# TRENDS

## of some **agri-environmental indicators** in the European Union

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# Contents

# Introduction

This publication "*Trends of some Agri-Environmental Indicators in the European Union*" is the fourth element of an informal series contributing to the collection of information for EU decision making and evaluation. It is particularly relevant at the moment when the Rural Development Policy has been evaluated and reshaped. In a context of environmental lobbying, sectorial pressure for trade-friendly income transfer to farmers and international negotiations, objective AE indicators are more than ever needed to describe the positive influence of agricultural practices on landscape, to quantify the pro- and con- effects of the agricultural activity on the environmental quality conservation and to monitor and assess the economical role of agriculture on the rural zones.

The work started in 2000 by re-addressing the problem from the classical land use analysis to a more innovative approach of landscape description (volume 1). This evolved into the question of agri-environmental indicators definition (volume 2) and computation (volume 3) integrating all available data sources (statistical surveys – FSS, LUCAS –, mapping – CORINE Land Cover – and administrative data – IACS). Temporal trends of agri-environmental indicators make up the core of this 2005 volume.



**Agri Environmental Indicators** are now well defined. Based on the Commission Communications (COM (2000) 20; COM(2001) 144), the IRENA operation clarified the concepts and data sources of 35 AE indicators:

- This publication deals mainly with the Land Use and Land Cover indicators (stocks and changes) derived from CLC2000, LUCAS, IFN forest inventory, and IACS.
- Additional indicators relating to cropping patterns, farm management and intensification/extensification are provided by the transect component of the LUCAS survey.
- Nitrate deposits from the EMEP network are reconstructed per administrative level.
- Economical indices are extracted from FSS and IACS data.

**Methods** which justify all our attention:

- Different indicators can cover the same topic and reveal different facets (Shannon or PAR indices, rural character in function of land use or population). The same indicators, applied on the same reference data, can even provide different values in function of the author's technical choices (Shannon Index).
- Bias to scale, methods and indirect flows require particular care.
- Photos and maps in the forest sector represent alternative sources of information. Images in general reduce the problem of results equivalence between image classification, photo interpretation and objective field measurements.
- Administrative data raises the problem of population definition, individual data protection and practical data access (and there is no guarantee of continuity of availability).

**Data sources** widely exist and their cross analysis widely applied:

- CORINE Land Cover remains one of the major sources and the progressive availability of the 2000 update allows trends calculation mainly for the indicators relating to Land Use or Land Cover linked amongst others with rural and agricultural landscapes. Cross comparison with NATURA 2000 sites allows further analysis of the effect of the protection measures.
- Farm Structure Survey represents the major source (with the FADN) of economical information on the agricultural sector. Its specific contribution to the agricultural intensity landscape trends is to be noted and could in addition contribute to the characterisation of the rural character of communes.
- LUCAS surveys, in addition to the land use and land cover data, provide a unique source of information on linear features. Its precise geographical referencing allows spatial heterogeneity analysis and its crossing with landscape maps leads to innovative fragmentation indicators. However, representation is not always guaranteed at regional level.
- IACS administrative data offer a potential huge contribution to AE indicators. The implementation of the digital GIS at MS level from 01.01.2005 allows the precise geographical location of all land-related Agro Environmental measures. Its use through the Farm Advisory System as a management and quality insurance tool at farm level represents a unique opportunity for data collection.

**Trends** quantification remains a major challenge, mainly due to the too limited time series:

- FSS is by far the richest data source when time series is the first criteria (certainly for census).
- CORINE Land Cover is now available for two dates (1990, 2000). The effort done to upgrade the initial 1990 work and to fully harmonise the inventory is of particular importance.
- LUCAS is now available for 2001 and 2003. The next survey is planned in 2006.
- The IACS-GIS data started only in 2005 at EU25 level
- Archive image data are available for long periods of time but their access and use implies high costs for geo-coding and photo-interpretation.

**Main quantitative Results** of this publication relates to:

- **Landscape trends:** calculated by landscape category, agricultural importance indices derived from 1990 and 2000 FFS surveys do not show significant change. To the contrary, the Agricultural intensity (including income data) presents real evolution in mountains (F) or Highlands (IE). Landscape fragmentation is particularly well described by LUCAS data (although the consideration regarding representation mentioned above should be kept in mind), going from a minimum index (3) in open land of Castilla Leon to a maximum value (14) in the Portuguese hill regions.
- **Land Use / Land Cover:** Diversity indices derived from the comparison of CLC2000 and CLC90 recorded more regions with increased indices. Even in case of decrease, detailed analysis shows that it can not always be considered as negative environmental evolution (replacement of arable land with pasture).
- **Linear elements**: LUCAS survey provides relevant information to characterise the internal division within agricultural land as well as their boundary transition with non agricultural uses/covers. Heterogeneity of landscape can be evaluated and varies from 20 to 100 metres of linear features per ha.
- **Rural character of communes:** two approaches or rural characterisation were tried based on CLC2000 and population densities. Computed at commune level, results are quite similar leading to rural areas of 89 and 86%. When aggregated

at NUTS3 level, results for predominantly rural areas can diverge and become respectively 76 and 40%.

- **Nitrogen deposits:** Restructured at NUTS 3 level, the EMEP 50 km grid data indicated an average decrease of 20% of Nitrogen deposit on agricultural land at EU level. Merged with the FSS survey, this data allows a nitrogen balance computation for policy reporting.
- **NATURA 2000 effectiveness:** when analysing the evolution between CLC 2000 and 90 separately for the NATURA 2000 sites and a whole country, a rather clear influence is observed. The initial low diversity in the NATURA 2000 sites is confirmed in time. On the contrary, their initial high fragmentation is reinforced.

## Trends in "Landscape State" based on farm structural characteristics and landscape heterogeneity

Paul Campling*, Ireen Librecht**, Koen Duchateau***
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The Meeus typology of landscapes is currently the only landscape baseline description at European level. There are seven broad landscape categories identified by Meeus on the basis of climatology, geomorphology, soils, ecology and occupational history. A case study approach is adopted to investigate the importance of agriculture in maintaining landscapes. The Farm Structure Survey (FSS) is used to derive farm structural indicators: Agricultural importance index, Land use importance, Agricultural intensity index. The Land Use/Cover Area Frame Statistical Survey (LUCAS) is used to derive indicators of landscape heterogeneity: Land Cover Transition Index and Fragmentation Index. Results show that there have not been significant changes in the selected agricultural landscape case studies between 1990 and 2000. Although changes are not detected the indicators do you show the diversity of landscapes across Europe. The indicators of landscape heterogeneity correspond with the perceived linear features and diversity of land cover associated with the selected agricultural landscape case studies, with the exception of Extremadura, where small walls have not been considered.



## Utilisation of CLC 90 & 2000 data for monitoring the impact of CAP developments on the rural landscape

E. Willems*, T. Lemmens**, B. Buffaria*
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This article analyses the impact on rural landscapes of the CAP reforms since the early nineties, based on a quantified comparison of CORINE Land Cover '90 and 2000. The comparison is based on three indices, namely a simple diversity index, the Shannon index and the perimeter/area ratio index, computed on a 3 × 3 km$^2$ grid cell. At first glance, for the available inventories, the comparison seems promising with a majority of regions having higher diversity in 2000 according to each of the three indices. To investigate the origin of diversity changes, a closer look is carried out to 2 regions, one with a significant high increase of diversity and another with a significant decrease.

### Land use and land cover trends in the Netherlands and Ireland based on CORINE Land Cover

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There are two land use and land cover indicators listed in the COM (2001) 144: "Land use: (topological) change" and "Land cover change", which are Driving Force and State indicators, respectively. Land use change (IRENA No. 12) relates to land development activities that have an important impact on the environment and landscape. Land cover change (IRENA No. 24) focuses on the relationship between agriculture and forest/semi-natural land, and internal land cover changes within agriculture. The Land and Ecosystems ACcounts (LEAC) method is used to produce both IRENA No. 12 and No. 24 indicators. Indicators are developed using a 3 km by 3 km grid, which is superimposed on the CLC 2000 change database, which has been constructed on the basis of 5 ha land cover changes. In the Netherlands, the total area of land use change from agriculture to artificial surfaces between 1986 and 2000 was 80,807 ha, which represents a percentage change from agriculture of 3.2%. In Ireland, the total area of land use change from agriculture to artificial surfaces between 1990 and 2000 was 31107 ha, which represents a percentage change from agriculture of 0.7%. Administrative regions with large conurbations tend to have larger areas of land that have been converted from agriculture to artificial surfaces than more rural regions. In general, there is relatively much more agricultural land lost to artificial surfaces in the Netherlands than in Ireland. In Ireland and the Netherlands the change in land cover results in a strong flow from agricultural to forest/semi-natural land between 1990 and 2000. Regional differences are quite pronounced in both Ireland and the Netherlands. In regard to internal land cover changes within agriculture there are larger net arable and permanent crop and pasture land cover changes in Ireland than in the Netherlands. In Ireland there is a strong net increase in arable and permanent cropland and a net decrease in pastureland. This change is supported by data from the Farm Structure Survey.





### The effect of the delineation as Natura2000 region on land cover change

Librecht Ireen, Michiels Petra, De Leus Tomas, Vandenbroucke Danny, Placido Hernandez-Aguilar**
* Spatial Applications Division Leuven, Belgium, ** EC DG ENV

In this article, the CLC datasets of 1990 and 2000 are used to evaluate land cover change in- and outside Natura2000 regions. The basic idea is that the majority of the Natura2000 sites is delineated in the period 1990-2000 and that the changes between 1990 and 2000 in- and outside Natura2000 regions will give an indication of the influence of the protection of the Natura2000 regions on land cover change. The method presented in this article is very useful since an automatic way to monitor the land cover inside Natura2000 sites has been developed. In the future, the method can be fine-tuned if more land cover data for more countries and complete Natura2000 datasets become available. The method can be used to make global assessments at EU-level, making use of existing data.

## Land Cover Changes Observed Inside and Outside Natura2000 Sites: Examples from Belgium

France Gerard, Michel Cornaert, Mirko Gregor, Konstantin Olschofsky, Jiri Sustera, Jan Kolar, Stefaan Follens, Desire Paelinckx, Sam Provoost

BIOPRESS project team

BIOPRESS –*Linking pan-European land cover change to pressures on biodiversity* – is an EC-GMES funded project which aims at providing decision makers with quantitative information on how changes in land cover and land use between the 1950'ies and 2000 have affected the environment and biodiversity in Europe. The project is measuring the land cover changes by backdating CORINE Land Cover 1990 (and 2000 when available) with interpreting aerial photographs of 1950'ies for 75 30 km × 30 km windows centred on Natura2000 sites and distributed across the main biogeographical regions of Europe. As an example, preliminary land cover change results observed inside and outside the Natura2000 sites are presented for three 30 km × 30 km windows located in Flanders, Belgium. In Flanders the implementation of Natura2000 has recently started and the overall changes observed inside and outside Natura2000 sites are very similar.

The next stage is for the BIOPRESS research team to carry out a detailed analysis of the changes observed and of their significance in terms of pressure on biodiversity.

## Estimation of land cover change matrices Use of ground surveys and photo-interpretation

Javier Gallego, Susan Christensen
EC DG JRC IES Land Management unit

Major land cover changes between two reference dates can be estimated from a sample of geographical units. Basic information can be obtained from ground visits or by photo-interpretation. This paper analyses two options: point surveys and photo-interpretation of satellite images. We present the approach followed in a pilot test for estimation of land cover change matrices with visual photo-interpretation of SPOT images on a site of 40 × 40 km in the area of Arles (South-East France). Some difficulties for such operations are underlined:

a) Risk of bias due to mislocation. Some comments are also given on the use of ground surveys on an area frame of points for the same purpose. In particular we analyse the possible consequences of providing or not providing the ground surveyor with the point observations in the previous visits. Such considerations could be useful for the possible application in LUCAS.
b) Need to regroup cells of the legend matrix.
c) Severe over-estimation of changes if comparison of classified images is applied.

## Analysis of territory diversity and of its evolution - Tools and methods of the National Forest Inventory (France)

Jean-Guy Boureau, Claude Vidal
Inventaire Forestier National

This article presents some tools and methods used by the French National Forest Inventory (NFI) to assess landscape diversity and its evolution throughout France. Four databases, each one covering the whole country, can be used for this purpose. Dendrometric (as well as land cover / land use) and ecological data, obtained through plot sampling techniques, are for example used to analyse land occupation diversity and its evolution but also afforestation rate on regional or natural entities. Possible uses of cartographic data, obtained by photo-interpretation of aerial covers, are presented in a separate paper: Mapping landscape changes with French NFI aerial photographs. The emphasis is laid here on the use of infrared aerial photographs. More than 400,000 pictures, from 1960 until today and satellite imagery by visual or automatic comparisons, are used for landscape study purposes.

*Keywords*: Landscape, aerial photograph, infrared, satellite imagery, comparison of pictures.

