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Linking Pan-European Land Cover Change to Pressures on Biodiversity

http://www.creaf.uab.es/biopress

Final Report
1st January 2003 – 31st December 2005
Sections 5 and 6

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CONTENTS

EXECTIVE SUMMARY – JAN'03 TO DEC'05

Contract n°	ENV-CT-2002-00178	Reporting period:	January 03 – December 05
Title	BIOPRESS - Linking Pan-European Land Cover Change to Pressures on Biodiversity		

Objectives:

BIOPRESS – Linking pan-European land cover change to pressures on biodiversity – is a 3 year EC-FPV project funded in the framework of the GMES 'Global Monitoring for Environment and Security' initiative (http://gmes.fdc.fr/what_is/home.html). It was the only GMES project under the priority theme "Land cover change in Europe".

BIOPRESS's main goal was to provide the EU-user community with quantitative information on how changes in land cover and land use has affected the environment and biodiversity in Europe. The project aimed at producing consistent and coherent sets of historical (1950 – 1990 – 2000) land cover change information in and around circa 75 Natura2000 sites located from the boreal to the Mediterranean, and from the Atlantic to the continental regions of Europe. These land cover change statistics would be converted into quantitative measures of pressures on biodiversity through the integration of socio-economic indicators. The impact of the land cover changes on biodiversity would also be assessed.

The change statistics were produced by means of two parallel activities, the backdating of CORINE land cover 1990 of circa 75 windows (30km x30km) with aerial photography of the 1950'ies and, the interpretation of aerial photography from 1950, 1990 and 2000 for circa 50 transects (2km x 15km). The windows were interpreted to identify the CORINE level 3 land cover and use classes to a minimum mapping unit of 25 ha. The transects, at the other hand, were interpreted to a minimum mapping unit of 0.5 ha.

Scientific achievements:

Data access

The BIOPRESS team established an operational online access point for metadata and data of relevant European datasets. The European data policy appears to be the major obstacle for easy access to European datasets even in case of projects that are financed by the European Commission. The INSPIRE initiative as well as the GMES framework could benefit from the experiences made in the BIOPRESS project in order to streamline access to European wide data relevant for environmental monitoring

Land Cover change

The methodological development for production of land cover change matrices was completed successfully ensuring the BIOPRESS team had the appropriate tools (list of 30km x 30km window sites, list of 2km x 15km transect sites, interpretation manual, quality assurance protocol and meta database designed to follow progress) and material (aerial photography) to successfully carry out the photo to photo (1950 – 1990 – 2000) interpretation of transects and CORINE Land Cover 1990 backdating (1950-1990). Several of the tools, in particular the interpretation manuals, have the potential of being adopted by GMES services and future EU projects (The GEOLAND and GSELAND projects were given copies of the manuals on request).

A total of 57 transects and 73 windows were interpreted. The results were stored in a database. The database will be made available to the wider research community in 2007.

The total extent of land cover changes that have occurred within all BIOPRESS windows account only to 9,62 % of the total measured area. In other words, 90,38% of the measured area within the BIOPRESS windows have shown no change of land cover at all. Overall the most important land cover conversions based on CORINE level 2 nomenclature can be summarised as one of the following:

- FROM shrub and/or herbaceous vegetation association TO forests, and its inverse conversion, FROM forest TO shrub and/or herbaceous vegetation association
- FROM heterogeneous agricultural areas TO urban fabric, as well as TO forest
- FROM arable land TO industrial, commercial, and transport units.

Because the focus was on biodiversity and historical land cover changes, it was clear from the start that Europe had to be sampled. Bias was introduced in the BIOPRESS samples by (1) relying on an expert to select a superset of samples including Natura 2000 sites and (2) the availability of aerial photography. The project's resources limited the total number of samples acquired. As a result some bio-geographical regions were under represented in the sample (Boreal and Mediterranean) whilst other regions were over represented (the Alpine, Atlantic, and Continental). So the development of an appropriate extrapolation approach was seen as a challenge from the beginning of the project. The key was to produce information which is useable in the data integration and which is meaningful, and reliable enough for use by our key stakeholder, the EEA. An extensive sensitivity analysis and the development of minimum land cover accordance maps have provided an excellent insight in the acquired land cover change data with respect to samples' representativeness of biogeographical areas and land cover.

Quality assurance and error propagation

The following problems were identified as the main sources of possible mistakes and lack of correspondence in windows:

- Ambiguity of CLC classes delineation.
- Quality of B&W AP.
- Availability of ancillary data.
- Separation of CLC classes in B&W AP (E.g. burnt areas).
- Diversity within class definition.
- Occurrence of polygon less than 0.5 ha.
- Amalgamation of objects less than 0.5 ha.
- Real changes omitted.
- Identification of questionable changes.
- Identification of point and linear features, questionable, ambiguity and unknown relevance

The quality of the input data was comparable for all transects, indicating that the comparability of results between partners and transects was unlikely to have been influenced by the quality of the input data.

The date of the aerial photos (1950, 1990 or 2000) proved to have no influence on the thematic consistency of the interpretations whereas the level of thematic detail did have a high impact. The geometric accuracy was more difficult to evaluated, still we found that the controllers identified more spatial structures than the local interpreters.

The quality of the interpretation depends on the land cover characteristics of the individual transects or windows.

An error model was developed describing each step of the land cover change production chain. We found that most error sources which reduced the interpretation quality such as image quality, unclear class definition and confusion caused by lax use of land cover and land use attributes in the definitions, can be almost completely reduced by using modern data sources and adjusting the interpretation methodology. However, knowledge and experience of the interpreter play an important role in manual visual interpretation of remotely sensed data.

Land cover change and pressures

A land cover change - pressure association matrix was developed. This matrix enabled the grouping of types of land cover changes related to one of the six pressures under consideration in BIOPRESS: Urbanisation, intensification, afforestation, deforestation, abandonment and drainage. This cross-tabulation matrix is a fundamental starting point in the analysis of land cover change, because it provides a national-scale assessment of not only the losses or gains in the area of specific land categories but what these changes represent in terms of types of pressures However, additional research is needed to analyse this matrix according to its various components in order to gain more insight into the potential processes that determine a pattern of land cover change.

It was impossible to derive a simple and practical list of indicators that would consistently explain the pressures on biodiversity. It was clear that there were multiple potential indicators, and the best indicators have not simply appeared out from the extensive data and information that already existed. In essence, the search for a coherent set of pressure indicators was a frustrating and time-consuming activity. It is clear from our effort that a single set of indicators would never explain the whole dynamics of anthropogenic pressures on biodiversity, and would go only some way towards meeting the needs for understanding the observed land cover changes.

The main research challenge faced was to define a pattern-process model of land cover dynamics in space and time in order to combine the local level measurement of the land cover changes (e.g. BIOPRESS windows) and the socio-economic indicators of a larger region (e.g. the countries). The proposed multi-representation model is based on the degree of variability in the behaviour of generalised statistics and their dependency of the spatial generalisation of the variable values at different spatial scales.

A systematic analysis of spatial coincidence between land cover types in CLC1990 and Annex1 habitat types recorded in Natura 2000 sites was carried out, translated into the EUNIS habitat classification and summarised per Biogeographical region. The work showed that a significant improvement could be made by adopting a

regional approach providing neater and more specific links between CLC classes and habitats than what has been available so far. It also identifies what the limitations are in attributing habitat types to CLC classes.
We found that the BIOPRESS land cover change product was suitable for quantifying some pressures on biodiversity but quite insufficient for the interpretation of land cover change related to other pressures:

- BIOPRESS contributed very positively to the quantification of urbanization across Europe between 1950 and 1990/2000.
- BIOPRESS land cover product made a useful contribution to the quantification of afforestation and deforestation across Europe between 1950 and 1990 but that these pressures could be better understood if (i) we had more points in time, closer together and (ii) more information on the condition of forest was derived from remote sensing and/or ancillary data was used to evaluate the ecological value of forested land.
- BIOPRESS will have underestimated the extent to which the pressure land abandonment is threatening biodiversity in Europe, in comparison to other existing assessments (e.g. MIRABEL but also national scale statements). However, it would be possible to increase the accuracy and the generic value of the BIOPRESS estimates by (i) broadening the definition of land abandonment i.e. modifying the pressure matrix, so that it matches what is meant in other assessments and (ii) by increasing the number of points in time.
- BIOPRESS was probably the first project to provide quantitative estimates about the shift from small scale to more large scale agriculture for such a large sample area across Europe and in this respect, this is a very important contribution to understanding changes in European biodiversity. However it is important to keep in mind that what has been quantified within BIOPRESS was only a small part of what is usually understood by farming intensification in biodiversity assessments. This means that, as was the case for land abandonment, BIOPRESS results will greatly underestimate the pressure farming intensification, compared to other assessments.

The main conclusion is that remote sensing products such as the BIOPRESS land cover change product can provide very helpful information in the field of biodiversity assessment. There is potential for improving this information, e.g. by adding time steps in the monitoring or using external data to help in the interpretation of land cover change. However, our work also shows that there are clear limitations in this contribution and that remote sensing will only provide part of the information.

One important recommendation that would lead to improve facilities for large scale biodiversity monitoring would be the integration of remote sensing products with in situ information. This recommendation forms the basis of a position paper produced jointly by BIOHAB (FP5 funded Concerted Action) and BIOPRESS.

Socio-economic relevance and policy implications:

The project supported the needs of DG-Environment and EEA in helping to implement and assess European policy on nature and biodiversity and contribute to the objective of enhancing the quality of the environment by helping to understand pressures on biodiversity arising from land cover change in the member states and accession countries.

The state of the environment is perceived as an important indicator of a high quality of life by a majority of European citizens. The European public increasingly expresses the wish to be informed by policy on the perceived threats to biodiversity. BIOPRESS supported the development of a European capacity for monitoring the state of the environment (GMES) to meet these information needs.

Conclusions:

BIOPRESS was one of the first wave of thematic projects which were funded through the GMES initiative. As a result its main objective was to produce information at European level which in the case of BIOPRESS was information on historical land cover change for the purpose of assessing past pressures on habitats and their associated biodiversity. A large part of the project's resources were used to deliver the land cover change database successfully and the outcome has not only been the delivery of data but also a set of tools for future European wide land cover monitoring. The real challenge was when trying to establish a link between land cover change and pressures on biodiversity. The development of the land cover change - pressure association matrix as a first step enabled the grouping of types of land cover changes related to one of the six pressures under consideration in BIOPRESS. This matrix has the potential to enhance the similar 'Land Cover Flow' matrix developed by the EEA as part of the EEA Land Accounting System. In theory the idea of integrating socio-economic data with land cover change data made sense but in practice the team struggled with the wide variety of data types, spatial and temporal resolutions. To assess the consequences of the observed Land cover changes on habitats and their biodiversity, BIOPRESS impact tables were developed using the same conceptual approach as that establish for the DPSIR assessment MIRABEL. The overall agreement between

MIRABEL and the BIOPRESS tables, which unlike MIRABLE provided quantitative estimates for a selected sample of land in each region, was an important result. This part of the work concluded that a land cover change product such as that produced by BIOPRESS was suitable for quantifying some pressures on biodiversity but quite insufficient for the interpretation of land cover change related to other pressures. The error propagation, quality assessment and data search exercises highlighted the importance of the availability of good quality, affordable data (e.g. aerial photography, digital elevation data, social and economic indicators) which for long term monitoring should be continuously collected in a consistent manner.

Keywords: Historical land cover change, pressures, impact, biodiversity, Natura2000, GMES

Chapter 1 BACKGROUND

The environment in which we live is changing dramatically. Many people are not directly noticing these changes in our environment since they occur at a slow and steady rate such as the gradual loss of agricultural land to build-up areas. However, these types of land use and land cover changes have a large impact on our environment and our biodiversity.

Most land use and land cover changes are caused by a combination of social, economic and natural processes which operate at all scales from the local to the global level. In principle, these changes can affect the environment and its biodiversity in a positive or negative manner. Environmental changes can be dramatic but are often subtle. Moreover the processes that lead to those changes (e.g. Agricultural policies combined with varying local employment opportunities lead to intensified use of some areas and abandonment of other areas) and their impact on biodiversity will be different in different parts of a country and of Europe.

To protect our environment, ensure sustainable use of its natural resources and maintain an acceptable level of biodiversity a wide variety of national and international legal mechanisms (e.g. Amsterdam Treaty 1997, Habitats Directive, EU Common Agricultural Policy and Kyoto Protocol) have been established. Protection requires monitoring and so these mechanisms have encouraged the establishment of a wide range of, often unconnected national and regional, environmental and biodiversity monitoring activities. Without a common method and/or reference point it has been difficult to consolidate or compare the findings of such activities to build up an overview of the environmental changes occurring across Europe.

The clearest indication of a change in the environment is when the land cover has changed and as a result information on Land cover and land cover change is believed to be one of these benchmark datasets which requires a common approach in recording across countries. Also, when considering the monitoring of biodiversity many have instinctively suggested land cover as a means of deriving information on habitats and their biodiversity.

Within the general framework of ‘building a European capacity for Global Monitoring for the Environment and Security’, the GMES initiative seeks to, amongst others, consolidate monitoring efforts to properly address the issues of land cover change. The work presented in this report focussed in particular on the production of Pan-European land cover change information and its suitability for monitoring habitats and their biodiversity and formed part of the first phase of the GMES activities which through their ‘try, test and report’ approach formed the basis for informing the implementation phase of GMES of the many hurdles that need resolving (e.g. issues related to data policy, scientific and technological issues, organisational issues, societal and economic aspect).

Chapter 2 SCIENTIFIC AND TECHNOLOGICAL OBJECTIVES

The main objectives of BIOPRESS were (Figure 2.1):
(Phase–I) - to produce information on land cover change which occurred during the period between 1950 and 2000 that is collected in an operational and consistent manner from samples which are representative of the main bio-geographical regions of Europe and including an area of importance for European biodiversity (NATURA 2000 site),
(Phase-II) - to develop and test strategies for inferring environmental pressures and impacts on biodiversity from the land cover change information and,
(Phase-II) - to assess alternative remote sensing options and evaluation findings and experiences of this project and other relevant projects to formulate recommendations for the future monitoring of the habitats of Europe.

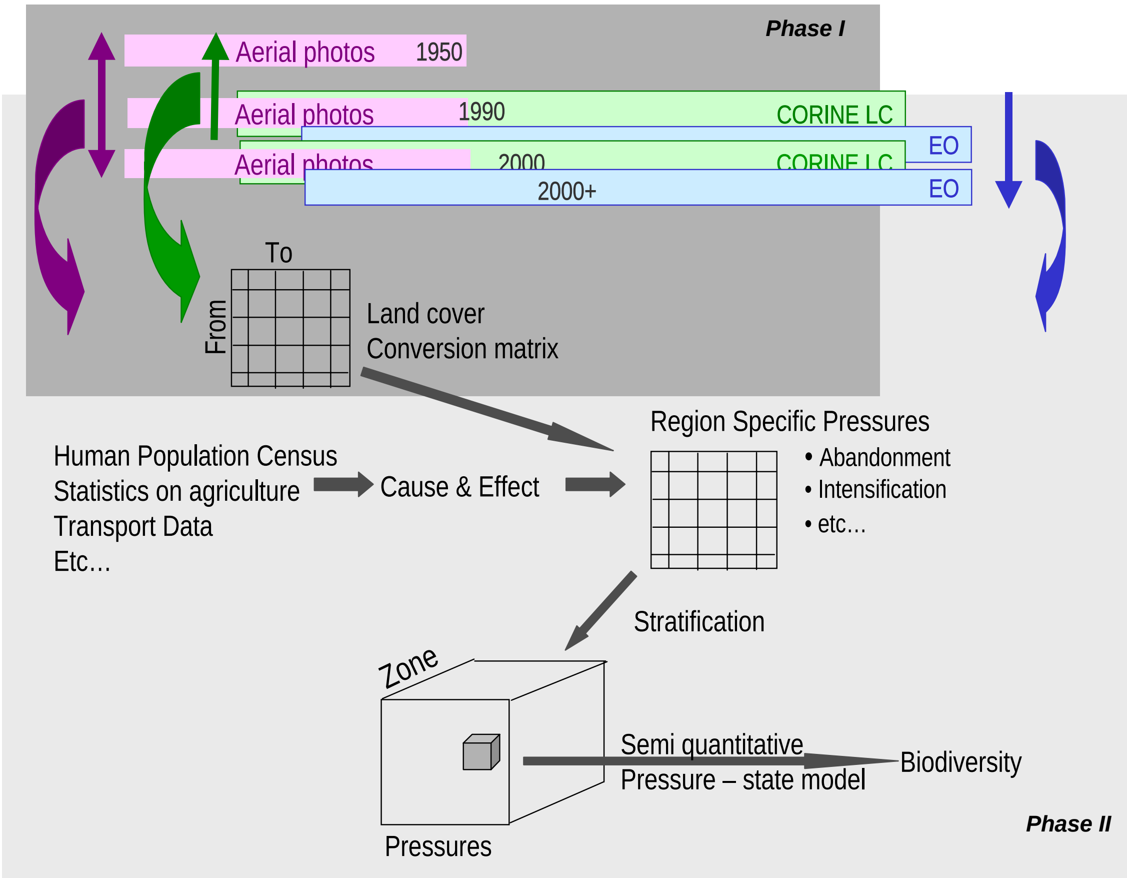


Figure 2.1 Schematic of the project's major work and research components. The more operational phase-I would produce land cover change information for the period between 1950-2000 whilst the exploratory phase-II would investigate ways in which land cover change information could be translated into measures of pressure and/or used to assess impact on biodiversity.

Although the link between land cover changes and pressures/impacts on biodiversity (Phase-II) is the heart of the project, the production of 1950'ies to 2000 land cover change information in a consistent manner is a prerequisite to phase-II.

Phase-I was very much operational in character and would produce a series of tested tools and methods developed to ensure the production of a land cover change dataset which is consistent across Europe. The proposed method was to sample Europe and extract land cover information as defined by the CORINE Land Cover nomenclature from aerial photography for three time points 1950, 1990 and 2000. This would involve 6 key steps:

1. The search and acquisition of different types of European boundary data, and NATURA 2000 data required for the design of the sampling strategy (WP1000)
2. A sampling strategy which would enable the selection of NATURA 2000 sites and thus samples (WP2200),
3. the search, acquisition and pre-processing of aerial photographs (WP2300),
4. a quality assured and manual interpretation of the photographs (WP2100, WP2400, WP3100, WP7000)
5. the assessment of the quality of the interpretation (WP 3300) and
6. the storage of interpretation results and its associated data and metadata in a central database (WP3000).

BIOPRESS' focus is on Pressures, State and Impact of the DPSIR framework (D = Drivers; R = Response) and the Pressure State Impact (PSI) model MIRABEL, would be driving the efforts in Phase-II. MIRABEL was originally designed as a tool for predicting pressures, impacts and scenarios of change, so the MIRABEL approach would not only be used to identify (and quantify) pressures on the basis of observed land cover changes in the past 50 years, but also aim to look at predicting impact on biodiversity. The focus would be on 6 key pressures: Urbanisation, Afforestation, Abandonment, Intensification (arable), Drainage and Deforestation and on the relationship between land cover changes and these 6 key pressures. Since there is not always a direct relationship, the idea was to exploit the use of social and economic indicators and develop a strategy to select the best indicators for specific pressures The teams' effort in Phase-II was organised as follows:

1. The search and acquisition of socio-economic indicator data (WP1000)
2. Characterisation of samples and stratification used in Phase-I and assessment of suitability of one or more spatial framework to support data extrapolation and data integration (WP2200, WP3200, WP4100).
3. The investigation of the causes (pressures) of the observed land cover changes (state) and the development of a generic model for data integration to quantify these pressures (WP4300).
4. The description and prediction of the consequences (impact) of the observed land cover changes (state) and pressures on biodiversity (WP4400)
5. The investigation of the propagation of error between the different stages of data processing (WP4500).
6. The investigation of ways to improve the detection of change in land cover and landscape features from multi-scale remotely sensed data (WP4200).

Chapter 3 APPLIED METHODOLOGY, SCIENTIFIC ACHIEVEMENTS AND MAIN DELIVERABLES

3.1 PHASE-I, 1950 TO 2000 LAND COVER CHANGE (WP2000, WP3000, WP7000)

3.1.1 METHODOLOGY

The applied method was designed to produce land cover change information collected in an operational and consistent manner from samples which are representative of the main bio-geographical regions of Europe and including an area of importance for European biodiversity (NATURA 2000 site. Land cover has been classified according to the CORINE Land Cover nomenclature with 44 classes at highest Level (Level 3). Land cover change was captured by means of two approaches with different scale of interpretation (Figure 3.1):

In the first approach, for regions ('windows') of ~ 30km x 30km in size, aerial photographs of the 1950s were compared against the 1990 CORINE Land Cover Map (CLC90). A minimum mapping unit of 25 ha was used which is in line with the standard CORINE Land Cover minimum mapping unit.

