

D01.02.01 Land cover maps for environmental modelling at multiple spatial scales

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Integrated Project

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Document Abstract

As described in the ECOCHANGE proposal, Task01.02.02 “Map production and aggregation”, two major products are generated within this WP. Firstly, land cover maps at high spatial resolutions will be produced for the European Union and for the reference years of 1960, 1990 and 2000. Secondly, thematic and spatial aggregated products will be derived at coarser spatial resolutions in order to synthesize the fragmentation and variability within coarser cells for biodiversity assessment and modelling. The name of the official deliverable is D01.02.01 “Land cover maps for environmental modelling at multiple scales” and includes this report, the digital land cover products and an interactive website to view the data at all thematic and spatial scales.

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1. Introduction

Background

The research presented is carried out under the ECOCHANGE project (FP6-036866) which is funded by the FP6 'Global Change and Ecosystems' programme (priority 6.3). This programme has the clear objective to assess and forecast changes in terrestrial biodiversity and ecosystems and changes in the ability of biodiversity and ecosystems to supply goods and services and to buffer them against climate and land use change. This will be made possible in ECOCHANGE by concentrating on improvements in three major areas, namely:

- the ability to predict biodiversity and species distribution patterns at a range of spatial scales sensitive to climate, land use and landscape structure
- the simulation of ecosystem processes and responses to a range of scenarios enabling the forecasting of expected changes in the biome distribution and its functioning, and
- the assessment of consequences of global change for ecosystems and plant species to provide goods and services to the population of the European Community.

Environmental protection became a major concern and challenge of the European Community. The European Commission (EC) needed good quality information on the state of the environment and natural resources to ensure an efficient implementation of European community policy. It was against this background that the CORINE (COoRdination of INformation on the Environment) programme was initiated by the European Commission (EC). Under the umbrella of this programme a land cover database (CLC1990) was created on basis of a common methodology and with a harmonized nomenclature.

Land cover is changing rapidly in many parts of Europe, particularly in areas with a high population density. The knowledge on these land cover changes is important for spatial planning, resource evaluation, ecological modelling etc. Furthermore, spatio-temporal models that describe and predict land cover change due to social and economic processes need reliable information on land cover changes in order to calibrate and validate these models (Kaufman and Seto, 2001). Against this background a new CLC database for the year 2000 was created together with a database containing the changes between CLC1990 and CLC2000. Both databases form the basis for the Pan-European Land Cover Mosaics (**PLCM1990** and **PLCM2000**) presented in this report. Besides, a database was created reflecting the land cover in Europe for 1960. This database helps in a better understanding of the major land cover changes in Europe.

These land cover databases are of special interest for further research to be carried out within the ECOCHANGE project. The land cover databases will be used as:

1. Input for land use scenario's;
2. Input for refined classifications into ecological meaningful classes (forest and grassland ecosystems);
3. Input for assessments on land cover fragmentation and associated habitats and/or PFT at landscape level;
4. Basis for the definition/derivation of landscape characteristics that can be the input for further modeling;
5. Framework for extrapolating modeling results.

Objective

The report describes the work carried out in the work package 1.2 ‘Remote Sensing based land cover and land use’ of the ECOCHANGE project. The main objectives of this work package are to assemble advanced land cover/use maps for 3 time steps (reference years of 1960, 1990, 2000) based on recently developed methodologies optimized for environmental modelling and assessment.

The document describes how the Pan-European Land Cover mosaics of 1960, 1990 and 2000 at different thematic and spatial detail were produced and what their specific characteristics are. In addition, the land cover changes between the mosaics of 1990 and 2000 and between 1960 and 1990 are discussed.

Boundary conditions

The spatial reference is extensively described in the document called ‘Analytical Protocol’ (*Analytical_protocol_WP1.2-version2.doc*). The land cover datasets described and produced in ECOCHANGE have to meet the requirements mentioned in the protocol. The geographic focus of the ECOCHANGE project is at least EU27+2 (including Norway and Switzerland (see Figure 1 and Table 1), with special emphasis on the alpine and arctic biogeographic regions.

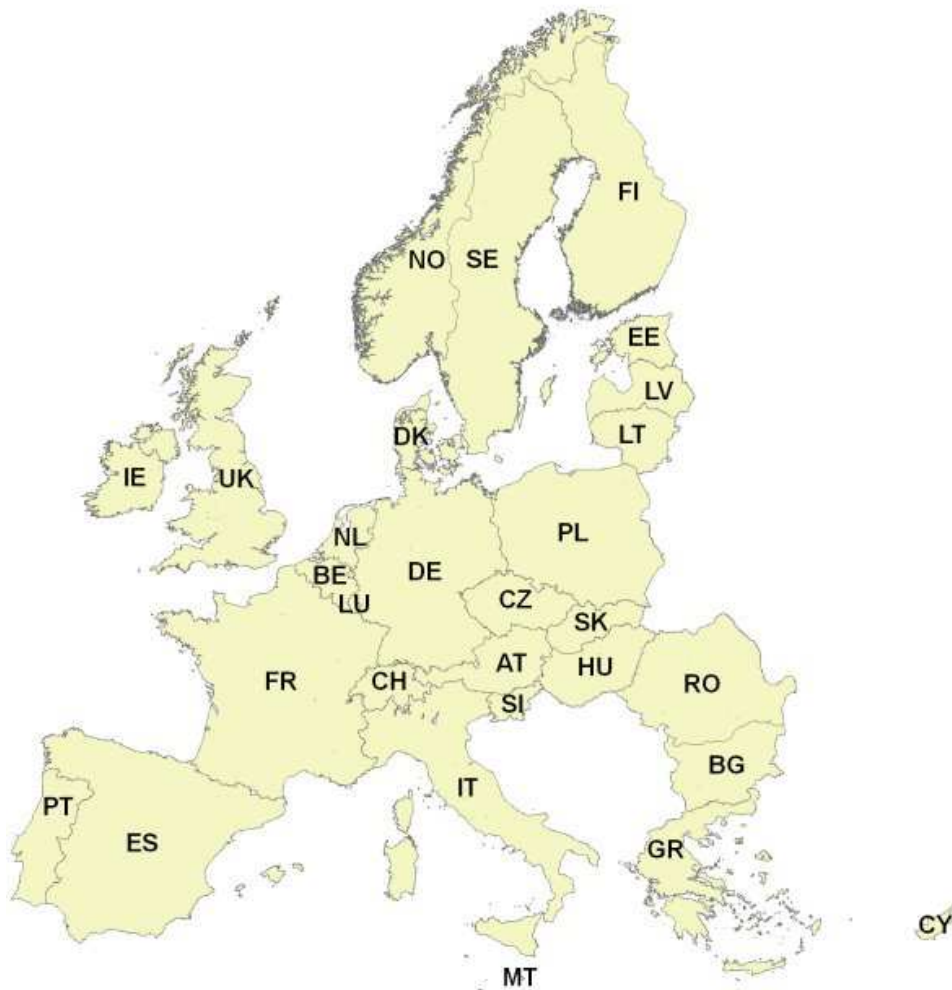


Figure 1. Minimal spatial extent of ECOCHANGE.

Table 1. Countries at least included in the extent of ECOCHANGE.

Code	Country Name	Code	Country Name
AT	Austria	IT	Italy
BE	Belgium	LT	Lithuania
BG	Bulgaria	LU	Luxembourg
CH	Switzerland	LV	Latvia
CY	Cyprus	MT	Malta
CZ	Czech Republic	NL	Netherlands
DE	Germany	NO	Norway
DK	Denmark	PL	Poland
EE	Estonia	PT	Portugal
ES	Spain	RO	Romania
FI	Finland	SE	Sweden
FR	France	SI	Slovenia
GR	Greece	SK	Slovak Republic
HU	Hungary	UK	United Kingdom
IE	Ireland		

The land cover mosaics will preferably have a Pan-European coverage which means that the spatial extent will be increased to Albania, Andorra, Belarus, Bosnia-Herzegovina, Croatia, Iceland, Kosovo, Liechtenstein, Macedonia, Moldavia, San Marino, Serbia and Montenegro, parts of Russia, Turkey and Ukraine. All land cover datasets need to have the INSPIRE standard projection for Europe, namely the lambert azimuthal equal are projection, called “ETRS_1989_LAEA”. For more details on the project parameters, see Annex I. The land cover datasets should be produced at a 100m resolution and aggregated to 500m and 1km resolutions. The maximum level of thematic detail is defined by the CORINE Land Cover (CLC) nomenclature at level 3. Thematic aggregations into CLC level 2, HISLU60 and ALARM classes are needed to make change statistics between 1960 and 1990 and to use the land cover data in land use modeling scenarios, respectively. In a later stage it can be decided to translate the data into Plant Functional Types (PFT) with the use of additional Remote Sensing time series. In the production process of the Pan-European land cover mosaics special focus is on the grassland and forest ecosystems.

Content of report

Chapter 2 ‘Data’ presents the different land cover data sets used in the compilation of the Pan-European Land Cover mosaics (PLCM-mosaics) of 1990 and 2000. These are amongst others the CORINE land cover data sets, PELCOM, GLC2000, and some national land cover data sets. The World Atlas of Agriculture which was used for the newly established **HISLU60** (Historical Land Use in 1960) are also introduced in this section.

Chapter 3 ‘Method’ deals with the processing of the different land cover datasets and the integration of these land cover data into Pan-European Land Cover mosaics of 1990 and 2000. Also, the methodology of spatial and thematic up-scaling of the **PLCM1990** and **PLCM2000** datasets into aggregated spatial and thematic datasets is presented.

Chapter 4 ‘Products’ presents the characteristics and statistics of the different land cover mosaics. In order of decreasing levels of thematic detail the mosaics at CLClevel3, CLC-level2, ALARM and HISLU are discussed. In case of spatial detail, it will be in the order of 100m, 500m and 1km spatial resolution.

Chapter 5 discusses the quality of the various data sets and chapter 6 discusses the quality of the identified land cover changes. Chapter 7 presents the outlook to the future.

2. Data

The following land cover data sources were identified within the framework of the project.

1. CORINE Land Cover 2000 (CLC2000)
2. CORINE Land Cover 1990 (CLC90)
3. CLCchange₉₀₋₀₀
4. PELCOM
5. GLC2000
6. HISLU60 (developed within ECOCHANGE)
7. AR2000 (Norwegian land cover dataset)
8. CH97 and CH85 (Swiss land cover datasets for the years 1985 and 1997 at CLC-level2)

CORINE Land Cover (CLC)

The CORINE (CO-ordination of INformation on the Environment) programme was initiated by the EU in 1985. A number of databases were created within this framework with the aim to give information on the status and changes of the environment. One of these databases is the CORINE Land Cover database (CLC). The reference year for this database is 1990 (range 1986 – 1995) and its geographical extent covers 24 countries (Annex II and Figure 2). The land cover information is derived from high resolution satellite data (Landsat-TM) by computer assisted visual interpretation in combination with ancillary data. The final CLC database consists of a geographical database describing land cover/use in 44 classes grouped into a three level hierarchical structure. The CORINE land cover nomenclature has 5 major categories at the first level, 15 land cover categories at the second level and 44 categories at the third level (Annex III). In Bossard et al. (2000) an extensive description is given for each CORINE land cover class, including detailed descriptions with particularities, inclusions and exclusions, photo's, and visual interpretation characteristics. The minimum mapping unit is 25ha and for line elements the minimum width is 100m. The scale of the land cover database is 1:100.000 (Heymann et al., 1994).

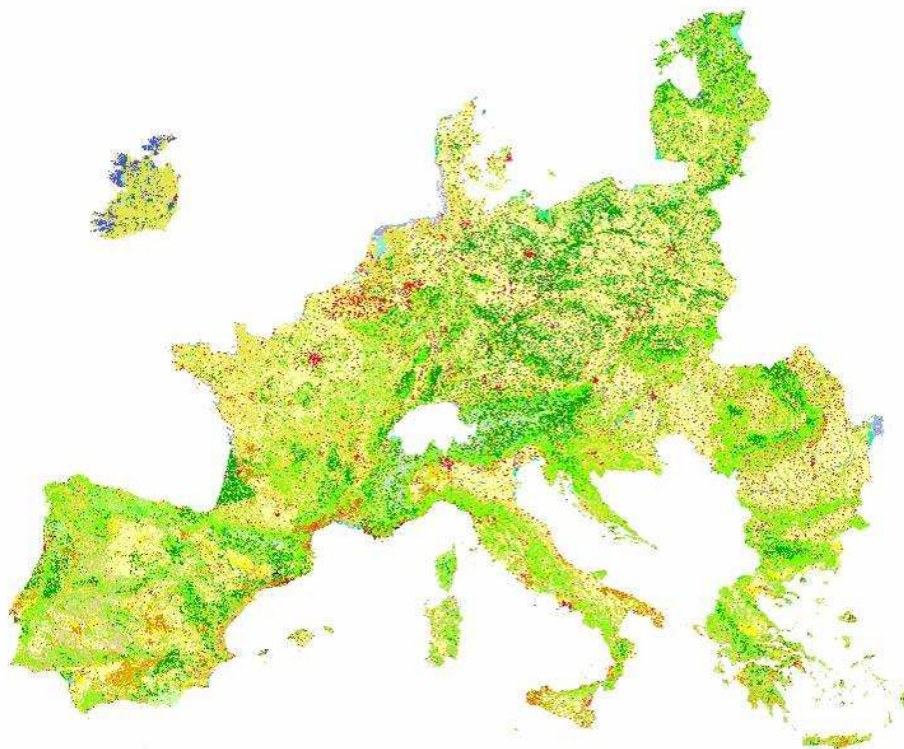


Figure 2. The geographical extent of CLC1990

The I&CLC2000 project (IMAGE2000 and CLC2000) started in 2000 with the ortho-rectification of Landsat 7 ETM+ satellite images. A new version of the CLC database for the reference year 2000 is based on those images (CLC2000). A technical and methodological guide for updating the CORINE Land Cover database helped with the unambiguous implementation of the project (Perdigao & Annoni, 1997). The focus of CLC2000 were land cover changes (>5ha) between 1990 and 2000. The report 'IMAGE2000 & CLC2000. Products and Methods' (Nunes de Lima, 2005) describes in detail all specifications of Image2000 & CLC2000. See also Büttner et al. (2004) and Feranec et al (2007a) for more details on the computer aided visual interpretation, geometrical and thematic correction/revision of CLC1990, and the change detection methods.

The result of CLC2000 project was a revised version of the CORINE Land Cover database 1990 (*CLC1990rev*), a CORINE Land Cover database 2000 (*CLC2000*) and a change database (*CLC-change 90-00*) containing all land cover changes larger than 5ha between 1990 and 2000. The CLC2000 database has an extended geographical coverage compared to CLC1990 as it includes 34 countries (see Annex II and Figure 3). The change database has a limited geographical coverage (25 countries) as the extend of CLC1990 was limited to 24 countries, i.e. all CLC90 countries and United Kingdom. The change database consists of attributes indicating the land cover of the 1990's and 2000. Two methodologies for generating the change database $clc90+changes = clc2000$ or $clc2000-clc90= changes$ were applied (Büttner et al., 2004 and Feranec et al, 2007b).



Figure 3. The geographical extent of CLC2000.

Assessment of the thematic accuracy of CLC2000 by using LUCAS (land use/cover area frame statistical survey) revealed that the accuracy requirement of 85% was fulfilled. At individual class level there were differences ranging from > 95% (rivers, lakes, industrial and commercial units and discontinuous urban fabric) to < 70% (sparse vegetation) (Büttner & Maucha, 2006).

Currently, the CLC2006 programme is running with the focus on land cover changes between 2000 and 2006. The methodology is comparable with the CLC2000 update; computer aided visual interpretation of changes larger than 5ha. The integration of land cover changes with CLC2000 will result in CLC2006. The CLC-change 00-06 database and CLC2006 will hopefully be ready at the end of 2008.

Global Land Cover of the year 2000 (GLC2000)

The global land cover data for the year 2000 (GLC2000) project, coordinated by the European Joint Research Centre (JRC), provides consistent global land cover information for the year 2000. The GLC2000 project followed a bottom-up approach to map world's land cover. The global land cover map was derived by merging 18 regional products made by regional experts. Consistency between the regional products was derived by classifying SPOT4-Vegetation dataset (spatial resolution 1km) and applying the land cover classification system (LCCS) produced by the United Nations (UN) (Di Gregorio, 2005). After harmonization and merging the individual regional products one global GLC2000 product with a generalized legend was produced (Bartholomé and Belward, 2005). The GLC2000 database has 23 classes (see Annex IV) and Figure 4.

