersfoort, Lat=52°09'22.178'' N; Lon=05°23'15.500'' E
Datum Shifts to ETRS89*	Method Bursa-Worlf (Position Vector)
x-translation	+565.04 m
y-translation	+49.91 m
z-translation	+465.84 m
x-rotation	-0.4094''
y-rotation	+0.3597''
z-rotation	-1.8685''
Correction of Scale	+4.0772 ppm
Source	BKG 2001
Remarks	Agreement for publishing transformation parameters for accuracy of coordinates of 0.3 m
CRS Definition	**Portugal**
CRS name:	PT_DLX(HAY) / TM_DLX- Datum DLX referring to Hayford in Transverse Mercator Projection with Portuguese parameters for Datum DLX
Projection:	Transverse Mercator (Gauss Krüger).
Scale at central meridian	1
Latitude of origin	39 40 00.00 N
Central meridian	-80 07 54.862 E (08 07 54.862 W)
False Easting	200000 m
False Northing	300000 m
Ellipsoid / Spheroid:	Hayford 1909 (International 1924)
Ellipsoid semi major axis	6 378 388 m
Ellipsoid inverse flattening	297
Datum name:	Castelo de S. Jorge (Lisbon), anchor point: Lat=38°42'43.631'' N, Lon=09°07'54.8446'' W
Datum Shifts to ETRS89*	Method Bursa-Worlf (Position Vector)
x-translation	-282.1 m
y-translation	-72.2 m
z-translation	+120.0 m
x-rotation	-1.529''
y-rotation	+0.145''
z-rotation	-0.890''
Correction of Scale	-4.46 ppm

Source	BKG 2001
Remarks	For applications to an accuracy of 2 m.
CRS Definition	**Portugal- Zone 25, Zone 26, Zone 28**
CRS name:	PT_AZO_OCCI / UTM
Projection:	Universal Transverse Mercator (UTM)- zone 25, zone 26, zone 28
Scale at central meridian	0.9996
Latitude of origin	00 00 00
Central meridian	-33 00 00 Zone 25, -27 00 00 Zone 26, -15 00 00 Zone 28
False Easting	500000 m
False Northing	0 m
Ellipsoid / Spheroid:	Hayford 1909 (International 1924)
Ellipsoid semi major axis	6 378 388 m
Ellipsoid inverse flattening	297
Datum name:	AZO_CEN-Graciosa Base SW, Portugal, Azores, Central Islands
Datum Shifts to ETRS89*	Method Bursa-Worlf (Coordinate Frame Rotation)
x-translation	-103.088 m
y-translation	162.481 m
z-translation	-28.276 m
x-rotation	-0.167’’
y-rotation	-0.082’’
z-rotation	-0.168’’
Correction of Scale	-1.504 ppm
Source	Centre for Geodesy and Cartography, Portuguese Geographical Institute
Remarks	
CRS Definition	**Sweden**
CRS name:	SE_RT90 / SE_TM- Datum RT90 in Transverse Mercator with Swedish parameters
Projection:	Transverse Mercator
Scale at central meridian	1.0
Latitude of origin	00 00 00 N
Central meridian	15 48 29.8 E
False Easting	1500000 m
False Northing	0 m
Ellipsoid / Spheroid:	Bessel 1841
Ellipsoid semi major axis	6 377 397.155 m
Ellipsoid inverse flattening	299.15281285
Datum name:	RT90
Datum Shifts to ETRS89*	Method Bursa-Worlf (Position Vector)
x-translation	+414.1 m
y-translation	+41.3 m
z-translation	+603.1 m
x-rotation	-0.855’’
y-rotation	+2.141’’
z-rotation	-7.023’’
Correction of Scale	0
Source	BKG 2003
Remarks	Agreement for publishing transformation parameters for accuracy of coordinates of 0.1 m, with full digits.
CRS Definition	**United Kingdom**
CRS name:	GB_OSGB36 / NATIONALGRID- Datum OSGB36 in Transverse Mercator Projection with UK parameters.
Projection:	Transverse Mercator
Scale at central meridian	0.9996012717
Latitude of origin	49 00 00 N
Central meridian	-02 00 00 E (02 00 00 W)
False Easting	400000 m
False Northing	-100000 m
Ellipsoid / Spheroid:	Airy
Ellipsoid semi major axis	6 377 563.3960 m
Ellipsoid inverse flattening	299.324964594
Datum name:	OSGB36, anchor point: no initial point, defined by the position of 11 stations from the Principal Triangulation (1783-1853)
Datum Shifts to ETRS89*	Method Bursa-Worlf (Position Vector)
x-translation	+446.4 m
y-translation	-125.2 m

z-translation	+542.1 m
x-rotation	+0.150''
y-rotation	+0.247''
z-rotation	+0.842''
Correction of Scale	-20.49 ppm
Source	BKG 2003
Remarks	Agreement for publishing transformation parameters for accuracy of coordinates of 5 m.[10]

[10] OSGB36 is an inhomogeneous system by modern standard, generally accuracy 2 m, in some areas it is no better than 5 m. see www.gps.gov.uk for a more accurate transformation in 1km grid areas (registration for internal auditing purposes necessary)