In the second approach, for transects of 2km x 15km, aerial photography from 1950, 1990 and 2000 were interpreted at a more spatially detailed minimum mapping unit of 0.5 ha.

The whole process involved 5 key steps (Figure 3.1):

(1) the selection of NATURA 2000 sites to position the windows and transects,
(2) the search, acquisition and pre-processing of aerial photographs,
(3) the manual interpretation of the photographs
(4) the assessment of the quality of the interpretation and
(5) the storage of interpretation results and its associated data and metadata in a central database.

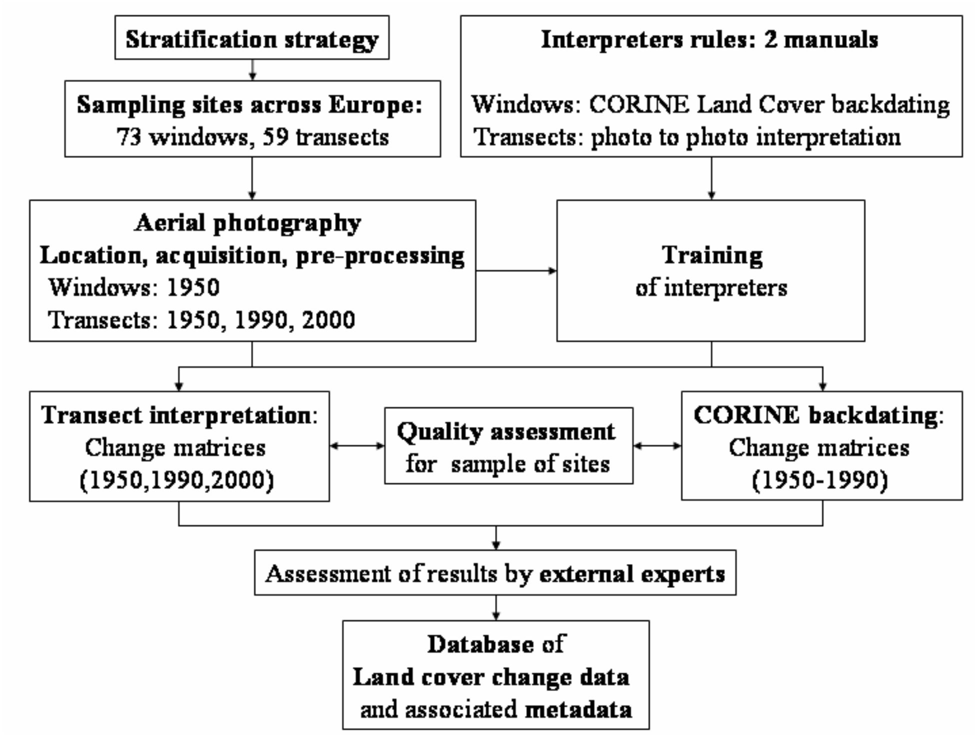


Figure 3.1 Schematic overview of the steps carried out to produce land cover change information from historical aerial photographs in a consistent manner for all 75 windows and 59 transects.

SAMPLING OF SITES

To ensure that the results of the analysis of land cover change could be interpreted in the wider European context, windows and transects that are truly representative of the diversity of European biogeography would have to be selected. However, the diversity in land cover and related local landscape features across Europe is very high and not randomly distributed so that a representative sample would invariably be stratified and large in size. Budgetary constraints resulted in an approach which aimed at ensuring the highest benefit from a limited (i.e. affordable) number of sample sites. The Biogeographical Regions Map of Europe (BRME) was used for stratification which would also provide close linkage to the Habitats Directive, Birds Directive, Emerald Network and NATURA 2000. This was particularly important as NATURA 2000 would be the starting point from which the windows and transect sites would be selected. However, direct access to the NATURA 2000 database which contains location and habitat description of all NATURA 2000 sites in Europe proved impossible because of restrictions on access to this source. So, a super-set of 229 NATURA 2000 sites of European importance were identified by an external expert (Pierre Devillers of the Royal Belgian Institute of Natural Sciences) with access to the database. Pierre Devillers used a combination of information within the NATURA 2000 database and his expert knowledge to select representative and important sites across Europe. The list of 229 sample sites was supplied as coordinates for the centre of the each of the NATURA2000 site (Figure 3.2) with the occurring Annex-I directive's habitats.

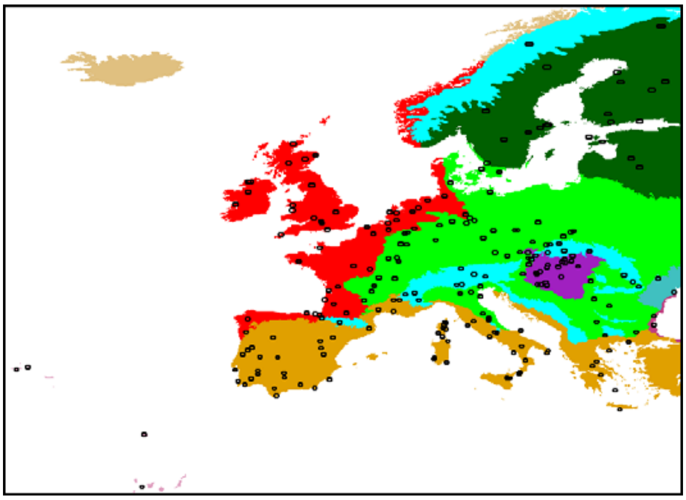


Figure 3.2 Distribution of candidate sites for BIOPRESS samples with respect to the bio-geographical zones. (BRME)

Next, a selection from the super-set of 229 sites was made, aimed at (i)generating a BRME area-weighted sample of 100 windows and (ii) representing as many of the 4 Annex-I habitats identified by the stakeholders as possible (i.e. freshwater habitats, natural and semi-natural grassland formations, raised bogs and mires and fens and Forests). In cases of equal number of habitats present per BRME region, window selection was done randomly.

In parallel the partners set out to select between 8 and 10 transects per partner country (United Kingdom, Finland, Belgium, The Netherlands, Germany, Spain, and Slovakia) according to the following rules:

- Each transect should be located inside a super-set window site and contain at least part of the Natura 2000 site located at the centre of that window.
- For each of the four pre-defined broad Annex-I habitat types, two representative transects should be selected. For additional transects, nationally important sites should be considered.
- Transects should represent a gradient of pressures on land cover starting from the edge of a NATURA2000 site and bearing towards an intensively used area (urban or industrial area).

AERIAL PHOTOGRAPHY

Two strategies were adopted to locate and acquire the aerial photos for the selected windows and transects. For transects and windows located in partner countries the search and acquisition of the aerial photos was the responsibility of the respective partners. Aerial photography for the remaining windows was provided by Cambridge Architectural Research Ltd (CAR Ltd), a company specialising in searching and acquiring historical aerial imagery for Europe, North America and the Far East. The search criteria for the aerial photography were:

- Photo cover for the windows must include the NATURA2000 centre point.
- The location of the windows can be shifted and or rotated to ensure better photo coverage provided that the NATURA2000 centre point is at least 5 km from the edge of the photo cover. The location of transects can be shifted as long as selection criteria (see above) are not compromised.
- The photographic coverage must be at least 75% of the window. Cloud coverage must be less then 10% and imagery must be snow free.
- The timeframe for windows data is between 1943 and 1959.
- The timeframes for transects data are between 1943 - 1959, 1988 -1992 and 1998-2002.
- Scale of photographs for windows is between 1:25,000 and 1:60,000 to produce digital scans (600 to 1200 DPI) of a resolution between 1m a 2m. For transects the scale is between 1:10,000 and 1:25,000 to produce a 0.5m to 1 m resolution.
- Digital scans are carried out from negatives, or from high quality prints.

It was clear from the beginning that these preset criteria combined with external factors such as data availibility, accessibility and cost would affect the final number of windows and transects. Also depending on the source of the photos, pre-processing was expected to involve any number of the following steps: (1) scanning of hard copy, (2) introducing fiducial marks, (3) ortho-rectification, and mosaicking.

MANUAL PHOTO INTERPRETATION

The problem with most European data sets is that they are inconsistent across regions and/or countries. This project aimed to produce change information which is consistent across sample sites, even if this was at the expense of detail. Consistency was felt to be more important than precision. One of the main steps taken to achieve consistency was the design of two manuals for photo interpretation:

- one clarifying the CLC level 3 class definition with respect to 1:25000 a 1:60000 scale black and white aerial photos (minimum mapping unit of 25ha) and providing rules for backdating CLC90 with photos (windows),
- another describing the CLC level 3 classes with respect to 1:10000 a 1:25000 scale photos (minimum mapping unit of 0.5ha) and providing rules for change detection from photo–to–photo interpretation (transects). The other steps taken to ensure consistency were training of the interpreters and quality assessment.

The interpretation approach adopted for the windows was to overlay the CLC90 polygons on mosaics of 50´ies photos and to focus on identifying change (Figure 3.3). The original 90'ies Landsat scenes from which CLC90 is derived were, where available, used to distinguish real changes from changes due to errors in the CLC90 database. Only the changes believed to be real were recorded. The resulting output was a CLC50 to CLC90 change matrix for each window.

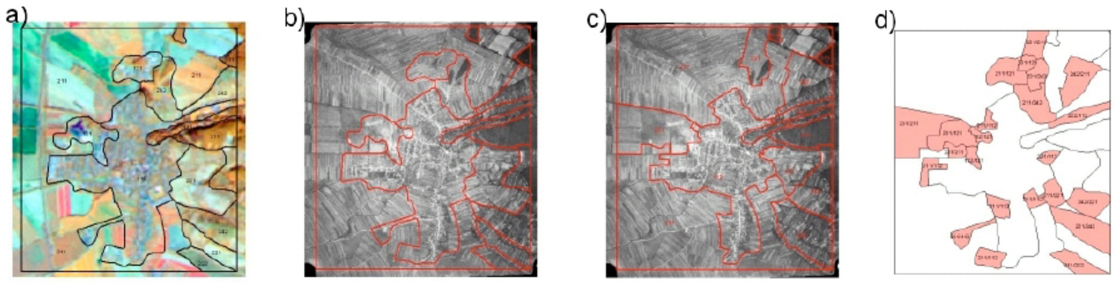


Figure 3.3 The interpretation approach adopted for CLC90 backdating(windows): a) CLC90 polygons overlaid on Landsat TM ; b) CLC90 polygons overlaid onto 1950'ies aerial photo; c) Interpretation of Aerial photo identifying real changes; d) resulting change polygons.

The approach adopted for the transects was to interpret the most recent aerial photographs first and then backdate (Figure 3.4). The first interpretation has polygons labelled with the land cover of 2000 (CLC00). In the second interpretation, using the aerial photos of 1990 (CLC90), only new lines are added. The newly created polygons receive a label with the land cover of 1990 and also 2000. For polygons that did not change the attributes of CLC200 are copied to CLC90. When the interpretation of 1990 is finished the same procedure can be followed for 1950 (CLC50). This ensures that the interpreter only adds lines and creates polygons if the land cover has changed. The results are polygons with multiple attributes which were used to produce change statistics.

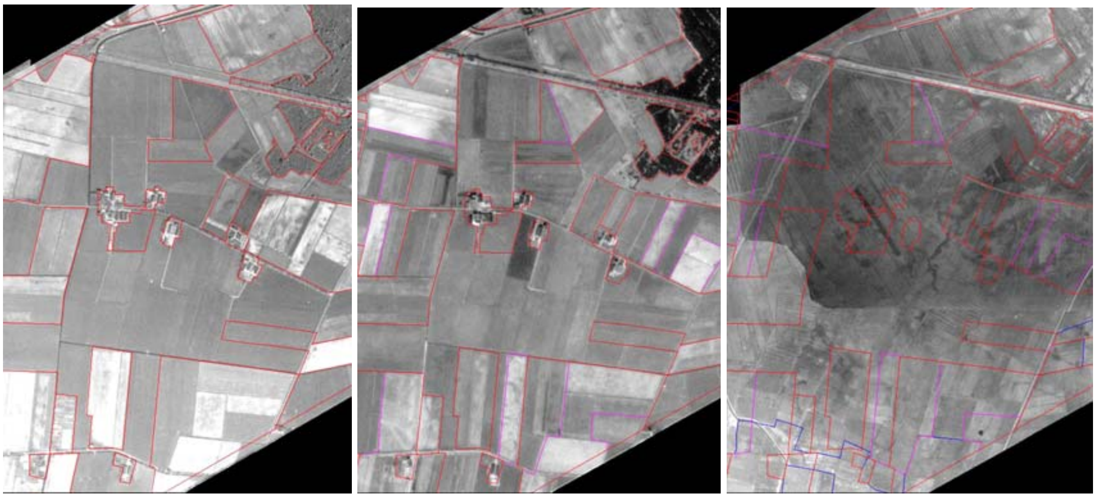


Figure 3.4 The interpretation approach adopted for photo-to-photo interpretation (transects): left, 1998 photo interpreted for an example transect located in The Netherlands; middle, 1986 photo with 1986 interpretation added to 1998 polygons; right, 1953 photo with 1953 interpretation added to 1986 polygons and 1998 polygons.

QUALITY ASSESSMENT

The aim of the quality assessment was to provide a measure of accuracy of the interpretations. It involved, (i) the estimation of the thematic, (ii) the geometric accuracy in the interpretation, (iii) the estimation of the consistency in identifying change and (iv) the assessment of the quality of the input data.

The general principle of any quality assessment (QA) procedure consists of comparing the obtained results with independent data. However, especially for 1950ties, no comparable independent dataset exists, so the QA procedures that were developed aimed at establishing a measure of the quality of the interpretation results (i.e. measure of consistency between interpreters).

For the **windows**, an independent expert (controller) would reinterpret sampled areas (5km x 5km verification units) that were identified within a selection of windows by placing a square grid 5km x

5km over the window area. Looking for 5km x 5km areas which include the most commonly occurring types of land cover changes of the country the window represented. The windows selected were those which showed the highest rate of change within one country. In total ~7 % of the total area interpreted was verified. The consistency *R* for a given window was calculated as:

$$R\% = A/N*100.$$

where *A* is the number of identical changes (i.e. in both size and type) and *N* is the number of all changes in given window identified by controller and interpreter. A window is rejected and returned to the interpreter for improvement when its consistency rate is below 85%.

For the **transects** a more extensive approach was adopted aimed at evaluating the thematic, geometric and change detection aspects of the interpretation. Here 18 transects were reinterpreted 6 times using a **point grid** sample, each time by a different independent controller and five transects were reinterpreted fully by one independent controller.

The geometric consistency were checked on the 18 transects by calculating the distance between each grid point and the first class boundary located directly north of that grid point. The distances for the local interpreter are derived from the original interpretation whilst the distances for the control are derived by six independent controllers directly from the aerial photos as illustrated on Figure 3.5.

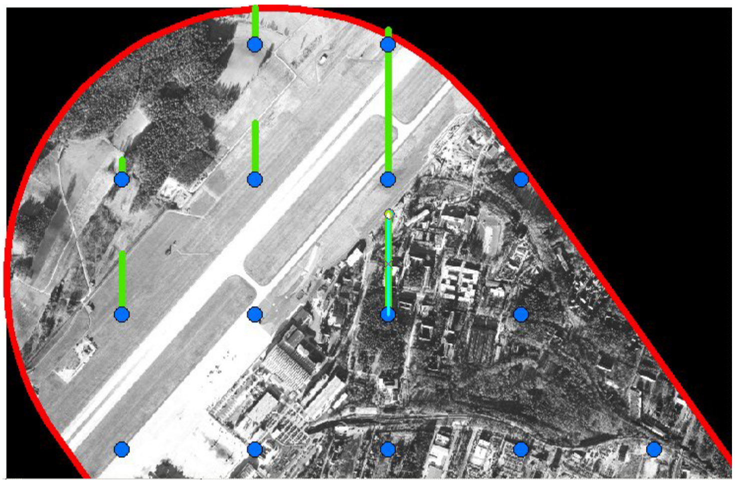


Figure 3.5 Example of distance measurements for some of the grid points

These seven independent sets of distance measurements (one interpreter and six controllers) allows calculation of variation and the standard error of all the distance measures differently for transition between two classes. Also variation between samples or regions and the impact of photo quality can be assessed. For the five fully reinterpreted transects, the geometric consistency was assessed by making a direct spatial comparison of interpreted boundaries buffered by 10 m (Figure 3.6). A 2x2 matrix is produced recording the boundary proportions (in terms of area falling within the boundary buffer) in the two interpretations (Table 3.1).

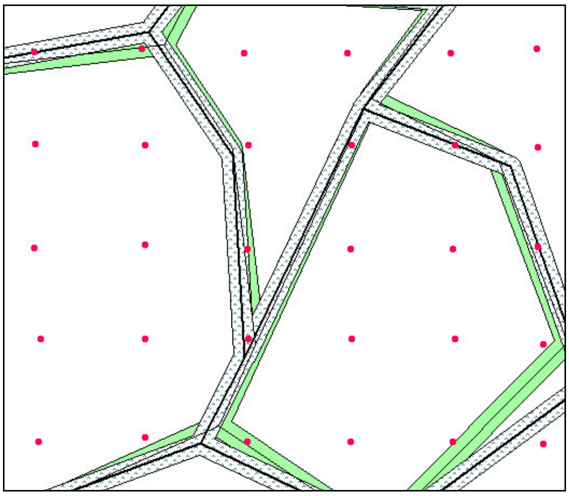


Figure 3.6 Example of verification of geometric accuracy of buffered boundaries

Table 3.1 The type of 2x2 matrix produced when comparing interpreted boundaries

		Controller's Interpretation	
		Boundary present	Boundary not present
Original interpretation	Boundary present	P_{11}	p_{12}
	Boundary not present	p_{21}	p_{22}

The quality of the aerial photo interpretation is highly dependent on the quality of the input data (i.e. the aerial photos). It is therefore necessary to characterise and quantify the influencing factors associated to the input data. Because of the large number of photos involved which were sourced from many different flight campaigns it is impossible to analyse each photograph individually and quantify every observed effect precisely. Hence a scoring system was developed for a set of 6 quality parameters (resolution, contrast/brightness, border effects, cloudiness, geometric accuracy, and number of flights) which were designed for the evaluation of transect photo mosaics. Each transect mosaic receives a score between 1 and 3 for each quality parameter. A high score corresponds with high quality.

The results of the scoring can then be summarized by means of a Quality Index which is the ratio of the total score achieved divided by the total achievable score. Assuming an equal weighting for each parameter, the Quality Index was defined as :

$$QualityIndex = \frac{achieved\,Points}{achievable\,Points} * 100$$

3.1.2 RESULTS

WINDOW AND TRANSECT SITES

Aerial photos of the 1950'ies were obtained, processed and interpreted for 73 window sites and 59 transect sites (Figure 3.7 on the right). The 73 windows are distributed across 17 countries, 36 are located in the 8 partner countries and 37 outside partner countries (Table 3.2). The total interpreted window area is 59297 km^2 and the total interpreted transect area is 1807 km^2. While for the transect sites full area coverage was achieved in most cases (i.e. 30 km^2 per transect) the resulting area interpreted per window site depended on the available photo-coverage and CLC90 coverage (Figure 3.8). 36 of the 73 windows (i.e. 49%) achieved more then 750 km^2 coverage. The lowest coverages achieved were for windows in Hungary and Romania. The exceptionally large average size of windows in Poland is caused by the merging of two partially overlapping windows into one.

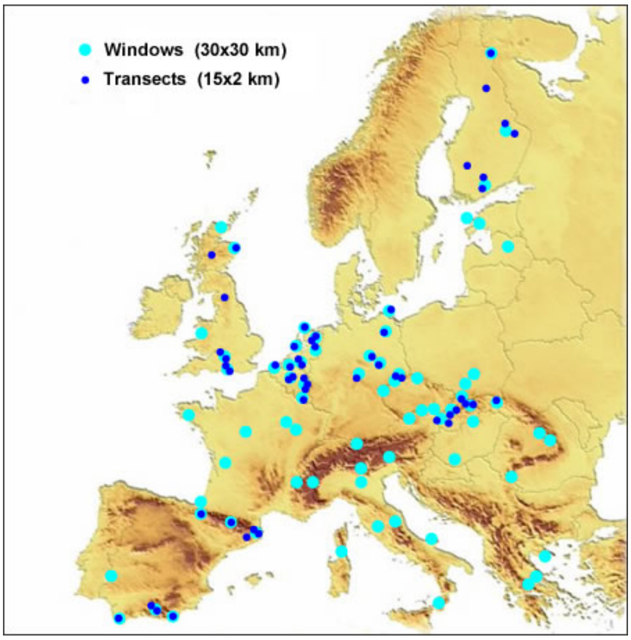


Figure 3.7 Window and transect distribution across Europe.