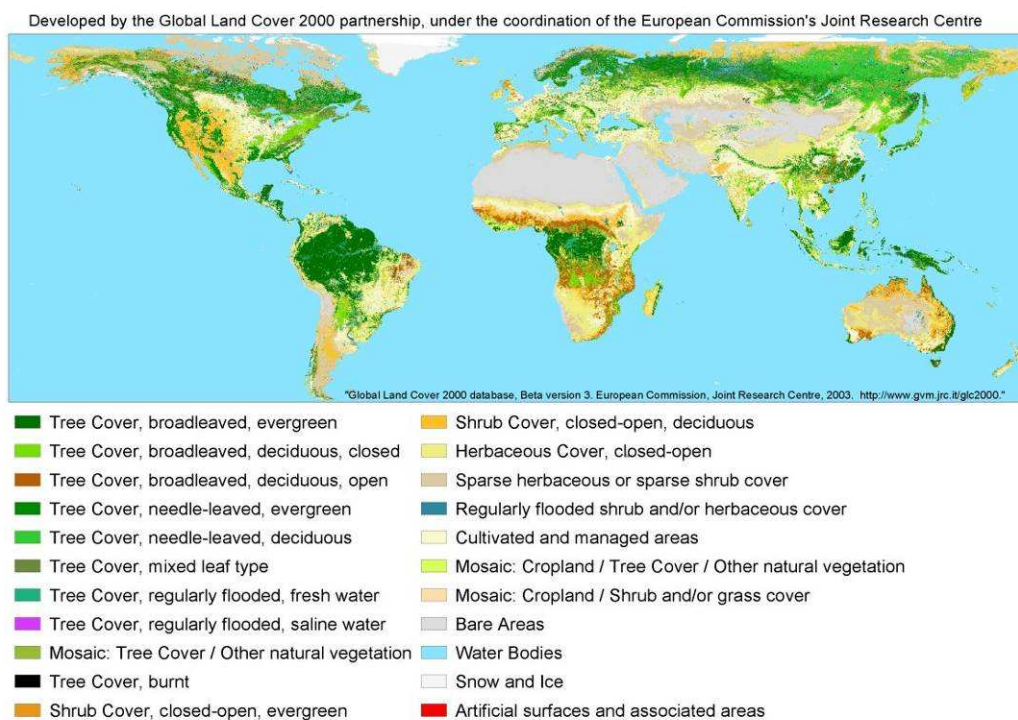


Figure 4. The Global Land Cover dataset for the year 2000 (GLC2000).

Different parts of Europe were covered by five regional map products with usually more detailed or regionally specific legends than the global one. The dominance of the GLC2000 class 'Cultivated and managed land' is striking throughout the European continent. Forests are limited to broadleaf deciduous, evergreen needle-leaved and mixed wooded areas. Europe shows also a significant degree of urbanization. Since GLC2000 provides global coverage, some classes rarely appear for Europe (Neumann et al, 2007).

PELCOM

The 1km resolution Pan-European Land Cover database PELCOM contains 16 thematic classes and is based on the interpretation of NOAA-AVHRR satellite data of 1997 (Mücher et al., 2001). Only the land cover classes urban areas, wetlands and water bodies have been derived from ancillary data sources. PELCOM was validated through independent interpretation of high resolution satellite images (mainly Landsat-TM images) distributed across Europe (7700 km²). Figure 5 shows the PELCOM database with the 16 different land cover classes.

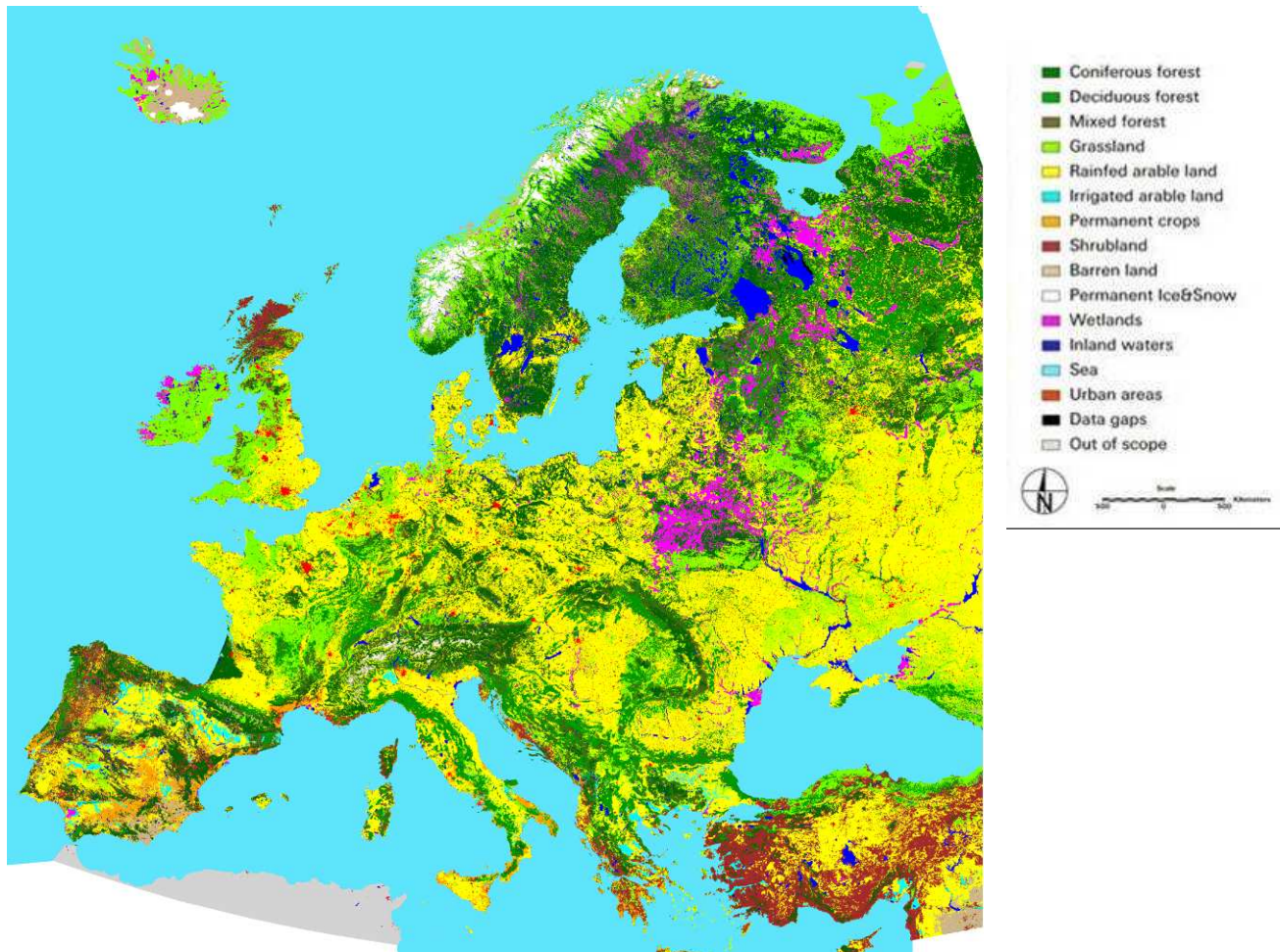


Figure 5. The PELCOM database.

HISLU60

No historical land cover information was available for the sixties that covers Europe and has a reasonable resolution. Therefore, it was decided to construct an historical land cover database based on information from the World Atlas of Agriculture published in 1969 that contains maps based on land use surveys from the fifties and sixties on a scale of 1:2.500.000 for most maps. The methodologies used to extract the information from the analog atlas into useful digital information are based on the same methodology as used for the construction of the historical land use database of the Netherlands (HGN) (Kramer & Dorland, 2007).

The hardcopy maps were scanned and georeferenced with the spline method available in ArcMap 9.2. In a pre-processing step, the redundant cartographic elements like text and boundaries were eliminated with a high-pass filter. A supervised classification procedure was used to classify the scanned maps. Signatures were prepared for each thematic class and in a two step approach the

maps were classified. First, a box classifier was used to assign all parts of the scanned maps that match exactly with the selected samples. Then all non-classified parts were classified using the maximum-likelihood classifier. In the last step, the post-processing, the remaining cartographic elements were removed using the Aggie procedure in Erdas Imagine 9.0 software. The following 7 classes are distinguished in the HISLU60 database: urban, arable land, grassland, forest, non-agricultural land, inland water and sea. For more information about the newly established see Chapter 4 Products and Figure 13.

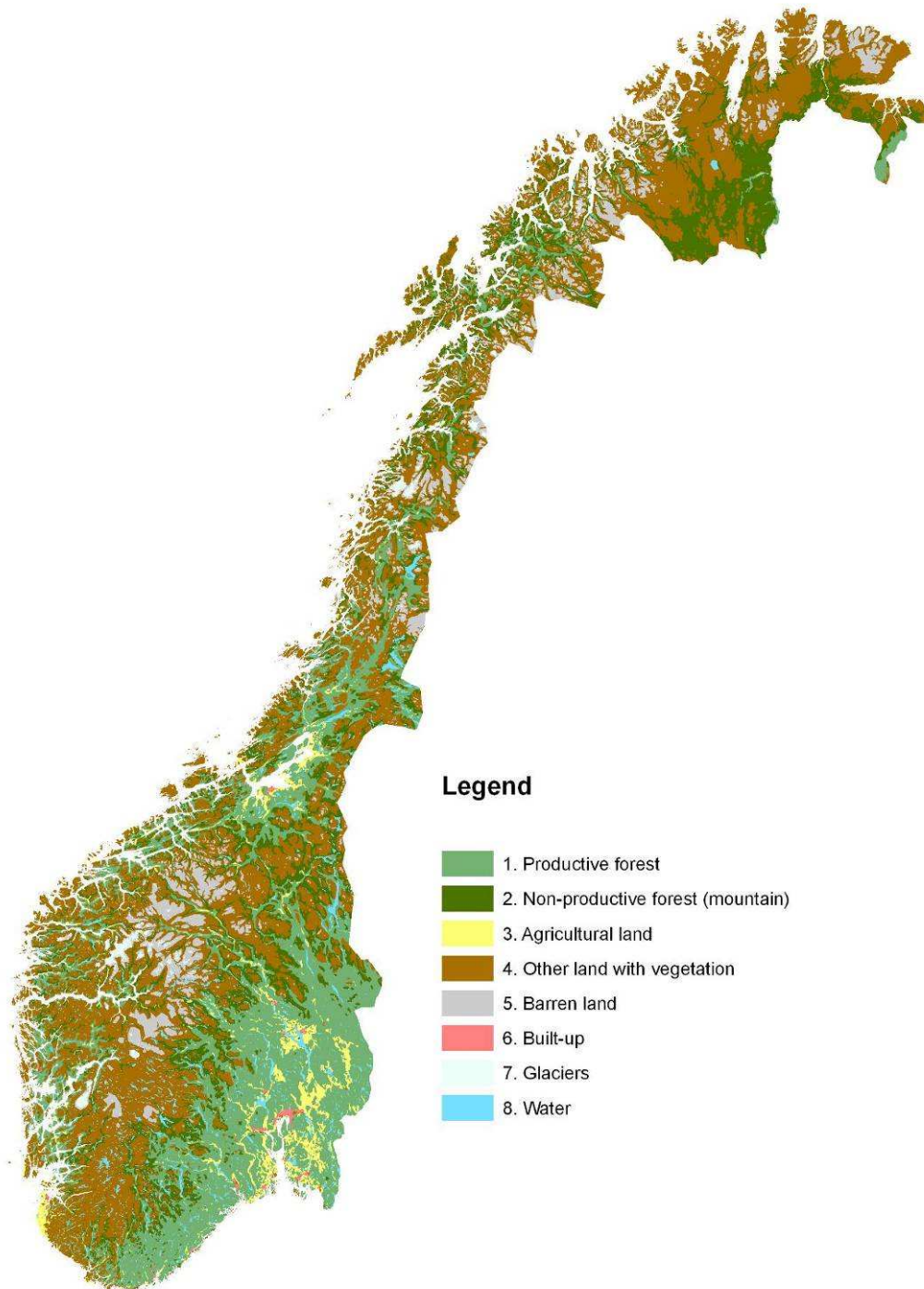
Since no CORINE land cover was available for the non-EU countries Switzerland and Norway it was decided to collect additional national data sets for these two countries.

Land Cover database of Norway (AR2000)

The land cover database of Norway is a vector database for the year 2000 (AR2000). It has the following 8 land cover classes: production forest, non-production forest, agricultural land, other land with vegetation, barren land, built-up areas, glaciers and water. The database is based on satellite images and different ancillary data sources (vegetation maps, digital map of the world). It can be seen as an update of the forest and land use map of Norwegian Atlas of 1983. A more spatial detailed database will become available in the near future (AR250). However, the thematic detail is not much higher ((8-10 classes). Land cover statistics for the AR2000 dataset are presented in Table 2. Some slight deviations (area in ha) from the data mentioned in Table 6 exist due processing of vector data into raster 100m*100m grids. Figure 6 shows you the original Norwegian AR2000 database.

Table 2. Land cover statistics for the Norwegian land cover dataset of the year 2000 (AR2000).

AR2000 - code	Nomenclature	ha	%
1	Production forest	8217114	25.5
2	Non-production forest	5750816	17.9
3	Agricultural land	1020613	3.2
4	Other land with vegetation	13563830	42.1
5	Barren land	2284439	7.1
6	Built-up areas	87053	0.3
7	Glaciers	289393	0.9
8	Water	972022	3.0
	Total	32185280	100.0



Legend

- 1. Productive forest
- 2. Non-productive forest (mountain)
- 3. Agricultural land
- 4. Other land with vegetation
- 5. Barren land
- 6. Built-up
- 7. Glaciers
- 8. Water

Figure 6. Land cover database of Norway for the year 2000 (AR2000) with 8 land cover classes.

Land Cover database of Switzerland (1985 and 1997)

The CORINE Land Cover datasets for Switzerland are based on the Swiss Land Use Statistics. The Swiss Land Cover datasets are available for the years 1985 and 1997 at a 100m spatial resolution and at level 2 of the CORINE nomenclature (13 classes). The Swiss Projection parameters can be found in Annex V. For the Swiss Land Use Statistics the delineation of land use/cover is based on sample points, while the CORINE Land Cover divides the area more or less in homogeneous areas of at least 25ha. These differences in delineation makes it difficult to convert the Swiss Land Use Statistics nomenclature directly into CLC level 3 classes. For this reason, a preference was made to convert the classes into CLC level 2 classes. A table has been established to convert the Swiss land use statistical classes into CLC level 2 classes. Table 3 shows the statistics for the CLC level 2

classes for Switzerland in the years 1985 and 1997. Figure 7 shows you the original Swiss land cover database for the year 1997.

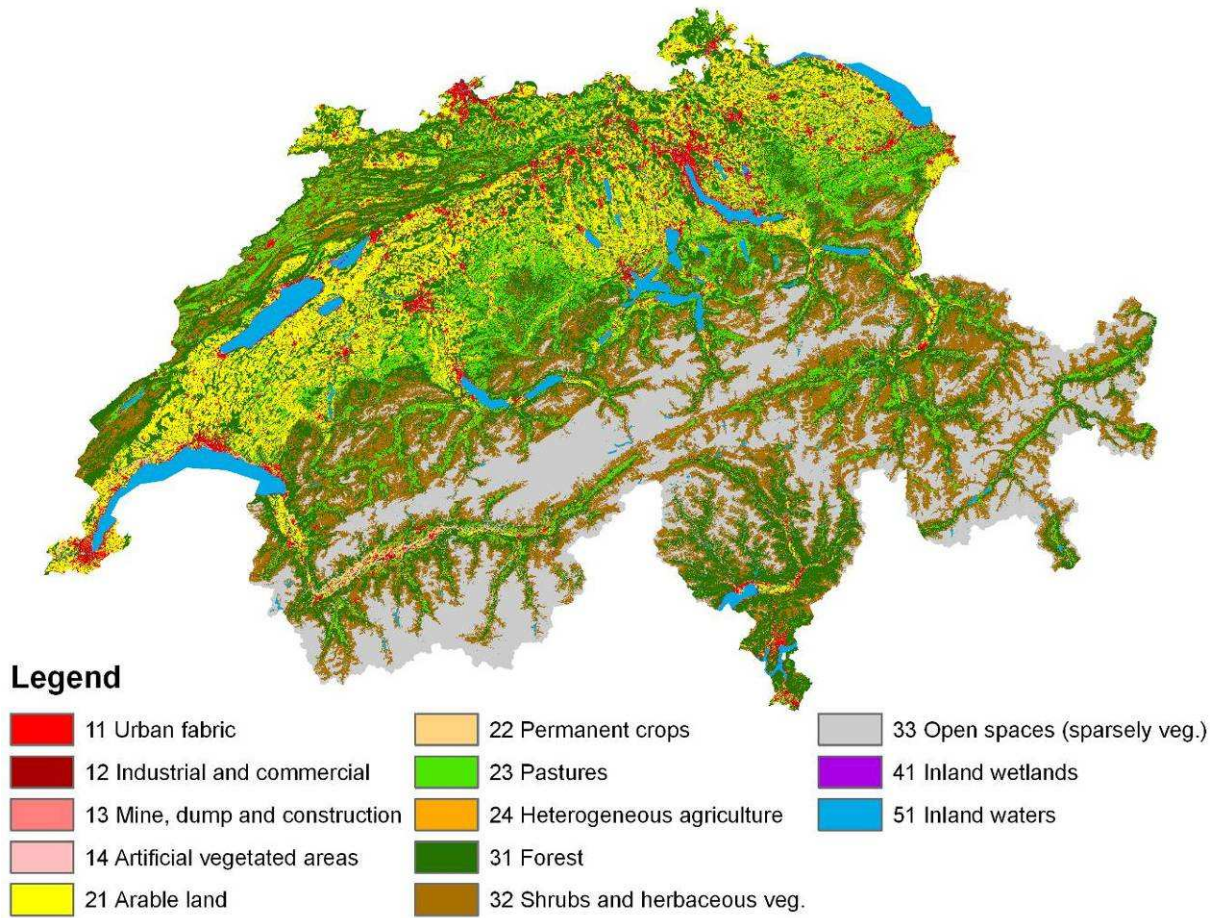


Figure 7. The CLC-level2 database of Switzerland for the year 1997.

Table 3. Statistics of CLC-level2 for the land cover database of Switzerland.