### Mapping landscape changes with French national forest aerial photographs

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The article deals with the use of French national forest inventory aerial images captured approximately every ten years on NUTS 3 extent in order to constitute forest database. French NFI competencies and skills in aerial interpretation were enlarged by mapping land cover evolutions with the aim of characterising landscape changes.

Methodologies defined about digitising techniques, changes detection and calculation of indexes in order to quantify the changes are illustrated by three examples developed in this paper.

One relates to the landscape changes in relation to fire risk in Mediterranean area, the second to the evolution of production chestnut forests in Corsica and the third to the changes from wetlands into agricultural fields and poplar groves in the Loire valley.

Those three examples outline that production of precise and objective data completed by the calculation of evolution indexes often contributed to solve problems that remained complex in the absence of objective data.

*Keywords*: Aerial images – Cartography – Land cover – Forest fires – Production chestnut forests – Wetlands – Evolution indexes

### Potential use of Rural Development Policy databases to derive Agri-Environmental Indicators

Els De Roeck, Olivier Léo
EC DG JRC IPSC Agrifish unit

The Rural Development Policy of the European Union took shape in the early nineties and is growing in importance ever since. From the start, it entailed a number of European, national or regional measures concerning the protection of environment in rural areas. Some years later, it became the $2^{nd}$ Pilar of the CAP through a unique framework in Council Reg. (EC) n° 1257/99. The present article examines the extent to which the (geo-)databases that are (to be) established for the management and control of these measures could be used to derive agro-environmental indicators. Surely they represent a tremendous source of information which should, in one way or another, be considered for the development of relevant AEIs over Europe: on the 35 AEIs proposed by the Commission (Commission communication COM(2001) 144 of 20/3/2001), 8 indicators were identified for which RD data sets could be an essential or a complementary source of information. However, as for any other Administrative dataset, the use of these data will face problems of individual/privacy protection, of quality/objectivity of the declared information, of nomenclature of objects, which will require further analysis, establishment of correspondences, specific process to aggregate and correct possible bias due to the nature of the data.

*Keywords*: Rural development, aid applications, geographic databases

## Use of the CORINE land cover to identify the rural character of communes and regions at EU level

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Currently, no common definition exists at the EU level of what constitutes a rural area. In this article, an attempt has been made to take into account the increasing importance of territorial dimension in rural development policy. It is considered that the share of agriculture, forestry and natural areas reveals the rural character of an area. For this purpose, CORINE Land cover inventory has been used.

Results are compared with the OECD approach based on population density.

Whereas results are promising at local level, they are less convincing at regional level mainly due to the heterogeneity of the local units inside NUTS-3. Therefore, a first trial has been made to combine, at NUTS-3 level, the population density approach with the land use approach. Results seem much better but work should continue in this line.

*Keywords*: rural development, rural character, territorial, typology, CORINE Land cover.





## Trend in atmospheric nitrogen deposition over the period 1990-2000

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Atmospheric Nitrogen deposition on agricultural land is one of the calculation components on the input side of agricultural Nitrogen balances. For providing an estimate of the regional atmospheric Nitrogen deposition the EMEP grid data on reduced and oxidised Nitrogen depositions were spatially redistributed to NUTS areas and Eurofarm districts. The Nitrogen depositions for the years 1990 and 2000 were compared. The derived figures on atmospheric nitrogen deposition showed a reduction for the majority of the European regions and countries. However, a limited number of regions, especially in Western Europe saw a growth from 1990 to 2000.

*Keywords*: Nitrogen balance, Nitrogen deposits, EMEP, Agri-environmental indicators

## Linear landscape features in the European Union Developing indicators related to linear landscape features based on LUCAS transect data

Gerd Eiden*, Pascal Jaques**, Richard Theis*
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This paper describes how data from the European Area Frame Survey LUCAS could be used to provide a coherent picture about linear landscape features throughout EU 15.

Linear landscape features, such as hedges, row of trees, grass margins (beetle banks) and traditional stonewalls are important characteristics in European agricultural landscapes for a number of reasons. Given these important roles, it is clear why the conservation, maintenance and restoration of linear landscape features in European agricultural landscapes have become the central theme in many agri-environmental programmes. However, despite their significance, information about the state and change of hedges and trees is rare and what little information is available from the Member States is barely comparable.

LUCAS may contribute to fill the information gap since data about the presence of linear features and is collected in a harmonised and comparable way all over Europe.

# Utilisation of CLC 90 & 2000 data for monitoring the impact of CAP developments on the rural landscape

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## 1. Introduction

Changing conditions in the sector, new challenges and a steady learning process have been reflected in the different reforms of the Common Agricultural Policy (CAP). The CAP has undergone considerable changes since the early years, when the focus was on the short-term counteracting of economic and social pressures, to the direct income payments, rural development and agri-environment measures applied today. The latest reforms have re-shaped the CAP as a policy based on two pillars: market policy and rural development policy, with a financial shift from the first to the second pillar.

It was in this context, in the late '90s, that a request was made to the Commission by the European Council for a series of agri-environmental indicators (AEI) to monitor the constantly evolving interaction between European agriculture and the environment. Landscape, land cover and land use were identified as important components of the 35 agri-environmental indicators listed in the Commission's subsequent Communication to the European Parliament and the Council[1].



In the first and second publications in this series, "From land cover to landscape diversity in the European Union" and "Towards agri-environmental indicators – Integrating statistical and administrative data with land cover information", two DG AGRI articles studied the potential of the CORINE land cover (CLC) inventory for computing land cover diversity indices. At that stage only one CORINE inventory was available, which restricted the analysis to a static, spatial, single dimension, whereas our interest is more focused on developments over time. With the availability of a second CORINE inventory for some Member States, a further step can be taken and an analysis made of the impact of the different CAP reforms on the rural landscape since the early '90s. This article will compare the CORINE 2000 and 90 inventories using three indices: the simple diversity index, the Shannon index and the perimeter/area ratio index. For the regions with the most significant changes in indices, it will also determine land cover developments over time.

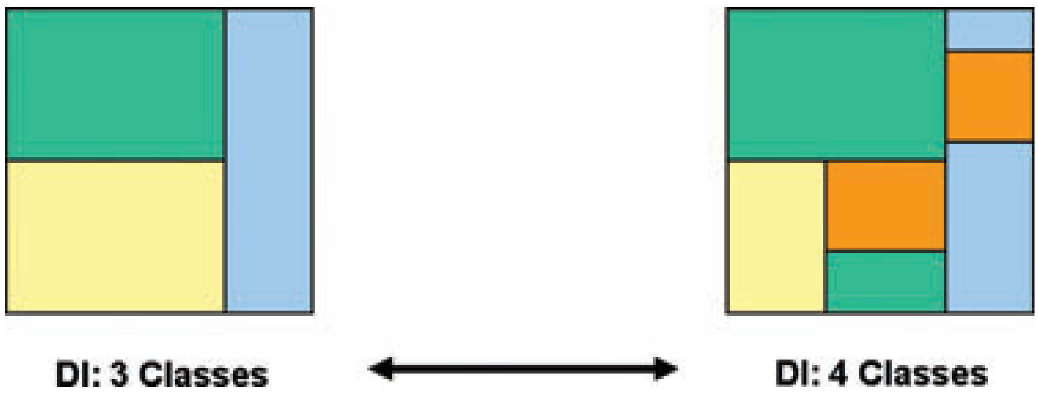
## 2. Methodology

For some EU-25 countries or a part of them, the CORINE land cover 2000 inventory is already available, in the form of preliminary results. The countries with a full coverage are Belgium, the Czech Rep., Ireland, Italy, Latvia, Luxembourg and the Netherlands, whereas partial results are available for France, Poland and Germany (the new "Länder"). The comparison with the inventory of 1990 has been carried out with the updated CORINE land cover 1990 inventory.

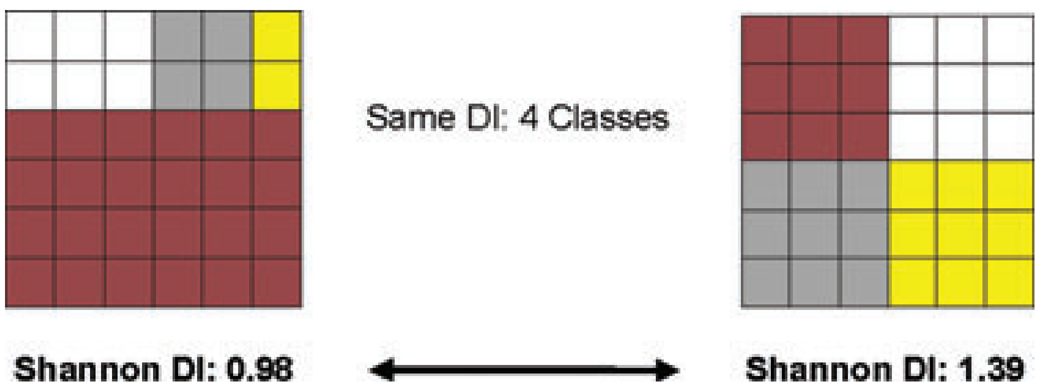
[1] "Statistical Information needed for Indicators to monitor the Integration of Environmental concerns into the Common Agricultural Policy" - COM (2001) 144.

## 2.1. Description of the indices

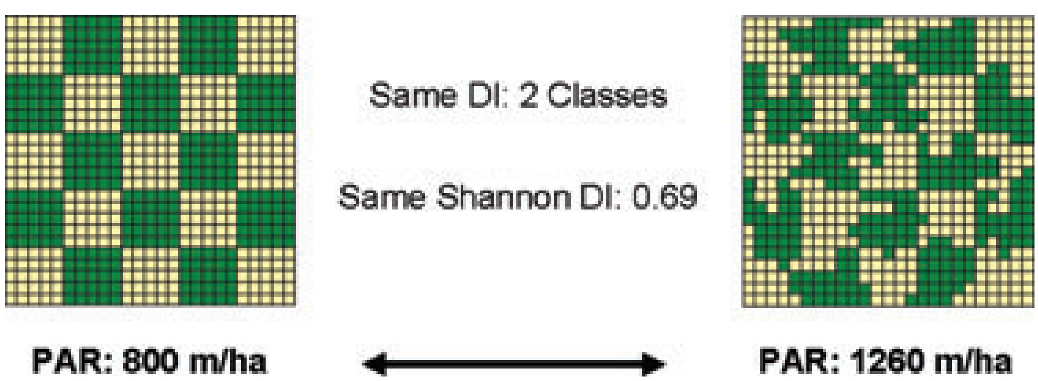
**Agricultural diversity index (DI):** the simplest way of capturing the diversity of the landscape is to count the cover classes in a unit area. The more classes there are the more diverse or rich the area is considered.




The **Shannon Diversity Index** (SDI) quantifies the diversity of the countryside based on two components: the number of different patch types and the proportional area distribution among patch types.




**Perimeter/Area Ratio (PAR):** An edge refers to the border between two different classes. Perimeter/Area Ratio, equals the length (in m) of all borders between different patch types (classes) in a reference area divided by the total area of the reference unit.




All 3 indices are computed in 2 steps:

- the base unit is a grid cell of $3 \times 3$ km$^2$, in which the indices are calculated,
- the results are aggregated at regional level (NUTS level 2 or 3),
- the median is used as the best estimator at regional level.

As for DG AGRI's previous articles, the number of CORINE Land Cover classes was reduced from 44 to 22. The finest differentiation (= lowest level) was used for agricultural classes (code 2) and shrub and/or herbaceous vegetation associations (code 3.2), the intermediate level for the other codes 3 (forests and open spaces with little or no vegetation) as well as for wetlands (code 4) and for water bodies (code 5) and no differentiation for artificial surfaces (code 1).