Table 3.2 The distribution and area coverage of window and transect sites on a country by country basis.

Country	Windows		Transects	
	No.	Mean size (km²)	No.	Mean size (km²)
Austria	3	806.08		
Belgium	5	872.82	8	33.88
Czech Rep.	5	867.50		
Estonia	2	784.09		
Finland	3	897.99	8	30.91
France	9	660.76		
Germany	6	805.99	9	30.81
Great Britain	5	864.08	8	26.48
Greece	4	764.68		
Hungary	2	412.46		
Italy	6	900.71		
Latvia	1	895.69		
Netherlands	5	813.69	9	30.59
Poland	2	1587.58		
Romania	3	438.72		
Slovakia	5	826.95	9	31.47
Spain	7	847.66	9	29.70
Total	73	59296.93	59	1806.76

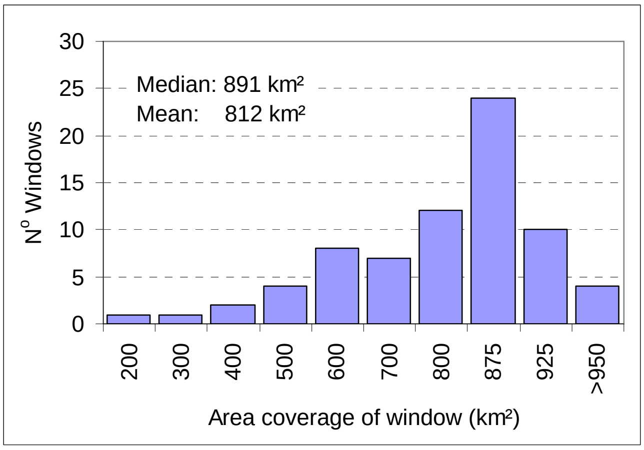


Figure 3.8 The area coverage distribution of the window sites

Figure 3.9 compares the relative area distribution per BRME zone, with the relative area distribution achieved by transect and window sites and the relative number distribution of the original super-set of sites (229 sites). Note that there are no transects within the Pannonian zone, although there are windows. Figure 3.9 shows that each set of samples has its own relationship with the area of each BRME zone. In general, the Alpine and Atlantic zones appear to be over-sampled, whereas the Boreal zone appears to be under sampled. Note also that the expert was biased in his selection towards NATURA 2000 sites located in the Mediterranean and the Pannonian zones.

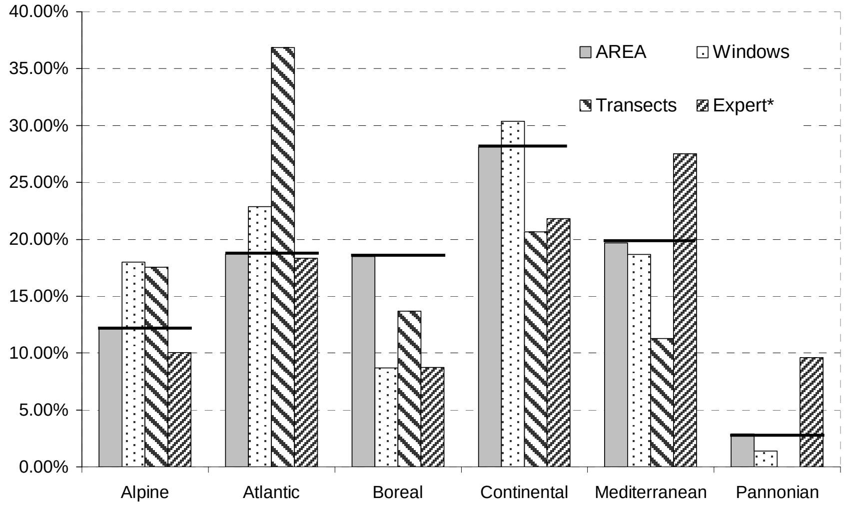
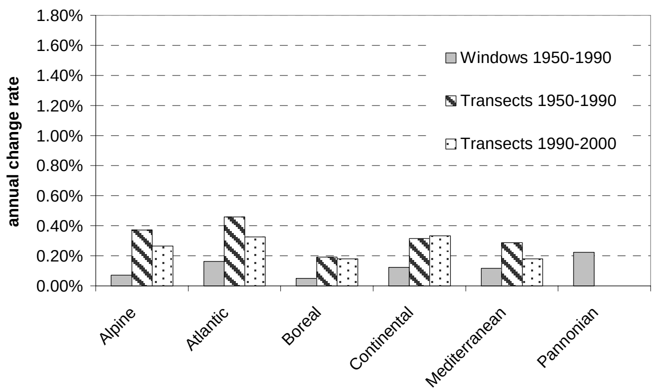


Figure 3.9 The relative area distribution per BRME zone (area) compared with the relative area distribution achieved by the transect and window sites and the relative distribution of the original super-set of sites (expert).

The variability in terms of CORINE land cover proportions of the BRME zones and the actual window and transects sites selected was investigated in detail to assess the use of the BRME as a spatial framework for extrapolating the land cover and land cover change data measured from the resulting window and transect sites (See further – Phase-II).

OBSERVED LAND COVER CHANGES

Although the size and location of the samples did not allow for an extrapolation across Europe to produce a European map of change, the data collected still produced some interesting results. Increasing the spatial resolution from 25 ha minimum mapping unit to 0.5 ha minimum mapping unit invariably led to an average of 2.8 times more area being identified as having changed. This increase represented on average 7% or 25% of the total area when interpreted at level1 or level 3 respectively. An increase in thematic detail (from 5 cover classes in level 1, to 15 classes in level 2, and 44 classes in level 3) not only caused an increase in the amount of change detected but also altered the trends observed in the annual rate of change (Figure 3.10).



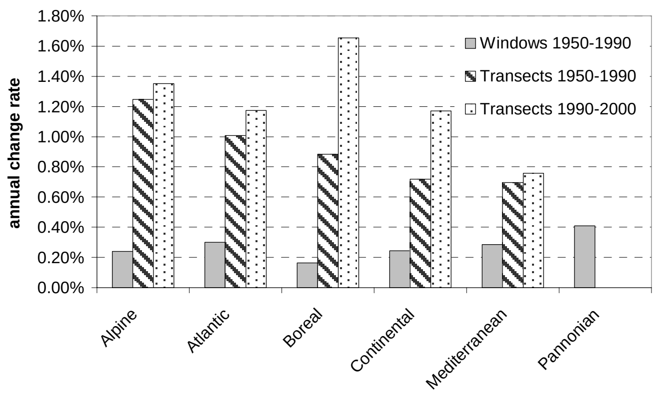


Figure 3.10 Annual rate of change based changes detected at CORINE Land Cover level 1 (left) and level 3 (right)

By grouping the land cover changes into major types of land cover conversion and organising the distribution of the spatial patterns of change for each BIOPRESS window into very large, large, medium, small, and very small it was interesting to notice that although the types of land cover conversions can be considered very similar for the BIOPRESS windows, they have very different spatial patterns associated to them. Overall the most important land cover conversions based on the spatial patterns associated with them can be summarised as one of the following:

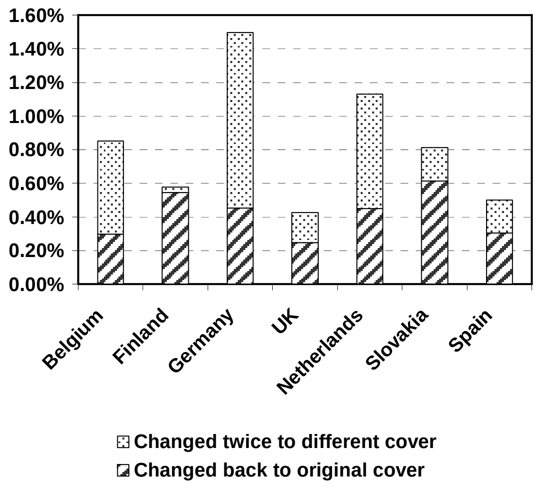


Figure 3.11 Proportions of sample area which have undergone changes twice.

- FROM shrub and/or herbaceous vegetation association TO forests, and its inverse conversion, i.e. FROM forest TO shrub and/or herbaceous vegetation association. Finland, where forest management is a key part of its economy showed an unusual large proportion of area which during the period of observation reversed back to its original cover (Figure 3.11). Further investigation confirmed these areas were associated to a forest – non-forest - forest conversion.
- FROM heterogeneous agricultural areas TO urban fabric, as well as TO forest
- FROM arable land TO industrial, commercial, and transport units.

QUALITY ASSESSMENT

Windows

43 windows with highest area of change in every country were assessed. 204 quality assessment units 5 km x 5 km were selected in these windows on positions where either dominant type of the land cover changes for given country occurs (to check areas with important changes) or strange and unexpected types of changes occurs. The minimum acceptable reliability rate was put to 0,85 (it means 85%); the average achieved reliability rate was 0,94.

The following problems were identified as the main sources of possible mistakes and lack of correspondence in windows:

- Ambiguity of CLC classes delineation.
- Quality of B&W AP.
- Availability of ancillary data.
- Separation of CLC classes in B&W AP (E.g. burnt areas).
- Diversity within class definition.
- Occurrence of polygon less than 0.5 ha.
- Amalgamation of objects less than 0.5 ha.
- Real changes omitted.
- Identification of questionable changes.
- Identification of point and linear features, questionable, ambiguity and unknown relevance

The quality assessment of interpretation was focussing on (1) the detection of errors and (2) the estimation of disputable changes. The number of errors introduced depends on the skills of the interpreter and the complexity of the area. The number of disputable changes depends on the quality of the input data and the types of land cover classes contained in window.

Because quality assessment was carried out on the same data as for the first interpretation, it is possible to detect clear errors only and there is no way to resolve disputable changes reliably. Consequently, it is not possible to quantify precisely all these eventual errors. We could only estimate the relative number of them. The resulting reliability rate comprises both these factors, errors and disputable changes, and the likelihood of the correctness of disputable change done by the interpreter was estimated by the controller to be less than 50%.

Some different classes look very similar and are easy to confuse; some classes are not easy to recognize without other information. Some classes can be demarcated easily, in so far as the quality of input data (especially radiometric quality and scale of photos) is good, but the delineation is very hard or nearly impossible with poorer quality photos (forests broad-leaved, coniferous and mixed). Some different classes look very similar even on excellent photos, they are easy to confuse, it is not easy to recognize without other information.

The most problematic classes and groups of classes which we found caused confusion are:

- 1.1.1. Continuous urban fabric – 1.1.2. Discontinuous urban fabric – 1.2.1. Industrial or commercial units
- 1.3.2. Dump sites
- 1.3.3. Construction sites
- 1.4.2. Sport and leisure facilities
- 2.1.1. Non-irrigated arable land – 2.3.1. Pastures: looking very similar, easy to confuse
- 2.2.1. Vineyards
- 2.2.2. Fruit trees and berry plantations – 2.2.3. Olive groves
- 3.2.2. Moors and heathland – 3.2.3. Sclerophyllous vegetation – 3.2.4. Transitional woodland-scrub
- 2.3.1. Pastures – 3.2.1. Natural grasslands: looking very similar, depending on degree of human interference , easy to confuse
- 2.4.x. *Heterogeneous agricultural areas* (especially 2.4.1. Annual crops associated with permanent crops, 2.4.2. Complex cultivation patterns)
- 3.1.x. (3.1.1. Broad-leaved forests 3.1.2. Coniferous forests 3.1.3. Mixed forests)
- 3.3.1. Beaches, dunes, sands – 333 Sparsely vegetated areas
- 3.3.4. Burnt areas
- 4.1.1. Inland marshes – 3.2.1. Natural grassland – 2.3.1. Pastures

Transects

Full re-interpretation: Across all transects and classification levels the controller confirms most of changes seen by the local interpreter. The amount of observed change increases with increasing thematic detail level. Changes took place mainly between 1950 and 1990 and the proportion of change that occurred between 1990 and 2000 have minor additional impact on the overall change calculated for the whole period (1950 and 2000). Differences between validation and local interpretation can be explained by the different background knowledge of the observed region. With respect to the geometric accuracy, a 94% consistency was found with the local interpretation.

Point re-interpretation: Table 3.3 gives the thematic overall accuracy calculated for the 3 time points and the 3 CLC classification levels, using the results from all grid points of all transects. The time point has no influence on thematic consistency but the level of thematic detail has a high impact.

Table 3.3 Overall thematic accuracy for all transects

Accuracy % good (>= 90%) Bad (< 50%)

	1950	1990	2000
CLC L3	54%	55%	53%
CLC L2	80%	81%	82%
CLC L1	91%	91%	91%

Table 3.4 shows a consistency in detecting change of 77% between the local interpreter and the controller. In 14% of the cases the controller found changes that were not detected by the local

interpreter and 9% are recognised by the local interpreter but not by the controller. These results are based on CLC level 3.

Table 3.4 Change accuracy for all validation points

		Validation	
		Change	No Change
	Change	25%	9%
Local Interpretation	No Change	14%	52%

Different approaches were used to investigate the geometric accuracy from the distance measures with varying results which lead to the conclusion that the approach developed was not suitable for its purpose.

Input data

Table 3.5 lists the calculated Quality Index for each of the pilot transects. It shows that the quality of input data varies slightly between transects and between partner but that generally the quality is more or less comparable. This indicates that the comparability of results between partners and transect is unlikely to be influenced by the quality of the input data. The higher the quality index, the better the quality of the input data. Only one of the 21 transects tested has a quality score below 80.

Table 3.5 The Quality Index per transect

Partner	Transect	Quality Index
1 UK	UK4	89
	UK9	81
	UK8	83
2 Spain	ES1	89
	ES2	85
	ES3	89
3 Finland	FI2	93
	FI4	91
	FI6	83
4 Netherlands	NL1	83
	NL5	93
	NL7	89
5 Belgium	BE3	93
	BE6	87
	BE7	93
6 Slovakia	SK2	93
	SK6	81
	SK7	81
7 Germany	DE1	78
	DE2	83
	DE3	81

Summary

The general outcomes of the quality assessment were:

- The quality of the input data is comparable for all transects.
- The point grid approach assesses thematic and change accuracy with higher than 80% for CLC level 2.

- In CLC level 3 the uncertainty class 6 caused the major variation in between local interpreter and controller.
- The assumption to take the local interpretation as reference was confirmed.
- The thematic accuracy is mainly dependent on the interpretation level, there is no impact of the different points of time.
- The proportion of grid points where most validation interpreters disagree with the local interpretation is less than 10%.
- Geometric accuracy was evaluated. The validating interpreters investigated more structures than the local interpreter.
- The quality of the interpretation depends on the land cover characteristics of the individual transects.

LAND COVER CHANGE DATABASE AND METADATABASE

Finally all interpretation were stored as GIS files and attributes and topology information transferred into a database were the results can be queried independently. The database also contains additional information derived from GIS data, for example such as country, BRME, social and economical data, NATURA 2000 habitats and metadata such as image quality or explanation of changes from local experts. General statistics on land cover characteristics and changes are presented dynamically on the internet complemented by the maps of land cover and land cover change.

3.2 PHASE-II

3.2.1 CHARACTERISING SAMPLES AND STRATIFICATION USED AND ASSESSING SUITABILITY OF SPATIAL FRAMEWORKS TO SUPPORT DATA EXTRAPOLATION AND INTEGRATION (WP2200, WP3200, WP4100).

CHARACTERISING SAMPLES AND STRATIFICATION USED

It was originally envisaged that WP2200 would examine the spatial structure of Europe in geographical, biological / ecological and socio-economic terms and thus derive a single stratification for extrapolating sample-based results. The choice of the final stratification strategy was to depend on two criteria; i) ensuring a representative sample of sites across Europe and ii) being able to quantify the uncertainty (precision) when extrapolating from sites to the European level. At least three alternative stratifications were to be investigated including bio-geographical and socio-economic classifications. An optimal stratification strategy was to be in place before the choice of sample sites was made.

Alteration to the work within WP2200 were caused by three situations:

- The crucial factor for extrapolating the BIOPRESS results at sample sites to the whole of Europe with a given measure of confidence is the number of sample sites present within each of the strata. As the number of strata increases, so the number of sample sites must also increase to adequately describe each stratum. With the limit on the number of sample sites within the BIOPRESS project it would at best only be possible to adequately describe a simple stratification. It was decided at the Kick-Off Meeting that a single currently available stratification should be selected that was acceptable to the BIOPRESS Team and the end user representatives.
- During the development of an optimal stratification, Task 2220 was to test the utility and sensitivity of the different stratifications using the CORINE land cover map (EEA, 2003) and the NATURA2000 database (ETC-NPB, 2003). Selected sites from the NATURA2000 database were to be characterised by their CORINE land cover. A Monte Carlo approach was then to be employed to investigate the sensitivity of the size and location of the selected sample sites in relation to the strata. As the BIOPRESS project was not given access to the NATURA2000 database it was not possible to carry out this analysis.
- Sample site selection was undertaken by a third party and provided to the BIOPRESS project as a super-set of sample sites across Europe. From the super-set a subset of sample sites would be produced by, and for the use of, the BIOPRESS project. The subset would be based on a range of factors, one of which would be the representativeness of the sites compared to the characteristics of the stratification.

So, the activities were re-focused to address the following:

- The characterisation of the BRME stratification in terms of CORINE land cover.
- The characterisation of the super set of sample sites in terms of CORINE land cover.
- An evaluation of the super set of sample sites with respect to the BRME stratification.
- An evaluation of the subset of sample sites with respect to the BRME stratification.

The proportions of three BIOPRESS aggregations of the CORINE Land Cover types: Agricultural, Forest and Semi-Natural were used to produce scatter plots (Figure 3.12) which identify similarities and differences between the biogeographical regions.

The scatter plots show a strong trend between Agricultural and Forest dominated regions (Figure 3.12 left). The main lowland temperate continental regions (Steppic, Pannonnian, Atlantic and Continental) are dominated by agricultural because of the suitable climatic conditions and the potential to exploit the land. The Mediterranean, Black Sea and Macaronesian regions have similar low amounts of woodland, but less agriculture due to the drier climate. The Agricultural appears to be replaced by Semi-Natural in most of these regions. The Boreal and Alpine regions fall at the opposite end of the

Agricultural – Forest spectrum being dominated by Forest (and a combination of Forest and Semi-Natural) land cover.

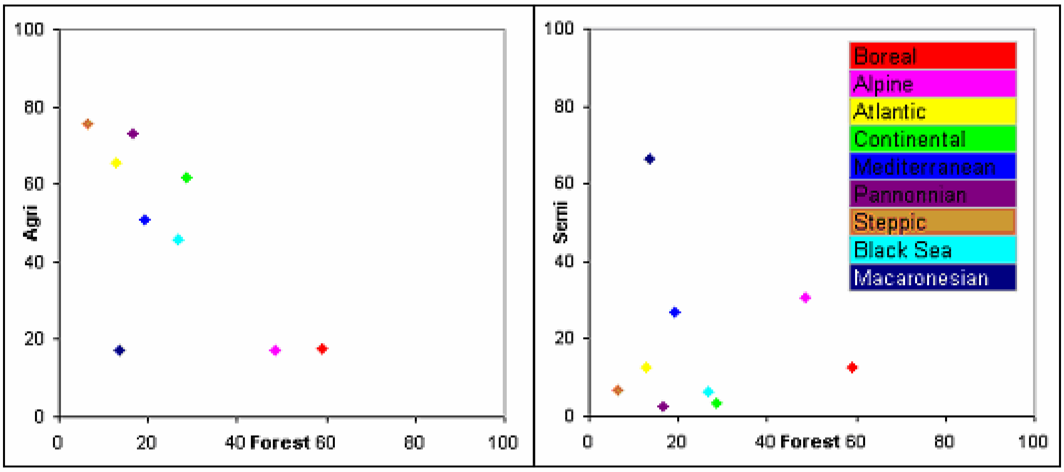


Figure 3.12 Scatter plots of the Percentage Proportions of Agricultural, Forest and Semi-Natural for the BRME Biogeographical Regions

The results described above support the development and use of the biogeographical regions in general terms. Some of the regions appear similar in terms of land cover and must be seen as geospatial distinctions. Other regions that would not at first be thought to be different, do have different land cover characteristics. Some of these differences may be due to a socio-economic influence or human impact which has sufficiently altered the environment to create a distinct biogeographical region. The BRME was therefore likely to provide an appropriate subdivision of Europe for studying biodiversity at the pan-European level defined within BIOPRESS.

The same BIOPRESS aggregations of the CORINE Land Cover types: Agricultural, Forest and Semi-Natural were used to characterize and compare the windows of the sample site subset (Figure 3.13).