CORINE Land Cover type		Corine85		Corine97	
		ha	%	ha	%
1.1	Urban fabric	118312	2.9	137797	3.3
1.2	Industrial, commercial and transport units	99744	2.4	111894	2.7
1.3	Mine, dump, and construction sites	15006	0.4	13842	0.3
1.4	Artificial non-agricultural vegetated areas	13576	0.3	15856	0.4

2.1	Arable land	492533	11.9	481295	11.7
2.2	Permanent crops	29763	0.7	31157	0.8
2.3	Pastures	456921	11.1	447626	10.9
2.4	Heterogeneous agriculture areas	94608	2.3	81863	2.0
3.1	Forests	1013953	24.6	1014456	24.6
3.2	Shrub and/or herbaceous vegetation associations	801198	19.4	803690	19.5
3.3	Open spaces with little or no vegetation	807221	19.6	802887	19.5
4.1	Inland wetlands	8621	0.2	8969	0.2
4.2	Coastal wetlands	0	0.0	0	0.0
5.1	Inland waters	173003	4.2	173127	4.2
5.2	Marine waters	0	0.0	0	0.0
Total		4124459	100.0	4124459	100.0

3. Method

Pre-processing

General

Before integration of all datasets, they were transformed into one standard projection (see Annex I) and they were transformed if necessary to a 100m spatial resolution. The Swiss land cover databases and the CORINE Land Cover (CLC) databases had already a 100m spatial resolution. All other datasets PELCOM, GLC2000 (both have a 1 km spatial resolution) and HISLU60 were converted from their original resolution to a 100m grid. This meant a subdivision of each 1km² gridcell into 100 cells of 1 ha.

Processing UK90

For the United Kingdom there exists only a CLC2000 and a change database. Although methodological not entirely right due to differences in minimum sizes in mapping units for CLC-changes and CLC90/CLC2000 databases, the CLC2000 and CLC-changes database were integrated. A CLC90 database for the UK was created by replacing the land cover of 2000 by the land cover from the change database of the 1990's for the areas changed between 1990 and 2000.

Recoding PELCOM and GLC2000 to the CORINE nomenclature

The CORINE Land Cover database is the most detailed land cover database of Europe. The most thematic detail can be found at the CLC level 3 nomenclature. For that reason, CLC-level3 nomenclature was used as a basis for integrating the other land cover databases with CLC90 and CLC2000.

The recoding of PELCOM and GLC2000 was straightforward as it was already done in several other projects (Mücher, 2004, Neumann, 2007). Only some small adaptations were made to the recoding tables of the 'PEENHAB-project' (Mücher, 2004). In the recoding of PELCOM to CLC-level 3 the 'Grasslands (class20)' was converted into 'Pastures (class 231)'. The 'Urban Areas (class 100)' were recoded into 'Discontinuous urban fabric (class 112)'. Concerning the recoding of GLC2000 into CLC-level 3 classes three changes were made. The class 'Bare Areas (class 19)' was recoded into 'Bare rocks (class 332)' (see also Neumann et al, 2007), the class 'Artificial surfaces and associated areas (class 22)' was recoded into 'Discontinuous urban fabric (class 112)', and the class 'Permanently irrigated land' was introduced in the used GLC2000 (class 23) version and converted into 'Permanently irrigated land (class 212)'. The recoding tables can be found in Annexes IV. The red codes are the codes that has been changed compared to the 'PEENHAB-project' (Mücher, 2004).

Recoding Swiss and Norwegian national land cover databases to the CORINE nomenclature

The recoding of the Swiss and Norwegian national databases had a two step approach. Firstly, the national legend was converted into a CLC-level 3 class, where possible. Secondly, the national data sets were integrated with PELCOM or GLC2000 to refine the classification.

The Norwegian land cover database distinguishes only 8 land cover classes. The same two step approach was used in the recoding of the Norwegian land cover database. In a first step, the eight

land cover classes were converted into a CLC level 3 class (see third column in Annex VI). Which meant that they were converted into the most prominent CLC level 3 classes (using expert knowledge). In a second step, the classes were refined with help of the GLC2000 database (4th and 5th column in Annex VI). Visual verification of the final database was done with images of Google Earth. Unfortunately, no data was available for 1990.

The Swiss land cover database describes the land cover at CLC level 2. The 13 Swiss classes were converted to the most related class of CORINE at level 3 (see second column in Annex VII). For example, industrial and commercial units (CLC level 3 class 121) will be the most prominent class in Switzerland within the industrial, commercial and transport units (CLC level 2 class 12). Furthermore, a CLC level 2 class could only be converted into a level 3 class that belongs to the level 2 group. For example, 24 can be converted into 242 or 243 but not into 231.

Secondly, the SWISS classes were refined with help of the PELCOM database (3rd and 4th column in Annex VII). The final Swiss land cover map is based on the integration with the PELCOM database and considering the CLC2000 land cover in the surrounding countries. During the recoding of Swiss land cover data into the final CLC level 3 products, the final objectives were kept in mind. In case of doubt, preference was given to grassland (pasture or natural grasslands) and/or forest classes, since the focus of ECOCHANGE is on these habitats. For the recoding of the 1985 and 1997 SWISS Land Cover datasets the same conversions rules were used.

European Integration

PLCM2000

The Pan-European Land Cover Mosaic for the year 2000 (**PLCM2000**) used the CLC2000 database as the starting point. The reclassified Norwegian and Swiss land cover databases for the year 2000 were added to the CLC2000 database. Gaps and missing countries were filled with the recoded PELCOM and the GLC2000 databases. Figure 8 shows the data sources used for the compilation of the PLCM2000 mosaic (see also Annex II). Besides the countries Iceland and Moldavia, Kosovo was also covered with the PELCOM database. Cyprus which is not indicated in the figure is covered by CLC2000.

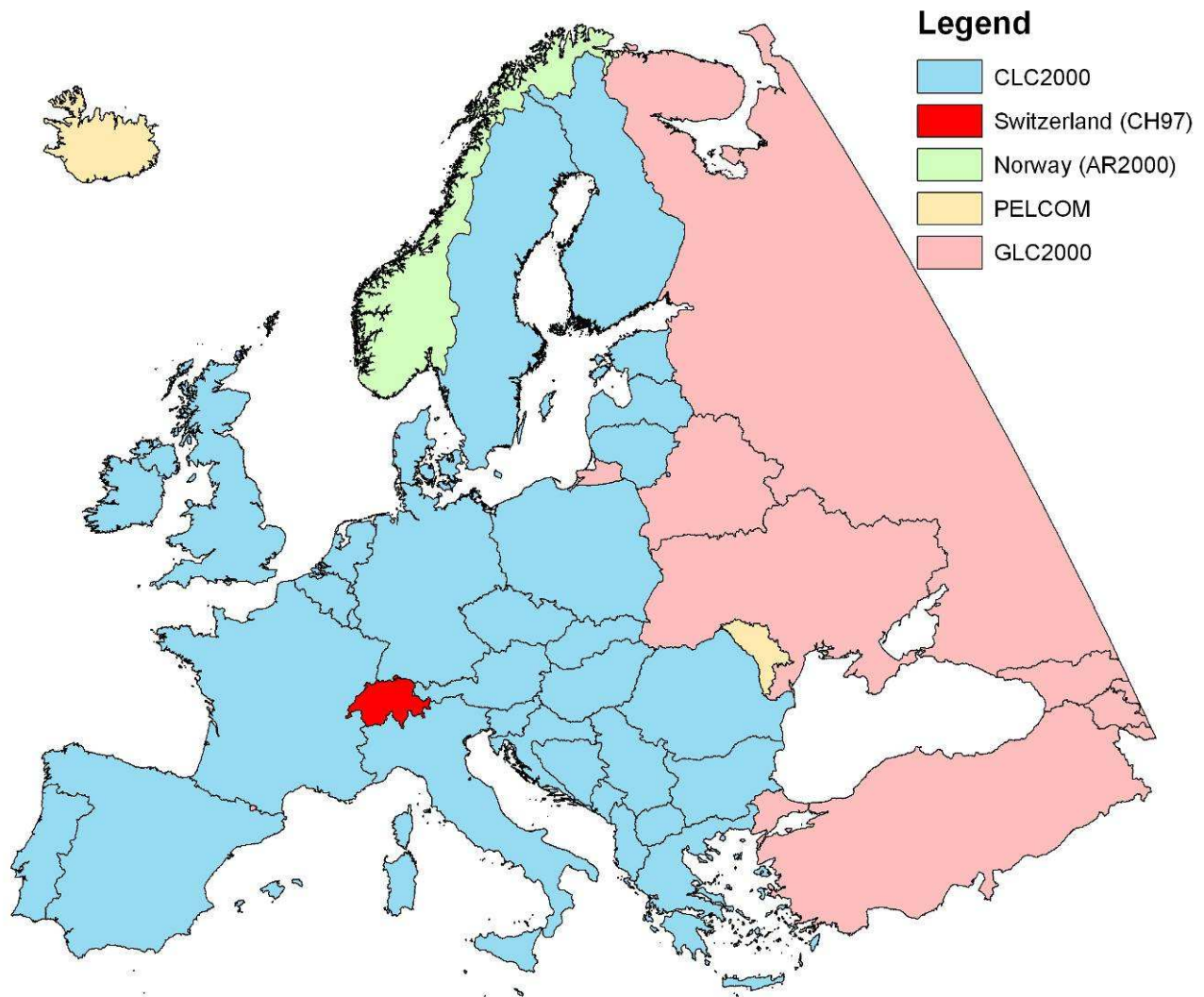


Figure 8. Overview of the data sources used to produce the Pan-European Land Cover mosaic for the year 2000 (PLCM2000).

PLCM1990

The Pan-European Land Cover mosaic for the year 1990 (**PLCM1990**) used the CLC1990 as a basis for the mosaic. The CLC90 database was extended with the reclassified Swiss land cover database for the year 1990 and the newly created land cover database for the United Kingdom. Missing countries were covered with the PLCM2000 mosaic (see Figure 9 and Annex II). Cyprus was also filled with land cover of the PLCM2000 database.

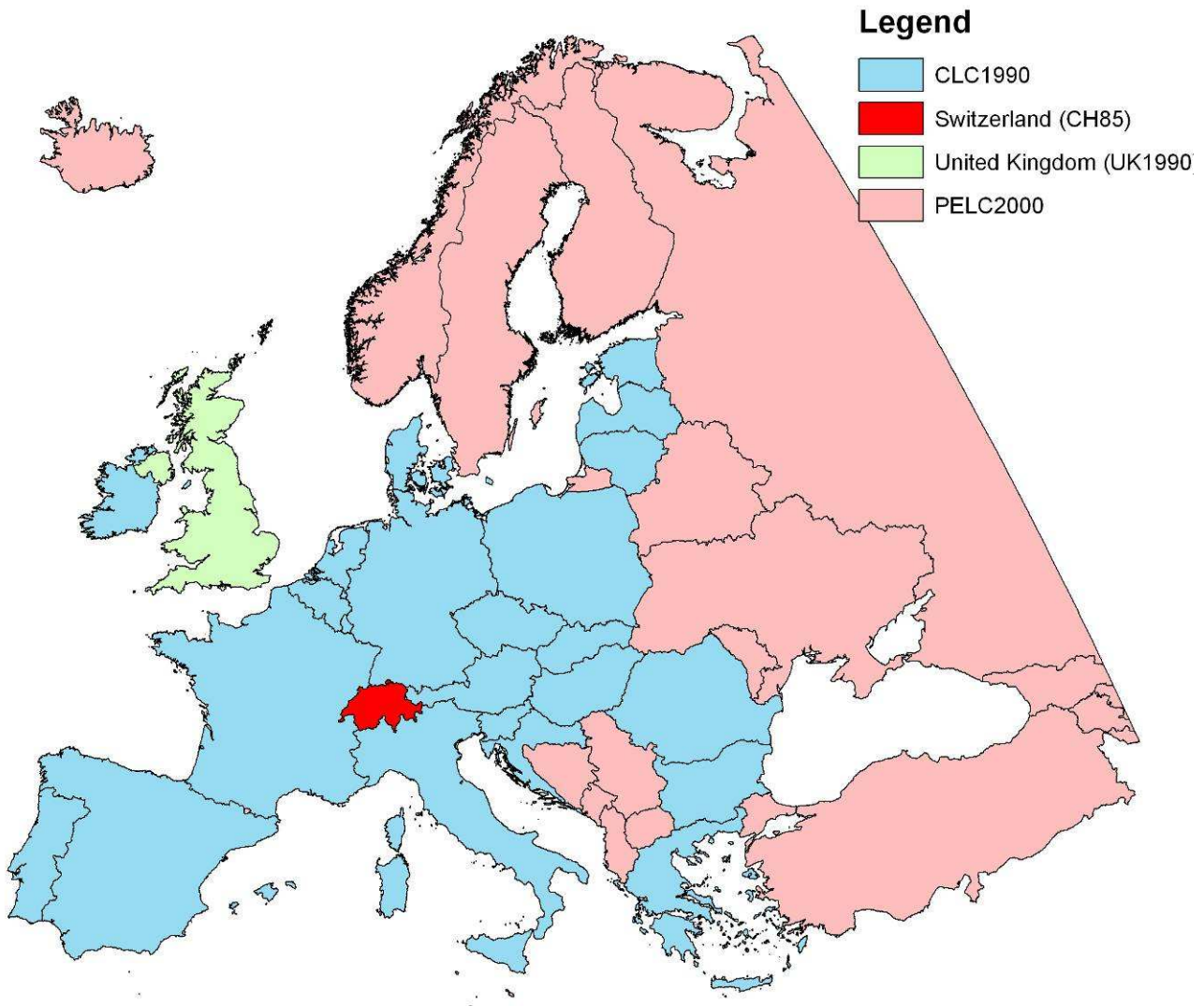


Figure 9. Overview of data sources used in the production of the Pan-European Land Cover mosaic for the year 1990 (PLCM1990).

Thematic aggregation

The PLCM1990 and PLCM2000 mosaics (at CORINE level three) were thematically aggregated to the following levels: CLC level2 (15 classes), ALARM (7 classes) and HISLU60 nomenclature (6 classes). Aggregation of the 44 classes at CLC level 3 into the 15 classes at CLC level 2 is straightforward. The aggregation of the PLCM mosaics into ALARM classes, which are in most cases CLC level 1 classes, can be found in Table 4. Aggregation of the PLCM mosaics to the HISLU60 nomenclature is similar to the aggregation towards the ALARM nomenclature. Only some small adaptations were made. Table 5 presents the recoding of CLC level 3 classes into the 7 HISLU60 classes.

Table 5. Recoding of CLC level 3 classes into HISLU60 classes.

CORINE	CORINE classes	HISLU	HISLU60 -code
Artificial surfaces	111, 112, 121, 122, 123, 124, 131, 132, 133, 141 and 142	Urban	1
Agricultural land without pastures	211, 221, 222, 223, 241, 242, 243 and 244	Arable land	2
Pastures and Natural grasslands	231 and 321	Grassland	3
Forests	311, 312 and 313	Forest	4
Semi-Natural areas (with exception of Natural grasslands) and Wetlands	322, 323, 324, 331, 332, 333, 334, 335, 411, 412, 421, 422 and 423	Non-agricultural land	5
Inland waters	511 and 512	Inland water	6
Marine water	521, 522 and 523	Sea	7

The reclassification of the CORINE level 1 class ‘Artificial surfaces’ into the ‘Urban’ HISLU60 class is straightforward. ‘Agricultural land’ is recoded into ‘Arable land’ with the exception of ‘Pastures’. Most discussion concerns the recoding of ‘Wetlands’ and ‘Semi-natural areas’ into ‘Non-agricultural land’ as part of the wetlands could be seen as ‘Inland waters’. ‘Natural grasslands’ and ‘Pastures’ are grouped into ‘Grasslands’. Recoding of ‘Inland waters’ and ‘Marine water’ into ‘Inland water’ respectively ‘Sea’ is straightforward.

ALARM LC classes

The land use types used within the work package 1.5 ‘land use modeling and scenarios’ are the following classes:

1. urban (U)
2. agriculture (A)
3. grassland (G)
4. forest (F)
5. biofuels (BF)
6. surplus land (S)
7. other fixed land cover (O)

The classes are defined in the ALARM project and will be used in scenario studies.

The thematic class biofuels (BF) does not relate to an actual land cover. It is a ‘future’ land cover class, because it is only present in the ALARM scenario’s and not in the baseline. The class Surplus land (S) is land that has no longer an economic value. It does not relate to a single land use class since it could be natural land evolved in different ways. The class Other fixed land cover (O) is e.g. water, glaciers, permanent ice, bare rocks and snow. The other classes have partly self-explaining definitions.

The link with the CORINE land cover (CLC) classes is given in Table 4. Most ALARM classes correspond with CLC level 1 classes. Exceptions are the CLC class pastures (231) which corresponds with the ALARM class grasslands. Surplus land (S) corresponds with amongst others the CLC classes ‘Shrub and/or herbaceous vegetation’ (32) and wetlands (4). Other fixed land cover (O) corresponds with the CLC classes ‘Open spaces with little or no vegetation’ (33) and water bodies (5).

Table 4. Conversion of CLC level 3 classes into ALARM classes.

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

Spatial aggregations

The spatial aggregations of the different thematic land cover mosaics were processed with the Aggie module of Erdas Imagine 9.1. The 100m land cover mosaics were used as an input for the spatial aggregation into 500 and 1km resolution databases (windows of 5*5 respectively 10*10 cells). The aggie module calculates the dominant class for each window. Thematic aggregation needs to be done before spatial aggregation.