**Table 1.** *CORINE land cover classes*

| Level 1 | Level 2 | Level 3 |
|---|---|---|
| 1. Artifical surfaces | 1.1. Urban fabrica | 1.1.1. Continous urban fabric<br>1.1.2. Discontinous urban fabric |
| | 1.2. Industrial, commercial and transport units | 1.2.1. Industrial or commercial units<br>1.2.2. Road and rail networks and associate land<br>1.2.3. Port areas<br>1.2.4. Airports |
| | 1.3. Mine, dump and construction sites | 1.3.1. Mineral extraction sites<br>1.3.2. Dump sites<br>1.3.3. Construction sites |
| | 1.4. Artificial non-agricultural vegetated area | 1.4.1. Green urban areas<br>1.4.2. Sport and leisures facilities |
| 2. Agricultural areas | 2.1. Arable land | 2.1.1. Non-irrigated arable land<br>2.1.2. Permanently irrigated land<br>2.1.3. Rice fields |
| | 2.2. Permanent crops | 2.2.1. Vineyards<br>2.2.2. Fruit trees and berry plantations<br>2.2.3. Olive groves |
| | 2.3. Pastures | 2.3.1. Pastures |
| | 2.4. Heterogeneous agricultural areas | 2.4.1. Annual crops associated with permanent crops<br>2.4.2. Complex cultivation patterns<br>2.4.3. Land principally occupied by agriculture, with significant areas of natural vegetation<br>2.4.4. Agro-forestry areas |
| 3. Forests and semi-natural areas | 3.1. Forests | 3.1.1. Broad-leaved forest<br>3.1.2. Coniferous forest<br>3.1.3. Mixed forest |
| | 3.2. Shrub and/or herbaceous vegetation associations | 3.2.1. Natural grossland<br>3.2.2. Moors and heathland<br>3.2.3. Schlerophyllous vegetation<br>3.2.4. Transitional woodland shrub |
| | 3.3. Open spaces with little or no vegetation | 3.3.1. Beaches, dunes and sand plains<br>3.3.2. Bare rock<br>3.3.3. Sparsely vegetated areas<br>3.3.4. Burnt areas<br>3.3.5. Glaciers and perpetual snow |
| 4. Wetlands | 4.1. Inland wetlands | 4.1.1. Inland marshes<br>4.1.2. Peatbogs |
| | 4.2. Coastal wetlands | 4.2.1. Salt marshes<br>4.2.2. Salines<br>4.2.3. Intertidal flats |
| 5. Water bodies | 5.1. Inland waters | 5.1.1. Water courses<br>5.1.2. Water bodies |
| | 5.2. Marine waters | 5.2.1. Coastal lagoons<br>5.2.2. Estuaries<br>5.2.3. Sea and oceans |

# 3. Results

## 3.1. CLC2000 Results

The aim of this article is to analyze the difference between the 1990 and 2000 CLC inventories. However, it will first shortly describe the regional 2000 results for the 3 diversity indices.

### 3.1.1. Simple diversity index

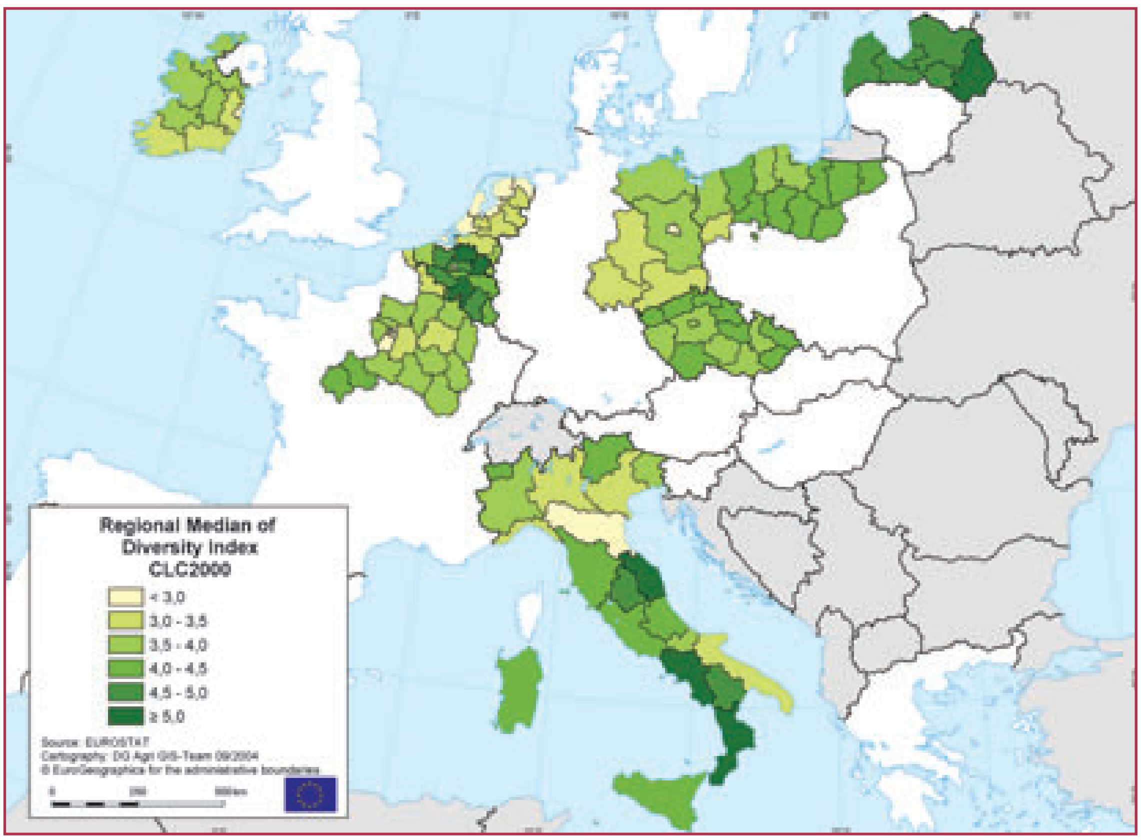
Map 1 shows the results of the simple diversity index at regional level: the darker the green, the higher the median of the diversity index. The average of the median for all regions analysed is 3.77, the lowest and highest values are 1.08 and 5.40. Predictably, the lowest values are recorded in regions with very important cities like Île-de-France, Brussels, Dublin and Berlin. However, values lower than 3 are also observed in 6 Dutch regions and in 1 Italian region, Emilia-Romagna. All these regions are highlighted in light green on the map. Of the 100 regions analysed, 7 recorded values are above 5: 3 regions in Belgium, 3 in Italy and 1 in Latvia. They are highlighted in dark green on the map. See Annex for all the details.

### 3.1.2. *Shannon diversity index*

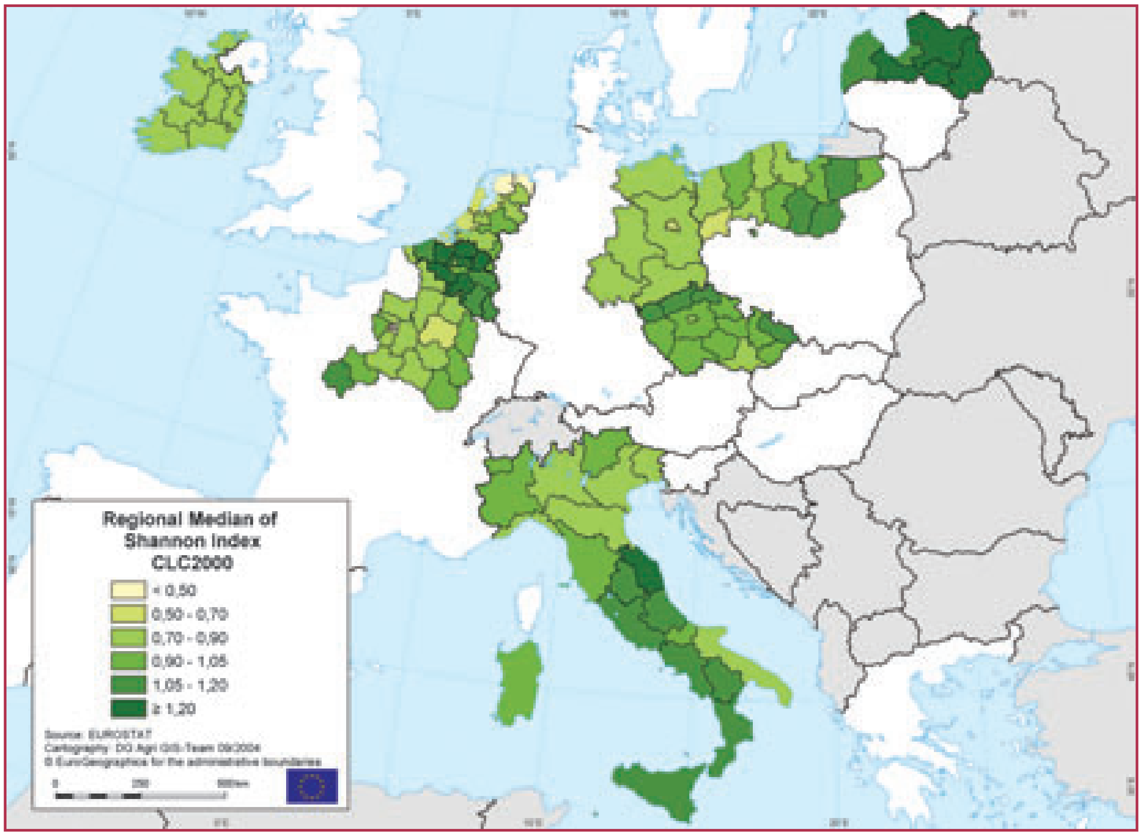
Map 2 shows the results at of a second diversity index, the Shannon index regional level. As for map 1, the darker the green, the higher the median of the Shannon index. The average of the median for all regions analysed is 0.91, the lowest and highest values are 0.05 (Paris) and 1.44 (Limburg-B). Values lower than 0.5 are observed in 6 French regions (all in Île de France) and 2 Dutch regions. 7 recorded values are above 1.2; 3 regions in Belgium, 3 in Italy and 1 in Latvia. They are highlighted in dark green on the map.



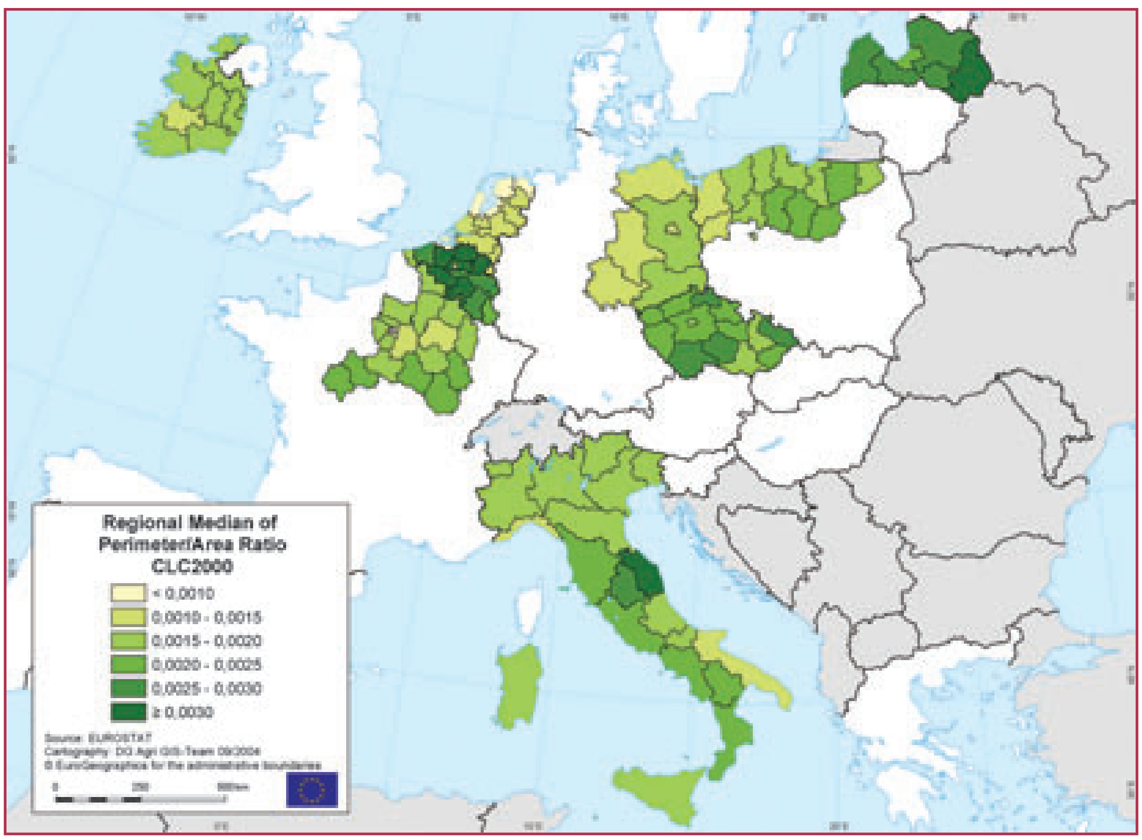





**Map 1.** *Simple Diversity Index*




**Map 2.** *Shannon Index*




**Map 3.** *Perimeter Area Ratio*

## 3.1.3. *Perimeter area ratio*

The results shown on map 3 for the third index, the Perimeter Area Ratio are very similar to the other two indices. The average of the median for all regions analysed is 0.0019, the lowest and highest values are 0.00014 (again Paris) and 0.0037 (Marche-I). Values lower than 0.001 are also observed in 4 French regions (all in Île de France) and 5 Dutch regions. 8 regions recorded values above 0.003: 6 regions in Belgium, 1 in Italy and 1 in Latvia. They are highlighted in dark green on the map.

## 3.2. Comparison CLC2000 with CLC90

Six maps are presented comparing the results for 1990 and 2000. For each of the 3 indices, the maps show the differences in absolute value and in percentage. The legend classes of the percentage maps are the same for the 3 indices. Negative temporal developments are highlighted in red and positives in green. The darker the color, the higher the difference. At the end of the article, an Annex presents the detailed results.