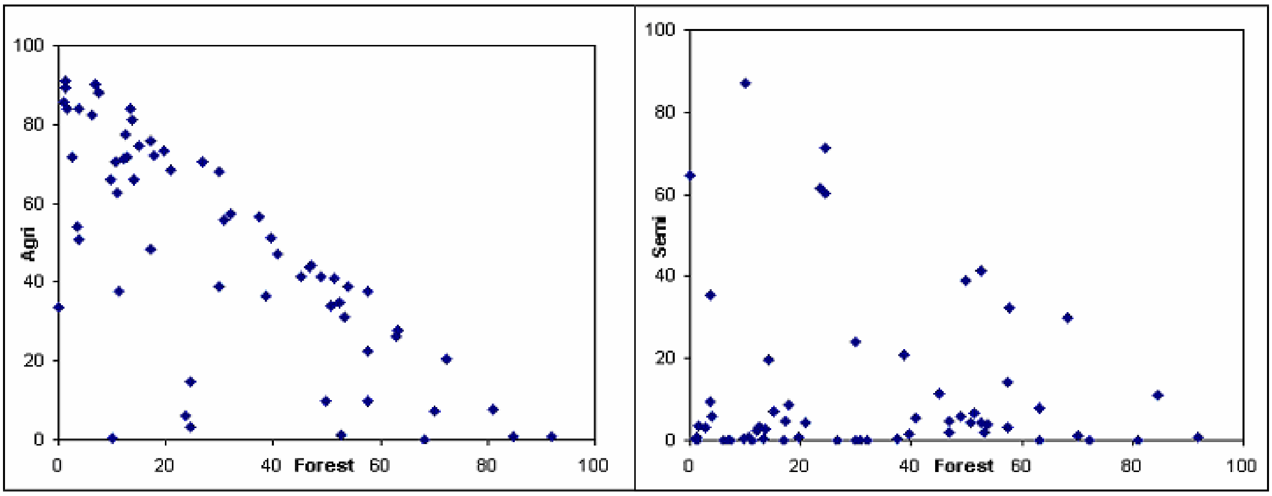


Figure 3.13 Scatter plots of the Proportion of Agricultural Areas, Forest and Semi-Natural Areas

As expected, the scatter plots above for the sample site subset windows gave similar general trends to the BRME. The general trend between Agriculture and Forest dominated locations was still present in the windows, but there appeared to be a clustering around areas dominated by agriculture. Some windows also appeared to represent a cluster having an even mix of agriculture and forest. This had been identified as a situation which did not really match any of the biogeographic regions. Even though the NATURA2000 sites had been established to protect habitats of a high conservation value, only 5 (8%) of the sample site windows in the subset were dominated by semi-natural habitats. If it is assumed that forest and semi-natural can be grouped then the windows dominated by these classes did not exceed those dominated by agriculture. This suggested that in most cases NATURA2000 sites are small fractions of the windows and are surrounded by developed land.

The selected sample site subset for the windows was found to represent the significant biogeographical regions with Europe, but that the results from the sample sites may not have been representative enough to describe and accommodate the variations between and within regions. The final window sample site subset will contained 75 locations which exhibited spatial and characteristic clustering controlled by the original selections by Pierre Devilllers, partner country location and the availability of historic aerial photography. It may have been possible to produce a more optimal set of sample sites relative to the Biogeographical Regions Map of Europe with full access the NATURA2000 database, time to performed the analysis originally planned and further time to properly consult on the representativeness of the sample sites. With hindsight and sufficient funds a much larger sample site set should have been selected and analysed. The European landscape is a complex pattern against which the Biogeographical Regions Map of Europe may be seen as an over generalization when analyzing land cover at the scale of CORINE and finer in the case of the WP3000 transects.

ASSESSING SUITABILITY OF SPATIAL FRAMEWORKS TO SUPPORT DATA EXTRAPOLATION AND INTEGRATION

The original objective of the WP was to develop a GIS framework to support and facilitate data integration within realistic and appropriate regions. Parcel-based systems were proposed as they offer an accurate representation of regions and landscapes and easily support the hierarchical structures which it was thought would be required to accommodate the range of spatial scales present within the landscapes at a pan-European level. WP4100 was to draw upon a searchable meta-database of available data sets, statistics on the sensitivity, accuracy and precision of different zonation schemes and a report detailing the optimal choice of zonation from Phase-I. WP4100 was to be made up of three tasks: to assemble all relevant socio-economic (geo-political, land use and policy) and environmental (physical and climatic) boundaries; to assess the boundary data in terms of extent, usefulness, quality and compatibility and to combine selected boundary data into a single layer or hierarchical stack as a GIS framework. The deliverables were to be an assembled pan-European boundary dataset, a report assessing the usefulness, quality and compatibility of boundary data and a hierarchical stack of boundary data implemented within a GIS system.

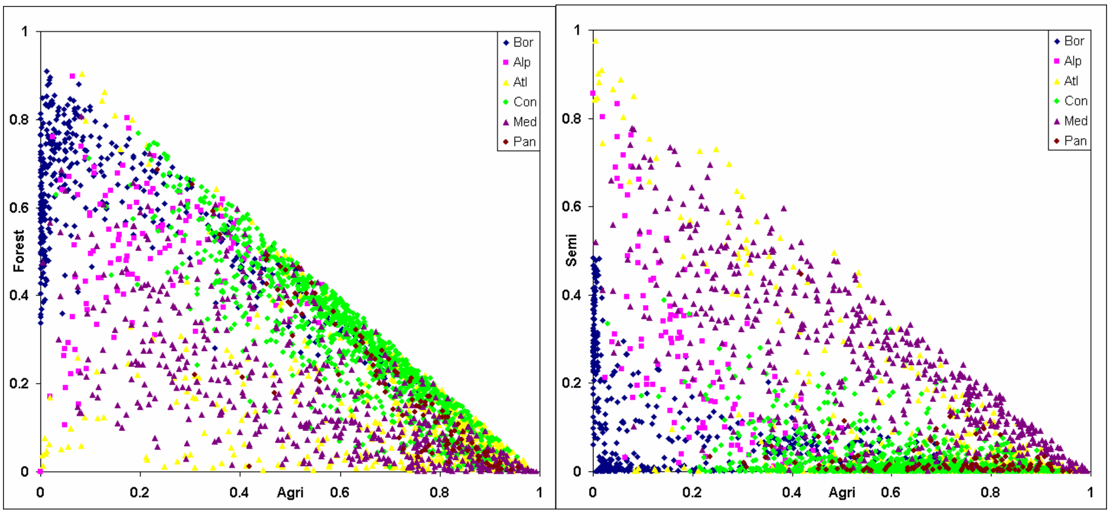
Based on the results of WP2200 and within the context of the developments in Phase-II, WP4100 was revised. The new objective of WP4100 was to assess the suitability of one or more GIS frameworks to support and facilitate data integration within realistic and appropriate regions. Parcel-based systems were still seen as the most appropriate for integration, but raster systems were also considered which may better represent the highly variable spatial structure of land cover within Europe. This WP also supported WP3200 which was responsible for producing a pan-European extrapolation of the land cover change information.

The task structure was adapted to fit the new requirements. The first step was to test the sensitivity of the use of the BRME as a GIS framework for extrapolation based on the numbers and distribution of windows and transects. Next the suitability of the selected framework for extrapolating / integrating ancillary datasets needed for pressure modelling would be assessed.

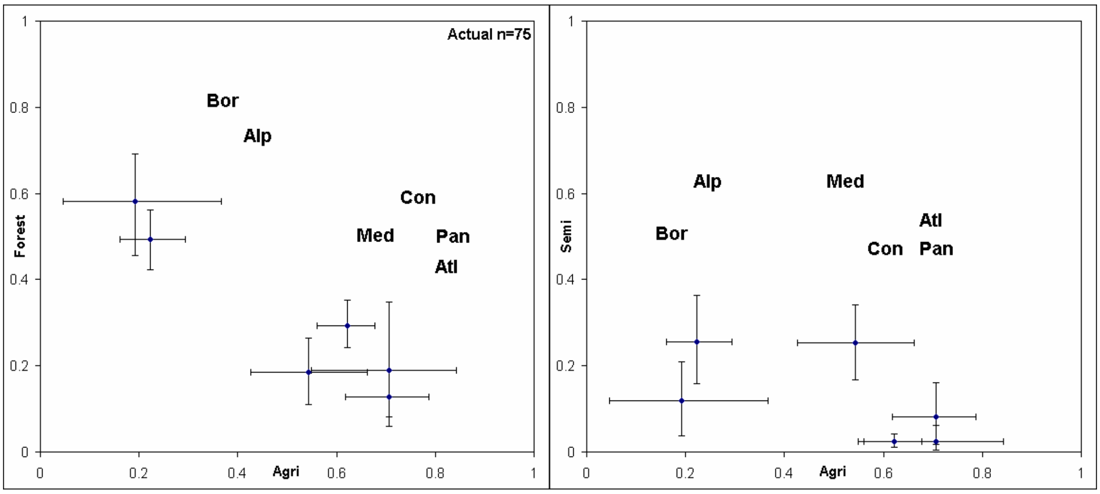
To assess the sensitivity of a sampling approach for the selected subset of sample sites it was necessary to estimate the variability present in the whole population of possible sampling units. A sample population was created from which a subset could be drawn. In this case the sample population was derived by the aggregation of the proportions of CLC1990 land cover information onto an appropriate grid related to the sample support. The subset was required to be stratified by the BRME zones so the population was subdivided based on the same zonation scheme. The full subsets were therefore made up of a number of separate subsets each related to a BRME zone.

A subset was then drawn randomly from the sample population and the characteristics of the subset assessed. The drawing and assessment of subsets was repeated a large number of times so that the distribution of the characteristics of the subsets could be obtained. From this distribution the variability caused by the sub-setting procedure was obtained. One thousand mean proportion results for each BIOPRESS land cover aggregation were sorted and the 50th and 950th were extracted as estimates of the variability for each land cover within the BRME zone.

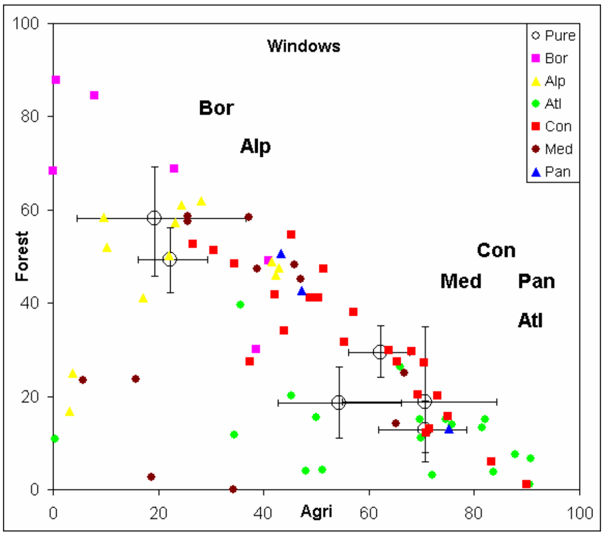
For the case of the BIOPRESS windows Europe was first subdivided with a 30 by 30 km grid. For each grid cell the proportions of the 44 CLC classes and the BRME zones were recorded. Grid cells were excluded if they contained less that 50 % land (in reality 50 % of all CLC classes except 523) leaving a total of 3455 grid cells. Further grid cells were excluded if they contained more than 1 BRME zone reducing the number of grid cells to 2711 (made up of Boreal (Bor): 409, Alpine (Alp): 124, Atlantic (Atl): 517, Continental (Con): 1014, Mediterranean (Med): 541 and Pannonian (Pan): 108). For each of the 2711 grid cells the proportions of Agriculture, Forest and Semi-Natural land covers were calculated using the BIOPRESS aggregation of the CLC classes. Scatterplots of the resulting proportions for the grid cells are shown below.



The variability plots below for Agriculture and Forest (left) and Agriculture and Semi-natural (right) show the results of using the actual number of windows per BRME zone (Bor: 6, Alp: 12, Atl: 19, Con: 23, Med: 12 and Pan: 3. Total: 75) used in BIOPRESS when repeatedly sub-setting the sample population. The BMRE zones are divided into two clusters in the scatterplot of Agriculture against Forest, but within each cluster there is a lot of overlap of the bars representing the variability within each BRME zone. The Agriculture against Semi-Natural scatterplot is similar although the Atlantic, Continental and Pannonian zones are closer together with small amounts of Semi-Natural while the Mediterranean zone forms another cluster with large amounts of Semi-Natural.

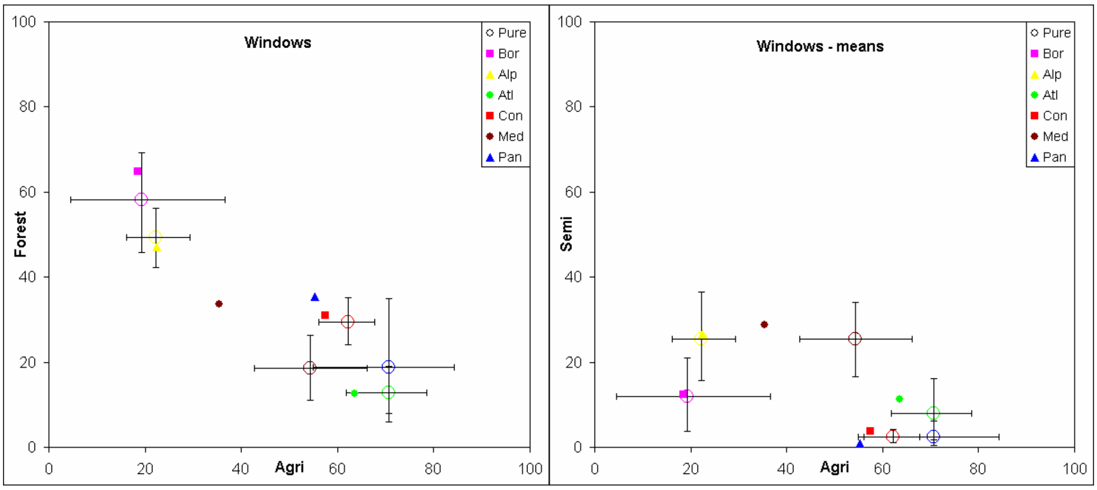


The land cover proportions of the selected windows (below) were compared to the variability plot of Agriculture against Forest for the sensitivity analysis using the actual number of samples per BRME to see how the selected windows related to the BRME zone means and their variability.



It was found that many of the points representing the selected windows lay at considerable distances away from the means of their BRME zone. Even though the Continental zone had quite small variability bars the Continental zone windows covered a broad area. The same could be said to a slightly lesser extent for the windows within the other BRME zones. This situation resulted in a considerable number of windows, appearing to be more similar to BRME zones other than the one they occupied in terms of their CLC land cover proportions. In one instance, three of the Mediterranean windows lay close to the Boreal BRME zone mean, due to them having unusually large proportions of forestry.

With the average land cover proportions within each BRME zone and the variability within each zone given the selected sample sizes based on the whole population, in it was possible to assess the representativeness of the selected windows subset. The scatterplots below compare the population results for each BRME zone to the means derived from the selected windows used by BIOPRESS.



The Alpine and Boreal zone means from the selected windows lay reasonably close to the values from the population means. The results for The Atlantic and Continental zones were toward the edge of the distributions (5 to 95 % limits), while the Mediterranean and Pannonian results were well beyond the limit of these distributions. Similar results were produced for the transect data set.

Due to the high variability within in BRME zones, it was unlikely that the BIOPRESS windows and transect data set would be adequate to describe the zones and their variability. The sensitivity analysis identified the need for more windows to adequately describe and differentiate between zones using a sample approach. A comparison between the population and sample results also suggested a bias in the sample selection toward Forest and Semi-natural related to the focusing of activity around N2000 sites. The windows were therefore less representative of the BRME zones as a whole than a random sample would be. When considering the transects, the sensitivity analysis more clearly highlighted the problems described above for the windows. The variability within the zones was higher relative to the number of transects and the impact of the bias caused by the N2000 sites was greater.

Overall it was concluded that the nature of the BRME and BIOPRESS sampling scheme for windows and transects were not appropriate for extrapolation of land cover change results across Europe within the context of the BRME and with any level of confidence.

3.2.2 Improving detection of change in land cover and landscape features from multi-scale RS data, covering the information needs of WP4300 and WP4400 (WP4200)

Medium Spatial Resolution but High Temporal Resolution Satellite Data

The long term goal is to develop a monitoring concept to identify future land cover changes within Europe. In addition to land cover changes obtained through e.g. the update of CORINE land cover (CLC2000), there is a need for alternative methods that are faster and cheaper and more responsive to major land cover changes within Europe:

Actual and reliable information on land use and land cover (LUC) is required for many application fields at various scale levels. The European landscape is continuously undergoing changes caused by a combination of socio-economic and climatic processes. To protect the environment and to ensure sustainable use of natural resources, a wide variety of national and international legal mechanisms have been established, which on their turn have resulted in various environmental monitoring activities. Examples are the Amsterdam Treaty from 1997, the EU Habitats Directive, the EU Common Agricultural Policy and the Kyoto Protocol. LUC changes play a major role in studying climate change and in particular the global carbon cycle. Conversion of landscapes, in particular forests, grasslands and agricultural lands, influence this carbon cycle. Moreover, it has a major impact on biodiversity. Remotely sensed data from satellites provide a basis for mapping LUC and LUC changes (Gutman et al. 2004).

On the one hand, global scale datasets from coarse resolution sensors provide information on land cover globally. In the US global land cover products have been derived using 1 km NOAA-AVHRR time series (Hansen et al. 2000). In Europe 1 km SPOT-VEGETATION data have been used for producing land cover products (Bartalev et al. 2003). Mücher et al. (2000) created a pan-European land cover map using NOAA-AVHRR data (PELCOM). The authors stated that the overall accuracy of AVHRR-derived land cover maps at a continental scale will not exceed 70 %. Moreover, the coarse scale AVHRR imagery is limiting the use for monitoring purposes due to the finer scale at which most land cover changes take place in Europe. Still these sub-kilometre scale changes are critical for monitoring changes in, e.g., sinks and sources of the carbon cycle or biodiversity.

On the other hand, more detailed studies at the regional and landscape scale are performed using Landsat, SPOT or ASTER data at spatial resolutions between 10 m and 30 m. Use of such data is not appropriate at the continental scale due to their limited spatial extent. The gap with the coarse resolution sensors may be filled as such imagery at 250 m from MODIS (Zhan et al. 2002) and at 300 m from MERIS is becoming available (Rast et al. 1999). The MODIS Science Team also stated that a detection method for land cover change should better be based on MODIS 250 m data than on MODIS 500 m or 1 km data (Zhan et al. 2002). Many land cover changes due to human activities occur at spatial scales near 250 m (Townshend and Justice 1988).

The enhanced spatial, spectral, radiometric and geometric quality of MODIS and MERIS data provides a greatly improved basis for mapping and monitoring land cover as compared to AVHRR data (Verstraete et al. 1999).

(Source: Clevers, J.G.P.W., M.E. Schaepman, C.A. Mücher, A.J.W. de Wit, R. Zurita Milla and H.M. Bartholomeus, 2005. Using MERIS on ENVISAT for Land Cover Mapping. IN: International Journal of Remote Sensing. Submitted).

Discussion about future monitoring concept started in January 2004 with the general framework which could be along different lines:

1. Sampling. Stratified random sampling is the preferred sampling methodology. Studies like the Country Side Survey in the UK and the BIOHAB project on habitat monitoring advocate the use of stratified random samples using climatic information as the main data source for stratification. When information is needed at a very detailed scale the hotspots can be monitored using very high resolution satellite data such as QUICKBIRD, IKONOS and SPOT-5 panchromatic. The advantage of systematic sampling is that very detailed information can be gathered, as for example on linear features, which is very valuable information from an ecological point of view.
2. Full cover monitoring. This can be implemented using low (eg. SPOT-VEGETATION) or medium resolution satellite data (eg. MERIS or MODIS), or even using high resolution satellite data (eg. Landsat-TM or SPOT-XS), as has been done in the CORINE land cover project.
3. Using Temporal Land Cover Model. For the identification of land cover changes it is also a good possibility to exploit the wealth of multi-temporal time series of satellite images. When the land cover change has been identified the time-series can also be exploited to characterise the change in it's timing (when did the change exactly occur ?) and the rate of change (rapid or gradual change). CEH has undertaken a program of work to test the feasibility of exploiting phenological signals in high frequency multi-temporal satellite data to detect areas of land cover change.

In report D38/40 major emphasis was placed on the exploitation of medium resolution satellite data to detect land cover changes within a full cover and temporal monitoring. A first hypothesis was that the update of CORINE land cover could be accelerated and at lower costs using MODIS or MERIS data. A second hypothesis was that CORINE land cover objects can be identified in a more automated and objective manner using MODIS/MERIS satellite data, reflecting the right information at the landscape level. The most relevant conclusions with respect to this research were:

- Identification of CORINE objects (level 2) on basis van MODIS satellite images and eCognition give reasonable to good results.
- Major exceptions are heterogeneous CORINE classes.
- Major advantage of segmentation of MODIS/MERIS satellite images is consistency, speed, actuality en low costs (CORINE land cover differs very much in approach for the Netherlands and Belgium).
- MODIS will be at least useful for monitoring expansion urban areas.
- Use of phenological signals for land cover mapping and change detection could be an important complimentary approach to the conventional high spatial resolution mapping of CORINE land cover mapping.