4. Products

General characteristics

The CORINE Land Cover datasets of 1990 and 2000 were the basis for the PLCM1990 and PLCM2000 Mosaic, respectively. The national datasets of Norway and Switzerland were used in addition. PELCOM and GLC2000 were used to extend the coverage to Pan-Europe for the PLCM2000. The CLC1990 and CH85plus were integrated for the PLCM1990. Thereafter, missing countries were filled with the PLCM2000 database. The PLCM databases have thematic classes at level 3 of the CORINE nomenclature and a 100m spatial resolution. During the production of the PLCM databases preference was given to the CLC databases and the local databases. The thematic and spatial detail is much higher for those databases when compared with the PELCOM and GLC2000 databases.

Refined Norwegian land cover database (AR2000plus)

The newly derived AR2000plus database has 15 CLC-level 3 classes. The original Norwegian AR2000 database, which had only 8 land cover classes, was refined with GLC2000. The AR2000plus was integrated into the PLCM2000 database. Table 6 presents the statistics of the database (ha per CLC-level 3 class). Figure 10 shows spatial distribution of land cover of the AR2000plus database which has much more detail in comparison to the original AR2000 database (see Figure 6).

Table 6. Land cover statistics of the refined Norwegian land cover database (AR2000plus).

CLC codes	CLC nomenclature	AR2000plus	
		ha	%
1.1.2	Discontinuous urban fabric	86909	0.3
2.1.1	Non-irrigated arable land	904345	2.8
2.3.1	Pastures	19784	0.1
2.4.3	Land principally occupied by agriculture with significant natural vegetation	94948	0.3
3.1.1	Broad-leaved forest	1675809	5.2
3.1.2	Coniferous forest	10208272	31.8
3.1.3	Mixed forest	2063556	6.4
3.2.1	Natural grasslands	1453572	4.5
3.2.3	Moors and heath lands	11253928	35.0
3.2.4	Transitional woodland-scrub	18161	0.1
3.3.2	Bare rocks	1515842	4.7
3.3.3	Sparsely vegetated areas	765023	2.4
3.3.5	Glaciers and perpetual snow	288449	0.9
4.1.1	Peat bogs	809765	2.5
5.1.2	Water bodies	971147	3.0
Total		32129510	100.0

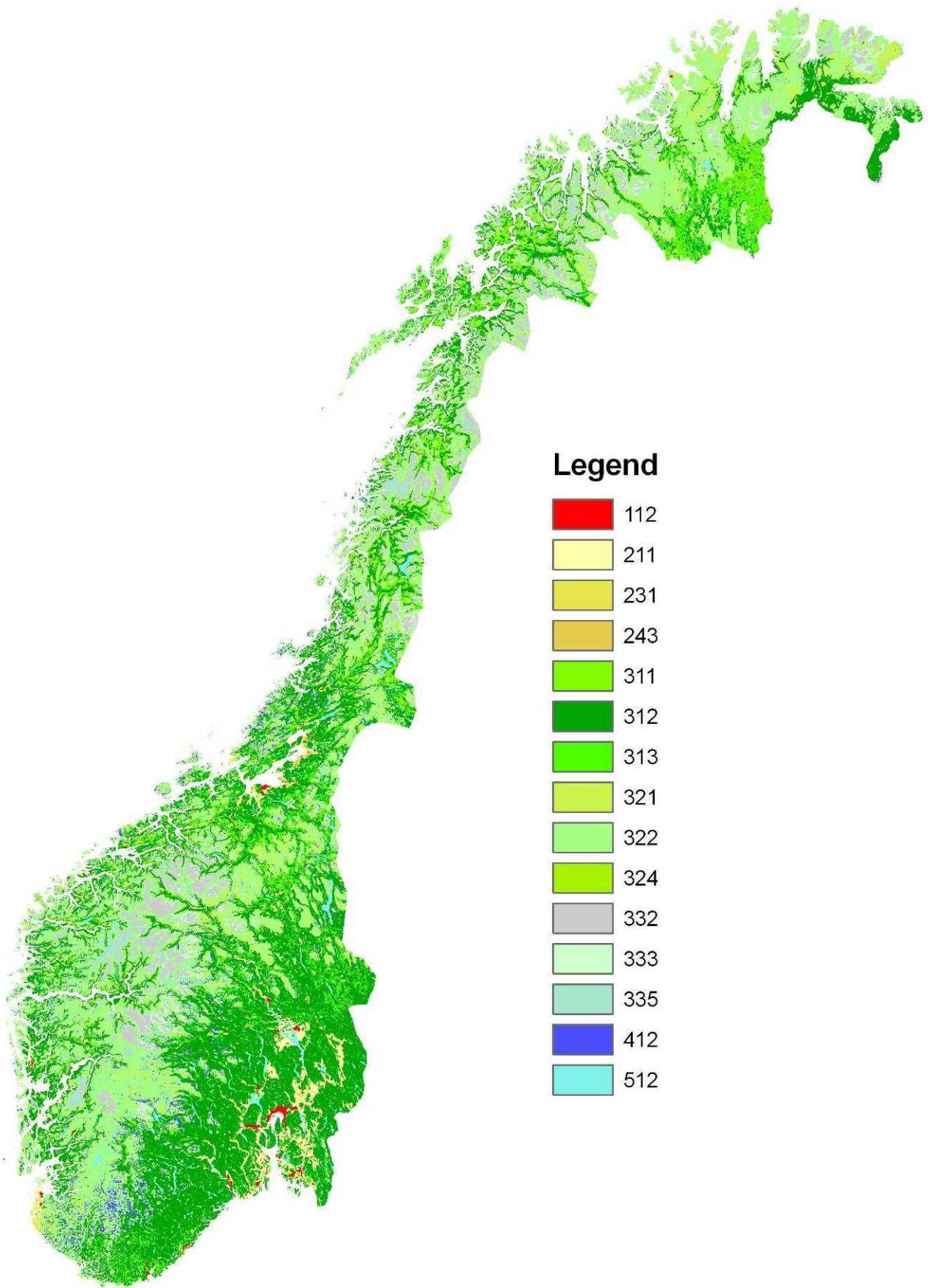


Figure 10. Spatial distribution of 15 CLC-level 3 classes of the Norwegian AR2000plus database as integrated in the PLCM2000 database.

Refined Swiss land cover databases (CH97plus and CH85plus)

The CH97plus and CH85plus both have 22 CLC-level3 classes. The original Swiss CH97 and CH85 databases with 13 land cover classes are both refined with the PELCOM database. The refinement, as mentioned already in the methodology, is in both cases based on the same recoding rules. The CH97 and CH85 databases reflect the land use in Switzerland for the years 1997 and 1985 whereas PELCOM reflects the land cover for the year 1997. The refined CH97plus and CH85plus databases were integrated in the PLCM2000 respectively PLCM1990 databases. Table 7 presents the statistics of both databases (ha per CLC-level 3 class). Figure 11 shows the Swiss CH97plus database which has more thematic detail than the original CH97 database (see Figure 7).

Table 7. Land cover statistics of the refined Swiss land cover databases (CH97plus and CH85plus).

CLC codes	CLC nomenclature	CH85plus		CH97plus		Change ha
		ha	%	ha	%	
1.1.2	Discontinuous urban fabric	118303	2.9	137777	3.3	19474
1.2.1	Industrial and commercial units	99751	2.4	111898	2.7	12147
1.3.3	Construction sites	15005	0.4	13844	0.3	-1161
1.4.1	Green urban areas	12579	0.3	14618	0.4	2039
1.4.2	Port and leisure facilities	1000	0.0	1245	0.0	245
2.1.1	Non-irrigated arable land	492663	11.9	481417	11.7	-11246
2.2.1	Vineyards	112	0.0	153	0.0	41
2.2.2	Fruit trees and berry plantation	29665	0.7	31025	0.8	1360
2.3.1	Pastures	457002	11.1	447708	10.9	-9294
2.4.2	Complex cultivation patterns	49571	1.2	41429	1.0	-8142
2.4.3	Land principally occupied by agriculture with significant natural vegetation	45041	1.1	40444	1.0	-4597
3.1.1	Broad-leaved forest	233908	5.7	234244	5.7	336
3.1.2	Coniferous forest	555218	13.5	556068	13.5	850
3.1.3	Mixed forest	225023	5.5	224334	5.4	-689
3.2.1	Natural grasslands	304422	7.4	306160	7.4	1738
3.2.3	Sclerophyllous vegetation	12051	0.3	12132	0.3	81
3.2.4	Transitional woodland-scrub	484894	11.8	485574	11.8	680
3.3.2	Bare rocks	221218	5.4	220799	5.4	-419
3.3.3	Sparsely vegetated areas	379877	9.2	376049	9.1	-3828
3.3.5	Glaciers and perpetual snow	206237	5.0	206145	5.0	-92
4.1.1	Inland marshes	8625	0.2	8974	0.2	349
5.1.2	Water bodies	173014	4.2	173142	4.2	128
		4125179	100	4125179	100	0

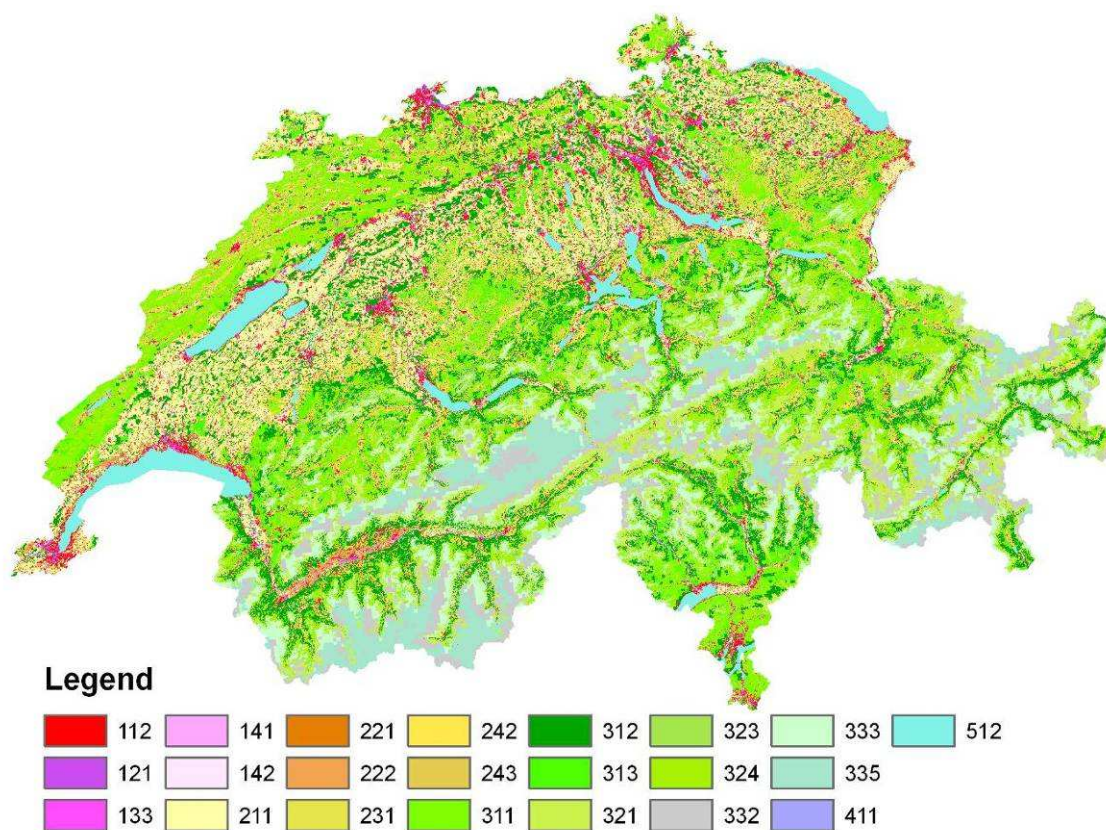


Figure 11. Spatial distribution of 22 CLC-level 3 classes of the Swiss C97plus database as integrated in the PLCM2000 database.

Pan-European Land Cover Mosaic 2000 (PLCM2000)

The Pan-European Land Cover Mosaic for the year 2000 (PLCM2000) was produced according to the CORINE nomenclature at level 3 and has a spatial resolution of 100m. Table 8 presents the statistics of PLCM2000 together with the statistics for the spatial aggregations to 500m and 1km. The different thematic aggregations to CLC level 2, ALARM classes and HISLU60 classes can be found in Annex VIII.

The main land cover classes in Europe are non-irrigated arable land (211), coniferous forest (312), broad-leaved forest (311) and mixed forest (313). Together they occupy 62.8% of Pan-Europe. Non-irrigated arable land covers already 30.9%. These large classes even increase in area in the process of spatial aggregation, see Table 8. All other classes decrease only slightly in acreage.

Forests (CLC-level 1 class) and grasslands (natural grasslands and pastures), important land covers in the ECOCHANGE project, occupy 31.8% and 8.0%, respectively. Shrub and/or herbaceous vegetation (CLC-level 2 class 32) and open spaces with little or no vegetation (CLC-level 2 class 33) occupy 13.2 and 4.3%, respectively. Artificial surfaces occupy only 2.3% of the Pan-European territory.

Pan-European Land Cover Mosaic 1990 (PLCM1990)

The Pan-European Land Cover mosaic for the year 1990 (PLCM1990) was produced according to the CORINE nomenclature at level 3 and has a spatial resolution of 100m. Table 9 presents the statistics of PLCM1990 together with the statistics for the spatial aggregations to 500m and 1km.

The different thematic aggregations to CLC level 2, ALARM classes and HISLU60 classes can be found in Annex IX.

The main land cover classes in Europe were in 1990 also the non-irrigated arable land (211), coniferous forest (312), broad-leaved forest (311) and mixed forest (313). Together they occupied 62.9% of the Pan-European territory. The non-irrigated arable land covers already 31.1%. As you see the differences with PLCM2000 are minimal in percentages. However, the absolute values can differ considerably. These large classes also increased in area through aggregation as you can see in the Table 9. All other classes decrease slightly in acreage.

Forests (CLC-level 1 class) and grasslands (natural grasslands and pastures) which are important land cover types in the ECOCHANGE project, occupy also 31.8% and 8.0% as in PLCM2000, respectively. Shrub and/or herbaceous vegetation (CLC-level 2 class 32) and Open spaces with little or no vegetation (CLC-level 2 class 33) occupy the same area in percentages. Artificial surfaces (CLC-level 1 class) occupy only 2.2% of the Pan-European territory which is a slightly less as in PLCM2000 (9000 km²). An important point to mention is that outside the 26 countries mentioned in Annex II, the land cover between PLCM1990 and PLCM2000 does not differentiate.

Table 8. Statistics per land cover class at CORINE level 3 for the year 2000 (PLCM2000) at different spatial resolutions (areas in km²).

CLC code	CLC nomenclature	100m	%	500m	%	1km	%
1.1.1	Continuous urban fabric	5879	0.07	5718	0.06	4837	0.05
1.1.2	Discontinuous urban fabric	150723	1.68	144567	1.61	126456	1.41
1.2.1	Industrial and commercial units	21230	0.24	19618	0.22	14679	0.16
1.2.2	Road and rail networks and associated land	1933	0.02	1167	0.01	439	0.00
1.2.3	Port areas	1027	0.01	977	0.01	821	0.01
1.2.4	Airports	2923	0.03	2899	0.03	2764	0.03
1.3.1	Mineral extraction sites	6242	0.07	5914	0.07	4291	0.05
1.3.2	Dump sites	1093	0.01	1064	0.01	860	0.01
1.3.3	Construction sites	1299	0.01	1030	0.01	592	0.01
1.4.1	Green urban areas	3050	0.03	2599	0.03	1631	0.02
1.4.2	Port and leisure facilities	8141	0.09	7639	0.09	5427	0.06
2.1.1	Non-irrigated arable land	2777293	30.94	2825114	31.48	2940069	32.79
2.1.2	Permanently irrigated land	35989	0.40	36224	0.40	36276	0.40
2.1.3	Rice fields	5872	0.07	5911	0.07	5965	0.07
2.2.1	Vineyards	39398	0.44	39820	0.44	39582	0.44
2.2.2	Fruit trees and berry plantation	25404	0.28	25365	0.28	24229	0.27
2.2.3	Olive groves	39964	0.45	40562	0.45	41443	0.46
2.3.1	Pastures	427840	4.77	426812	4.76	420303	4.69
2.4.1	Annual cops associated with permanent crops	9898	0.11	9934	0.11	9943	0.11
2.4.2	Complex cultivation patterns	272039	3.03	268564	2.99	257096	2.87
2.4.3	Land principally occupied by agriculture with significant natural vegetation	219845	2.45	204031	2.27	167313	1.87
2.4.4	Agro-forestry areas	31888	0.36	32174	0.36	32875	0.37
3.1.1	Broad-leaved forest	888219	9.90	889123	9.91	893619	9.97
3.1.2	Coniferous forest	1275517	14.21	1294857	14.43	1343726	14.99
3.1.3	Mixed forest	691295	7.70	687431	7.66	678633	7.57
3.2.1	Natural grasslands	285698	3.18	278123	3.10	253945	2.83
3.2.2	Moors and heath lands	202243	2.25	204025	2.27	209294	2.33
3.2.3	Sclerophyllous vegetation	98448	1.10	98625	1.10	99833	1.11
3.2.4	Transitional woodland-scrub	596695	6.65	583474	6.50	555685	6.20
3.3.1	Beaches, sand, dunes	3795	0.04	2751	0.03	1761	0.02
3.3.2	Bare rocks	82777	0.92	82336	0.92	81814	0.91
3.3.3	Sparsely vegetated areas	280189	3.12	277038	3.09	268715	3.00
3.3.4	Burnt areas	2848	0.03	2782	0.03	2456	0.03
3.3.5	Glaciers and perpetual snow	17088	0.19	16986	0.19	16618	0.19
4.1.1	Inland marshes	116058	1.29	112751	1.26	103332	1.15
4.1.2	Peat bogs	79693	0.89	75932	0.85	68907	0.77
4.2.1	Salt marshes	3115	0.03	3019	0.03	2704	0.03
4.2.2	Salines	757	0.01	756	0.01	797	0.01
4.2.3	Intertidal flats	10408	0.12	10336	0.12	10201	0.11
5.1.1	Water courses	11080	0.12	7460	0.08	5316	0.06
5.1.2	Water bodies	231335	2.58	228208	2.54	221654	2.47
5.2.1	Coastal lagoons	5635	0.06	5672	0.06	5783	0.06
5.2.2	Estuaries	3249	0.04	3203	0.04	3215	0.04
5.2.3	Sea and ocean		0.00		0.00		0.00
Total		8975113	100	8973086	100	8965899	100