## 3.2.1. *Luxembourg*

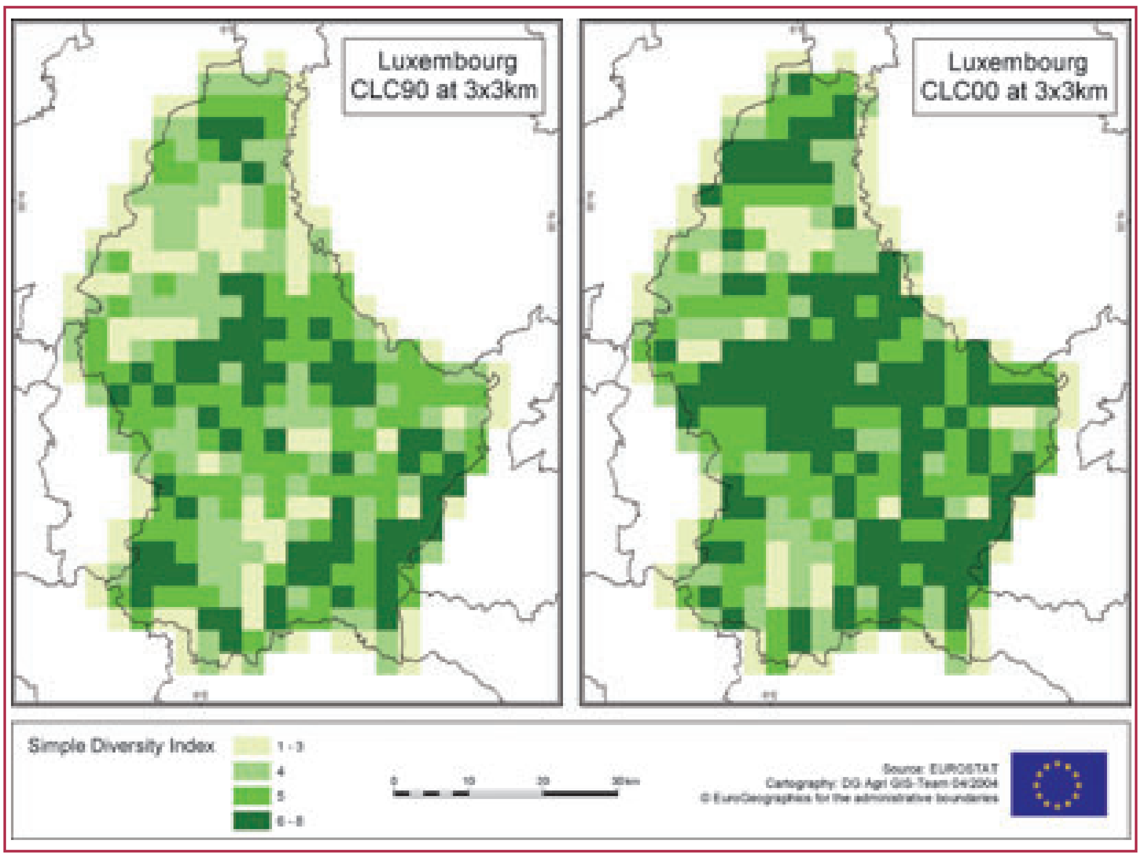
Between 1990 and 2000, the artificial classes increased by 23%, whereas the agricultural classes, forests, and semi-natural areas were reduced by 0.7% and 4.1%. This decrease in class 3 is solely due to a significant decline of the forest area (class 3.1) of more than 6%, only partially compensated by an increase of the transitional woodland shrub (class 3.2.4).

The three indices have a positive temporal development ranking from 5% for the Shannon index to 13% and 15% for the diversity index and the perimeter/area ratio index respectively.

Hereby, the methodology followed to carry out the analysis for all regions is explained








**Map 4.** *1990 & 2000 Simple Diversity Indices in Luxembourg*

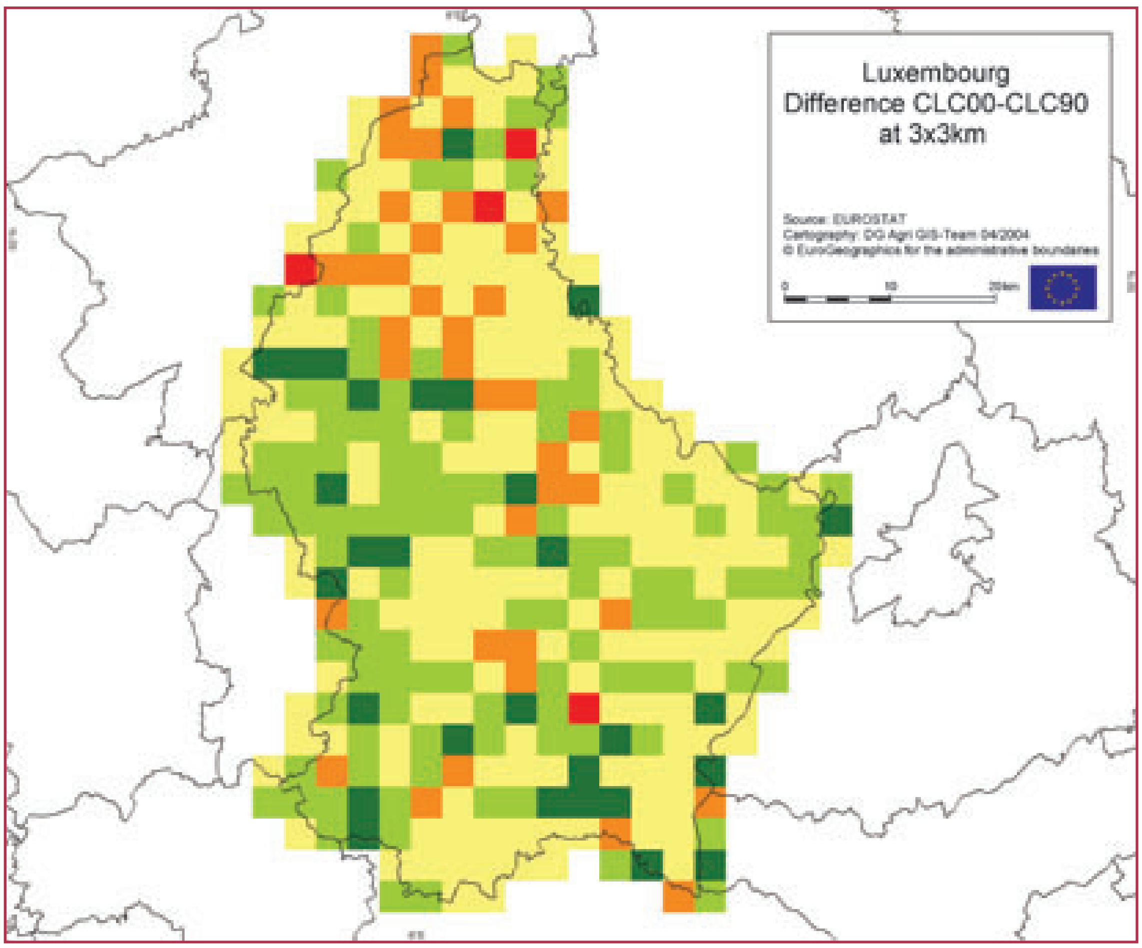
for Luxembourg. Map 4 represents a visualization of the 1990 and 2000 simple diversity indices, calculated for each grid cell of 3 × 3 km². The darker the grid cell, the higher is the diversity. It is clear that the 2000 map (right side) contains more dark cells than the 1990 map, mainly at the extreme north part and central part of the country.

Map 5 is another illustration of the differences between the 1990 and 2000 inventories. The yellow squares indicate no development, neither negative nor positive. The orange and red grid cells indicate a negative temporal development: orange 1 class less and red 2 or more classes less in 2000 than in 1990. Green squares highlight the positive developments, light green 1 class more and dark green, at least two classes more in 2000. With the exception of the extreme south west of the country, more green grid cells are visible than orange or red ones.

## 3.2.2. *Belgium*

On average, the median of the diversity index of Belgium decreased slightly from 4.58 in 1990 to 4.52 in 2000, hence by –1.4%. However, as explained in chapter 3.1, the Belgian regions are still among the regions with the highest indices. At regional level, all regions experienced a lower index in 2000 than in 1990. The most important negative development occurred for Brussels (–6%). Other significant decreases were observed in 2 other regions, Luxembourg (–0.15 in absolute value or 3.3%) and Liege (–0.11 or –2.6%).

With the Shannon index, the average decrease for the Belgium is 0.8% (–0.009 in absolute value). Only 2 regions have a small positive development for this index of about 0.3%, namely Brabant wallon and Hainaut. In 2 regions, the decrease was significant (+3%), again Luxembourg and Liege.




**Map 5.** *Luxembourg, Difference in Diversity in Grid Cells (2000 vs 1990)*

The perimeter/area ratio index also decreased between 1990 and 2000 for Belgium, as a whole, by 2%. This index declined in all regions, the highest decline (10.3%) being recorded in the highest populated region, Brussels.

In Brussels, the region with the most negative development, the artificial areas increased by 95 ha or 0.7%. This increase is linked with a 48 ha decrease for agricultural areas and with a 52 ha decrease for forests and semi-natural areas.

For Liege, another region which recorded a significant decrease in diversity, the artificial areas increased with 1300 ha (+1.8%), and the forests with 1700 ha (+1.6%). This was mainly due to a loss of 1200 ha of agricultural areas (–4.6%), mainly arable land and pastures, and a loss of 1700 ha of transitional woodland.

Finally, Luxembourg, the third region with a significant decrease of 2 indices, recorded a 3300 ha increase in forests (+1.5%) and a 360 ha in artificial areas (+1.4%), nearly exclusively due to a loss of 3200 ha of transitional woodland and of 450 ha of agricultural land.

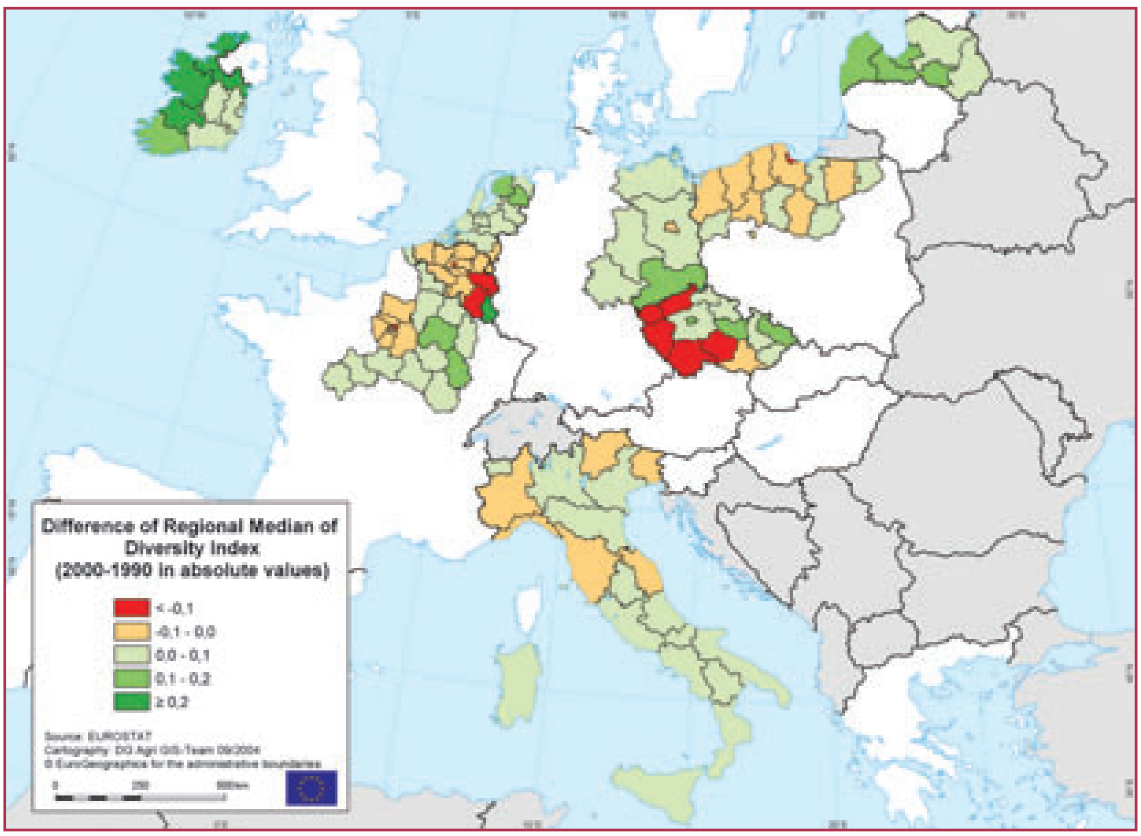
### 3.2.3. *The Netherlands*

The median of the diversity index of the Netherlands increased from 2.86 in 1990 to 2.92 in 2000 or 2.2%. At regional level, only one region, namely Limburg, experienced a lower index in 2000 than in 1990 (3.75 vs 3.81). Nevertheless, this region has still the highest index. All the other regions have higher indices ranking from +0.5% to +6.8%. The highest increase occurred for a region in the North, Friesland, with a very low diversity index, only about 2 different classes in the squares $3 \times 3$ km$^2$.