SEMI-AUTOMATIC DETECTION OF SMALL LANDSCAPE ELEMENTS

Within report D39 there was a general interest in the detection of historic dynamics of landscape features, next to the detection of historic land use changes. The dynamics of the landscape elements, such as linear features and small biotopes, have a major impact on the landscape structure and therewith on the sustainability of the landscapes for specific populations and therefore on biodiversity. The manual identification and interpretation of linear and point features on aerial photographs within the BIOPRESS project appeared to be very time consuming. However, identifying these elements is relevant in the framework of biodiversity. Therefore, this work has been carried out to support the interpretation of small landscape elements via semi-automated image processing algorithms. Evaluation of the potential for semi-automated detection of certain landscape characteristics using the segmentation software eCognition and VHR satellite images led to the following conclusions:

- The use of very high resolution satellite imagery for the detection of small landscape elements allows a cheaper collection of data at the scale of BIOPRESS transects, compared to airborne images. This implies that time series are more likely to be acquired. Satellite imagery permits the harmonisation of the data, as there are only a few different satellites.
- Detection and classification of small landscape elements using an object-oriented approach offers more possibilities than a pixel-based method. It allows bringing texture, colour and shape of the formed objects into account. Further on, it allows working at different scales, because landscape objects over the world have a multitude of different dimensions.
- This object-oriented approach facilitates the elaboration of a semi-automated small landscape element detection that can be used on all European BIOPRESS transects. The specific strength of this method is to sensibly facilitate the work of an image interpreter (operator) as it indicates where the elements are located and if they meet all necessary criteria.
- As a result, there exists a large potential to extract small landscape elements from VHRSI. Even if it is already time and cost efficient for some small landscape elements, further research on this object-oriented classification can still sensibly contribute to a time and cost efficient, objective and high-quality BIOPRESS element detection technique.

3.2.3 INTEGRATION OF SOCIO-ECONOMIC DATA TO QUANTIFY PRESSURES FROM LAND COVER CHANGE (WP4300)

WP4300 has investigated the causes, i.e pressures, of the observed land cover changes, i.e. state and developed a generic model for data integration and analysis in order to quantify the pressures (Figure 3.14).

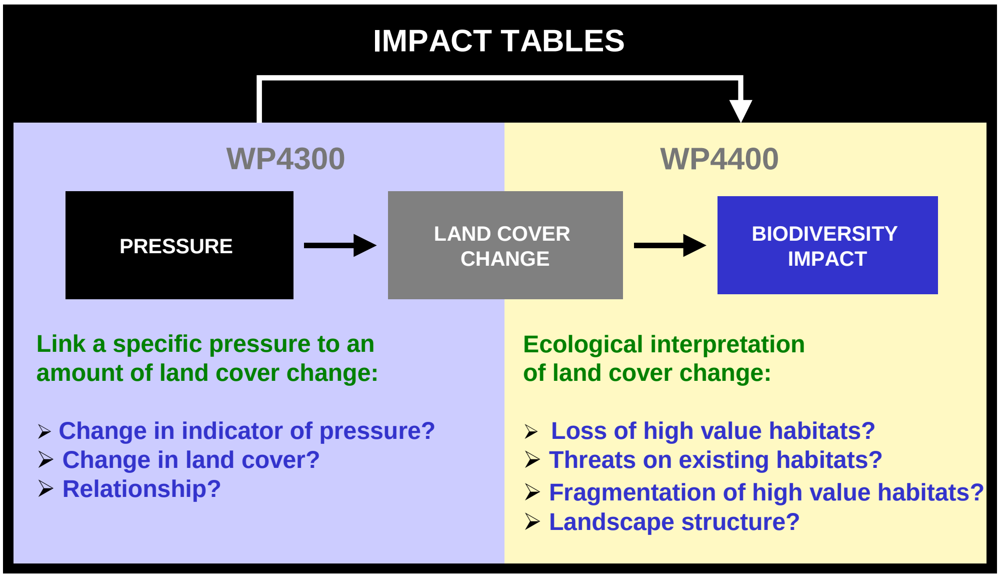


Figure 3.14 - Schematic overview showing the close relationship between WP4300 and WP4400

The main tasks carried out in this work package can be described as one of the following:

- Identify indicators for quantifying the pressures and obtain the relevant socio-economic and agricultural data sets. A time series of this data will be required.
- Develop and implement a generic integration model to reconcile the spatial resolution of the socio-economics (i.e. European, national or regional level) with the land cover change.
- Develop and implement a methodology to be used for quantifying the pressures at the European level that have prompted the change in cover.

MAPPING LAND COVER DYNAMICS INTO PROCESSES

It is well known that land-cover change is not a unidirectional process (e.g., forests being converted to agriculture). In the Land Cover Change Matrix, each land cover conversion was associated to a unique particular process, which was meant to represent a specific anthropogenic pressure on the biodiversity of a Natura2000 site. This assumption is far from being satisfactory. First, the same land cover change might be associated to two different processes at the same time, depending on where the land cover change took place in the first time. Second, it is not advisable to assume that any type of land cover change is always a pressure on a habitat. We dealt with these issues by applying expertise knowledge to carry out the final mapping of land cover conversions into pressures using the Land Cover Change Matrix. This cross-tabulation matrix (Figure 3.15) is a fundamental starting point in the analysis of land cover change, but a substantial research is needed to analyse the matrix according to its various components in order to gain much insight as possible concerning the potential processes (i.e. pressures) that determine a pattern of land cover change.

Definition of pressures

In the BIOPRESS project, pressures have been defined as the processes that can be determined by the spatial patterns of land cover changes that are related to habitat fragmentation at local scale. In other words, the processes determine how land cover changes may affect local environmental conditions of Natura2000 sites. They have also been used to account for the land cover changes observed outside/inside the Natura2000 sites between 1950 and 1990. The Land Cover Change Matrix was used to directly identify the pressures that caused changes from one land cover category to another, using the levels 2 and 3 of the CORINE nomenclature. The processes operating with lower intensity that are inducing changes in the internal structure within a land cover category could not be identified. Therefore, the Land Cover Change Matrix developed in the BIOPRESS project can be considered as a compact format for representing the pressures that have resulted into different transitions between all possible land cover categories (e.g. Figure 3.16).

Selection of the main pressures

Six main pressures were selected for the statistical analysis of land cover change patterns in combination with economic development, technology, and other social factors:

- Agricultural Intensification (I): includes agricultural conversions as well as cases in which human-altered areas become transformed into a more intensive practice by changing the natural cover.
- Land Abandonment (Ab): includes the cropping cessation and conversion into early successional, herbaceous habitats. The transition to woody, later-successional habitats has been considered as a Mediterranean extension of Afforestation.
- Afforestation (A): includes the conversion of open (more or less natural) habitats into forests or macchias.
- Deforestation (D): we have distinguished deforestation from afforestation instead of considering the first as a relaxation of the second. Both are in fact *affecting* biodiversity in different ways.
- Drainage (Dr): in a broad sense, includes all changes affecting aquatic habitats that are transformed into more terrestrial ones: disappearance of wetlands, but also changes in rivers and in estuarine areas. We have included land gain from intertidal and sea areas in the Netherlands, as well as the lost of peatlands drained due to agricultural practices or replaced by forests in Finland.
- Urbanisation (U): includes the transformation to urban covers but also to related covers (road system, leisure areas, construction sites ….)

TO\T1	1.1.1.	1.1.2.	1.2.1.	1.2.2.	1.2.3.	1.2.4.	1.3.1.	1.3.2.	1.3.3.	1.4.1.	1.4.2.	2.1.1.	2.1.2.
1.1.1. Continuous urban fabric										U	U	U	U
1.1.2. Discontinuous urban fabric	U		U		U					U	U	U	U
1.2.1. Industrial or commercial units										U	U	U	U
1.2.2. Road and rail networks and associated land	U		U		U					U	U	U	U
1.2.3. Port areas	U									U	U	U	U
1.2.4. Airports	U	U	U							U	U	U	U
1.3.1. Mineral extraction sites	U	U	U	U	U	U			U			U	U
1.3.2. Dump sites	U	U	U	U	U	U			U			U	U
1.3.3. Construction sites	U	U	U	U	U	U						U	U
1.4.1. Green urban areas	U	U	U	U	U	U	U	U	U			U	U
1.4.2. Sport and leisure facilities	U	U	U	U	U	U	U	U	U			U	U
2.1.1. Non-irrigated arable land	U	U	U	U	U	U	U	U	U	U	U		I
2.1.2. Permanently irrigated land	U	U	U	U	U	U	U	U	U	U	U	I	

Figure 3.15 Part of the Pressure - Land Cover Change association matrix showing changes associated to Urbanisation

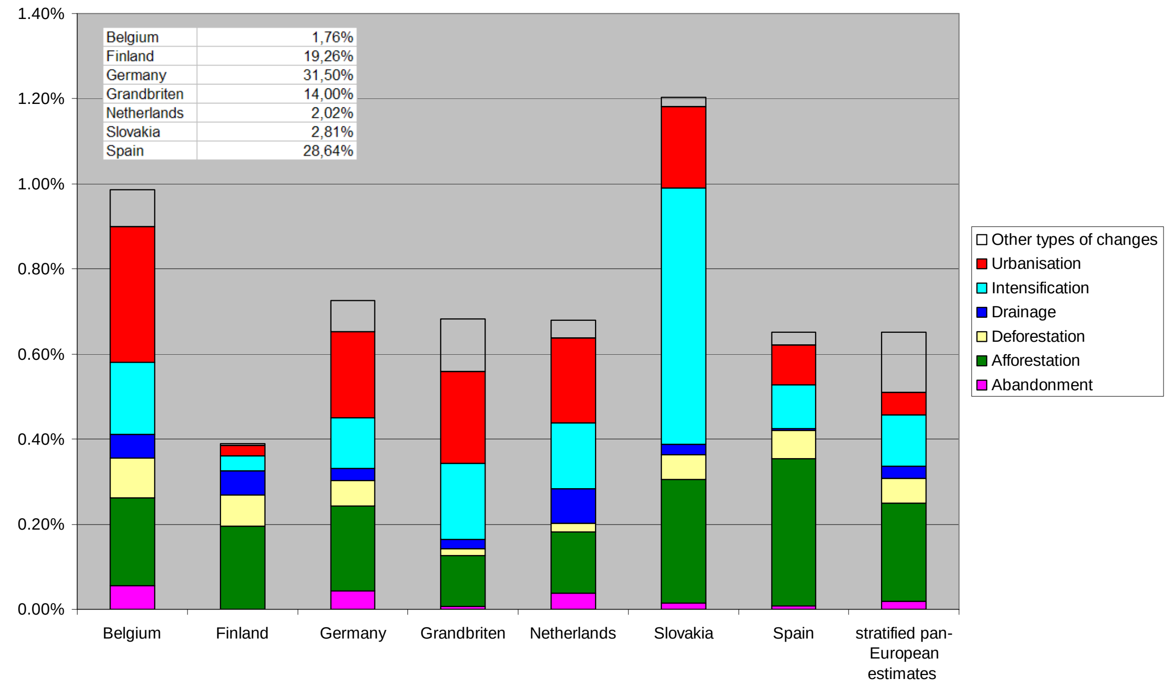


Figure 3.16 The proportion of area changed associated to the different types of pressures for the different European countries represented by the transects.

Mapping Land Cover Dynamics Into Processes By Developing A Multi-Representation Model

The integration model for the quantification of pressures was defined at two levels: European level and window/transect level. For the latter, 4 windows were selected, located in the Netherlands, Spain, Finland, and Slovakia. In this way, the Atlantic, Mediterranean, Boreal, and Alpine and Panonian bio-geographical regions would be represented in.

The main research challenge faced in the WP4300 was to define a pattern-process model of land cover dynamics in space and time in order to combine the local level measurement of the land cover changes (e.g. BIOPRESS windows) and the socio-economic indicators of a larger region (e.g. the countries). The proposed multi-representation model is based on the degree of variability in the behaviour of generalised statistics and their dependency of the spatial generalisation of the variable values at different spatial scales.

Much of the research analysing spatio-temporal patterns in land cover has emphasised the impact of fragmentation on biophysical factors such as natural vegetation and a general decline in the spatial extent and connectivity of wetlands, and wildlife habitat. Therefore, we have focussed on the socioeconomic activity that is also impacted by land cover change at different levels of abstraction (scales).

Dealing with heterogeneous data sets obtained from different sources of socio-economic indicators in conjunction with the BIOPRESS land cover product, in order to link their patterns to a specific anthropogenic process, and thus to understand better the socio-economic dimensions of land cover changes.

The increasing volume and diversity of data sets overwhelm the traditional spatial analysis techniques that are oriented towards studying small and homogeneous data sets. Traditional statistical methods, particularly, spatial statistics, have high computational burdens. These techniques are confirmatory and require the researcher to have a priori hypothesis. Therefore, traditional spatial analytical techniques cannot discover new and unexpected patterns, trends, and relationships that can be hidden deep within very large and diverse data sets.

Geographic Knowledge Discovery (GKDD) is a response to the complexity and volumes of data being generated and stored in operational and scientific databases. Data mining is only one component of the larger GKDD process, which goes beyond the traditional domain to accommodate data not normally amenable to statistical analysis. Statistics involves a small clean (noiseless) numeric database scientifically sampled from a large population with specific questions in mind. Many statistical models require strict assumptions (such as independence and normality). In contrast, the data being collected and stored in many enterprise databases are noisy, non-numeric, and possibly incomplete. These data are also collected in an open-ended manner without specific questions in mind. Certainly, the data sources used in the WP4300 have such characteristics.

What is needed in short term to have socio-economical indicators in place to assess pressures on biodiversity?

Selecting indicators involves choosing measures, but also considering WHAT, WHERE and WHEN the data supporting these measures should be gathered. The efforts made by the WP4300 team in selecting a list of indicators has shown the importance of developing projects to test assumptions and statistical historical trends of socio-economic indicators before they are fully implemented within a monitoring programme. Three main issues have been identified as the primordial importance for having socio-economic indicators available for statistical analysis. They are:

<u>Representativeness of Indicators</u>

In WP4300, this was definitely the case for determining how many indicators were needed to explain the processes at different scales within our model. Getting all data, all of the time, is a fine principle, and if can be achieved, a worthwhile objective. However, for various reasons is not a practical solution. Even if as much data as possible is to be examined, survey and modelling, still require representative data sets. It is critical to build up a structure of representative indicators at different levels of scale, both in space and time. This structure will actually be part of a model which will be able to show how the indicators relate to each other. It will be certain indicators that will allow samples to be taken, and as a result, selecting a suitable level of detail for a set of indicator will be a consistent and logical decision

<u>Missing Values</u>

In the WP4300, missing values formed a very important issue in preparing the data sets from 1950's until today. Missing values can cause considerable distortion in the analysis if their values are replaced without elsewhere capturing the information that they were missing. Although missing-value estimating methods are available to produce mathematically optimal values, they are very complex, and vary with the type of data they are applied to (e.g. categorical versus numerical data). The method taken in the WP4300 was to use unbiased estimators that have produced an estimate whose expected value was the value that would be estimated by the population. Therefore, the estimated values have not changed important characteristics of the values present when the estimates were included with the existing values. However, in some cases the number of missing values was higher than 50% of their population. Therefore, 24 BIOPRESS windows were not taken into account in the statistical analysis because of their large amount of missing values which are present in the European and national statistics.

<u>Variability in importance, in space, and in time</u>

Indicators are variables that my change in importance according to the pressure being analysed. The actual values that an indicator can have contain some sort of pattern and are distributed across the variable's range in some particular way. They also may change their conditions at a defined location over time. It may be, for example, that for some countries, the range of the values of an indicator has taken a limited number of values, meanwhile for other countries, many instances were bunched together. Unfortunately, current monitoring programmes still use different basic data formats for geo-referencing which hampers a spatial variability analysis. The data sets used in the analysis carried out in the WP4300 presented a variety of temporal and spatial scales, as well as unknown accuracy.

Because of a lack of long-term monitoring data, it was not easy to differentiate between population fluctuations and real trends (patterns).

DATA MINING

We have selected the C4.5 (CTree) technique for finding a generalisation model based on a decision-tree representation, determined by information gain search using entropy heuristics (Quinlan 1993). In essence, this technique builds recursively decision trees by following a top-down approach (from general concepts to particular examples). A hierarchical model is constructed, starting from analysing the entire target data set, partitioning it into subsets (i.e. levels of abstractions) using the information gain measures, and repeating the partitioning procedure until the best decision tree is found. A description of tree growing then induces to a set of rules that explain the splitting criteria used to create meaningful subsets. There are dozens of splitting techniques that have been proposed in the literature, such as information gain, and gain ratio. Whether a model is intended for description, classification or generalisation, the aim is to capture only the true characteristics of the data but not the noise and randomness. In the context of trees, this concern translates into the problem of finding the right sized trees. Techniques used to find right sized trees, includes pruning. When more than one tree can describe a data set perfectly, we need metrics to quantify the accuracy of trees. Individual decision trees have high variance in terms of generalisation accuracy; therefore many authors have suggested combining the results from multiple decision trees. Trees cause data fragmentation, which reduces the probabilistic significance of near-leaf nodes. A solution to this is the use of soft splits.

Creating the target data set

This step included selecting a data set containing the variables (indicators) on which data mining was meant to be performed. Three main data sources were used to create the target data set. They were:

- The New Cronos database provided by Eurostat. This database contains macroeconomic and social statistics data covering some of the European Union (EU) Member states and also some of the central European countries. The data are organised into 'Key indicators on EU policy' and nine statistical themes, which are then subdivided into collections of data tables. This was the main source of information since it provided data from 1991 to 2000 for 35 indicators. Unfortunately, the data availability was hampered from performing the analysis for earlier than 1991. Moreover, in total 24 BIOPRESS windows were not taken into account in the statistical analysis because of the large amount of missing values found in this database.
- The Important Bird Area (IBA) database contains habitat information for one or more species of birds, including sites for breeding, wintering, and/or migrating birds. The IBA Program is designed to be proactive, voluntary, participatory, science-based and credible. The program also works to identify, monitor and conserve sites for birds. The database provides information about threats (pressures) throughout Europe and the world.
- The BIOPRESS database, providing information about land cover changes occurred between 1950 and 1990, and their respective identified pressures. This database also provided information about the location and size of 316 Natura2000 sites and the 6 European Biogeographical Regions.

The target data set consists of a set of 3181 cases (records) containing the values of the selected 52 socio-economic indicators for the period from 1991 to 2000, the location and size information of 316 Natura2000 sites and 6 European biogeographical regions, as well the information about the land cover change transitions and their respective processes.

Data Cleaning and Pre-Processing

This step included the basic strategy for handling missing data fields, and accounting for time sequencing information from 1991 to 2000, as well as deciding DBMS issues, such as data types, schema, and mapping of missing and unknown values. In the WP4300, missing values formed a very important issue in preparing the target data set. The method used was based on unbiased estimators that have produced an estimate whose expected value was the value that would be estimated by the population. Therefore, the estimated values have not changed important characteristics of the values present when the estimates were included with the existing values. However, in some cases the number of missing values was higher than 50% of their population. Therefore, 24 BIOPRESS windows were not taken into account in the analysis because of their large amount of missing values found in the European statistics.

Data Projection

This step included finding useful objects to represent the data, keeping in mind that the goal was to reduce the effective number of variables under consideration and find invariant representations for the data. The main spatial objects have been modelled using the multi-representation model developed in the WP4300.

Data Mining: Searching for Interesting Patterns

For this step we have selected the C4.5 technique to be used for searching for patterns in the target data set. There were two relevant factors: the function of the model (i.e. generalisation) and the representational form of the model (i.e. information gain). The model contains parameters that are to be determined from the target data set. The decision tree model is based on a generalisation representation, determined by information gain search using entropy heuristic.

Quality of the rules

Three quality measures were be used to define the quality of the rules obtained from the analysis. They are:

- Support of a rule, which is the relation, defined by how many records comply with the rule, and the total number of records in the training set.
- Confidence level of a rule is the relation defined by how many records complies with the rule and the output class, and how many records comply with the rule.
- Capture of a rule, which shows the percentage of the cases the rule has captured in the decision tree.

The figure 3.17 shows the main values obtained for the computed rules.