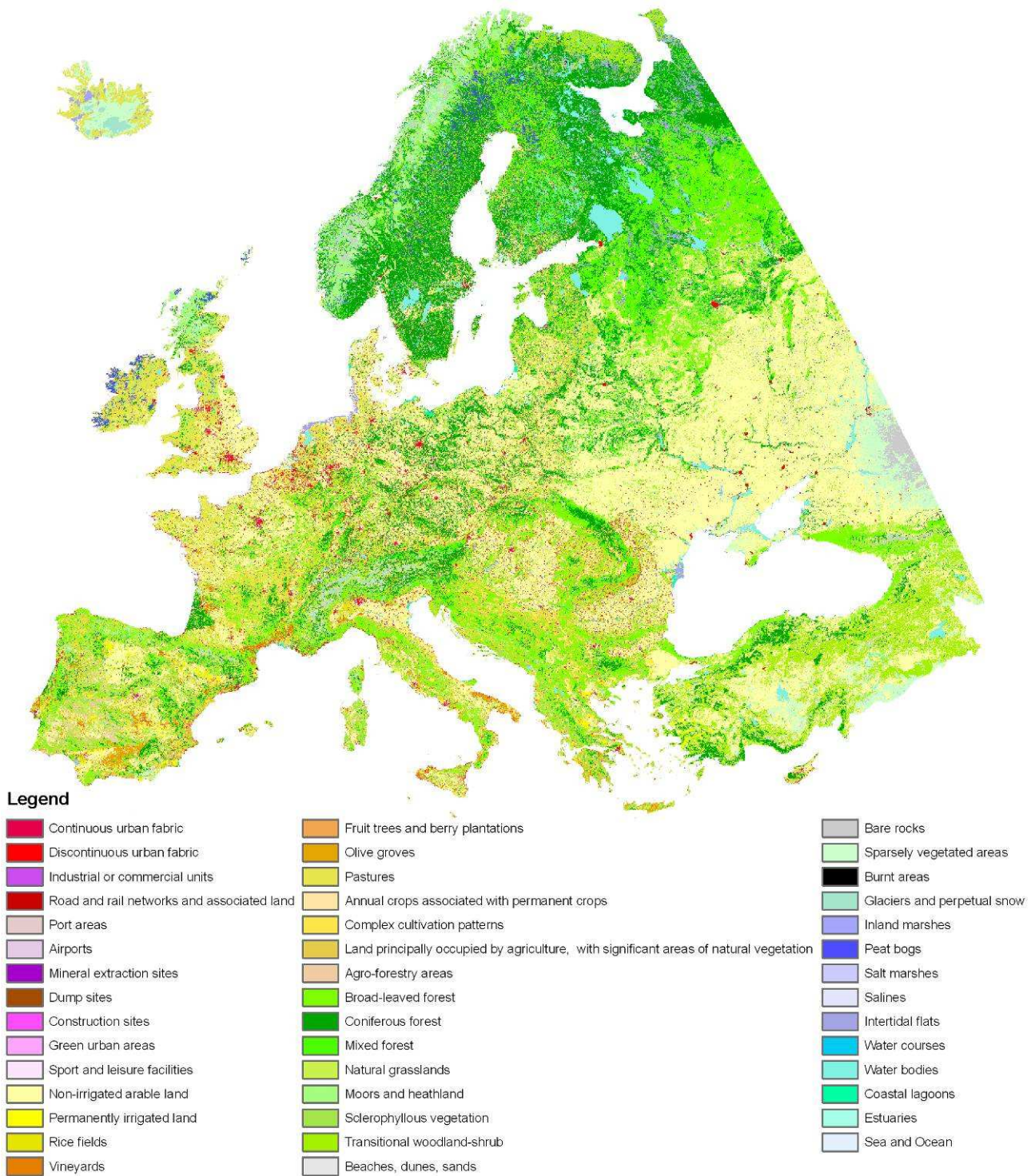


Figure 12. Spatial distribution of land cover of the Pan-European Land cover mosaic for the year 2000 (PLCM2000) at level 3 of the (CORINE land cover nomenclature).

Table 9. Statistics per land cover class at CORINE level 3 for the year 1990 (PELCM1990) at different spatial resolutions (area in km²).

CLC code	CLC nomenclature	100m	%	500m	%	1km	%
1.1.1	Continuous urban fabric	5690	0.06	5522	0.06	4630	0.05
1.1.2	Discontinuous urban fabric	146396	1.63	140056	1.56	121729	1.36
1.2.1	Industrial and commercial units	18715	0.21	17160	0.19	12561	0.14
1.2.2	Road and rail networks and associated land	1589	0.02	983	0.01	364	0.00
1.2.3	Port areas	987	0.01	935	0.01	784	0.01
1.2.4	Airports	2876	0.03	2847	0.03	2702	0.03
1.3.1	Mineral extraction sites	5697	0.06	5386	0.06	3991	0.04
1.3.2	Dump sites	1101	0.01	1069	0.01	853	0.01
1.3.3	Construction sites	1143	0.01	941	0.01	659	0.01
1.4.1	Green urban areas	3019	0.03	2590	0.03	1639	0.02
1.4.2	Port and leisure facilities	7270	0.08	6786	0.08	4749	0.05
2.1.1	Non-irrigated arable land	2786951	31.05	2835054	31.59	2950045	32.90
2.1.2	Permanently irrigated land	32954	0.37	33186	0.37	33141	0.37
2.1.3	Rice fields	5922	0.07	5970	0.07	6055	0.07
2.2.1	Vineyards	39574	0.44	39982	0.45	39710	0.44
2.2.2	Fruit trees and berry plantation	25327	0.28	25254	0.28	24055	0.27
2.2.3	Olive groves	39455	0.44	40017	0.45	40745	0.45
2.3.1	Pastures	429288	4.78	428154	4.77	421162	4.70
2.4.1	Annual crops associated with permanent crops	10250	0.11	10291	0.11	10270	0.11
2.4.2	Complex cultivation patterns	272389	3.03	268818	3.00	257270	2.87
2.4.3	Land principally occupied by agriculture with significant natural vegetation	220838	2.46	204944	2.28	168215	1.88
2.4.4	Agro-forestry areas	31454	0.35	31718	0.35	32429	0.36
3.1.1	Broad-leaved forest	885532	9.87	886273	9.88	890467	9.93
3.1.2	Coniferous forest	1277539	14.23	1297112	14.46	1346407	15.02
3.1.3	Mixed forest	691619	7.71	687758	7.66	679161	7.57
3.2.1	Natural grasslands	287928	3.21	280298	3.12	256045	2.86
3.2.2	Moors and heath lands	203431	2.27	205229	2.29	210609	2.35
3.2.3	Sclerophyllous vegetation	100017	1.11	100189	1.12	101392	1.13
3.2.4	Transitional woodland-scrub	591544	6.59	578220	6.44	550264	6.14
3.3.1	Beaches, sand, dunes	3850	0.04	2809	0.03	1810	0.02
3.3.2	Bare rocks	82715	0.92	82268	0.92	81706	0.91
3.3.3	Sparsely vegetated areas	280206	3.12	277044	3.09	268696	3.00
3.3.4	Burnt areas	3219	0.04	3145	0.04	2830	0.03
3.3.5	Glaciers and perpetual snow	17195	0.19	17091	0.19	16734	0.19
4.1.1	Inland marshes	116082	1.29	112788	1.26	103339	1.15
4.1.2	Peat bogs	80746	0.90	76991	0.86	69917	0.78
4.2.1	Salt marshes	3121	0.03	3024	0.03	2710	0.03
4.2.2	Salines	742	0.01	739	0.01	783	0.01
4.2.3	Intertidal flats	10500	0.12	10429	0.12	10288	0.11
5.1.1	Water courses	11071	0.12	7446	0.08	5299	0.06
5.1.2	Water bodies	230359	2.57	227287	2.53	220771	2.46
5.2.1	Coastal lagoons	5639	0.06	5675	0.06	5791	0.06
5.2.2	Estuaries	3252	0.04	3204	0.04	3222	0.04
5.2.3	Sea and ocean		0.00		0.00		0.00
Total		8975194	100	8973174	100	8965999	100

Pan-European Land Cover mosaic for the year 1960 (HISLU60)

The main land cover for the Pan-European mosaic for the year 1960 (HISLU60) is arable land (38.6%) with forest occupying a considerable amount of the Pan-European territory (25.4%). Due to spatial aggregations to coarser scales major land cover classes still increase in acreage. All other classes are more less constant or decrease slightly in area (see Table 10).

Table 11 presents the statistics of the PLCM1990 database according to the HISLU60 nomenclature. In following section 'Pan-European Land Cover Changes 1960-1990' a short comparison will be made between HISLU60 and the PLCM1990 thematically aggregated to HISLU classes.

Table 10. Statistics per land cover class for HISLU60 at different spatial resolutions (area in km²).

HISLU60	100m		1960		1km	
	100m	%	500m	%	1km	%
Urban	21360	0.24	21165	0.24	19887	0.22
Arable land	3462462	38.58	3463369	38.69	3485096	38.94
Grassland	1722231	19.19	1722380	19.24	1725444	19.28
Forest	2277614	25.38	2277674	25.44	2267626	25.34
Non-agricultural land	1213539	13.52	1213102	13.55	1204215	13.46
Inland water	196207	2.19	196019	2.19	193070	2.16
Sea	80661	0.90	79242	0.89	74098	0.83
Total	8974074	100	8951786	100	8949549	100

Table 11. Statistics per land cover class for the PLCM1990 database recoded to the HISLU nomenclature and aggregated to various spatial resolutions (area in km²).

HISLU classes	100m		1990		1km	
	100m	%	500m	%	1km	%
Urban	194483	2.17	180827	2.02	149620	1.67
Arable land	3465116	38.61	3504936	39.06	3595102	40.09
Grassland	717216	7.99	698470	7.78	643819	7.18
Forest	2854690	31.81	2876751	32.06	2935273	32.73
Non-agricultural land	1493368	16.64	1470659	16.39	1416475	15.79
Inland water	241430	2.69	232789	2.59	219111	2.44
Sea	8891	0.10	8825	0.10	8786	0.10
Total	8975194	100	8973257	100	8968186	100

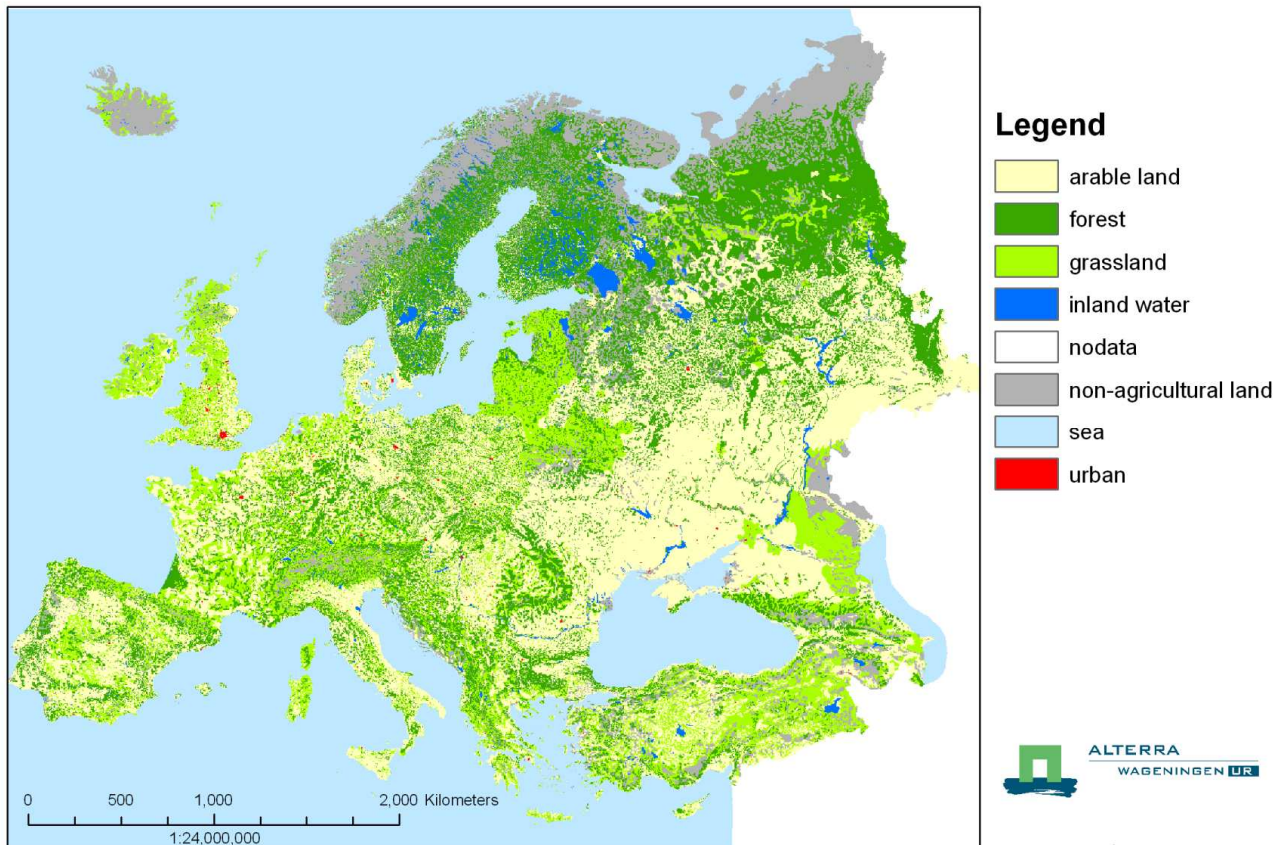


Figure 13. Historical Land use database for the reference year 1960 (HISLU60) derived by digital processing from on the World Atlas of Agriculture..

Pan-European Land Cover Changes 1990-2000

The land cover changes between the years 1990 and 2000 are derived from CORINE land cover. For the countries that are not covered by CORINE, the land cover is equal for both 2000 and 1990, see Annex II. The Pan-European Land Cover Changes (PLCMC1990-2000) indicates for areas changed in land cover; what was the land cover in 1990 and in 2000 (as a shape file). The area outside the countries included in the CLC90-00 database are represented as no data. However, this does not mean that there has not occurred any land cover change in that period.

The exception is Switzerland for which different national land cover databases were used for the PLCM mosaics of 1990 and 2000. The national Swiss land cover databases are pixel based and the methodology used in the production makes it difficult to monitor changes between the databases. The changes show a very fragmented picture (speckled image). Furthermore, the refinement of the Swiss national land cover databases of 1985 and 1997 does not introduce land cover changes if the CLC-level 2 land cover classes did not change. The PELCOM database was used in both cases to refine the CLC-level 2 classes. However, the differences in land cover between 1990 and 2000 were taken into account in the statistics in Annex X.

Annex X presents the land cover changes between the 1990 and 2000 for different spatial and thematic resolutions. The statistics presented deal with the entire PLCM1990 and PLCM2000 databases. An important remark related to the figures is that you have to take into account that they only refer to 25 European countries (Annex II) and Switzerland. Expressing them as relative values with not adapting the total area will result in false conclusions.

The overall general picture regarding land cover changes between 1990 and 2000 is an increase of artificial surfaces with approximately 9000km², an decrease in agricultural areas with almost 9000 km². The wetlands have slightly decreasing in acreage with approximately 1000 km², which is compensated with an increase in water bodies. Forest and semi-natural areas remain more or less the same. A more detailed analysis of land cover changes at country level and/or landscape level can be found in Haines-Young & Weber (2006) and Feranec et al. (prep/submitted).

Pan-European Land Cover Changes 1960-1990

A first attempt was made to compare the land cover of the HISLU60 database with the PLCM1990 database. In other words, an attempt was made to identify the land cover changes over the period 1960-1990. The PLCM1990 database was aggregated thematically to the HISLU60 nomenclature as shown in Table 5. The thematic aggregation of CLC classes into HISLU60 classes went fine since the land cover classes in both databases are comparable in the area.

A comparison of the land cover statistics can be best made at a 1km resolution. Comparisons at finer resolution does not make sense since the HISLU60 database is based on hardcopy maps at a scale of 1:2.500.000.