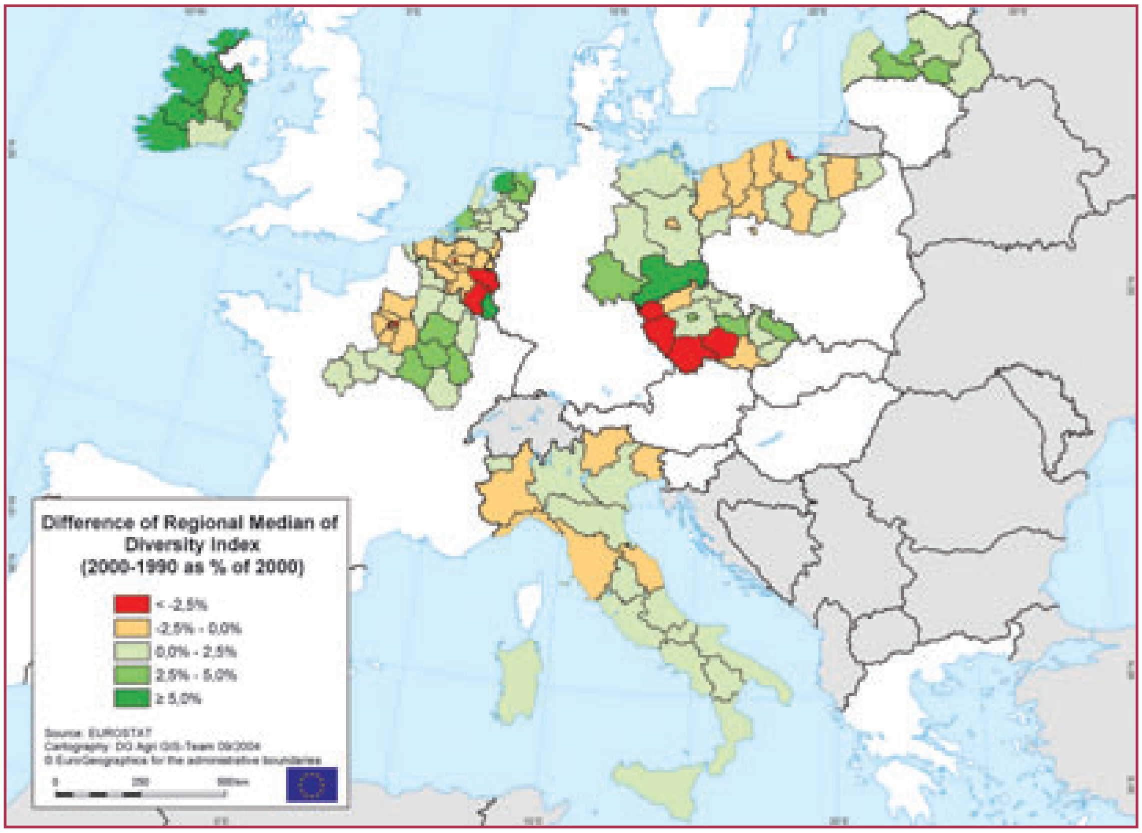
With the Shannon index, the average increase for the Netherlands is 3.1% (+0.02 in absolute value). All regions have a positive development for this index ranking from +1.2% for Limburg to +6.4% for Friesland. The highest increase in absolute value (+0.037) is observed in Overijssel.

The perimeter/area ratio index increased between 1990 and 2000 by 1.5% for the






**Map 6.** *Development of the Simple Diversity Index in Absolute Value*




**Map 7.** *Development of the Simple Diversity Index in %*

Netherlands as a whole. Four regions, mostly located in the south west part of the country, have a negative development, the highest decline (–0.000046 or – 4.7%) being recorded in a highly populated region, Noord-Holland. The 3 other negative developments are very small. The highest positive developments (>6.5%) occurred in two northern regions, Friesland and Drenthe.

For Friesland, the region with the most positive development, the artificial areas, increased by 6000 ha or 43%. This important increase is linked with a 9000 ha decrease (or –2.7%) of agricultural areas, mainly pastures (–3.6%). Forests and semi-natural areas recorded a small decrease of 1.9%, whereas a significant increase occurred for wetlands (+1800 ha or +20%) and a smaller one for water bodies (+2.7%).

For Limburg, which recorded a negative development for 2 of the indices, the loss of 7000 ha of agricultural areas (–4.6%) was entirely compensated by the same area increase of artificial surfaces (+23.5%). The other classes were more or less stable with a small decline of 400 ha or 1.4% for forests and semi-natural areas.

### 3.2.4. *Ireland*

In Ireland, the diversity index increased, between 1990 and 2000, in all regions but one, Dublin, with a low index of about 2.7, where there was no development at all. For Ireland, the increase was 5.7%, three regions, located in the western part of the island, recording an increase above 9%, namely Border (+0.44 in absolute value), West (+0.43) and Mid-west (+0.34).

On average, the Shannon index increased by 8.0%, ranging from 3.5% in Dublin (+0.026 in absolute values) to 12.7% in Mid-west (+0.100). The same for two other regions, with the diversity index increasing above 9%, Border and West. In no region, a decline of the Shannon index is observed.

The increases in temporal development are even higher with the perimeter/area ratio index. Again, no Irish region recorded a negative temporal development. At national level, the increase is nearly 9%. At regional level, the lowest increases of about 5% occurred in Midland and Dublin, whereas for three regions where above the national average, Border (+14%), West (+15%) and Mid-west (+16%), same regions as for the two other indices.

For Dublin, the Irish region with the lowest positive development, the gain of 5500 ha (+20%) of artificial areas, was entirely due to the loss of the same amount of hectares of agricultural land (–10%), with an important reduction of pastures (–8000 ha or –27%), only partially compensated by an increase of 2400 ha (or 10%) of arable land. Wetlands, water bodies, forests and semi-natural areas were unchanged in the 2000 inventory compared to 1990'one.

The artificial surfaces of the Mid-west region (IE023) increased by 3000 ha or 29%. The agricultural areas were only marginally reduced by 0.9% (5700 ha). The dramatic decline of 18000 ha (–26%) in wetlands was entirely compensated by a 21000 ha increase (+23%) of forests and semi-natural areas of which 18000 ha (+53%) of transitional woodland shrub (class 3.2.4).

### 3.2.5. *Italy*

In Italy, the 3 indices remained remarkably stable between 1990 and 2000. On average, the perimeter area ratio decreased by less than 0.04% whereas very small increases occurred for the Shannon index (+0.04%) and the simple diversity index (+0.14%).

For the simple diversity index, the positive and negative changes are below 2%. Only 2 regions recorded decreases above 1%, namely Piemonte (–1.6%) and Liguria (–1.2%) and 1 region had a positive development above 1%, Emilia-Romagna (+1.5%).

For most of the regions, the Shannon index was stable, with changes lower than 1%. The only exceptions were Liguria (–4.6%), Piemonte (–2.7%), Emilia-Romagna (+1.4%) and Molise (+1.1%).

The temporal development of the perimeter/area ratio index was also very small for most of the regions. Only 3 regions recorded changes between 1990 and 2000 above 1%, namely Piemonte (–4.0%), Liguria (–3.2%) and Calabria (+1.1%).

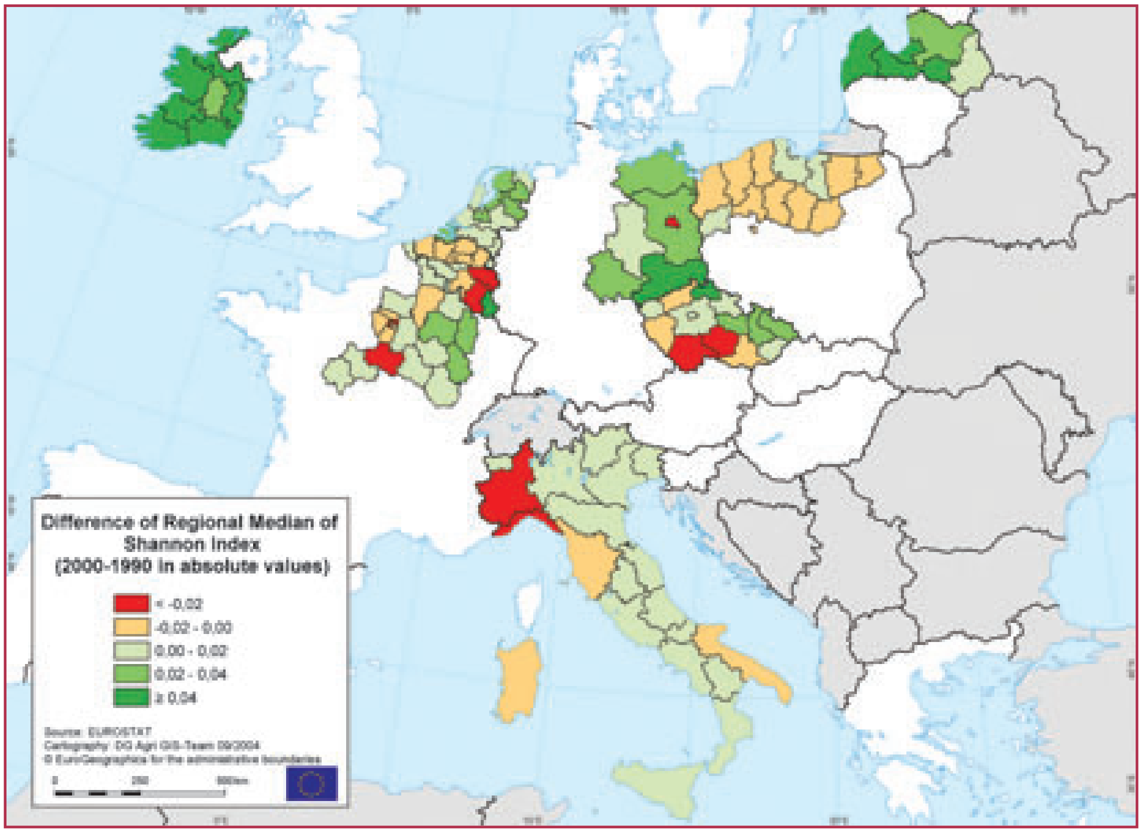
In Piemonte, artificial areas increased significantly by 9000 ha (+8.2%). Agricultural areas were reduced by 12000 ha (–1%). All agricultural classes decreased with the exception of a slight increase of permanent crops (+250 ha). Open spaces with little or no vegetation increased by 1300 ha (+6.6%). Forests also increased by 47000 ha (+5.9%) whereas transitional woodland shrub declined by 39000 ha.

Liguria recorded stable artificial areas (+0.3%) and a small decline of agricultural areas ( 660 ha or –0.8%). Two semi-natural classes, namely natural grassland and sclerophyllous vegetation, decreased by 500 ha (–2.4%) and 1200 ha (–10%) respectively. Forests had a very positive development of 151000 ha over time as opposed to transitional woodland shrub (–150000 ha).