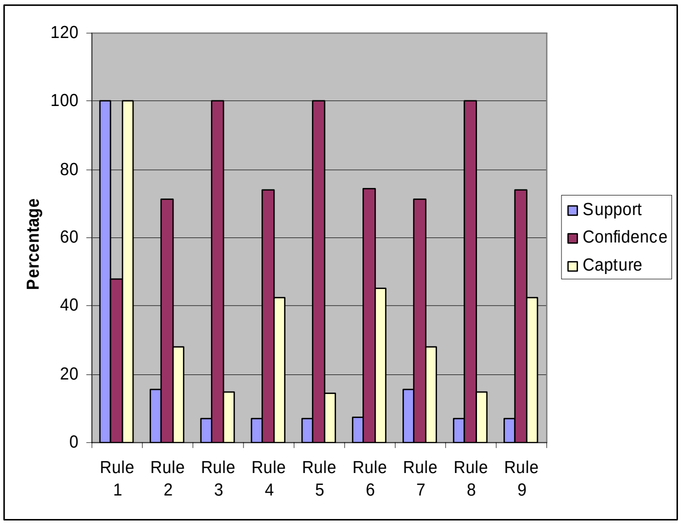


Figure 3.17 Main values obtained for the rule computed in the data mining analysis

Interpretation of the rules

The overall results of the data mining analysis show that the Biogeographical regions were the main spatial unit for the generalisation of the patterns into a specific pressure. Nine indicators out of the 53 indicators have provided the highest information gain in the model. For example, population density has provided the highest information gain and therefore, it was used for generating the rules for the

Atlantic, Continental and Mediterranean regions. On the other hand, indicators such as the economic active population and primary production were used for building the rules for the Continental region alone. Table 3.6 provides the overview of the nine indicators that have provided the highest information gain for building the decision trees within the Atlantic, Continental, and Mediterranean Biogeographical regions.

Table 3.6 The socio-economic indicators that explained the pressures by European biogeographical region

	Gross Domestic Produc at market prices	Gross fixed capital formation by private sector (% GDP)	Economic active population (per 1000hab)	Primary production (1000 tons od oil equivalent -	Gross fixed capital formation by private sector	Total employment (per 1000 hab)	Total imports (1000 tons od oil equivalent - TOE)	Population density	Fertliser consumption (nitrogenenous)
Atlantic	x					x		x	x
Continental		x	x	x				x	x
Mediterranean	x	x			x	x	x	x	

The results also shown that the data mining analysis has not succeeded in finding patterns and associating them to a specific pressure for the Alpine, Boreal, and Panonian regions. Several possibilities for explaining these results have been anticipate as being one of the following:

- The selected 53 socio-economic indicators were not representative for explaining the land cover change processes
- The target data set contains information from 1991 to 2000, and perhaps the variability in time should cover a longer period (e.g. 1960 to 2000)
- The sampling scheme of the BIOPRESS windows used for these biogeographical regions was inappropriate (variability in space)
- The data mining technique was inappropriate, and another approach should be used.

Therefore, more research is needed to investigate the main reasons for exploring how socio-economic indicators could be used to discover patterns that can explain a specific anthropogenic process within these biogeographical regions. Nevertheless, some spatial patterns were found in the patch sizes of land cover changes observed in the BIOPRESS windows located in these biogeographical regions.

3.2.4 LINKING LAND COVER CHANGE TO PRESSURES ON BIODIVERSITY (WP4400)

The link between land cover change and pressures on biodiversity is the heart of the BIOPRESS project. The main objective of WP4400 was to look at the consequences of the observed LCC on biodiversity, namely on the impact of changes in the extent and spatial distribution of habitats. It was agreed from the start of the project that WP4400 would build upon the MIRABEL DPSIR framework funded by the EEA to underpin the assessment of European biodiversity by extending the existing "impact tables" to include quantified pressures associated with land use change. It was also envisaged that the development of WP4400 would allow us to assess to what extent land cover change statistics, and more specifically BIOPRESS phase I product, could contribute to biodiversity assessment.

The objectives mentioned above were addressed in two ways. The first was a regional analysis of the relationships between CLC classes and the EUNIS habitat classification and the second step a spatial analysis at the window and transect levels of changes in the spatial extent and distribution -number and size of patches - of CLC classes important for biodiversity. These analyses enabled us to produce regional impact tables according to the MIRABEL framework and discuss the contribution of the BIOPRESS Phase I product to the MIRABEL Biodiversity assessment.

QUANTIFYING RELATIONSHIP BETWEEN CLC CLASSES AND HABITATS

It is clear that the 44 categories of land cover in CORINE are far too broad to consider habitats per se. In WP4400, a systematic analysis of spatial coincidence between land cover types in CLC1990 and Annex1 habitat types recorded in Natura 2000 sites was carried out, translated into the EUNIS habitat classification and summarised per Biogeographical region (BIOPRESS deliverable D45).

Out of the 44 CLC classes, 23 had a one to many links with Annex 1 habitats and therefore could be analysed. Another 2 CLC classes were excluded because they represented a mosaic of habitats, meaning a link too loose to be accurately quantified (2.4.2 and 2.4.3)
This work showed that significant improvement could be made by adopting a regional approach. D45 provided neater and more specific links between CLC classes and habitats than what has been available so far. It also identifies what the limitations are in attributing habitat types to CLC classes.

CHANGE IN THE SPATIAL DISTRIBUTION OF CLC CLASSES

This assessment focussed on land cover types that (i) are known to be important for biodiversity and (ii) have changed drastically in extent between 1950 and 1990 in the sampled areas. This assessment is using BIOPRESS phase I data at the three spatial levels at which they are available, i.e the 73 30km * 30 km windows (low redsolution) and the 59 15*2 km transects (high resolution).BIOPRESS phase I product was processed in ArcInfo and polygons dissolved according to the land cover type at one time. We estimated the average land cover extent per window / transect (ha) as well as information on the spatial distribution of habitats, i.e. the average number of patches per window / transect and the average size of patches per window/transect.

It appears from this analysis that BIOPRESS phase I results have given interesting estimates for changes in land cover resulting from specific pressures. It should be kept in mind that these estimates are only valid for the BIOPRESS sample itself. However, we have observed some consistent trends across the whole sample of windows and transects which tends to give such particular trends a generic value. One example was the repetitive and systematic decline by 10 to 30% of CLC units 2.4.2 and 2.4.3, which represent small scale agriculture.

REGIONAL ASSESSMENT

This regional assessment builds upon the previous DPSIR assessment MIRABEL (Petit et al., 2001). There was little to be gained in reassessing biodiversity impacts in great detail as this was the task carried out in MIRABEL and little knowledge has been made available since. Instead, we focused on BIOPRESS phase results I and assessed to what extent the trends observed in windows and transects were in line with the MIRABEL assessment, and if not, for what reasons.

MIRABEL was carried out by gathering as much available information as possible for regions of Europe and then by summarising this information in impact tables. BIOPRESS, on the other hand, provided quantitative estimates for a selected sample of land in each region (e.g. Table 3.7)

Given fact that both exercises used very different approaches for assessing threats to biodiversity in Europe, it is fair to say that the agreement between the two is rather important.
When there were differences, it resulted either from discrepancies in the definition of some pressures in BIOPRESS and MIRABEL, e.g. land abandonment and farming intensification or from known and quantified biased in the BIOPRESS sample, e.g. urbanization was overrepresented in transects.

WP4400 has taught us that a land cover product such as BIOPRESS phase I was suitable for quantifying some pressures on biodiversity but quite insufficient for the interpretation of land cover change related to other pressures:

- BIOPRESS contributed very positively to the quantification of urbanization across Europe between 1950 and 1990/2000.
- BIOPRESS land cover product made a useful contribution to the quantification of afforestation and deforestation across Europe between 1950 and 1990 but that these pressures could be better understood if (i) we had more points in time, closer together and (ii) more information on the condition of forest was derived from remote sensing and/or ancillary data was used to evaluate the ecological value of forested land.

- BIOPRESS will have underestimated the extent to which the pressure land abandonment is threatening biodiversity in Europe, in comparison to other existing assessments (e.g. MIRABEL but also national scale statements). However, it would be possible to increase the accuracy and the generic value of the BIOPRESS estimates by (i) broadening the definition of land abandonment i.e. modifying the pressure matrix, so that it matches what is meant in other assessments and (ii) by increasing the number of points in time.
- BIOPRESS was probably the first project to provide quantitative estimates about the shift from small scale to more large scale agriculture for such a large sample area across Europe and in this respect, this is a very important contribution to understanding changes in European biodiversity. However it is important to keep in mind that what has been quantified within BIOPRESS was only a small part of what is usually understood by farming intensification in biodiversity assessments. This means that, as was the case for land abandonment, BIOPRESS results will greatly underestimate the pressure farming intensification, compared to other assessments.

Table 3.7 example of a BIOPRESS impact table for the Mediterranean Region

	I.1 Arable / gardens I2 Cultivated gardens X7interspersed	I1 Arable / gardens X08 Rural mosaics	E1.3 Xeric grassland E1.4 Tall grass E1.5 Montane grassland	F5.5 Mediterran. shrub F5.1 Arboresc. matorral,	G5 Lines of trees X1 Land sparsely wooded	B1 Coastal dunes E1Dry grasslands F3 Medit. scrub
CLC class	**2.4.2**	**2.4.3**	**3.2.1**	**3.2.3**	**3.2.4**	**3.3.1**
Net change 1950-90	↓ 20-30 %	↓ 20-30 %	- 5 % →	↓ 5-10 %	↓ 10-20 %	↓ 10-20 %
Urbanisation	⇩	↓				↓
Afforestation		⇩	↓	↓	⇩	⇩
Deforestation			↑		⇧	
Conversion to Agriculture				⇩	⇩	⇩
Intensification	⇩	⇩	⇩			
Extensification Abandonment		⇩	⇧		⇧	⇧

Arrows represent the amount of habitat lost (going down) or gained (going up) as a result of a specific pressure. Small arrows represent 1 to 3% conversion, medium arrows 3 to 10% and large arrows 10 to 20%. In red, change of major biodiversity concerns

Discussion And Conclusion

Our main conclusion is that remote sensing products such as the BIOPRESS phase I land cover change product can provide very helpful information in the field of biodiversity assessment. There is potential for improving this information, e.g. by adding time steps in the monitoring or using external data to help in the interpretation of land cover change. However, our work also shows that there are clear limitations in this contribution and that remote sensing will only provide part of the information.

One important recommendation that would lead to improve facilities for large scale biodiversity monitoring would be the integration of remote sensing products with in situ information

3.2.5 ERROR PROPAGATION BETWEEN DIFFERENT STAGES (WP4500)

The objectives of the work package WP4500 were to understand, quantify and rank the sources of uncertainty in the final pan-European land cover change products. This was accomplished through the following steps:

- Model the propagation of errors from the raw data (un-corrected air photos) through all its stages to the pan-European maps of land cover changes.
- Compare estimates of land cover change from WP7000 with land cover change from WP3000.
- To understand sources of errors due to different definitions and imprecise definitions of land cover and land cover change.
- Map the most probable error to evaluate the final pan-European land cover change product.

Which translated into a number of distinct tasks with as main task the construction of an error model related to the processing chain of phase I:

- Generation of process chain and
- Deriving of errors sources within this process chain
- Generation of general error model for interpretation
- Determination of sampling error to verify extrapolation results (WP3200)
- Comparison of 2 interpretation scale levels 1:20.000 (WP3000) and 1:100.000 (WP7000)
- Discussing the influence of imprecise land cover/use definitions

Inputs for these tasks were the results of the quality assurance work (WP2400), the land cover interpretations and change statistics (WP3000), and the results of the extrapolation (WP3200).

PRODUCTION CHAIN AND DERIVED ERROR SOURCES

Figure 3.18 gives an overview on the production chain and determined errors of final output as it was used in the BIOPRESS project. Errors that occur in early stages of production chain and can not be cleared by the user propagate to the next production step. For example, insufficient image quality interfere the classification process.

<u>Selection of test sites</u>

Finally 59 transects with sufficient data cover and quality for all three time horizons were analysed. Selection was biased in consideration the use of Natura2000 sites, by local expert knowledge to include pressure impact and by focusing on project partner countries. Further 73 windows across Europe could be analysed for 1950 with the available budget. In the BIOPRESS project data availability and data quality proved to be also constricting the sample location in reality.

<u>Acquisition of image data</u>

Insufficient image cover or image quality of input data result in an iterative additional selection process of samples sites, but especially for point of time 1950 images are limited in geometric and spectral image quality and gaps in the transects/windows cover needed to be accepted. American and British military archives appeared to be the main source for pan-European available historical air photos. The lack of data is not a source of error but it is a limitation for the final user, as no statements on changes could be given for these regions.

<u>Image data pre-processing</u>

Quality of input aerial photographs seems to have a major impact of interpretation accuracy in BIOPRESS. Geometric correction and geo-referenced adaptation of single photograph by using a set of pass points is a legal method to decimate the error caused by distortion through optical and topographic impacts. For this point of errors in the process chain, the solely error, which can be estimated authentically is the Mean Square Error (MSE), given for the set of reference points. Spectral correction of image data is advisable for better differentiating of mapping classes on detail transect interpretation level. For visual interpretation of aerial photography an adaptation of grey values for merging particular photos is not essential necessary, but this process can assist the classification accuracy.

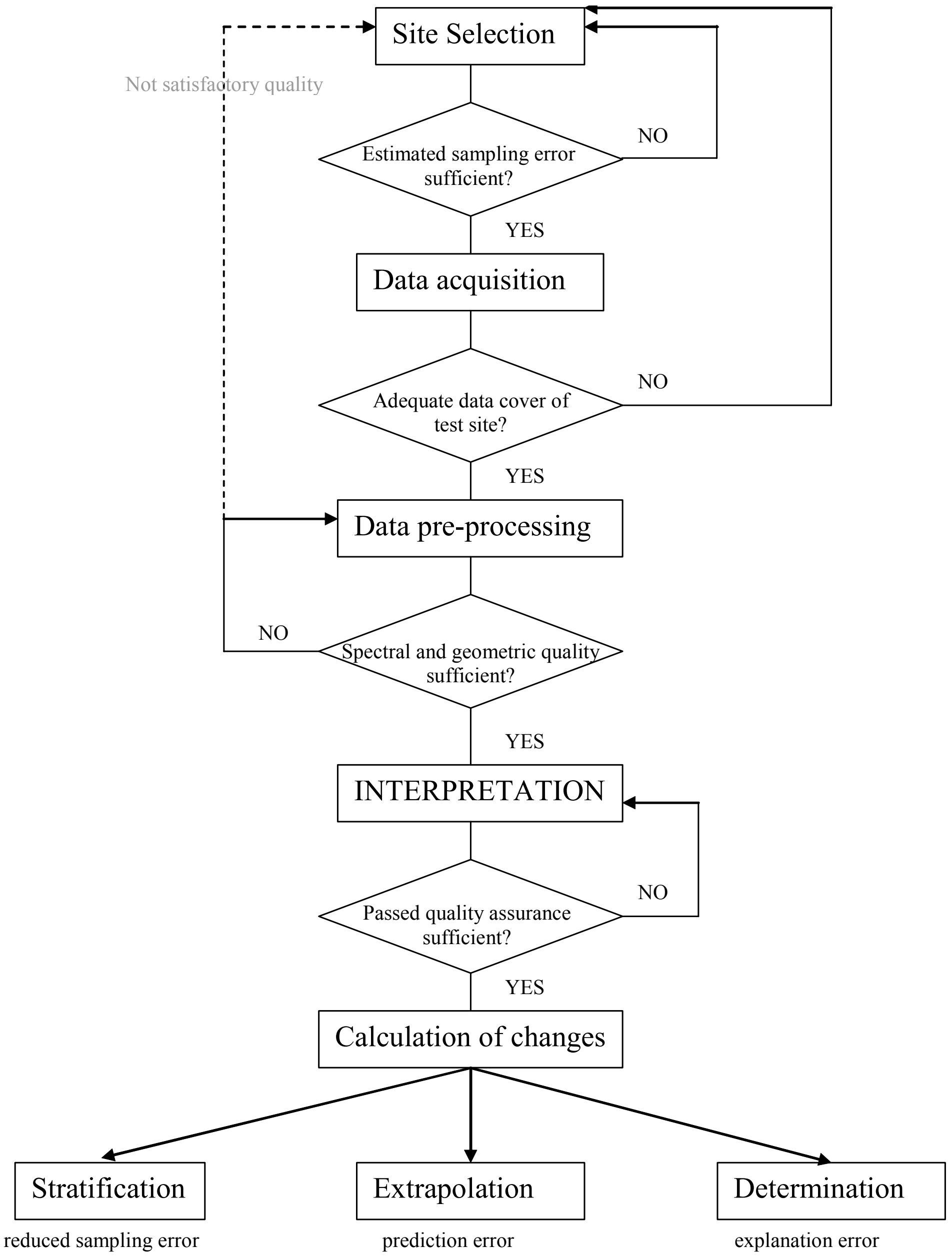


Figure 3.18 Production chain for 1950, 1990 and 2000

Interpretation

Next to image quality the major error in the BIOPRESS project is caused by interpretation errors, due to imprecise definitions of land cover classes or missing training of interpreters. Depending on the experience of the interpreter this can be an important source of error which is hardly quantifiable. The clarity of class definitions has a huge impact on the interpretation accuracy. Within the scope of this project the minimum mapping unit (MMU) plays an important role for the classification accuracy. The summary of interpretation error consists of a chain of systematic, random and individual interpreter errors. The overall interpretation error is described more in detail in chapter 0.0.0

Quality assurance

In BIOPRESS no historical reference data for 1950 ties and limited ground truth for 1990 and 2000 were available. Therefore the interpretation of systematically chosen samples has been repeated by independent interpreters for verification. Window interpretations were checked by a most change related sampling strategy. Another opportunity for verification was the interaction with local experts or comparison with other auxiliary data (like for example biotope maps) that every partner implemented in the interpretation process. Quality assurance showed the applicability of the used methodology for historical photographs for the windows and transects at least for CLC level 2. CLC level 3 show only slight increase of changes in windows compared to CLC level 2. For transects most inconsistency were found in CLC level 3 as result of insufficient image quality and confusions of used land cover definitions.

Calculation of land cover changes

Land cover changes between two time periods can be calculated by intersecting two independent interpretations in a GIS system. As both interpretations can biased by specific interpretation errors, derived changes are biased too. The interacting of interpretation error between two interpretations is described in report D15_16 in detail.

Stratification

Stratification focuses on grouping elements to minimise variation of a certain variable of interest within these groups (strata) and maximising between groups. For the variable of interest the sampling error can be calculated by weight (for example area) of individual strata. The ratio of sampling error with stratification and sampling error without stratification is called the stratification gain. General stratification schemata like biogeographical regions reduced the variation and also the sampling error, but for each landscape element specific optimal stratification schemata can be defined.

Extrapolation

The aim of extrapolation is to upscale results from samples to regional or pan-European level. The error depends on the binding between variables, here land cover characteristic in test sites and pan-Europe, and the quality of sample selection (see chapter 0.0.0). Analysis of similarity between land cover structures of the samples and European land cover characteristics illustrates the quality of sampling as demonstrated in work package 3200. However, it is questionable if landscape structure is sufficient for change prediction and therefore it would be dangerous to apply for results of this product.

Determination

For a better understanding of land cover changes and driving forces for changes, socio economic data were collected for each transect and analysed by geo-statistical models and the semi-quantitative pressure state model MIRABEL. Highly generalised models on pan-European level can result in misinterpretation of regional situation and pressures. Main reasons are on the one hand very specific local developments and on the other hand too general socio-economic data which are based on larger spatial level than transect interpretation.

Error Model

There are different sources of errors in the interpretation process. These errors depend on each other in complex manner. Some errors within the process chain, especially if they have random nature, can compensate each other, so the output seems correct. Error sources, which occur at an early stage of process chain, for example image quality, can have major effect than errors occurring in the end of the process chain.

Figure 3.19 illustrates the developed error model for land cover interpretation for one time period. The simplest form of an error model would have been one equation, which depends from all possible error sources and circumstances that may lead to misinterpretation. For a better understanding of error propagation individual errors with specific impacting variables have been separated. The overall error E is the proportion of wrong interpreted area Ac and the total interpreted area A. The proportion of incorrect interpreted area is calculated, depending on the size or fragmentation of polygons e(size) and the interpreter's expertise e(interpreter). The quality of interpretation depends on the image quality, site characteristics like topography and the precise, well-defined interpretation methodology. The process of interpretation relays on these influences and it is one major error source as it tries to generalise pixel elements with a coherent attributes like trees, houses and other objects to land cover classes. Due to the class dependency of this developed general error model, it can be used to quantify the impact of each error and increase the interpretation accuracy by this information for a number of selected validated samples. It could be implemented, together with geo-statistic methods into a classification supporting program that reflects empiric results from the verification and error quantification. Use of digital ortho-rectified images from satellite or new airborne photo cameras support such a cost efficient automated system. The project BIOPRESS could provide the theoretic background, however it did not aim on a realisation of such a system.