Comparison of HISLU60 and PLCM1990 (recoded to HISLU LC classes) indicates the most important land cover changes between 1960 and 1990 is the increase of urban area (from nearly 20.000 to nearly 150.000 km²). Although urban areas occupy a relatively small area of Europe. Arable land in both databases is of the same magnitude (3.5 million km²). The area occupied during those 30 years seems to be more or less stable (only an increase of 0.1 million km²). Grasslands diminished significantly in area with 1 million km² (from 1.7 million to 0.7 million km²) which is a decrease of 12% in 30 years !. The forest area increased with 0.6 M km² (from 2.3 to 2.9 million km²) between 1960 and 1990. The area of non-agricultural land is of the same magnitude (1.2-1.4 million km²). However, the area seems to be increasing from 13.5% in 1960 to 15.8% in 1990 which looks to be in contrast with the general opinions of decreasing non-agricultural areas. Inland waters did not really change in area since they still occupy an area of around 200.000 km² (2.2-2.4%).

Table 12 lists all the land cover products made within the ECOCHANGE project.

Table 12. This table shows all the land cover products. The three main land cover databases HISLU60, PLCM1990 and PLCM2000 (indicated in grey and bold letter type) have been aggregated to various thematic resolution (CORINE level 3, CORINE level 2, ALARM and HISLU60 nomenclature) and spatial resolutions (100m, 500m and 1000m)

Nr	List Output Data files*	Description	Size
1	hislu60_100m.img	HISLU60 database with a 100 m spatial resolution	45,892,580
2	hislu60_500m.img	HISLU60 database with a 500 m spatial resolution	2,216,724
3	hislu60_1km.img	HISLU60 database with a 1000 m spatial resolution (original)	5,344,768
4	lc1990_alarm_100m_v2.img	PLCM1990 thematically aggregated to the ALARM nomenclature	128,277,329
5	lc1990_alarm_500m_v2.img	PLCM1990 thematically aggregated to the ALARM nomenclature and a spatial resolution of 500 m.	12,743,103
6	lc1990_alarm_1km_v2.img	PLCM1990 thematically aggregated to the ALARM nomenclature and a spatial resolution of 1000 m.	3,704,444
7	lc1990_hislu60_100m_v2.im	PLCM1990 thematically aggregated to the HISLU60 nomenclature	127,442,000
8	lc1990_hislu60_500m_v2.im	PLCM1990 thematically aggregated to the HISLU60 nomenclature and a spatial resolution of 500 m.	12,674,704
9	lc1990_hislu60_1km_v2.img	PLCM1990 thematically aggregated to the HISLU60 nomenclature and a spatial resolution of 1000 m.	3,666,096

10	lc1990_level2_100m_v2.img	PLCM1990 thematically aggregated to CORINE level two	187,500,347
11	lc1990_level2_500m_v2.img	PLCM1990 thematically aggregated to CORINE level two and a spatial resolution of 500 m.	19,397,978
12	lc1990_level2_1km_v2.img	PLCM1990 thematically aggregated to CORINE level two and a spatial resolution of 1000 m.	5,631,526
13	lc1990_level3_100m_v2.img	The original PLCM1990 land cover database (at CORINE level 3 and a 100 m spatial resolution)	180,464,900
14	lc1990_level3_500m_v2.img	The PLCM1990 land cover database aggregated to a 500 m spatial resolution	23,783,135
15	lc1990_level3_1km_v2.img	The PLCM1990 land cover database aggregated to a 1000 m spatial resolution	6,933,964
16	lc2000_alarm_100m_v2.img	The PLCM2000 land cover database aggregated to the ALARM nomenclature	128,789,636
17	lc2000_alarm_500m_v2.img	The PLCM2000 land cover database aggregated to the ALARM nomenclature and a 500m spatial resolution	12,779,378
18	lc2000_alarm_1km_v2.img	The PLCM2000 land cover database aggregated to the ALARM nomenclature and a 1000m spatial resolution	3,714,561
19	lc2000_hislu60_100m_v2.im	The PLCM2000 land cover database aggregated to the HISLU60 nomenclature	127,961,247
20	lc2000_hislu60_500m_v2.im	The PLCM2000 land cover database aggregated to the HISLU60 nomenclature and a 500m spatial resolution	12,711,585
21	lc2000_hislu60_1km_v2.img	The PLCM2000 land cover database aggregated to the HISLU60 nomenclature and a 1000m spatial resolution	3,675,297
22	lc2000_level2_100m_v2.img	The PLCM2000 land cover database aggregated to level 2 of the CORINE nomenclature	188,297,544
23	lc2000_level2_500m_v2.img	The PLCM2000 land cover database aggregated to level 2 of the CORINE nomenclature and a 500m spatial resolution	19,463,595
24	lc2000_level2_1km_v2.img	The PLCM2000 land cover database aggregated to level 2 of the CORINE nomenclature and a 1000m spatial resolution	5,651,519
25	lc2000_level3_100m_v2.img	The original PLCM2000 land cover database (at CORINE level 3 and a 100 m spatial resolution)	181,100,778
26	lc2000_level3_500m_v2.img	The original PLCM2000 land cover database aggregated to a 500m spatial resolution	23,841,616
27	lc2000_level3_1km_v2.img	The original PLCM2000 land cover database aggregated to a 1000m spatial resolution	6,951,538

All data sets listed above can be viewed and explored from the following temporary web mapping tool site: <http://www.synbiosys.alterra.nl/ecochange/plcm.aspx>. This site should be made available through the ECOCHANGE website.

5. Quality assessment of land cover datasets

CORINE Land Cover

The CLC2000 database was validated according to two methods: a reinterpretation of IMAGE2000 data based on LUCAS codes and photographs and an automatic comparison of CLC2000 codes and LUCAS land use and land cover codes (Büttner & Maucha, 2006). The validation was directed to the areas for which LUCAS data was available. The reinterpretation approach resulted in a total reliability of CLC2000 of $87.0 \pm 0.8\%$ fulfilling the 85% accuracy requirement. The result of the automatic comparison between CLC2000 and LUCAS was an average accuracy of $74.8 \pm 0.6\%$. The validation at class level was limited to 22 out of the 44 CLC classes. The highest class level reliability was obtained by rivers, lakes, industrial and commercial units and discontinuous urban fabric ($>95\%$). Arable land, permanently irrigated land, agro-forestry and coniferous forest obtained 90-95% of reliability. The lowest class level reliability was obtained for the sparse vegetation class ($<70\%$). According to our knowledge there is no European validation available regarding the CORINE Land Cover database of 1990.

PELCOM

The PELCOM database was validated on basis of the reinterpretation of 40 mainly Landsat TM images spread over Europe. In total 7700 km^2 was covered in the assessment. The overall accuracy was 69.2%. Class accuracies varied between classes. Arable land and coniferous forest (occupying the largest areas in Europe) had accuracies and reliabilities of around 80%. While small and fragmented land cover classes such as shrubland and wetlands had very low accuracies and reliabilities. Main problems in validation were the heterogeneous mixed pixels and the georeferencing of the AVHRR data (Mucher et al., 2001).

GLC2000

The global land cover map for the year 2000 (GLC2000) produced by Joint Research Centre (JRC) in collaboration with 30 partner institutes has been validated. The accuracy assessment relied on two methods: a confidence-building method (quality control based on a comparison with ancillary data) and a quantitative accuracy assessment based on a stratified random sampling of reference data. The sample site stratification used an underlying grid of Landsat data and was based on the proportion of priority land cover classes and on the landscape complexity. A total of 1265 samples sites have been interpreted. The overall accuracy of the dataset reached 68.6%. Error statistics were provided from both the producer and user perspective (Mayaux et al., 2006).

National land cover datasets

The Swiss national CORINE Land Cover databases of 1997 and 1985 with CLC level 2 nomenclature are based on the Swiss national land use statistics. During the production process the CLC figures were compared with the land use statistics. Unfortunately, accuracy statistics of the Swiss CLC databases were not available. Accuracy statistics of the Norwegian land cover dataset were neither available.

HISLU60

The assessment of the HISLU60 dataset was published in a paper called “Compilation and assessment of Pan-European land cover changes” (Hazeu et al., 2008) which was presented at the EARSeL conference in Turkey. Large parts of this section were taken from that paper.

The quality of the HISLU60 database was assessed with the following independent data sources:

1. national land cover database of the Netherlands for 1960 (HGN60),
2. Swiss national statistics for 1972, and
3. 73 BIOPRESS windows of 30 by 30 km across Europe for the year 1950 (Gerard *et al.* 2006; Hazeu & Mùcher 2005).

The HGN60 database is a Dutch historical GIS database containing the land use of the Netherlands for the year 1960. The database is a raster database of 25 by 25m and contains 10 different land uses. It is based on topographical map sheets that were scanned and classified with a semi-automatic classification method. The entire Netherlands was covered with map sheets of different reconnaissance dates (Kramer & Dorland, in prep).

The Swiss national land cover dataset of 1972 goes back to land use statistics of 1960s. This data were used to validate the HISLU60 dataset for Switzerland. The original 12 land use classes were converted into the 7 HISLU classes.

BIOPRESS’s focussed on past land cover changes from 1950 to 2000, which may have had an impact on habitats and their associated biodiversity. For a selection of 73 windows of 30 by 30km across Europe aerial photographs of the 1950s were compared against CLC1990. A minimum mapping unit of 25 ha was used which is in line with the standard CORINE Land Cover minimum mapping unit. The CLC nomenclature was used in the interpretation and land use change analysis (Gerard et al., submitted).

For all three data sources the land cover classes were converted to the HISLU60 nomenclature. The validation for the Netherlands with HGN1960 covers the Dutch territory with a border of sea around (area of 41739 km²). The validation for Switzerland covers an area of 41366 km². The validation of HISLU60 with the BIOPRESS data from 1950 covers a total area of 59304 km² across Europe.

Comparison of HISLU60 with PLCM1990 indicates a very strong increase in urban and forest areas at the expense of grasslands (Table 10 and 11). After a first assessment of the HISLU60 dataset it appeared that the urban area was largely underestimated. A combination with the urban areas of the Digital Chart of the World (DCW) resulted in a better estimation of urban areas around 1960. The improved HISLU60 data are presented in Table 13 (2nd and 3rd column).

Table 13. Area (km² and %) of 7 HISLU land cover classes for the years 1960, 1990 and 2000. The spatial resolution is 1 by 1 km.

HISLU Classes	HISLU60		PLCM1990		PLCM2000		PLCM1990-	PLCM2000-
							HISLU60	PLCM1990
	km2	%	km2	%	km2	%	km2	km2
Urban	87057	0.97	149620	1.67	157924	1.76	62563	8304
Arable land	3432502	38.27	3595102	40.09	3587947	40.01	162600	-7155
Grassland	1716263	19.13	643819	7.18	640629	7.14	-1072444	-3190
Forest	2260972	25.21	2935273	32.73	2935987	32.74	674301	714
Non-agri.land	1205102	13.44	1416475	15.79	1416887	15.80	211373	412
Inland waters	193284	2.15	219111	2.44	219956	2.45	25827	845
Sea	74259	0.83	8786	0.10	8769	0.10	-65473	-17
Total	8969439	100	8968186	100	8968099	100		

* discrepancies in total areas due to small differences in extent
 * HISLU60 data deviate slightly from Table 10 due to recent improvements with DCW

The differences in thematic, spatial and temporal detail between the validation data sets and the HISLU60 database hampers a direct assessment. The assessment results have to be dealt with care. They give only an indication of the overall accuracy of the HISLU60 database. Outcomes from other regional assessments may be different.

Table 14. Omission (accuracy) and commission (reliability) errors for the three HISLU60 assessments. The index (HISLU60/reference dataset) indicates under- or overestimation of a land cover class in the HISLU60 dataset.

HISLU classes	HGN1960		BIOPRESS1950			SWISS1970			
	Om. error	Com. error	Index	Om. error	Com. error	Index	Om. error	Com. error	Index
Arable land (class 1)	0.57	0.46	1.23	0.57	0.63	0.90	0.16	0.60	0.27
Grassland (class 2)	0.57	0.64	0.89	0.46	0.22	2.13	0.51	0.24	2.13
Forest (class 3)	0.28	0.27	1.05	0.52	0.55	0.95	0.37	0.38	0.97
Non-agricultural land (class 4)	0.39	0.37	1.04	0.11	0.40	0.28	0.64	0.56	1.14
Inland water (class 5)	-	-	-	0.28	0.25	1.11	0.61	0.67	0.91
Urban (class 6)	0.16	0.46	0.35	0.29	0.66	0.43	0.06	0.65	0.10
Sea (class 7)	0.85	0.86	0.99	0.91	0.68	0.46	-	-	-
Overall accuracy	0.58			0.48			0.38		

* Sea and inland water are taken together in HGN1960 assessment
 * HGN60 assessment with fruit trees/ orchards of HISLU recoded to Grassland
 * BIOPRESS assessment with new HISLU60 dataset

Table 14 shows that the accuracies (omission errors) and reliabilities (commission errors) of the HISLU60 database are low for all three validation data sets (HGN1960, BIOPRESS 1950 and SWISS1970). All error figures indicate limited class accuracies and reliabilities (in most cases below 60%). The overall accuracy of the HISLU60 database ranges from 38.4 – 58.1% depending on the used reference dataset. The accuracy assessment with the Swiss data resulted in the lowest overall accuracy while the BIOPRESS assessment took an intermediate position with 48.1%. These low accuracies are a clear indication to restrict the change analysis only to regional or national statistics. A more detailed analysis of changes does not make sense as the pixel (1 by 1 km) or locational accuracy is very low as indicated by all three assessments.

An index, defined as the HISLU60 area divided by the area of the reference (validation) dataset was calculated per HISLU60 class for each assessment study. The index is an indication for the extent of under- or overestimation of the surface area in the HISLU60 database compared with the reference datasets.

Differences in the index between the three assessments is small and around 1 for the HISLU classes forest and inland water, indicating similar surface areas in both the HISLU60 and the reference datasets. All three assessments indicate a low index value for the urban class indicating a large underestimation of urban area in the HISLU60 database. Despite the improvement of urban area due to the combination of HISLU60 data with the DCW database, the area is still largely underestimated (Table 14, column 7). The other indices for the three assessments vary largely and over- or underestimation of land cover are in contradiction with each other. Arable land is largely overestimated (23%) in the Netherlands but underestimated in the other case studies. Grassland is underestimated according to the Dutch case-study but largely overestimated (and in equal amounts) in the Swiss and BIOPRESS assessments. Non-agricultural land is largely underestimated according to the BIOPRESS data.

A detailed assessment for the Netherlands revealed large regional differences in index values. Only arable land (all overestimation) and urban area (all underestimation with the exception of Friesland)

present the same trends for all provinces. Table 15 shows the regional variation for the HISLU land use classes between HISLU60 and the HGN60 reference dataset. The 2nd column shows the difference in ha between HISLU and HGN, the second column indicates the relative size of the discrepancy between the two datasets and the index shows the ratio between HISLU and HGN(4th column). Non-agricultural land, urban area and water are largely underestimated in Gelderland while in Friesland they are (slightly) overestimated. Furthermore, it is clear that both provinces have a much larger overestimation of arable land than the mean figure for The Netherlands (see Table 14).

Table 15. Variation in surface area (ha) between HISLU60 and the HGN60 reference dataset for two Dutch provinces.

	Province Gelderland			Province Friesland		
	HISLU-HGN (ha)	% of total	Index	HISLU-HGN (ha)	% of total	Index
Arable land	84725	16.5%	2.07	25319	4.4%	1.80
Grassland	-64400	-12.5%	0.78	-43594	-7.6%	0.84
Forest	15269	3.0%	1.17	2356	0.4%	1.32
Non-agriculture	-13006	-2.5%	0.48	7356	1.3%	1.44
Urban	-12688	-2.5%	0.23	113	0.0%	1.03
Water	-9900	-1.9%	0.03	8450	1.5%	1.04

The comparison of HISLU60 data with the BIOPRESS data shows large regional differences. One important discrepancy between both datasets is the overestimation of grasslands in the Mediterranean countries on behalf of the non-agricultural class. The majority (>80%) of moors and heath lands (CLC class 322), sclerophyllous vegetation (CLC class 323) and sparsely vegetated areas (CLC class 333) are not classified as non-agricultural land. The area occupied by those classes is for more than 50% classified as grasslands in the HISLU60 database.

6. Assessment of land cover changes in Europe

1990-2000

The land cover changes between PLCM1990 and PLCM2000 refer to those countries that have both CLC databases available. Weber (2007), Haines-Young & Weber (2006) and Feranec et al. (submitted) elaborate on these land cover changes between CLC1990 and CLC2000.

The CLC-changes between 1990 and 2000 were not validated by the EEA (European Environmental Agency). The changes were only verified during the different verification missions by an external team. At national level they were sometimes validated (eg. The Netherlands) (Hazeu, 2003). A possible source for validating land cover changes between 1990 and 2000 are more detailed national land cover (change) databases. However, access can be difficult for other countries and it is also the question if they are existing.

1960-1990

The assessment of historical land cover changes is difficult due to various reasons. The most important ones are:

1. The comparison of different datasets is difficult due to differences in thematic and spatial detail.
2. The objectives, methodology and production is different for historical land cover datasets and not comparable with more recent datasets. The comparability of the datasets and therefore the assessment of changes is complicated.
3. Historical land cover datasets are produced with the best available data sources. One dataset is often a combination of different data sources. Therefore, the temporal (and thematic) variation within one dataset can be large.
4. Validation of a historical dataset is difficult as independent reference data sources are very limited. Collection of 'new' data is not possible.