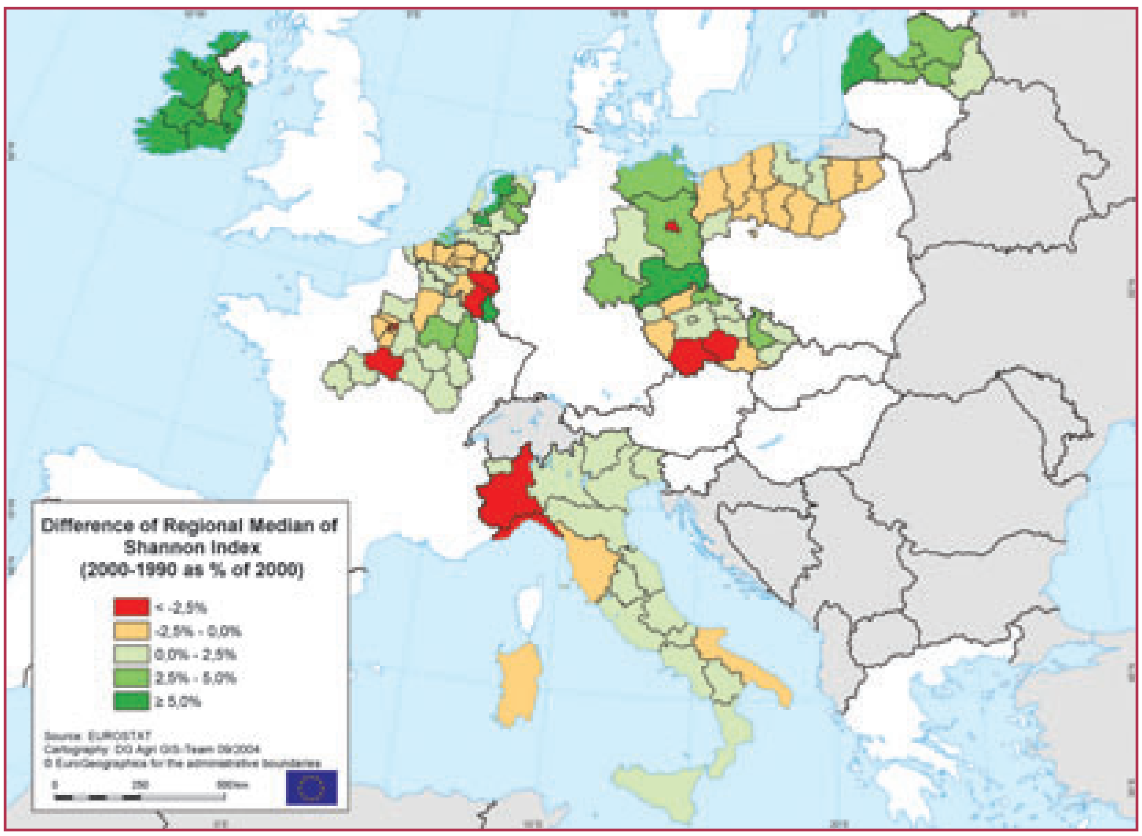
Emilia-Romagna, which recorded small increases for the 3 indices, saw an important increase of her artificial areas (+10500 ha or +10%). Agricultural areas declined significantly by 25000 ha (–1.5%), being mainly arable land and complex cultivation patterns. However, forests and transitional woodland shrub recorded positive developments with +13500 ha (+2.8%) and +2200 ha (+4%) respectively. Wetlands also increased by 260 ha (+11%).

### 3.2.6. *Czech Republic*

For the Czech Republic, the average median of the diversity index is slightly lower in 2000 compared to 1990 (–0.033 or –0.8%). Of the 14 Czech regions, 6 have a lower diversity index in 2000 of which two, Jihocesky and Karlovarsky, record decreases above 5%. Prague is the region with the highest positive development (>4%).




**Map 8.** *Development of the Shannon Index in Absolute Value*




**Map 9.** *Development of the Shannon Index in %*

On average, the Shannon index is slightly positive, +0.006 or +0.6%. Five Czech regions recorded a negative temporal development of the Shannon index. The biggest decrease occurred again for Jihocesky (–2.8%) and Vysocina (–2.6%). Four regions had a significant higher Shannon index in 2000 compared to 1990, Liberecky (+4%), Olomoucky (+2.6%), Pardubicky (2.3%) and Moravskoslezsky (+2.2%).

On average, the perimeter/area ratio index decreased by 0.00003 or 1%. For nine regions, the index is lower in 2000 compared to 1990, the most significant decreases were recorded in the same regions as the other indices, Jihocesky (–7%) and Vysocina (–6%). Significant positive developments above 3% were observed in 4 regions, Olomoucky (+4.9%), Prague (+3.9%), Moravskoslezsky (+3.9%) and Karlovarsky (+3.6%)

The Czech region with the most negative temporal development, Jihocesky, recorded a very small increase of her artificial surfaces (+100 ha or +0.4%). All other classes at level 1 remained nearly unchanged. However arable land decreased by 40000 ha or 11%, this loss being entirely compensated by the same area increase of pastures, which more than doubled the 1990 area.

The Czech region recording a significant increase of the Shannon index, namely Liberecky saw a small increase of her artificial areas (+200 ha or +1.1%). All other classes at level 1 remained unchanged, but here again an important shift from arable land to pastures. These 315000 hectares represent on the one hand, a loss of one third of arable land and on the other hand, pasture areas tripled.





### 3.2.7. *Latvia*

For Latvia, the temporal development in all regions is positive, ranking from +1.1% to 3.1%. This is also the case for the Shannon index and the perimeter/area ratio index, where the minimum increases are 1% and the maximum increases are 6% for the Shannon index and 11% for the perimeter/area ratio index.

Kurzeme, which recorded the highest increase of the diversity indices, recorded no change for any of the classes. For the agricultural classes, the small decrease of 1400 ha of arable land was entirely compensated with the same increase in pastures.

For the region with the smallest increase, Latgale (+1% for all three indices) also, they were also no changes recorded at level 1 of the nomenclature. However, the opposite case occurred at Kurzeme, pastures were reduced by 14000 ha, corresponding to the same increase of arable land.

### 3.2.8. *Germany*

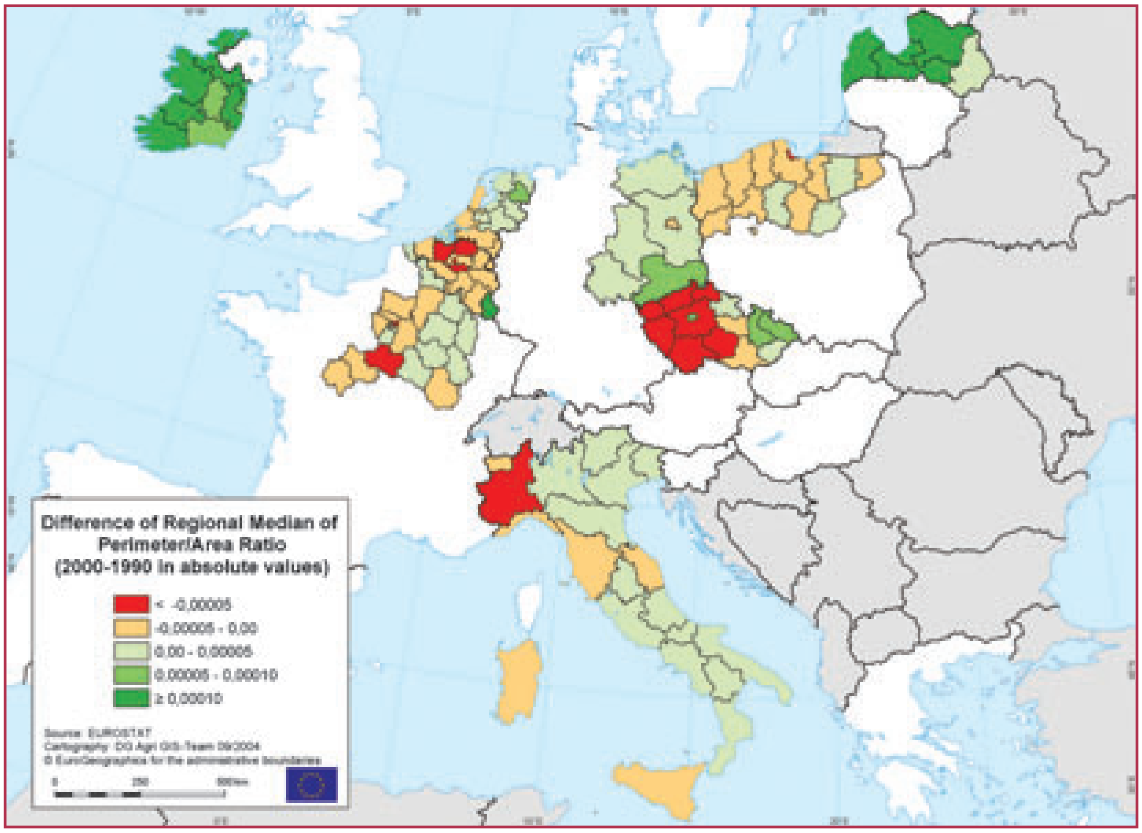
For Germany, only partial results for the “Länder” are available namely the following regions: Berlin, Brandenburg, Mecklenburg-Vorpommerrm, Sachsen, Sachsen-Anhalt and Thüringen. Only one region, Berlin (–1%), has a lower diversity index for 2000, than for 1990. All other regions have a positive development of this index, with the highest increase in Sachsen (+5.3%).

The results of the Shannon index are close to those of the diversity index, with the same urban region, Berlin, having a negative development (–3.9%) and the five others having a positive development. Again, the highest (5.2%) index is recorded for Sachsen.

For Berlin, the perimeter/area ratio index is the same for 2000 than for 1990. For the other regions, the increases rank from 2% to 3.6% for Sachsen.

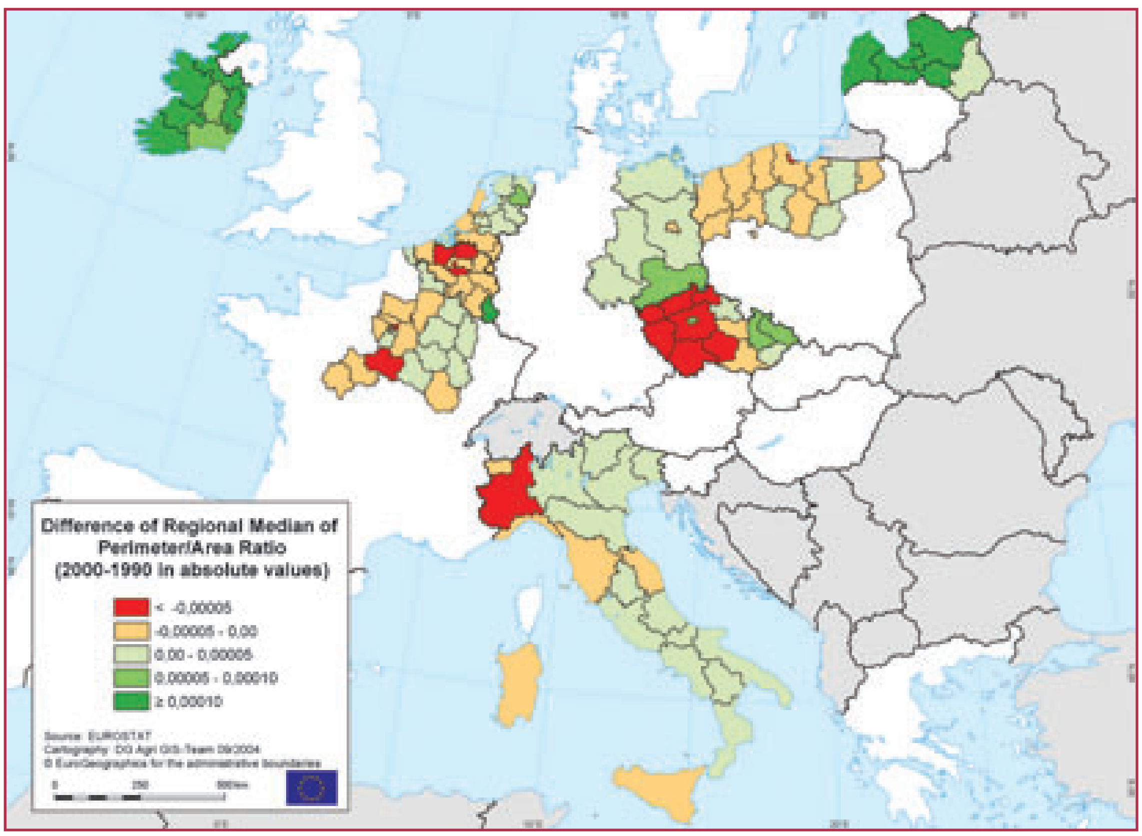
For the region Berlin, the marginal gain of artificial areas of 370 ha or +0.6% corresponds almost exactly to the loss of agricultural areas (–340 ha). Forests and semi-natural areas, as well as wetlands and water bodies remained unchanged.

The Sachsen region, which recorded the highest temporal development increase, recorded a small increase of 4000 ha for artificial land (+2%). The reduction of agricul-




**Map 10.** *Development of the Perimeter Area Ratio in Absolute Value*






**Map 11.** *Development of the Perimeter Area Ratio in %*

tural areas (–20000 ha or –1.9%) was exclusively due to a significant decrease of arable land (–58000 ha or –5.8%), being only partially compensated by increases in pastures (+20000 ha or +53%) and in complex cultivation patterns (+18000 ha or +100%). Forests and semi-natural areas increased by 12000 hectares (+26%).

Increases occurred mainly for forests (class 3.1) and open spaces with little or no vegetation (class 3.3). Water bodies increased significantly from 15000 to 20000 hectares.

### 3.2.9. *France*

For France, only partial results are available for the north-eastern regions. On average, the simple diversity index was very stable for these regions. However, one region located close to Paris, Seine-Saint-Denis, had a very negative development (–22%) between 1990 and 2000 for this index, as it was also the case for the two other indices, with 56% for the Shannon index and –16% for the perimeter area ratio. These high negative results have to be treated with caution as it has to be considered that it is a very small region and that the 3 indices are very sensitive to the size of a region.

For the other regions, the change of the simple diversity index ranks from –3.9% in Hauts-de-Seine to +4.1% in La Marne. Significant positive developments were also observed in Haute-Marne (+3.5%), Aube (+2.8%) and Yonne (+2.6%).