This developed error model depends on different options of impact sources. Limitations were for example the used interpretation methodology, as it was demonstrated in work package 2400. Particularly the use of ambiguous classes for forest and agricultural classes cause this result, which was due to a combination of insufficient image quality and uncertainties in the class definition.

$$e_{(\text{imagequality})} = \underbrace{f(c, e_d, s, t)} \qquad e_{(\text{topogaphy})} = \underbrace{f(c, e_d, \text{inc}, \exp)}$$

$$e_{(\text{processing})} = \underbrace{f(e_{(\text{image quality})}, e_{(\text{topograpy})})}$$

$$e_{(\text{confusion})} = \underbrace{f(c, c_o, dc_o)}$$

transition from raster to polygon

$$e_{(\text{size})} = \underbrace{f(a_i, fr)} \qquad e_{(\text{interpreter})} = \underbrace{f(c, e_{(\text{processing})}, e_{(\text{confusion})}, xp)}$$

$$A_c = \sum_{i=1}^{m} a_i e_{(\text{size})} e_{(\text{interpreter})}$$

$$E = \frac{A_c}{A} \qquad A = \sum_{i=1}^{m} a_i$$

c = land cover class
e_d = error distance from nadir (image centre)
s = contrast, brightness, and proportion of any kind of artefacts, for example clouds
t = time of day and season

fr = degree of fragmentation of delineated object
xp= Experiences and local knowledge of interpreter
A_c= sum of area of incorrect classified polygons

inc= inclination
exp = exposition object towards sensor
c_o= neighbourhood land cover class o next to c

dc_o = distance to neighbourhood land cover class o next to c
a_i = area of polygon I
A= total area

Figure 3.19 Error model for estimation of total classification error E (%) for one interpretation

SELECTION ERROR

As described in chapter 0.0.0 the selection of test sites was biased in consideration the use of pre-selected Natura2000 sites, by local expert knowledge to include pressure impact and by focusing on project partner countries. To determine the accuracy of sampling strategy a bootstrapping approach was executed using the functionality of ArcInfo and MySQL. A defined set of square samples which simulate windows with 30km edge length were randomly selected across Europe. The land cover characteristics of these samples were calculated by intersecting of samples with the pan-European CLC90 vector data set. Figure 3.20 shows the results of the bootstrapping analysis. The figure indicates the relation between sampling error of specific land cover class proportion and number of samples. The mean sampling error of proportion of artificial surface is around twice the error of forest and semi-natural surface, or agricultural surface. At least 300 samples should be selected and classified to achieve a stable sampling error concerning land cover classes. Additionally the test site locations in BIOPRESS were constricted by data availability and data quality.

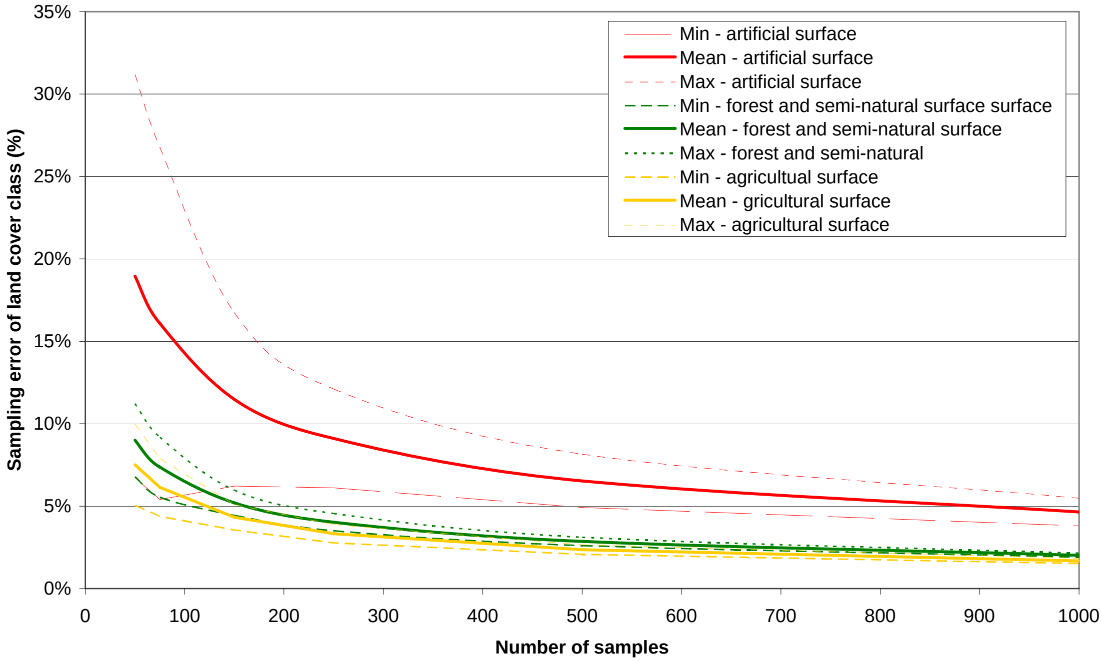


Figure 3.20 Estimation of sampling error using a bootstrapping approach, The solid line indicates the mean and the discontinuous lines show the minimum and maximum of sampling error per land cover class (probability value = 0.05). Red = artificial surface, Yellow = agricultural surface, Green = forest and semi-natural surface.

Scale Dependency Of Interpretation Methodology

Table 3.8 shows the land cover changes in the intersecting parts of transects and windows. Higher CLC level results in higher proportion of land cover changes within both transects and windows. The different proportions of changes at transect and window level indicate the differences between the interpretation scales. The minor consistency between the locations of land cover changes observed in both interpretation levels (transects and windows) increases with more detailed CLC level. In contrast, the consistency between location and class of land cover changes decreases with higher CLC level.

The interpretation scale should be adapted to the needs of user. Therefore the aim of study has to define the detail of interpretation. For example, classification of small habitats which could not be exactly determined is not meaningful at scale 1:100.000.

Table 3.8 Mean proportion of land cover changes occurred in transect and windows

	Level1	Level2	Level3
Transects changes	15,5%	32,0%	37,1%
Windows changes	6,9%	11,3%	11,5%
Consistency in change location	5,0%	7,9%	8,5%
Consistency in changes location and classes	3,5%	2,5%	1,7%

IMPRECISE DEFINITION OF LAND COVER AND LAND USE

The CORINE nomenclature has been developed to face pan-European characteristics, technical aspects of used data source and needs of potential users like environmental protection agencies or landscape planers. Thus the final nomenclature was a compromise including pure land cover classes like water bodies and land use classes like for example annual crops associated with permanent crops. These combined classes differ in their characteristics across Europe and specific structures are associated with them. Because of this complexity the interpreter knowledge of structure and local conditions needs to be high. To understand sources of errors due to different definitions and imprecise definitions of land cover and land cover change the producer's accuracy of different land cover classes are calculated. Table 3.9 shows the result of this analysis for all transects at CLC level 2.

Table 3.9 Producer's accuracy of CLC level 2 classes for three different time horizons in all 59 transects

	producer's accuracy		
CLC	**LC50**	**LC90**	**LC00**
11	0,75	0,81	0,80
12	0,56	0,72	0,73
13	0,42	0,54	0,43
14	0,35	0,41	0,45
21	0,84	0,84	0,85
22	0,50	0,47	0,43
23	0,55	0,55	0,54
24	0,24	0,17	0,18
31	0,90	0,90	0,91
32	0,78	0,80	0,79
33	0,59	0,59	0,60
41	0,68	0,69	0,68
42	0,56	0,72	0,77
51	0,85	0,87	0,85
52	0,80	0,84	0,83

By reducing the CLC level, which is equivalent to reducing the interpretation detail depth and therefore reducing potential misinterpretation by further general class descriptions, the accuracy increases. Some classes like for example 21 have higher consistency than other like 12. This may be caused by the low number of samples for verification, missing interpreter knowledge or unclear methodology for application on aerial photographs. The uses of ambiguous classes on dominant land cover classes, for example 316 for forests, lead to uncertainties in CLC level 3.

For a stable investigation of errors due to imprecise definition of land cover and land use classes a specific verification methodology would be needed BIOPRESS were not designed for. Different site land cover compositions across Europe, different quality of aerial photographs and very different interpreter experiences resulted in misinterpretations within this project. One methodological approach for estimation of these uncertainties could be the interpretation of a set of equal sized land cover samples that should be analysed by different interpreters for more land cover and land use driven methods to quantify the results in detail.

CONCLUSION

Each step of the production chain has been described and analysed towards potential error sources to model the propagation of errors from the test site selection through all its stages to the pan-European maps of land cover changes. An error model was developed and the potentials for limitation of errors were discussed. The selection error is calculated by use of bootstrapping approach and examples on the relation between sampling error and number of samples for selected land cover classes are presented. Supported by quality assurance results from work package 2400 and experiences from image interpretation hypotheses for potential limitations in land cover interpretation were derived. Therefore distribution of potential error sources in Europe could be plotted on pan-European maps, by use of auxiliary data. The following conclusions can be drawn from the analyses:

- Errors that occur in early stages of production chain and can not be cleared by the user propagate to the next production step.
- Comparison of window and transect approach demonstrated differences as result of different interpretation scale. Transects showed three times more changes than windows and consistency in change detection is low between transects and windows.
- Aerial photographs show much more structures and differences than being assessed by the applied methodology with CORINE nomenclature, but image quality and expertise of interpreter are major limiting factors.
- Use of historical aerial photographs with insufficient quality was the main limiting factor, followed by weaknesses of the land cover definitions. High variability of different interpretations in level three for the same sites demonstrates the need for enhancement of interpretation methodology.
- Diversity in terms of land cover proportion in Europe is very high and generalisation may lead to bias or under-estimation of changes. One general optimal sampling strategy on pan-European level for all kind of pressures on biodiversity is impossible.
- Various disturbances in used data sources like geometric uncertainties between CLC 1990 and CLC 2000 and too generalized information like missing location of habitats inside of NATURA2000 sites lead to errors in quantitative and qualitative analysis (see report D50-53).

In BIOPRESS a method for quantification of land cover changes has been developed and applied to various samples. Most errors, that reduced the interpretation quality like image quality, unclear class definition and confusion caused by lax use of land cover and land use, can be almost completely reduced by modern data sources and after adjustment of interpretation methodology. However, knowledge and experience of the interpreter play an important role in manual visual interpretation of remotely sensed data.

3.2.6 DATA SEARCH AND DATA ACCESS (WP1000)

The objectives of ‘Data Search and Data Access’ were:

- To identify existing European datasets related to land cover, land use, Natura 2000 and the 6 pressures (intensification, abandonment, afforestation, deforestation, urbanisationand drainage) acting on the environment.
- To streamline and coordinate access to these datasets by developing and implementing an in-house meta-database.
- To coordinate access to the metadata of aerial photos being acquired during Phase-I.

The methodological approach followed was in line with the three objectives stated above:

- identification of datasets,
- organising access to these datasets and
- organising access to metadata of national datasets.

At first, a large number European datasets that were potentially relevant in the framework of BIOPRESS were identified and priorities were indicated. Fifty datasets were identified of which fifteen were actually been ordered and obtained. European datasets are available at a multitude of different organisations, companies and institutions. Each of those has a different policy for licensing, data use restrictions, etc. making it a long task to obtain the relevant datasets. The most relevant datasets could be obtained from the following organisations: GISCO, Eurogeographics, EEA – European Environment Agency, EC DG Environment, EC JRC, Alterra.

When summarising the problems encountered during the process of searching for data access, it became clear that the European data policy is not straightforward, varies from project to project, from

DG to DG and changes over time. Moreover data requests are lengthy and updates tend to take a long time to become available via the official channels.

One of the datasets being crucial to the BIOPRESS project was the European Natura 2000 boundaries. Despite important efforts, it appeared impossible to obtain the dataset.

Table 3.10 gives an overview of the data sets that were available to the BIOPRESS consortium, including a metadata quality rating. The quality of the metadata was rather variable and depends strongly on the source of the data.

Table 3.10 Overview of the data sets that are currently available to the BIOPRESS consortium.

Data set #	Dataset name	Source	Rating	Comments
22	Environmental Classification of Europe	Alterra, Netherlands	*	
31	Biome Classification	Vito, Belgium	*	
42	Biogeographical Regions Map of Europe	EEA	**	
23	Pan-European Land Cover Monitoring (PELCOM)	Alterra, Netherlands	**	
36	Digital Map of European Ecological Regions (DMEER)	EEA	*	
10	CLC90 European 250 m Grid	EEA	***	
10	CLC90 European 100 m Grid	EEA	***	
3	CLC90 European Vector dataset	EEA	***	
33	Nationally designated areas	EEA	*	
5+24	SABE Commune boundaries (1991, scale 1/1.000.000), and population figures (1981,1991)	EuroGeographics	****	Metadata extracted from GISCO metadatabase
5+24	SABE Communes (1991, point objects), and population figures (1981,1991)	EuroGeographics	****	Metadata extracted from GISCO metadatabase
5+24	SABE Commune boundaries (1991, scale 1/100.000), and population figures (1981,1991)	EuroGeographics	****	Metadata extracted from GISCO metadatabase
45	Modelled light emissions for EU	Imperial College, London	*	
41	CORINE biotopes	EEA	**	
46	NewCronos	Eurostat	*	Further investigation required in order to extract relevant themes.
47	Europe Level 1 Provinces	ESRI	****	
48	Europe Level 2 Provinces	ESRI	****	

Metadata rating :
* no metadata sheet available; metadata extracted from other sources (reports, flyers, …)
** metadata sheet available, dataset poorly documented
*** metadata sheet available, fairly well documented dataset – no standardized metadata
**** metadata sheet available, well documented dataset using standardized metadata

Once the datasets were identified and obtained, they needed to be made available to the other consortium partners. To this purpose, the metadata were made available via a searchable online metadatabase. For most datasets, the metadatabase also allowed online downloading of the data set itself. The metadatabase uses ArcGIS functionality for storing data, describing datasets using metadata and publishing metadata. This allowed us to describe the data sets in a uniform way using a dedicated tool and to make both metadata and data easily available to the BIOPRESS partners.

The BIOPRESS metadatabase was created in ArcGIS through the ArcCatalog application and was published to a ArcIMS metadata service. It could be explored either by using ArcCatalog or by using the Metadata Explorer via an Internet browser.

ArcIMS Metadata Services were made up of the ArcIMS Spatial Server combined with data residing in a relational database. The data in this database is accessed using ArcSDE, which is required to use ArcIMS Metadata Services.

Searching for metadata through the Metadata Explorer is quick and efficient because users can perform searches based on any combination of geographic extent, content type, data format, or keyword. When a search is initiated, the ArcIMS Metadata Server accesses the data using ArcSDE and returns the results of the search in an easy-to-read format.

The two metadata standards that were most commonly used for metadata of geospatial data are the following:

- FGDC (Federal Geographic Data Committee) Metadata Standard (FGDC-STD-001-1998) (http://www.fgdc.gov/metadata)
- ISO Technical Committee (TC)211 Metadata Standard 19115 (previously known as 15046-15) (http://www.isotc211.org/)

The FGDC is more commonly used in the US whereas ISO is adopted more frequently in Europe. Currently some initiatives are ongoing in order to harmonise both standards (http://www.fgdc.gov/metadata/whatsnew/fgdciso.html).

Due to technical characteristics of the ArcGIS software, the FGDC standard was adopted for describing the datasets available within the BIOPRESS project.

The framework and technical solution that was put in place for organising access to the European datasets was equally applicable to the third objective, namely organising access to the national datasets via their metadata. In the case of national datasets such as aerial photos, each partner established contact with the relevant national organisation to obtain the necessary datasets. The digital data were stored decentralised by the partners but they could be fully described with their metadata using ArcGIS and the ArcIMS metadata service.

Chapter 4 CONCLUSIONS INCLUDING SOCIO-ECONOMIC RELEVANCE, STRATEGIC ASPECTS AND POLICY IMPLICATIONS

BIOPRESS was one of the first wave of thematic projects which were funded through the GMES initiative. As a result its main objective was to produce information at European level which in the case of BIOPRESS was information on historical land cover change for the purpose of assessing past pressures on habitats and their associated biodiversity. A large part of the project's resources were used to deliver the land cover change database successfully and the outcome has not only been the delivery of data but also a set of tools for future European wide land cover monitoring (two interpretation manuals and a quality assurance method) and a position paper outlining a sampling framework and strategy for future monitoring of European habitats.

Because the focus was on biodiversity and historical land cover changes, it was clear from the start that Europe had to be sampled. Bias was introduced in the BIOPRESS samples by (1) relying on an expert to select a superset of samples including Natura 200 sites and (2) the availability of aerial photography. The project's resources limited the total number of samples acquired. The work, that was involved in determining the representativity of the samples with respect to the European landscape, lead to a better understanding of the variability of Europe in terms of its land cover composition.

The real challenge was when trying to establish a link between land cover change and pressures on biodiversity. The development of the land cover change - pressure association matrix as a first step enabled the grouping of types of land cover changes related to one of the six pressures under consideration in BIOPRESS: Urbanisation, intensification, afforestation, deforestation, abandonment and drainage. This matrix has the potential to enhance the similar 'Land Cover Flow' matrix developed by the EEA as part of the EEA Land Accounting System. In theory the idea of integrating socio-economic data with land cover change data made sense but in practice the team struggled with the wide variety of data types, spatial and temporal resolutions.

To assess the consequences of the observed LCC on biodiversity, namely on the impact of changes in the extent and spatial distribution of habitats, BIOPRESS impact tables were developed using the same conceptual approach as that establish for the DPSIR assessment MIRABEL. The overall agreement between MIRABEL and the BIOPRESS tables, which unlike MIRABLE provided quantitative estimates for a selected sample of land in each region, was an important result. This part of the work concluded that a land cover change product such as that produced by BIOPRESS was suitable for quantifying some pressures on biodiversity but quite insufficient for the interpretation of land cover change related to other pressures.

The error propagation, quality assessment and data search exercises highlighted the importance of the availability of good quality, affordable data (e.g. aerial photography, digital elevation data, social and economic indicators) which for long term monitoring should be continuously collected in a consistent manner.

BIOPRESS aimed at generating a representative sample of land cover change products from 1950-2000, which is indicative of states and trends in biodiversity in the selected nature protection sites. The project has therefore supported the needs of DG-Environment and EEA in helping to implement and assess European policy on nature and biodiversity and contribute to the objective of enhancing the quality of the environment by helping to understand pressures on biodiversity arising from land cover change in the member states and accession countries.

The state of the environment is perceived as an important indicator of a high quality of life by a majority of European citizens. The European public increasingly expresses the wish to be informed by policy on the perceived threats to biodiversity. BIOPRESS supported the development of a European capacity for monitoring the state of the environment to meet these information needs.

The conservation of biological diversity provided by nature protection sites is increasingly seen as the provision of a service by the land managers. Land management practices in these sites have a direct impact on land cover and land cover change, and will determine the state of the environment in these sites. This is critical for the state of the environment as a whole, because of the high significance of the nature protection sites (e.g. NATURA 2000) for the state of biodiversity in Europe.The recognition of land management practices aiming at provision of a certain land cover type as a service is a major step towards a sustainable agricultural development. Various schemes to encourage the conservation of biological diversity through economic stimulation of farmers and land managers already exist on national and European scales. The economic importance of maintaining landscapes lies in their value for tourism, recreation, and the conservation of biological and genetic resources. BIOPRESS is expected to facilitate these economic developments by

- delivering a unique historic analysis of how land cover changes act as pressures on biological diversity across Europe in very different environments;
- developing a sampling scheme for representative nature protection sites across Europe usable for future monitoring and environmental reporting;
- contributing to the harmonization of monitoring methods in different countries and climatic zones in Europe for detecting land cover change and assessing its impacts on nature;
- contributing to the establishment of a European capability for monitoring the state of the environment using satellite and airborne remote sensing, the emerging European spatial data infrastructure, existing data sources and environmental indicators;
- empowering the European Environment Agency to report on the impacts of land cover change on biodiversity in the 2005 report "State of the environment".

The skills base in the participating organisations in information technology, data integration, conservation and biodiversity were increased through multi-disciplinary and trans-boundary collaboration. This is expected to have spin-off effects on the technical skills present in Europe's regions, and enhance Europe's competitiveness globally by pooling experts from different disciplines concerned with environmental monitoring. In the less economically favoured countries the project has improved employment opportunities by enhancing the information technology skills and bringing experts from accession countries together with experts from EU member states. The consortium was lead by a young female scientist and about 1/3 of the people involved in BIOPRESS were female, two of which were given work package leadership. In all cases BIOPRESS is expected to have had a positive impact on these people's careers ranging from promotion to better changes for future employment. The project also provided training and supervision by taking on two undergraduate interships and one PhD student.