Based on these assumptions and the limited accuracy of the HISLU60 dataset, the assessment of 1960-1990 land cover changes has been limited to regional statistics. A pixel to pixel validation is not valid. The NUTSx administrative regions were used for the statistical analysis. The NUTSx dataset divides Europe in administrative regions of comparable size. The focus of the change analysis was directed to the grassland and forest land covers. After all, these classes are the most important ones within the ECOCHANGE project.

With the indices calculated for the HISLU60 assessment, a regional assessment (NUTSx) of the land cover changes for the 1960-1990 period was carried out. The index (HISLU60 area/reference dataset area) was calculated per HISLU60 class for each assessment study. The BIOPRESS and Swiss indices of Table 14 were used to calculate a mean index.. However, these results did not deviate much. On basis of this index a new normalized HISLU60 area (HISLU60_{norm}) per NUTSx region was calculated for the grassland and forest classes. The normalized 1960 values were used in the regional analysis of changes for the 1960-1990 period (Hazeu et al., 2008).

Figure 14 shows the percentage of changes in forest or grassland expressed as percentage of their normalized 1960 area per NUTSx regions ((PLCM1990-HISLU60_{norm})/HISLU60_{norm}). The total forest area increases with 236122 km² and the grassland area decreases with 563730 km² for the EU27+2. These figures show a similar trend as the statistics presented in Table 13.

The general picture for the forests in Europe shows an increase in forest area for NUTSx regions in Norway, Sweden and the Central Southern part of Europe. Extreme increases are limited (Norway, Scotland, Ireland, Estonia and small part of France). NUTSx regions with an extreme increase for grassland areas are located in Norway, Ireland, Britain and Portugal. The decrease in grassland area is pronounced in large parts of Europe (yellow NUTSx regions).

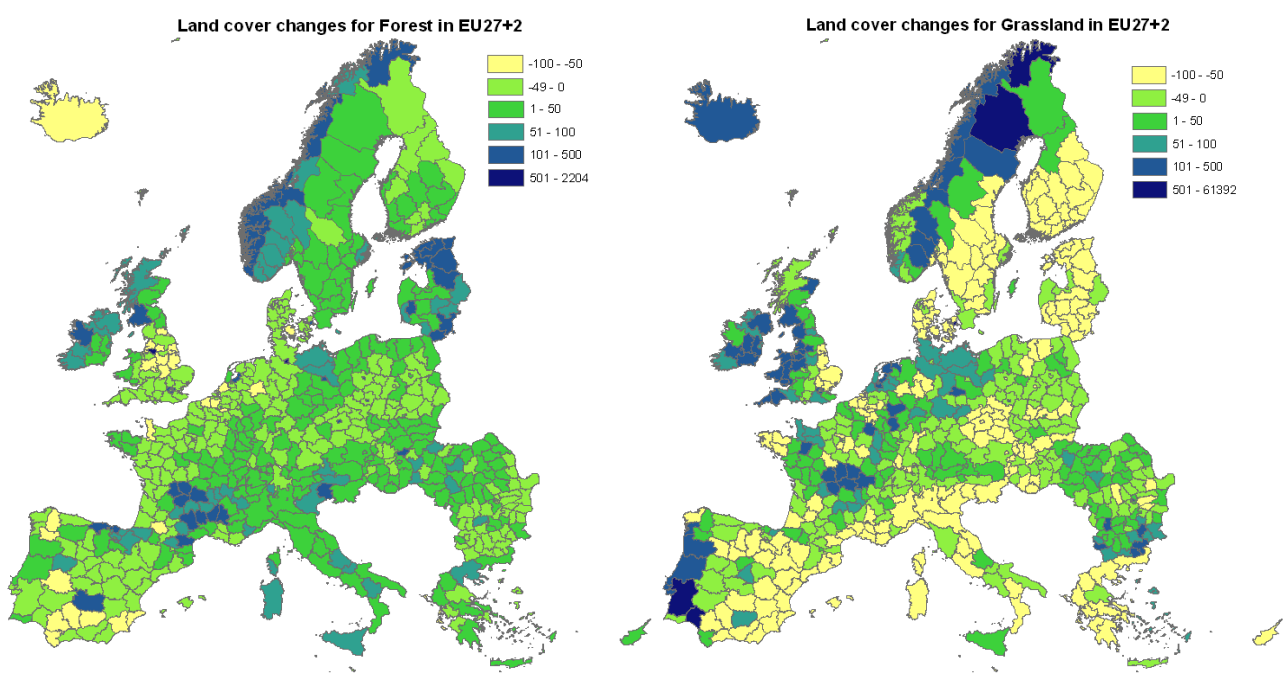


Figure 14. Spatial distribution of the amount of changes during the 1960-1990 period for forest (left) and grasslands (right) in Europe for NUTSx regions. The increase and decrease are expressed as percentage of the 1960 area.

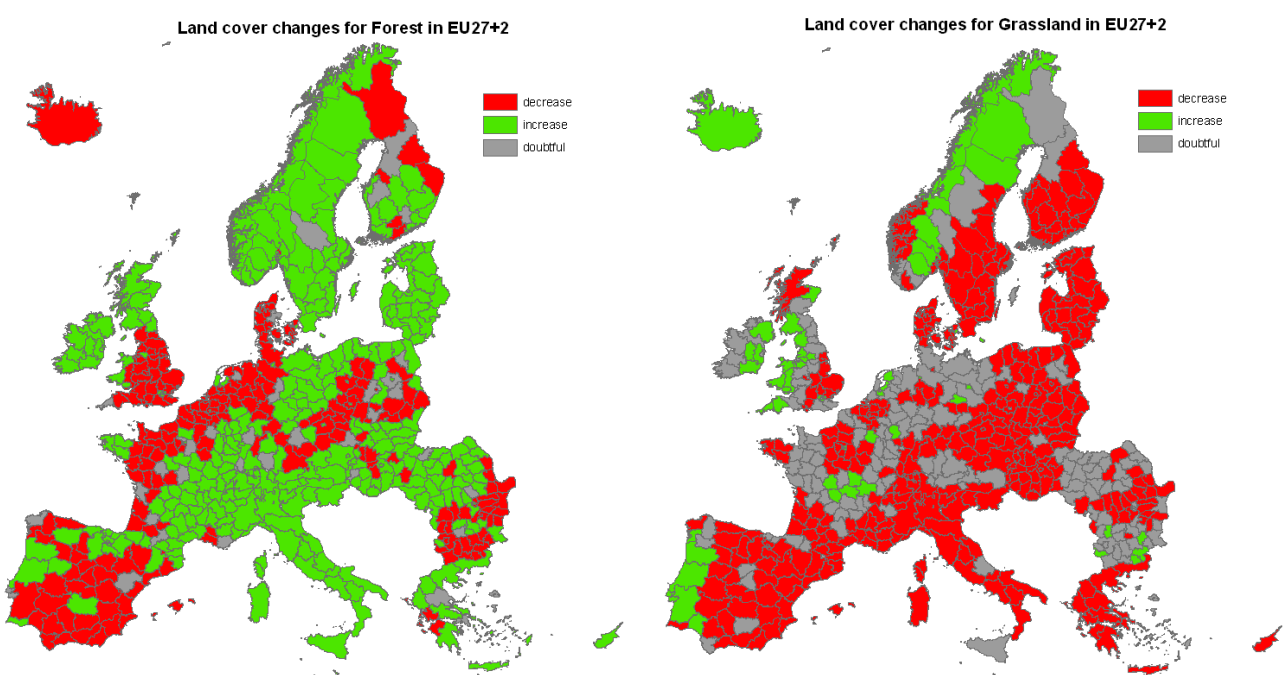


Figure 15. Spatial distribution of NUTSx regions with an increase or decrease of forest and grasslands. Non-significant changes are in grey.

Very strong increases of forest or grassland have to be interpreted with care. Very small areas of grassland/forest in 1990s and much larger area in 1960s will result in decreases of nearly 100% for

specific NUTSx region. Furthermore, changes are also doubtful if the direction (increase or decrease) of changes between 1990-1960 and 1990-1960norm are not similar (Figure 15).

A final check of the direction and magnitude of changes per NUTSx region could be a comparison with the land cover change statistics for BIOPRESS windows located entirely within one NUTSx region. Another possibility could be a comparison with land use statistical databases if they contain data of 1960s at NUTSx administrative level.

7. Outlook to the future

Assessment of land cover datasets

The CLC2000 database was validated on basis of LUCAS data (Büttner & Maucha, 2006). The overall thematic accuracy is above 85%. PELCOM reaches an overall accuracy of 69.2% (Mucher et al., 2001) and GLC2000 has an overall accuracy of 68.6% (Mayaux et al., 2006). All databases have accuracy figures at class level. The most important classes arable land and coniferous forest have accuracy levels above the overall accuracy. The Swiss national CLC database has been compared with the original Swiss Land Use Statistics on which it was based. The validation figures for CLC90 and the Norwegian land cover datasets were not available

The assessment of the HISLU60 database was restricted to land cover data with a spatial resolution of 1 km and 7 HISLU60 classes. The production of a Pan-European land cover map for 1960 was determined by the availability of non-digital cartographic maps. Consistency of such maps in thematic and spatial detail are limited according to current requirements. Improvements of the urban areas of the HISLU60 database resulted in better but still low accuracies.

The overall accuracy of the HISLU60 database on basis of three independent data sources is low (<60%). Therefore, a pixel comparison of changes between 1960-1990 is difficult. Analysis of changes in regional land cover statistics (at NUTSx level) helps in understanding processes (e.g. afforestation, urbanization) within the European landscapes. However, regional differences in the quality of the HISLU60 database implies to use the land cover change indications with care.

Assessment of land cover changes

The validation of land cover changes between 1990-2000 was not considered at European scale. The changes were only verified by a external team during the production of CLC2000. A possible source for validating land cover changes between 1990 and 2000 are more detailed national land cover (change) databases.

As a pixel to pixel comparison of the HISLU60 dataset with reference data showed low accuracies, the land cover changes between 1960 -1990 has to be assessed at a regional or an even less detailed level. Calculation of a normalized 1960 land cover on basis of HISLU/reference dataset ratios can helped in analysing historical land cover changes. Comparison with BIOPRESS 1950-1990 statistics helped to better interpret the results of the regional land cover change assessment presented in this deliverable.

Historical change analysis remains difficult and needs to be further explored in new projects. Results of a historical land cover change analysis needs to be validated and interpreted in relation to the way they are produced and used. Lack of independent (spatial) historical data hamper the validation of historical land cover changes.

Recoding

After comments of the users of the land cover products the recoding of land cover classes into CLC-level 3 classes can be adapted to fit more the goals of the users. Also, after verifying the PLCM1990 database recoded to HISLU classes some adaptations could be made to make a change analysis between this database and the HISLU60 database useful for different applications.

Fragmentation analysis

The land cover databases HISLU60, PLCM1990 and PLCM2000 will be used in the fragmentation analysis. In the near future the landscape metrics will be selected and the level of detail on which analysis will take place (class or landscape level). Also a decision will be taken on which land cover products the fragmentation analysis will be performed.

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Annexes

Annex I. Definition of the INSPIRE standard projection ETRS_1989_LAEA

```
PROJCS ["ETRS_1989_LAEA"],  
GEOGCS["GCS_ETRS_1989"],  
DATUM["D_ETRS_1989"],  
SPHEROID["GRS_1980",6378137.0,298.257222101],  
PRIMEM["Greenwich",0.0],  
UNIT["Degree",0.0174532925199433],  
PROJECTION["Lambert_Azimuthal_Equal_Area"],  
PARAMETER["False_Easting",4321000.0],  
PARAMETER["False_Northing",3210000.0],  
PARAMETER["Central_Meridian",10.0],  
PARAMETER["Latitude_Of_Origin",52.0],  
UNIT["Meter",1.0]
```

Annex II. Availability and use of different land cover datasets in the compilation of PLCM90 and PLCM2000.

Country	2000	1990	changes
<i>Albania</i>	CLC2000	idem	no
<i>Andorra</i>	GLC2000	idem	no
Austria	CLC2000	CLC1990	yes
Belgium	CLC2000	CLC1990	yes
<i>Bosnia and Herzegovina</i>	CLC2000	idem	no
Bulgaria	CLC2000	CLC1990	yes
<i>Croatia</i>	CLC2000	CLC1990	yes
Cyprus	CLC2000	idem	no
Czech Republic	CLC2000	CLC1990	yes
Denmark	CLC2000	CLC1990	yes
Estonia	CLC2000	CLC1990	yes
Finland	CLC2000	idem	no
France	CLC2000	CLC1990	yes
Germany	CLC2000	CLC1990	yes
Greece	CLC2000	CLC1990	yes
Hungary	CLC2000	CLC1990	yes
Ireland	CLC2000	CLC1990	yes
Italy	CLC2000	CLC1990	yes
<i>Liechtenstein</i>	CLC2000	idem	no
Latvia	CLC2000	CLC1990	yes
Lithuania	CLC2000	CLC1990	yes
Luxembourg	CLC2000	CLC1990	yes
<i>Macedonia</i>	CLC2000	idem	no
Malta	CLC2000	idem	no
Netherlands	CLC2000	CLC1990	yes
Norway	AR2000+GLC2000	idem	no
Poland	CLC2000	CLC1990	yes
Portugal	CLC2000	CLC1990	yes
Romania	CLC2000	CLC1990	yes
<i>San Marino</i>	CLC2000	CLC1990	yes
Slovakia	CLC2000	CLC1990	yes
Slovenia	CLC2000	CLC1990	yes
Spain	CLC2000	CLC1990	yes
Sweden	CLC2000	idem	no
Switzerland	CH97+PELCOM	CH85+PELCOM	no
United Kingdom	CLC2000	CLC2000+changes	yes
<i>Serbia and Montenegro</i>	CLC2000	idem	no
<i>Iceland</i>	PELCOM	idem	no
<i>Kosovo</i>	PELCOM	idem	no
<i>Moldavia</i>	PELCOM	idem	no
<i>Pan-Europe</i>	GLC2000	idem	no

Albania: not EU27 with CLC2000 (and sometimes CLC1990)

Andorra: not EU27 and no CLC2000

Austria: EU27 with CLC2000 and CLC1990

Cyprus: EU27 with only CLC2000

Norway: not EU27 and local LC

Annex III. Nomenclature of different land cover datasets.

CORINE Land Cover

Level 1	level 2	Level 3	
1 Artificial surfaces	1.1 urban fabric	1.1.1 Continuous urban fabric	1
		1.1.2 Discontinuous urban fabric	2
	1.2 industrial, commercial and transport units	1.2.1 Industrial and commercial units	3
		1.2.2 Road and rail networks and associated	4
		1.2.3 Port areas	5
		1.2.4 Airports	6
	1.3 mine, dump and construction sites	1.3.1 Mineral extraction sites	7
		1.3.2 Dump sites	8
		1.3.3 Construction sites	9
	1.4 artificial non-agricultural vegetated areas	1.4.1 Green urban areas	10
1.4.2 Port and leisure facilities		11	
2 Agricultural areas	2.1 arable land	2.1.1 Non-irrigated arable land	12
		2.1.2 Permanently irrigated land	13
		2.1.3 Rice fields	14
	2.2 Permanent crops	2.2.1 Vineyards	15
		2.2.2 Fruit trees and berry plantation	16
		2.2.3 Olive groves	17
	2.3 Pastures	2.3.1 Pastures	18
	2.4 heterogeneous agricultural areas	2.4.1 Annual cops associated with permanent crops	19
		2.4.2 Complex cultivation patterns	20
		2.4.3 Land principally occupied by agriculture with significant natural	21
		2.4.4 Agro-forestry areas	22
	3 Forests and semi-natural Areas	3.1 Forest	3.1.1 Broad-leaved forest
3.1.2 Coniferous forest			24
3.1.3 Mixed forest			25
3.2 shrub and/or herbaceous Vegetation associations		3.2.1 Natural grasslands	26
		3.2.2 Moors and heath lands	27
		3.2.3 Sclerophyllous vegetation	28
		3.2.4 Transitional woodland-scrub	29
3.3 open spaces with little or no vegetation		3.3.1 Beaches, sand, dunes	30
		3.3.2 Bare rocks	31
		3.3.3 Sparsely vegetated areas	32
		3.3.4 Burnt areas	33
		3.3.5 Glaciers and perpetual snow	34
4 Wetlands	4.1 inland wetlands	4.1.1 Inland marshes	35
		4.1.2 Peat bogs	36
	4.2 coastal wetlands	4.2.1 Salt marshes	37
		4.2.2 Salines	38
		4.2.3 Intertidal flats	39
	5 Water bodies	5.1 inland waters	5.1.1 Water courses
5.1.2 Water bodies			41
5.2 marine waters		5.2.1 Coastal lagoons	42
		5.2.2 Estuaries	43
		5.2.3 Sea and ocean	44

Annex IV. Recode tables for GLC2000 and PELCOM into CLC (CORINE Land Cover) classes

Annex IV.a. Recoding of the PELCOM land cover database into the CORINE nomenclature.

PELCOM		CORINE		
code	classname	code	classname	Class nr
11	Broadleaf forest	3.1.1	broadleaf forests	23
12	Coniferous forest	3.1.2	coniferous forest	24
13	Mixed Forest	3.1.3	mixed forest	25
20	Grasslands	2.3.1	pastures	18
31	Rainfed-arable	2.1.1	non-irrigated arable land	12
32	Irrigated land	2.1.2	permanently irrigated land	13
40	Permanent crops	2.2.1	vineyards	15
50	Shrubland	3.2.3	sclerophyllous vegetation	28
60	Barren land	3.3.3	sparsely vegetated areas	32
70	Permanent ice and snow	3.3.5	glaciers and perpetual snow	34
80	Wetlands	4.1.1	inland marshes	35
91	Inland waters	5.1.2	water bodies	41
92	Sea	5.2.3	sea and ocean	44
100	Urban areas	1.1.2	discontinuous urban fabric	2

Annex IV.b Recoding of the GLC2000 land cover database into the CORINE nomenclature.