For the Shannon index, another region closely located to Paris, Hauts-de-Seine, recorded a significant decrease (–17%). The same explanation as for Seine-Saint-Denis is valid for this small region. Another significant negative development of this index was observed for Loiret (–5.8%). Of the 21 regions, two regions recorded increases above 3%, namely La Marne (+3.7%) and La Meuse (+3.7%).

The perimeter area ratio declined significantly between 1990 and 2000 for Loiret ( 6.0%) and Hauts-de-Seine (–4.8%). These significant negative developments were compensated by an increase of 5.7% for Val-de-Marne.

The French region with the most negative temporal development, Seine-Saint-Denis, recorded a significant increase of her artificial surfaces (+235 ha or +1.1%); arable land increased also significantly by 44 ha (+6%). All other agricultural classes diminished dramatically. In particular, permanent crops and pastures, which both halved in area. In Loiret, another region which recorded negative development of the indices, artificial surfaces increased significantly (+1600 ha or +4.7%). Agricultural areas as a whole declined by 1800 ha (–0.4%), with a decrease of arable land (–2700 ha or –0.7%), only partially compensated by an increase of 1500 ha of pastures (+2.9%).

La Marne, one of the regions in which the indices increased, recorded an increase of 1100 ha of artificial areas (+3.7%). It was the contrary to other regions, where agricultural areas remained relatively stable (<0.1%). Forests decreased by more than 9000 ha or –6.4%, only partially offset by an 8400 ha increase of transitional woodland shrub. For La Meuse, the pattern is quite similar. Agricultural areas remained unchanged over time (<0.04%) hiding in fact, two phenomena: a decrease of 6800 ha of pastures and an increase of 6700 ha arable land. Forests decreased by more than 14000 ha or 6.4%, completely compensated by a 14000 ha increase of transitional woodland shrub.

### 3.2.10. *Poland*

As was the case for France, only partial results are available for the Polish northern regions. On average, the simple diversity index decreased between 1990 and 2000 by 0.02 in absolute value or 0.6% for these regions. The change of the simple diversity index ranks from –4.1% in the region Gdansk-Gdynia-Sopot to +0.7% in Koszalinski. Of the 14 Polish regions with results available, only four others beside Koszalinski recorded very small increase of this index.

The Shannon index was very stable for the available regions. No region recorded a change above 1%.

The developments of the perimeter area ratio were more in line with the simple diversity index. On average, a small decrease of 0.1% was observed. Only 3 regions recorded very small increases of less than 0.2%, whereas a significant negative development was again observed for Gdansk-Gdynia-Sopot (–4.4%).

Gdansk-Gdynia-Sopot recorded a significant increase of their artificial areas between 1990 and 2000 (+650 ha or +4.4%). On the other side, agricultural areas decreased by 620 ha or 5.1%, applicable to mainly arable land and complex cultivation pattern. The other classes remained stable.

In Gorzowski region, which recorded a small positive development for the 3 indices, artificial areas increased slightly (+100 ha or 0.9%). Agricultural areas decreased by 1000 ha or 0.4%, mainly due to a reduction of 1600 ha (–1%) of arable land, whereas pastures increased by 500 ha (+0.7%). Open space areas with little or no vegetation were significantly reduced by 150 ha or –18%, partially compensated by a 100 ha (+14%) of inland wetlands. Forests had a positive development of 2900 ha (+1.1%) unlike transitional woodland shrub (1900 ha).

## 4. Discussion

Notably, it should be mentioned that no discrepancies were observed between the results of the calculations of the three indices, as already demonstrated in DG AGRI's article in the second common publication (Willems et al, 2001). In that article, the strong correlation between the regional Shannon index and the simple diversity index was highlighted. However, differences were observed in the intensity of the changes between the indices, such as for Luxembourg, where median increases of 12%, 5% and 13% were recorded for the diversity index, the Shannon index and the perimeter/area ratio index, respectively.

At national level, for four of the seven complete countries, all three indices are higher in 2000 compared with 1990. The increases rank from 1% for the perimeter/area ratio index in the Netherlands to 13% for the same index in Luxembourg. The increases are low in the Netherlands, medium in Latvia and significant in Ireland and Luxembourg. In the Czech Republic and Italy the indices are more or less stable between 1990 and 2000, whereas in Belgium small decreases (<2%) are observed.

At regional level, according to the Shannon and perimeter/area ratio indices, all Irish and Latvian regions have greater diversity in 2000 compared with 1990. In the Netherlands, all regions have a higher Shannon index in 2000, whereas some regions have a lower diversity and perimeter/area ratio index in 2000. In the new German Länder only the Berlin region has a lower diversity and a lower Shannon index in 2000; for all the other regions the three 2000 indices were higher than in 1990. With the exception of a very small increase in the Shannon index for 2 regions, the Belgian regions recorded lower indices in 2000 compared with 1990. In Italy, with the exception of 2 or 3 regions, the indices are very stable over time. For the Czech regions, the results are more contrasted, with significant negative as well as positive developments in the indices. Surprisingly, and unlike the German capital, Prague recorded positive developments in all three indices. NUTS3 regions of the Île de France recorded negative developments, sometimes very substantially so, as for Seine-Saint-Denis and Hauts-de-Seine. Of the other French regions, only Loiret had significantly lower indices in 2000 compared with 1990. Some NUTS3 regions of Champagne-Ardenne and Lorraine recorded higher indices in 2000. The Shannon indices were remarkably stable in the available Polish regions. Only one region recorded a negative development of more than 4% for the simple diversity index and the perimeter area ratio.

Although at first glance results from the comparison of the CORINE 2000 and 1990 inventories seem promising, with a majority of regions showing higher indices in 2000, whichever index is used, a deeper analysis is needed of the structure of the changes. It is obvious that not all increases in diversity are positive, for example increases in houses and settlements are the first steps towards urbanisation.

To investigate the origin of diversity changes we will have a closer look at two regions, one with a significantly high increase in diversity, the other with a significant decrease.

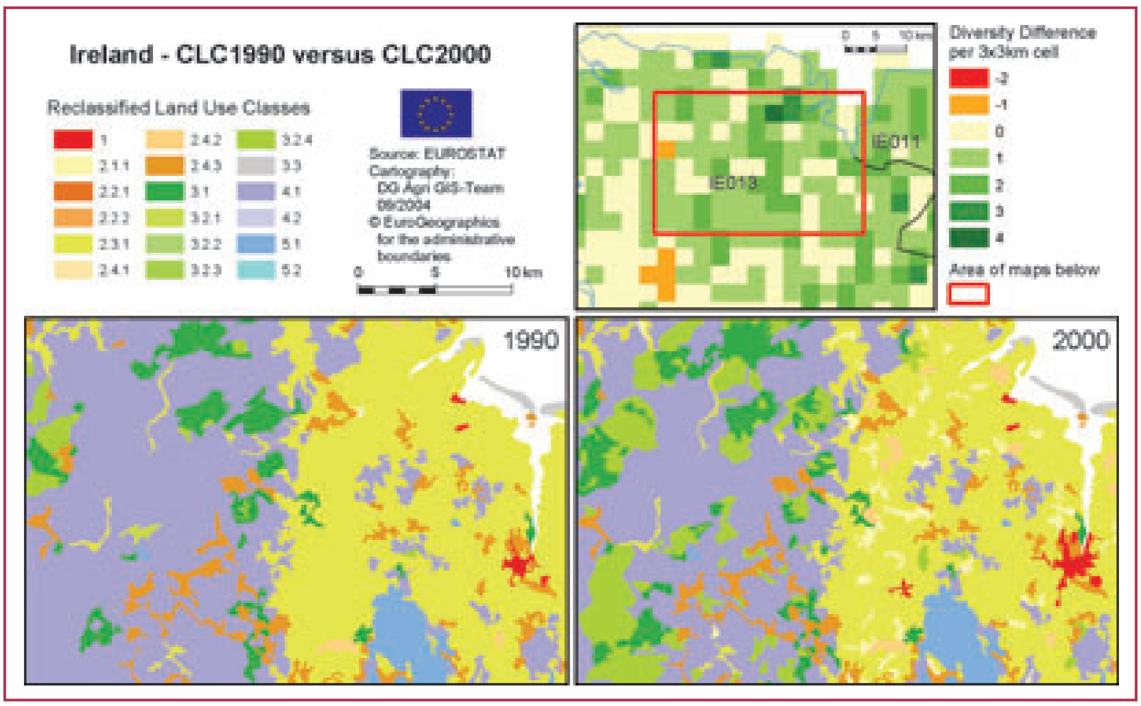
The region with the highest increase in diversity can be found in north-west Ireland: some 3 × 3 km squares have a diversity that increases by 3 or even 4 classes, as can be seen on map 12. The darker green the square, the bigger the increase in diversity.

The most interesting part of this in-depth analysis is to compare the reclassified maps for 1990 and 2000. A much more heterogeneous distribution of polygons and patches is immediately apparent, resulting in more classes per 3 × 3 km square. The biggest changes are insertions of transitional woodland shrub (3.2.4) into inland wetlands (4.1), and areas with pastures (2.3.1) converted to arable land (2.1.1). Only one polygon of artificial surface did not exist in 1990, and another expanded slightly. It is clear that this small increase is not responsible for the large increase in diversity for this part of Ireland: the increasing diversity is not due to urbanisation but is the result of a positive landscape evolution.

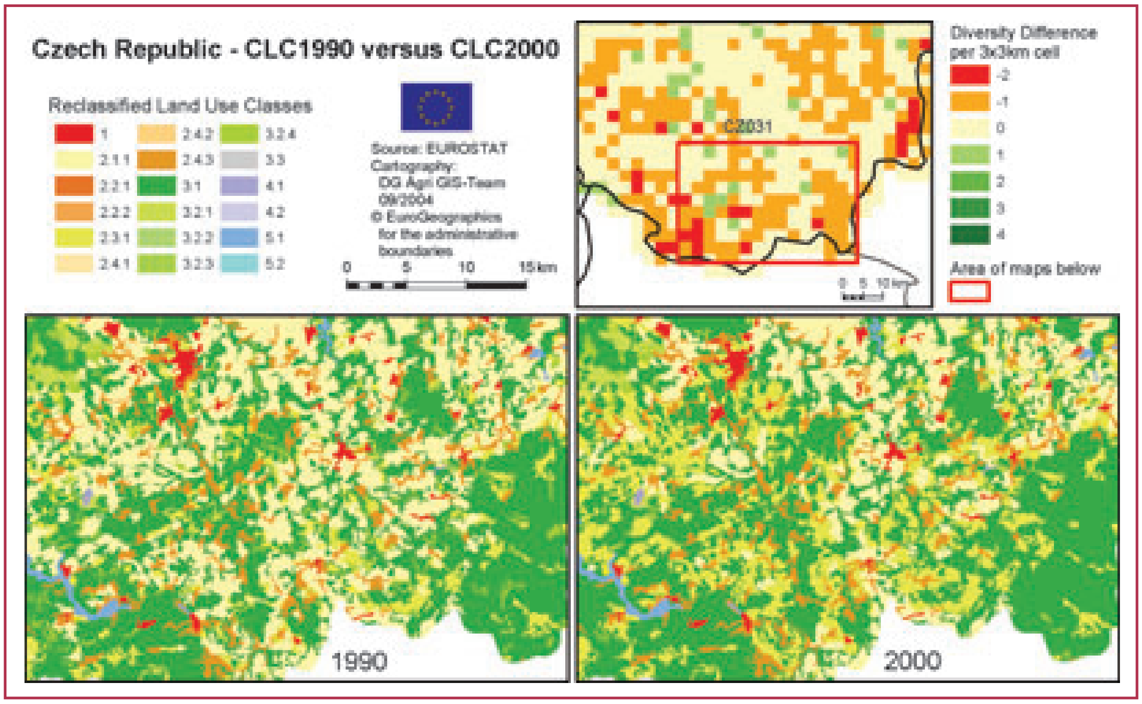
Looking at the south-western part of the Czech Republic (map 13), the opposite evolution can be detected: the diversity indices of a significant number of 3 × 3 km squares are lower in 2000 than in 1990. Although some light green squares appear, most squares are yellow, orange or even red because of a negative difference.

The reclassified land cover maps for 1990 and 2000 show the changes that have caused this decrease in diversity. In the first place, a large number of parcels have converted from arable land (2.1.1) to pasture (2.3.1), so large areas of continuous pasture appear in 2000. As a result, the class “arable land” no longer contributes to diversity. Moreover, a few areas of “transitional woodland shrub” (3.2.4) inside the forests (3.1) have disappeared in favour of more forest area. Both these developments have contributed to a lower diversity.






**Map 12.**




**Map 13.**

## 5. Conclusions

More regions recorded higher diversity indices in 2000 than in 1990. Even where regions recorded lower indices in 2000 compared with 1990 developments need not always be seen as negative for the environment, as the example of the Czech regions illustrates. For these Czech regions, the decline in diversity is mainly due to a decrease in arable land and an increase in pastures.