Chapter 5 DISSEMINATION AND EXPLOITATION OF THE RESULTS

5.1 GMES RELATED ACTIVITIES (WP5000)

The specific objective of WP5000 was to collect feedback from partners regarding problems (technical, scientific, all aspects of data accessibility, data quality, organisational, legal and institutional hurdles) encountered at each stage of the development and production process

The experiences of the BIOPRESS team were communicated to the cross-cutting-assessment teams DPAG and BICEPS by the following means:

- Participation of the project coordinator in meetings of the GMES forum and submission of results in the form of posters and presented papers.
- Participation of the project coordinator in meetings of the GMES Project Leaders Group, notably that following the 3rd GMES Forum in Athens.
- Formal written responses to structured requests for information and opinion from Cross-cutting Assessments.
- Reaction to final reports to Cross-cutting Assessments.

During the final year of the project further input in the GMES process was provided:

- Written comments were given on the GMES fast track services proposed for land cover.
- A presentation was given at a UK GMES workshop organised by the UK - Department for the Environment, Food and Rural Affairs.
- The coordinator gave a presentation as an invited speaker at GMES funded project GEOLAND in February 2006.
- A position paper was produced as a collaboration result between BIOPRESS and BIOHAB: Sampling framework and strategy for monitoring of European habitats. Position paper of BIOHAB & BIOPRESS research community. Version 2 (13th of December 2005). Principal contributors to this version: BIOHAB: Bob Bunce, Rob Jongman, Sander Mücher, Marta Pérez-Soba & Geert de Blust. BIOPRESS: Konstantin Olschofsky (Univ Hamburg), Sander Mücher (Alterra), Raul Köhler (Univ Hamburg), Mirko Gregor (GIM), Richard Wadsworth (CEH) and Sandra Luque (METLA). This paper has been and will be actively advertised by the BIOPRESS coordinator and partners.

5.2 GENERAL DISSEMINATION ACTIVITIES (WP6000)

The BIOPRESS web page is operational at http://www.creaf.uab.es/biopress/ and further improved during the lifetime of the project. A reduced version of the BIOPRESS database was linked to the webpage.

A project leaflet was produced.

BIOPRESS was successful in acquiring an exhibition space at the Communicating European Research 2005 event which took place in Brussels on 14-15 November 2005. A flash movie was produced as the main attraction of the BIOPRESS stand which was manned throughout the exhibition by at least 2 BIOPRESS staff. There were BIOPRESS bookmarks and pens to give away. The BIOPRESS stand attracted a good number of people from a wide range of backgrounds.

The afternoon session of the final workshop in the premises of the Royal Museum for Central African in Tervuren (Brussels) on the 14 December 2005 presented the key findings to international and national stakeholders.

A BIOPRESS book was compiled containing the results of the transect interpretations. It is entitled “Land cover change in Europe from the 1950’ies to 2000. Aerial photo interpretation and derived statistics from 59 samples distributed across Europe” and about 400 prints will be produced and distributed free of charge. The team decided to substitute the CD by the Book and a BIOPRESS summary report adapted from Section 6 of the final report. The BIOPRESS summary report will be the responsibility of CEH, BIOPRESS coordinator and will be produced as a pdf file as part of the dissemination activities which will continue after February 2006 (Technology Implementation Plan).

Presentations were given at targeted workshops and conferences (see list below).

Although the EEA will still become the steward of the BIOPRESS data after the completion of the project, the team also decided to have copies of the database and electronic copies of the original photo mosaics with all partners.

5.2.1 PRESENTATIONS

- Presentation at the BioHab (FPV concerted action) workshop held in Lisbon in February'03. BIOPRESS is one of BioHab's stakeholders.
- Dr Julius Oszlanyi participated at the Scientific Committee meeting of the European Environment Agency in Copenhagen on 4-5 March 2003 where he delivered on 5th FP projects of ILE SAS. The project BIOPRESS was described and commented.
- Presentations to the Natura2000 Scientific Committee in May 2003
- Presentation of preliminary outputs of BIOPRESS project at the third GMES Forum held in Athens (June'03).
- Invited presentation to the Irish national GMES committee in Dublin in October 2003
- Poster presentation at the final GMES Forum in Baveno (Italy) in November, 2003
- Oral presentation given by Geoff Smith (CEH) at the Macaulay workshop - RSPSoc 2004, Aberdeen, 6-7 September 2004.
- Poster presentation by Geoff Smith (CEH) at RSPSoc 2004, Aberdeen, 7-10 September 2004.
- Attendance by TU_Dresden team at BIOMETRIC- Conference in Munich in October 2004.
- Oral presentation at LUCC conference "Integrated assessment of the land system:The future of land use" from 28-30 October 2004 at Institute for Environmental Studies in Amsterdam (http://www.geo.ucl.ac.be/LUCC/lucc.html): Wachowicz, M. and C.A. Mücher, 2005. Space-Time Modelling for the Explanation of Convergence patterns. Proceedings LUCC Conference, 28-30 October 2004, Institute for Environmental Studies, Amsterdam. In press.
- Poster presentation was given by Sandra Luque (Metla) at the PEER conference in Helsinki, 17 – 18 November, 2004.
- Poster presentation at the EPBRS Conference "Biodiversity research that matters! from December 10-13, 2004 in Amsterdam (http://www.netherlands.biodiv-chm.org/epbrs/).
- Sandra Luque (METLA) presented as an invited speaker at the International Conference on Biodiversity, Science and Governance. Paris, UNESCO, 24-28 January 2005. WORKSHOP 12: Biodiversity Indicators and the 2010 target: Scientific challenges in meeting and assessing progress towards the 2010 biodiversity targets and related goals – Round-Table. Indicators of sustainable development (panelist John Hutton, IUCN, T. Schaaff, Unesco, FAO, the CBD Global Strategy for Plant Conservation, B. Dias, Brazil, and S. Luque, Cemagref).
- Sandra Luque (METLA) presented as an invited speaker at the AlterNet (A Long-term Biodiversity, Ecosystem and Awareness Research Network - FPVI) workshop: Impacts of the main anthropogenic and natural drivers and pressures on biodiversity (Lead: Stefan Klotz & Lars Lundin). Presentation: Indicators to monitor changes and conservation in Natura 2000 sites: a focus on drivers, pressures and states. Hamburg, Germany. 17-18 February 2005.
- BIOPRESS presentation by Sander Mücher (ALTERRA) on the 14th of April 2005 for the expert meeting Ecosystems & landscapes at the Centre for Geo-Information, Alterra, Wageningen.
- BIOPRESS presentation by Sander Mücher (ALTERRA) on the 23rd of May 2005 for a high delegation of Chinese directors within the EU-China Environmental Management Cooperation Programme Study Tour. Visit Wageningen University and Research Centre on the May 23rd, 2005.
- Sandra Luque (METLA) participated at the AlterNet joint workshop between Work Packages I3 (establishing a network of LTER sites), R3 (drivers and pressures on biodiversity) and R6 (forecasting of biodiversity). Madrid 6-9 June 2005. Presentation: Aims and methods in analyzing

available studies of the impact of drivers and pressures on biodiversity (Stefan Klotz, Sandra Luque, Jutta Stadler).

- Presentation by Gerard Hazeu at the International Cartographic Congress, 9-16 July 2005, La Coruña, Spain. Title of the presentation was: “ Monitoring land cover changes in and around Natura2000 sites”.(Alterra).
- Presentation by Konstantin Olschofsky of extrapolation work at the PEER conference. (Univ. Hamburg)
- Presentation by Konstatin Olschofsky of BIOPRESS results to national experts (BONN/ Dresden). (Univ Hamburg) IALE Workshop “Current Trends in Landscape Ecology”Presented by IALE officers,
- Presentation by S.Luque Invited Speaker as IALE Vice-President: "Quantifying pressures on biodiversity to Understand Spatial Patterns". Center for Environmental management (CEM), School of Geography, University of Nottingham, UK.
- Presentation by S. Luque, H. Huitu and S. Petit. Quantifying pressures on biodiversity to Understand Spatial Patterns: A temporal and Spatial approach. (Présentation oral) Conférence IALE France. Patrons et processus, Quels acquis pour l’Ecologie du Paysage ? Quelles orientations futures ? 16-18 novembre, 2005. Marseille, France.
- Presentation by S. Luque and H. Huitu. Can the quantification of pressures on biodiversity help to understand spatial patterns? (Oral presentation) Session: Understanding Biodiversity. The 6th Open Meeting of the Human Dimension of Global Environmental Change Research Community (IHDP), University of Bonn, Germany 9-13, October 2005.
- Presentation by Sandra Luque as Invited speaker, AlterNet (A Long-term Biodiversity, Ecosystem and Awareness Research Network - FPVI) workshop: Impacts of the main anthropogenic and natural drivers and pressures on biodiversity (Lead: Stefan Klotz & Lars Lundin). Presentation: Indicators to monitor changes and conservation in Natura 2000 sites: a focus on drivers, pressures and states. Hamburg, Germany. February 17-18.

5.2.2 MEETINGS

- BIOFORUM - ILESAS is involved in this 5th Framework Programme project and participated in meeting in Sofia (BG) in September 2004
- GMES – possibilities for co-operation. ILESAS had a meeting with Polish Space Office. Zvolen, Slovakia, 15.10.2004. Presentation of the BIOPRESS project in meeting
- BioHab -ILESAS is partners in this 5th Framework Programme project and attended the workshop in Wageningen (The Netherlands) in November 2004
- BioScene – ILESAS is partners in this 5th Framework Programme project and attended the workshop in Zurich (Switzerland) in January 2005.
- ILESAS attended an EEA meeting on Land and Ecosystem accounting, Copenhagen 15-16 March 2005, information about Biopress was presented
- BioHab - ILESAS is partners in this 5th Framework Programme project and attended the workshop in Faro (Portugal) in March-April 2005
- Expert meeting on multi-scales mapping and integrated analysis of landscape & green corridors, 26-27 May 2005, EEA Copenhagen. Sander Mucher participated as a representative of the BIOPRESS project.
- ALTER-net – ILESAS is partner in this 6th Framework Programme Network of Excellence and attended several workshops for respective research activities during reported period
- PEER Seminar “Geo-Information Pillar”, 15-16 November 2005, Montpellier, France. Poster presentation BIOPRESS. (Alterra).
- BioHab - ILESAS is partners in this 5th Framework Programme project and attended the final workshop in Brussels (Belgium) in November 2005 (ILESAS).
- ALTER-net – ILESAS is partner in this 6th Framework Programme Network of Excellence and attended several workshops for respective research activities during reported period (ILESAS).

- BioScene – ILESAS is partners in this 5th Framework Programme project and attended the International conference"Biodiversity conservation and sustainable development in mountain areas of Europe" (Ioannina, Greece) in September 2005 (ILESAS).
- EEA EIONET meeting,, Copenhagen is planned for 1-2 March 2006: presentation of BIOPRESS results has been requested and will be prepared (ILESAS).

5.2.3 COOPERATION WITH OTHER RELEVANT INSTITUTIONS AND (EU) PROJECTS

- ALTER-net – ILESAS is partner in this 6th Framework Programme Network of Excellence and attended several workshops for respective research activities during reported period – Sandra Luque, represented BIOPRESS at several of these Alternet workshop.
- Monica Wachowicz (ALTERRA) has initiated a co-operation with Prof. Willem Bouten, the University of Amsterdam, Institute for Biodiversity and Ecosystems Dynamics (IBED) through the supervision of a PHD student. The aim is to design and implement new spatial data mining algorithms that assist the researcher in discovering hidden patterns in large environmental data sets. The BIOPRESS data will be used to test the algorithms.
- Monica Wachowicz (ALTERRA) is organising with Sylvain Labbe (CEMAGREF, FRANCE) the PEER Workshop on Geo-Information Pillar. PEER is the network on Partnership for European Environmental Research, which is interested in building a research agenda in geo-information for environmental issues inside the PEER geo-information pillar. The workshop will be held in Montpellier in November'05, where Sander Mucher (ALTERRA) and Sandra Luque (METLA,) will organise a session on Linking Land Cover to Ecosystem Modelling, which is an opportunity to discuss further the results coming out of the BIOPRESS Project.
- Sandra Luque (METLA) spend considerable time building up important links for the project in relation to EU resources PEER & AlterNET.
- For the work undertaken under WP 4300, Sandra Luque (METLA) is interacting with the socio-economic team of SENSOR - Sustainability Impact Assessment: Tools for Environmental, Social and Economic Effects of Multifunctional Land Use in European Regions - EU FP6 Integrated Project Synergy.
- A grant was obtained during the previous reporting period from AlterNet to link work between BIOPRESS and the EU funded network of excellence AlterNET: 2005-2006 "Indicators to monitor changes and conservation in Natura 2000 sites: A focus on Drivers, Pressures and States." ALTER-Net (A Long-term Biodiversity, Ecosystem and Awareness Research Network - FPVI) Internal funded project – Participants Institutions: Cemagref, ILESas, CEH, Alterra (coordinator: Sandra Luque, Cemagref). Euros 50. The work started in this reporting period and will continue after the conclusion of BIOPRESS.
- PEER (Partnership for European Environmental Research) initiative – from the side of Cemagref: Seminar. Global Earth Observation and Environmental Monitoring: The role of geoinformation. Sander Mucher (ALTERRA) Sandra Luque (Cemagref) session co-ordinator & rapporteur: "Biodiversity and ecosystem modelling". Montpellier, FRANCE.
- AlterNet – from the side of Cemagref: Participation on AlterNet joint workshop between Work Packages I3 (establishing a network of LTER sites), R3 (drivers and pressures on biodiversity) and R6 (forecasting of biodiversity). Klotz S., Luque S., Stadler J. Aims and methods in analyzing available studies of the impact of drivers and pressures on biodiversity (Oral Presentation): Madrid 6-9 June, 2005.

Chapter 6 MAIN LITERATURE PRODUCED

6.1 REFEREED JOURNALS

Clevers, J.G.P.W., M.E. Schaepman, C.A. Mücher, A.J.W. de Wit, R. Zurita Milla and H.M. Bartholomeus, 2005. Using MERIS on ENVISAT for Land Cover Mapping. IN: International Journal of Remote Sensing. Accepted.

Metzger, M.J., R.G.H. Bunce, R.H.G Jongman, C.A. Mücher and J.W. Watkins, 2005. A climatic stratification of the environment in Europe. In: Global Ecology and Biogeography. In print.

A.G. Thomson, S.J. Manchester, R.D. Swetnam, G.M. Smith, R.A. Wadsworth, F.F. Gerard. 2006. The use of digital aerial photography and CORINE-derived methodology for monitoring recent and historic changes in land cover near UK Natura 2000 sites for the BIOPRESS project. International Journal of Remote Sensing. Accepted.

Feranec, J., Hazeu, G.W., Christensen, S. & Jaffrain G., 2006 (accepted). CORINE Land Cover change detection in Europe (Case studies of the Netherlands and Slovakia). Land Use Policy.

Feranec, J., Cebecauer, T., Hazeu, G.W. & Jaffrain, G., 2006 (submitted). Cartographic aspects of land cover change detection (over- and underestimation in the I& CORINE Land Cover 2000 Project). The Cartographic Journal.

6.2 BOOK

Gerard et al. 2006. Land cover change in Europe from the 1950'ies to 2000. Aerial photo interpretation and derived statistics from 59 samples distributed across Europe. K. Olschofsky and R. Kohler (eds). Pp 364. (proof in Annex).

6.3 CONFERENCE PROCEEDINGS

Bugár, G., 2003: Evalaution of the land cover and biodiversity changes in Europe (BIOPRESS project) (in Slovak). - In: Novák, S. (ed.) 2003: Geographical aspects of the region of Central Europe (in Czech). Geografie XIV., Pedagogická fakulta MU Brno, Brno, p. 270-274., ISBN 80-210-3208-1

Bugár, G., Hreško, J, 2003: Land cover and biodiversity changes from the sustainability of natural resources point of view (in Slovak). – In: Izakovičová, Z. (ed.): Proceedings of the conference „Slovakia one year after Johannesburg". Bratislava, ILE SAS: 143-148

Hazeu.G.W., C.A. Mücher & M. Wachwicz, 2005. Monitoring land cover changes inside and outside Natura2000 sites. In: Proceedings (on CDROM)of the International Cartographic Congress, 9-16 July 2005, La Coruña, Spain.

Gerard, F., Brems E., Bugar G., Gregor M., Hazeu G., Janssens E., Kohler R., Kolar J., Luque S., Manchester S., Mucher S., Olschofsky K., Oszlanyi J., Petit S., Pino J., Pons X., Roscher M., Smith G., Sustera J., Thomson A., Tuominen S., Halada L., Hresko J., Wachowicz M., Wadsworth R., Wyatt B., Ziese H. 2004. BIOPRESS - Linking Pan-European Landcover Change to Pressures on Biodiversity. NERC Earth Observation Conference

Smith, G., Gerard, F., Brems E., Bugar G., Gregor M., Hazeu G., Janssens E., Kohler R., Kolar J., Luque S., Manchester S., Mucher S., Olschofsky K., Oszlanyi J., Petit S., Pino J., Pons X., Roscher M., Sustera J., Thomson A., Tuominen S., Halada L., Hresko J., Wachowicz M., Wadsworth R., Wyatt B., Ziese H. 2004. Deriving long term land cover change from aerial photography to assess pressures on biodiversity. Macaulay workshop - RSPSoc 2004

Luque, S., Gerard, F., Brems E., Bugar G., Gregor M., Hazeu G., Janssens E., Kohler R., Kolar J., Manchester S., Mucher S., Olschofsky K., Oszlanyi J., Petit S., Pino J., Pons X., Roscher M., Smith G., Sustera J., Thomson A., Tuominen S., Halada L., Hresko J., Wachowicz M., Wadsworth R., Wyatt B., Ziese H. 2004. 2004. Historical land cover change in and around Natura2000 sites for assessing and predicting impact on biodiversity. PEER Conference.

Luque S., Huitu H. Petit, S. 2005. Quantifying pressures on biodiversity to Understand Spatial Patterns: A temporal and Spatial approach. - Abstract in Proceedings - IALE France. November 16-18 Marseille, France.

Luque, S., Huitu, H. 2005. Can the quantification of pressures on biodiversity help to understand spatial patterns? Abstract in Proceedings. The 6th Open Meeting of the Human Dimension of Global Environmental Change Research Community, University of Bonn, Germany 9-13 October.

Gerard, F. M. Wachowicz, K. Olschofsky, G. Smith, S. Luque, E. Brems, G. Bugar, M. Gregor, G. Hazeu, Huitu, H E. Janssens, R. Kohler, J. Kolar, S. Manchester, S. Mucher, , J. Oszlanyi, S. Petit, J. Pino, X. Pons, M. Roscher, J. Sustera, A. Thomson, S. Tuominen, L. Halada, J. Hresko, R.Wadsworth, B. Wyatt, H. Ziese. 2005. Quantifying past pressures on biodiversity in Europe by combining socio economic indicators with land cover change data. Abstract in Proceedings. The 6th Open Meeting of the Human Dimension of Global Environmental Change Research Community, University of Bonn, Germany 9-13 October.

Oszlányi, J., Halada, Ľ., Hreško, J., Bugár, G., 2003: Linking pan-European land cover change to pressures on biodiversity. FP-V global monitoring for environment and security (GMES). – In: 13th International Symposium on Problems of Landscape Ecological Research, 30 September – 3 October, 2003 Mojmírovce

6.4 REPORTS

Wachowicz, M.and C.A. Mücher, 2005. Space-Time Modelling for the Explanation of Convergence patterns. In: Proceedings LUCC Conference, 28-30 October 2004, Institute for Environmental Studies, Amsterdam. Report number: W-05/04, p. 27-28, published on February 2005.

Hazeu, G.W. and C.A. Mücher, 2005. Historic land use dynamics in and around Natura2000 sites as indicators for impact on biodiversity. Phase I of the BIOPRESS project for the Netherlands. Alterra Report 1077, Wageningen, the Netherlands.

6.5 PLANNED LITERATURE

Bezák, P., Petrovič, F., Bugár, G., 2006: Assessment of the pressures on biodiversity based on land cover changes - a case study in Central Slovakia. – Planned for submission in 2006 to Ecology (Bratislava)

Bugár, G., Halada, Ľ., Bezák, P., Petrovič, 2006: Land cover changes 1949-2003 and pressures on the biodiversity in Slovakia. - In: 14th International Symposium on Problems of Landscape Ecological Research, 4.-7. October, 2006, Stará Lesná, Slovakia.

Gerard F. et al, Thousands of aerial photographs to determine Europe's land cover changes of the past 50 years, planned for submission in 2006 to Landscape and Urban Planning.

Smith, G.M. et al., An assessment of sampling schemes to monitoring land cover changes in Europe.

Wachowicz, et al. Discovery of spatial patterns of observed land cover changes at multiple levels of detail using association rules., planned for submission in 2006 to Journal of Environment Management.

Wachowicz, et al. Using spatio-temporal decision rules for the design of a multi-representation model. Planned for submission for the GI Science 2006 Conference.