GLC code	GLC2000	CORINE code	CORINE Classname	Class nr
1	Tree Cover, broadleaved, evergreen	311	Broadleaf forests	23
2	Tree Cover, broadleaved, deciduous, closed	311	Broadleaf forests	23
3	Tree Cover, broadleaved, deciduous, open	311	Broadleaf forests	23
4	Tree Cover, needle-leaved, evergreen	312	Coniferous forest	24
5	Tree Cover, needle-leaved, deciduous	312	Coniferous forest	24
6	Tree Cover, mixed leaf type	313	Mixed forest	25
7	Tree Cover, regularly flooded, fresh	-	-	-
8	Tree Cover, regularly flooded, saline, (daily variation)	-	-	-
9	Mosaic: Tree cover / Other natural vegetation	312	Coniferous forest	24
10	Tree Cover, burnt	334	Burnt areas	33
11	Shrub Cover, closed-open, evergreen	324	Transitional woodland shrub	29
12	Shrub Cover, closed-open, deciduous	324	Transitional woodland shrub	29
13	Herbaceous Cover, closed-open	321	Natural grasslands	26
14	Sparse Herbaceous or sparse shrub cover	333	Sparsely vegetated areas	32
15	Regularly flooded shrub and/or herbaceous cover	411	Inland marshes	35
16	Cultivated and managed areas	211	Non-irrigated arable land	12
17	Mosaic: Cropland / Tree Cover / Other Natural Vegetation	211	Non-irrigated arable land	12
18	Mosaic: Cropland / Shrub and/or Herbaceous cover	211	Non-irrigated arable land	12
19	Bare Areas	332	Bare rocks	31
20	Water Bodies (natural & artificial)	512	Inland water bodies	41
21	Snow and Ice (natural & artificial)	335	Glaciers and perpetual snow	34
22	Artificial surfaces and associated areas	112	Discontinuous urban fabric	2
23	Permanently irrigated land	212	Permanently irrigated land	13
24	No data			

Annex V. Projection parameters of the Swiss land cover products

Projection: Hotine_Oblique_Mercator_Azimuth_Center

Parameters:

False_Easting: 600000.000000

False_Northing: 200000.000000

Scale_Factor: 1.000000

Azimuth: 90.000000

Longitude_Of_Center: 7.439583

Latitude_Of_Center: 46.952406

Linear Unit: Meter (1.000000)

Geographic Coordinate System:

Name: GCS_CH1903

Angular Unit: Degree (0.017453292519943299)

Prime Meridian: Greenwich (0.000000000000000000)

Datum: D_CH1903

Spheroid: Bessel_1841

Semimajor Axis: 6377397.155000000300000000

Semiminor Axis: 6356078.962818188600000000

Inverse Flattening: 299.152812799999990000

Annex VI. Recoding and production of CLC for Norway.

	AR2000	CLC-level3	GLC2000	CLC-level3 NO+
Production Forest	1	312	2 and 3 6 10 rest	311 313 324 312
Non-production forest	2	312	2 and 3 6 10 rest	311 313 324 312
Agricultural land	3	211	13 17 and 18 rest	231 243 211
Other land with vegetation	4	322	9 13 15 rest	324 321 412 322
Barren land	5	332	12-15 rest	333 332
Built-up areas	6	112	all	112
Glaciers	7	335	all	335
Water	8	512	all	512

Annex VII. Recoding and production of CLC for Switzerland.

CLC-level2	CLC-level3	PELCOM-CLC codes	CLC-level3 CH+
11	112	all	112
12	121	all	121
13	133	all	133
14	141	18	142
		rest	141
21	211	all	211
22	222	15	221
		rest	222
23	231	all	231
24	242	23-25, 28, 32,34	243
		rest	242
31	312	23	311
		25	313
		rest	312
32	321	28	323
		23, 24 and 25	324
		rest	321
33	333	32	332
		34	335
		rest	333
41	411	all	411
42	-	-	
51	512	all	512
52	-	-	

Annex VIII. Thematic aggregation of PLCM2000 database (CLC-level 2, ALARM and HISLU60) for 100m², 500m² and 1km² spatial resolutions (area in km²).

CLC code	CLC level2 classes	100m ²	%	500m ²	%	1km ²	%
11	Urban fabric	156601	1.74	149228	1.66	128280	1.43
12	Industrial, commercial and transport units	27113	0.30	24641	0.27	18780	0.21
13	Mine, dump and construction site	8635	0.10	7919	0.09	5494	0.06
14	Artificial, non-agricultural are	11191	0.12	10186	0.11	6907	0.08
21	Arable land	2819154	31.41	2859273	31.87	2950905	32.91
22	Permanent crops	104766	1.17	105350	1.17	103963	1.16
23	Pastures	427840	4.77	423163	4.72	407925	4.55
24	Heterogenous agricultural areas	533670	5.95	515867	5.75	475911	5.31
31	Forests	2855031	31.81	2887205	32.18	2974722	33.17
32	Shrub and/or herbaceous vegetation	1183084	13.18	1163968	12.97	1116291	12.45
33	Open spaces with little or no vegetation	386698	4.31	382096	4.26	371670	4.14
41	Inland wetlands	195751	2.18	186482	2.08	161211	1.80
42	Maritime wetlands	14279	0.16	14147	0.16	13821	0.15
51	Inland waters	242415	2.70	234494	2.61	222298	2.48
52	Marine waters	8884	0.10	8855	0.10	8920	0.10
Total		8975113	100	8972871	100	8967098	100

ALARM classes	100m ²	%	500m ²	%	1km ²	%
Urban	203540	2.27	189824	2.12	157921	1.76
Agriculture	3457590	38.52	3496685	38.97	3585409	39.98
Grassland	427840	4.77	417781	4.66	391400	4.36
Forest	2855031	31.81	2876808	32.06	2933370	32.71
Surplus land	1393115	15.52	1367191	15.24	1298946	14.48
Other fixed land cover	637996	7.11	624839	6.96	601054	6.70
Total	8975113	100	8973128	100	8968100	100

HISLU classes	100m ²	%	500m ²	%	1km ²	%
Urban	203540	2.27	189817	2.12	157924	1.76
Arable land	3457590	38.52	3497343	38.98	3587947	40.01
Grass land	713538	7.95	694959	7.74	640629	7.14
Forest	2855031	31.81	2877166	32.06	2935987	32.74
Non-agricultural land	1494115	16.65	1471360	16.40	1416887	15.80
Inland waters	242415	2.70	233704	2.60	219956	2.45
Sea	8884	0.10	8820	0.10	8769	0.10
Total	8975113	100	8973168	100	8968099	100

Annex IX. Thematic aggregation of PLCM1990 database (CLC-level 2, ALARM and HISLU60) for 100m², 500m² and 1km² spatial resolutions (area in km²).

CLC code	CLC level2 classes	100m ²	%	500m ²	%	1km ²	%
11	Urban fabric	152086	1.69	144549	1.61	123434	1.38
12	Industrial, commercial and transport units	24167	0.27	21906	0.24	16472	0.18
13	Mine, dump and construction site	7941	0.09	7321	0.08	5265	0.06
14	Artificial, non-agricultural are	10289	0.11	9325	0.10	6253	0.07
21	Arable land	2825828	31.48	2866140	31.94	2957570	32.98
22	Permanent crops	104356	1.16	104852	1.17	103203	1.15
23	Pastures	429288	4.78	424526	4.73	408849	4.56
24	Heterogeneous agricultural areas	534932	5.96	516890	5.76	476755	5.32
31	Forests	2854690	31.81	2886798	32.17	2974220	33.17
32	Shrub and/or herbaceous vegetation	1182921	13.18	1163870	12.97	1116595	12.45
33	Open spaces with little or no vegetation	387185	4.31	382557	4.26	372086	4.15
41	Inland wetlands	196828	2.19	187576	2.09	162235	1.81
42	Maritime wetlands	14362	0.16	14230	0.16	13892	0.15
51	Inland waters	241430	2.69	233563	2.60	221439	2.47
52	Marine waters	8891	0.10	8859	0.10	8932	0.10
Total		8975194	100	8972960	100	8967200	100

ALARM classes	100m ²	%	500m ²	%	1km ²	%
Urban	194483	2.17	180838	2.02	149642	1.67
Agriculture	3465116	38.61	3504244	39.05	3592488	40.06
Grassland	429288	4.78	419116	4.67	392523	4.38
Forest	2854690	31.81	2876383	32.06	2932610	32.70
Surplus land	1394111	15.53	1368237	15.25	1300279	14.50
Other fixed land cover	637506	7.10	624396	6.96	600658	6.70
Total	8975194	100	8973215	100	8968200	100

HISLU classes	100m ²	%	500m ²	%	1km ²	%
Urban	194483	2.17	180827	2.02	149620	1.67
Arable land	3465116	38.61	3504936	39.06	3595102	40.09
Grassland	717216	7.99	698470	7.78	643819	7.18
Forest	2854690	31.81	2876751	32.06	2935273	32.73
Non-agricultural land	1493368	16.64	1470659	16.39	1416475	15.79
Inland water	241430	2.69	232789	2.59	219111	2.44
Sea	8891	0.10	8825	0.10	8786	0.10
Total	8975194	100	8973257	100	8968186	100

Annex X. Land cover changes for the thematic aggregations (CLC-level 3 (Annex Xa), CLC-level 2 (Annex Xb), ALARM (Annex Xc) and HISLU60 (Annex Xd)) for 100m², 500m² and 1km² spatial resolutions (area in km²).

Annex Xa.

CLC code	CLC nomenclature	1990	2000	change	1990	2000	change	1990	2000	change
		100m ²			500m ²			1km ²		
1.1.1	Continuous urban fabric	5690	5879	189	5522	5718	196	4630	4837	207
1.1.2	Discontinuous urban fabric	146396	150723	4326	140056	144567	4512	121729	126456	4727
1.2.1	Industrial and commercial units	18715	21230	2515	17160	19618	2458	12561	14679	2118
1.2.2	Road and rail networks and associated land	1589	1933	344	983	1167	184	364	439	75
1.2.3	Port areas	987	1027	40	935	977	43	784	821	37
1.2.4	Airports	2876	2923	47	2847	2899	52	2702	2764	62
1.3.1	Mineral extraction sites	5697	6242	545	5386	5914	528	3991	4291	300
1.3.2	Dump sites	1101	1093	-8	1069	1064	-5	853	860	7
1.3.3	Construction sites	1143	1299	156	941	1030	89	659	592	-67
1.4.1	Green urban areas	3019	3050	31	2590	2599	9	1639	1631	-8
1.4.2	Port and leisure facilities	7270	8141	871	6786	7639	853	4749	5427	678
2.1.1	Non-irrigated arable land	2786951	2777293	-9658	2835054	2825114	-9941	2950045	2940069	-9976
2.1.2	Permanently irrigated land	32954	35989	3035	33186	36224	3038	33141	36276	3135
2.1.3	Rice fields	5922	5872	-50	5970	5911	-59	6055	5965	-90
2.2.1	Vineyards	39574	39398	-176	39982	39820	-162	39710	39582	-128
2.2.2	Fruit trees and berry plantation	25327	25404	77	25254	25365	111	24055	24229	174
2.2.3	Olive groves	39455	39964	508	40017	40562	546	40745	41443	698
2.3.1	Pastures	429288	427840	-1448	428154	426812	-1342	421162	420303	-859
2.4.1	Annual crops associated with permanent crops	10250	9898	-353	10291	9934	-358	10270	9943	-327
2.4.2	Complex cultivation patterns	272389	272039	-350	268818	268564	-255	257270	257096	-174
2.4.3	Land principally occupied by agriculture with significant natural vegetation	220838	219845	-993	204944	204031	-913	168215	167313	-902

2.4.4	Agro-forestry areas	31454	31888	434	31718	32174	456	32429	32875	446
3.1.1	Broad-leaved forest	885532	888219	2687	886273	889123	2849	890467	893619	3152
3.1.2	Coniferous forest	1277539	1275517	-2022	1297112	1294857	-2255	1346407	1343726	-2681
3.1.3	Mixed forest	691619	691295	-324	687758	687431	-327	679161	678633	-528
3.2.1	Natural grasslands	287928	285698	-2230	280298	278123	-2175	256045	253945	-2100
3.2.2	Moors and heath lands	203431	202243	-1188	205229	204025	-1205	210609	209294	-1315
3.2.3	Sclerophyllous vegetation	100017	98448	-1569	100189	98625	-1564	101392	99833	-1559
3.2.4	Transitional woodland-scrub	591544	596695	5151	578220	583474	5254	550264	555685	5421
3.3.1	Beaches, sand, dunes	3850	3795	-55	2809	2751	-58	1810	1761	-49
3.3.2	Bare rocks	82715	82777	62	82268	82336	68	81706	81814	108
3.3.3	Sparsely vegetated areas	280206	280189	-16	277044	277038	-6	268696	268715	19
3.3.4	Burnt areas	3219	2848	-370	3145	2782	-363	2830	2456	-374
3.3.5	Glaciers and perpetual snow	17195	17088	-107	17091	16986	-105	16734	16618	-116
4.1.1	Inland marshes	116082	116058	-23	112788	112751	-37	103339	103332	-7
4.1.2	Peat bogs	80746	79693	-1053	76991	75932	-1059	69917	68907	-1010
4.2.1	Salt marshes	3121	3115	-5	3024	3019	-4	2710	2704	-6
4.2.2	Salines	742	757	15	739	756	17	783	797	14
4.2.3	Intertidal flats	10500	10408	-92	10429	10336	-93	10288	10201	-87
5.1.1	Water courses	11071	11080	9	7446	7460	14	5299	5316	17
5.1.2	Water bodies	230359	231335	976	227287	228208	921	220771	221654	883
5.2.1	Coastal lagoons	5639	5635	-4	5675	5672	-3	5791	5783	-8
5.2.2	Estuaries	3252	3249	-3	3204	3203	-1	3222	3215	-7
5.2.3	Sea and ocean									
Total		8975194	8975113		8973174	8973086		8965999	8965899	

Annex Xb.

CLC code	CLC level2 classes	1990	2000	changes	1990	2000	changes	1990	2000	changes
		100m ²			500m ²			1km ²		
11	Urban fabric	152086	156601	4515	144549	149228	4679	123434	128280	4846
12	Industrial, commercial and transport units	24167	27113	2946	21906	24641	2735	16472	18780	2308
13	Mine, dump and construction site	7941	8635	694	7321	7919	598	5265	5494	229
14	Artificial, non-agricultural are	10289	11191	902	9325	10186	861	6253	6907	654
21	Arable land	2825828	2819154	-6674	2866140	2859273	-6866	2957570	2950905	-6665
22	Permanent crops	104356	104766	410	104852	105350	498	103203	103963	760
23	Pastures	429288	427840	-1448	424526	423163	-1364	408849	407925	-924
24	Heterogenous agricultural areas	534932	533670	-1262	516890	515867	-1023	476755	475911	-844
31	Forests	2854690	2855031	341	2886798	2887205	406	2974220	2974722	502
32	Shrub and/or herbaceous vegetation	1182921	1183084	164	1163870	1163968	98	1116595	1116291	-304
33	Open spaces with little or no vegetation	387185	386698	-487	382557	382096	-461	372086	371670	-416
41	Inland wetlands	196828	195751	-1076	187576	186482	-1094	162235	161211	-1024
42	Maritime wetlands	14362	14279	-83	14230	14147	-83	13892	13821	-71
51	Inland waters	241430	242415	985	233563	234494	931	221439	222298	859
52	Marine waters	8891	8884	-7	8859	8855	-4	8932	8920	-12
Total		8975194	8975113		8972960	8972871		8967200	8967098	

Annex Xc.

ALARM classes	1990	2000	changes	1990	2000	changes	1990	2000	changes
		100m ²			500m ²			1000m ²	
Urban	194483	203540	9057	180838	189824	8986	149642	157921	8279
Agriculture	3465116	3457590	-7526	3504244	3496685	-7559	3592488	3585409	-7079
Grassland	429288	427840	-1448	419116	417781	-1335	392523	391400	-1123
Forest	2854690	2855031	341	2876383	2876808	425	2932610	2933370	760
Surplus land	1394111	1393115	-996	1368237	1367191	-1047	1300279	1298946	-1333
Other fixed land cover	637506	637996	491	624396	624839	443	600658	601054	396
Total	8975194	8975113		8973215	8973128		8968200	8968100	

Annex Xd.

HISLU classes	1990	2000	changes	1990	2000	changes	1990	2000	changes
		100m ²			500m ²			1000m ²	
Urban	194483	203540	9057	180827	189817	8990	149620	157924	8304
Arable land	3465116	3457590	-7526	3504936	3497343	-7593	3595102	3587947	-7155
Grass land	717216	713538	-3678	698470	694959	-3511	643819	640629	-3190
Forest	2854690	2855031	341	2876751	2877166	415	2935273	2935987	714
Non-agricultural land	1493368	1494115	747	1470659	1471360	701	1416475	1416887	412
Inland waters	241430	242415	985	232789	233704	915	219111	219956	845
Sea	8891	8884	-7	8825	8820	-5	8786	8769	-17
Total	8975194	8975113		8973257	8973168		8968186	8968099	