However, these first results must be analysed with caution, as when this article was written only a few countries are complete and most of the inventories are preliminary. Moreover, even if the specification for both inventories was the same, and even if CLC90 has been revised by CLC2000, the differences recorded could be artificial, because the level of detail in the photo-interpretation is not really the same. The bias can be particularly strong for landscape diversity indicators. For this reason, a validation with finer resolution data is necessary to check that the changes identified are real.

To carry out this "fine tuning" validation exercise it would be worth having complete availability of the CLC2000 inventories for all countries.

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## 7. Annex

| | | Simple Diversity Index | | | | Perimeter/Area Ratio | | | | Shannon Index | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NUTS | Name | 1990 | 2000 | Diff. | Diff.(%) | 1990 | 2000 | Diff. | Diff.(%) | 1990 | 2000 | Diff. | Diff.(%) |
| BE1 | BRUXELLES/BRUSSEL | 2,571 | 2,429 | –0,14286 | –5,88% | 0,000847 | 0,000768 | –0,0000790 | –10,29% | 0,578 | 0,578 | 0,00000 | 0,00% |
| BE21 | ANTWERPEN | 5,354 | 5,302 | –0,05178 | –0,98% | 0,003385 | 0,003323 | –0,0000621 | –1,87% | 1,446 | 1,438 | –0,00768 | –0,53% |
| BE22 | LIMBURG (B) | 5,434 | 5,402 | –0,03259 | –0,60% | 0,003460 | 0,003414 | –0,0000455 | –1,33% | 1,452 | 1,442 | –0,01026 | –0,71% |
| BE23 | OOST-VLAANDEREN | 4,752 | 4,747 | –0,00472 | –0,10% | 0,003651 | 0,003575 | –0,0000758 | –2,12% | 1,350 | 1,340 | –0,00984 | –0,73% |
| BE24 | VLAAMS BRABANT | 4,773 | 4,769 | –0,00421 | –0,09% | 0,003624 | 0,003593 | –0,0000317 | –0,88% | 1,352 | 1,347 | –0,00453 | –0,34% |
| BE25 | WEST-VLAANDEREN | 3,836 | 3,811 | –0,02505 | –0,66% | 0,003018 | 0,002997 | –0,0000209 | –0,70% | 1,109 | 1,104 | –0,00477 | –0,43% |
| BE31 | BRABANT WALLON | 4,346 | 4,320 | –0,02584 | –0,60% | 0,002661 | 0,002608 | –0,0000528 | –2,03% | 1,029 | 1,032 | 0,00339 | 0,33% |
| BE32 | HAINAUT | 4,899 | 4,871 | –0,02809 | –0,58% | 0,003232 | 0,003210 | –0,0000215 | –0,67% | 1,263 | 1,267 | 0,00422 | 0,33% |
| BE33 | LIEGE | 4,468 | 4,355 | –0,11345 | –2,61% | 0,002888 | 0,002850 | –0,0000373 | –1,31% | 1,124 | 1,091 | –0,03302 | –3,03% |
| BE34 | LUXEMBOURG (B) | 4,830 | 4,678 | –0,15190 | –3,25% | 0,002816 | 0,002795 | –0,0000213 | –0,76% | 1,230 | 1,195 | –0,03500 | –2,93% |
| BE35 | NAMUR | 5,099 | 5,078 | –0,02111 | –0,42% | 0,003064 | 0,003047 | –0,0000177 | –0,58% | 1,347 | 1,341 | –0,00564 | –0,42% |
| **BE** | **AVERAGE** | 4,578 | 4,524 | –0,05469 | –1,43% | 0,002968 | 0,002925 | –0,0000423 | –2,05% | 1,207 | 1,198 | –0,00938 | –0,77% |
| | **MINIMUM** | 2,571 | 2,429 | –0,15190 | –5,88% | 0,000847 | 0,000768 | –0,0000790 | –10,29% | 0,578 | 0,578 | –0,03500 | –3,03% |
| | **MAXIMUM** | 5,434 | 5,402 | –0,00421 | –0,09% | 0,003651 | 0,003593 | –0,0000177 | –0,58% | 1,452 | 1,442 | 0,00422 | 0,33% |
| CZ01 | PRAHA | 3,517 | 3,674 | 0,15725 | 4,28% | 0,001709 | 0,001778 | 0,0000695 | 3,91% | 0,793 | 0,806 | 0,01263 | 1,57% |
| CZ020 | STREDOCESKY | 3,940 | 3,962 | 0,02149 | 0,54% | 0,002171 | 0,002121 | –0,0000505 | –2,38% | 0,927 | 0,932 | 0,00487 | 0,52% |
| CZ031 | JIHOCESKY | 4,459 | 4,163 | –0,29542 | –7,10% | 0,002709 | 0,002525 | –0,0001844 | –7,30% | 1,060 | 1,032 | –0,02851 | –2,76% |
| CZ032 | PLZENSKY | 4,094 | 3,931 | –0,16344 | –4,16% | 0,002322 | 0,002226 | –0,0000957 | –4,30% | 0,993 | 0,985 | –0,00728 | –0,74% |
| CZ041 | KARLOVARSKY | 4,321 | 4,092 | –0,22895 | –5,59% | 0,002589 | 0,002499 | –0,0000896 | –3,58% | 1,111 | 1,117 | 0,00605 | 0,54% |
| CZ042 | USTECKY | 4,555 | 4,444 | –0,11114 | –2,50% | 0,002463 | 0,002391 | –0,0000715 | –2,99% | 1,071 | 1,059 | –0,01209 | –1,14% |
| CZ051 | LIBERECKY | 4,327 | 4,339 | 0,01222 | 0,28% | 0,002916 | 0,002861 | –0,0000552 | –1,93% | 1,139 | 1,187 | 0,04758 | 4,01% |
| CZ052 | KRALOVEHRADECKY | 4,189 | 4,194 | 0,00519 | 0,12% | 0,002351 | 0,002362 | 0,0000107 | 0,45% | 1,005 | 1,006 | 0,00184 | 0,18% |
| CZ053 | PARDUBICKY | 4,054 | 4,163 | 0,10881 | 2,61% | 0,002288 | 0,002279 | –0,0000086 | –0,38% | 0,990 | 1,013 | 0,02334 | 2,30% |
| CZ061 | VYSOCINA | 4,168 | 3,986 | –0,18137 | –4,55% | 0,002647 | 0,002505 | –0,0001421 | –5,67% | 1,010 | 0,985 | –0,02527 | –2,57% |
| CZ062 | JIHOMORAVSKY | 4,018 | 3,990 | –0,02811 | –0,70% | 0,001741 | 0,001727 | –0,0000149 | –0,86% | 0,883 | 0,879 | –0,00358 | –0,41% |
| CZ071 | OLOMOUCKY | 3,916 | 3,967 | 0,05044 | 1,27% | 0,001892 | 0,001989 | 0,0000967 | 4,86% | 0,883 | 0,907 | 0,02383 | 2,63% |
| CZ072 | ZLINSKY | 4,214 | 4,259 | 0,04446 | 1,04% | 0,002051 | 0,002086 | 0,0000345 | 1,65% | 0,963 | 0,982 | 0,01896 | 1,93% |
| CZ080 | MORAVSKOSLEZSKY | 4,287 | 4,431 | 0,14405 | 3,25% | 0,002415 | 0,002512 | 0,0000972 | 3,87% | 1,061 | 1,085 | 0,02443 | 2,25% |
| **CZ** | **AVERAGE** | 4,147 | 4,114 | –0,03318 | –0,80% | 0,002305 | 0,002276 | –0,0000288 | –1,05% | 0,992 | 0,998 | 0,00620 | 0,59% |
| | **MINIMUM** | 3,517 | 3,674 | –0,29542 | –7,10% | 0,001709 | 0,001727 | –0,0001844 | –7,30% | 0,793 | 0,806 | –0,02851 | –2,76% |
| | **MAXIMUM** | 4,555 | 4,444 | 0,15725 | 4,28% | 0,002916 | 0,002861 | 0,0000972 | 4,86% | 1,139 | 1,187 | 0,04758 | 4,01% |
| DE3 | BERLIN | 2,731 | 2,705 | –0,02564 | –0,95% | 0,001093 | 0,001093 | 0,0000000 | 0,00% | 0,704 | 0,678 | –0,02618 | –3,86% |
| DE4 | BRANDENBURG | 3,415 | 3,501 | 0,08638 | 2,47% | 0,001495 | 0,001526 | 0,0000305 | 2,00% | 0,840 | 0,862 | 0,02220 | 2,57% |
| DE8 | MECKLENBURG-VORP. | 3,483 | 3,517 | 0,03423 | 0,97% | 0,001434 | 0,001478 | 0,0000438 | 2,96% | 0,841 | 0,865 | 0,02401 | 2,78% |
| DED | SACHSEN | 3,179 | 3,356 | 0,17669 | 5,26% | 0,001599 | 0,001658 | 0,0000594 | 3,58% | 0,780 | 0,822 | 0,04237 | 5,15% |
| DEE | SACHSEN-ANHALT | 3,052 | 3,062 | 0,00990 | 0,32% | 0,001188 | 0,001215 | 0,0000262 | 2,16% | 0,702 | 0,711 | 0,00880 | 1,24% |
| DEG | THUERINGEN | 2,925 | 3,023 | 0,09778 | 3,23% | 0,001349 | 0,001397 | 0,0000480 | 3,44% | 0,725 | 0,750 | 0,02589 | 3,45% |
| **DE** | **AVERAGE** | 3,131 | 3,194 | 0,06322 | 1,89% | 0,001360 | 0,001394 | 0,0000347 | 2,36% | 0,765 | 0,781 | 0,01618 | 1,89% |
| | **MINIMUM** | 2,731 | 2,705 | –0,02564 | –0,95% | 0,001093 | 0,001093 | 0,0000000 | 0,00% | 0,702 | 0,678 | –0,02618 | –3,86% |
| | **MAXIMUM** | 3,483 | 3,517 | 0,17669 | 5,26% | 0,001599 | 0,001658 | 0,0000594 | 3,58% | 0,841 | 0,865 | 0,04237 | 5,15% |
| FR101 | PARIS | 1,083 | 1,083 | 0,00000 | 0,00% | 0,000142 | 0,000142 | 0,0000000 | 0,00% | 0,052 | 0,052 | 0,00000 | 0,00% |
| FR102 | SEINE-ET-MARNE | 3,064 | 3,060 | –0,00388 | –0,13% | 0,001480 | 0,001478 | –0,0000021 | –0,14% | 0,711 | 0,726 | 0,01488 | 2,05% |
| FR103 | YVELINES | 3,667 | 3,636 | –0,03115 | –0,86% | 0,001861 | 0,001824 | –0,0000373 | –2,04% | 0,916 | 0,913 | –0,00332 | –0,36% |
| FR104 | ESSONNE | 2,973 | 2,967 | –0,00543 | –0,18% | 0,001599 | 0,001622 | 0,0000229 | 1,41% | 0,794 | 0,791 | –0,00238 | –0,30% |
| FR105 | HAUTS-DE-SEINE | 1,611 | 1,550 | –0,06111 | –3,94% | 0,000796 | 0,000759 | –0,0000368 | –4,84% | 0,257 | 0,220 | –0,03705 | –16,86% |
| FR106 | SEINE-SAINT-DENIS | 2,045 | 1,679 | –0,36688 | –21,86% | 0,000466 | 0,000400 | –0,0000658 | –16,46% | 0,317 | 0,203 | –0,11386 | –56,18% |
| FR107 | VAL-DE-MARNE | 2,214 | 2,214 | 0,00000 | 0,00% | 0,000575 | 0,000610 | 0,0000347 | 5,69% | 0,259 | 0,256 | –0,00292 | –1,14% |
| FR108 | VAL-D'OISE | 3,914 | 3,863 | –0,05105 | –1,32% | 0,001828 | 0,001795 | –0,0000337 | –1,88% | 0,907 | 0,895 | –0,01170 | –1,31% |
| FR211 | ARDENNES | 3,571 | 3,617 | 0,04559 | 1,26% | 0,001785 | 0,001790 | 0,0000054 | 0,30% | 0,884 | 0,890 | 0,00587 | 0,66% |
| FR212 | AUBE | 3,408 | 3,507 | 0,09827 | 2,80% | 0,001564 | 0,001604 | 0,0000398 | 2,48% | 0,738 | 0,745 | 0,00721 | 0,97% |

| NUTS | Name | Simple Diversity Index 1990 | 2000 | Diff. | Diff.(%) | Perimeter/Area Ratio 1990 | 2000 | Diff. | Diff.(%) | Shannon Index 1990 | 2000 | Diff. | Diff.(%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FR213 | MARNE | 3,201 | 3,339 | 0,13801 | 4,13% | 0,001199 | 0,001229 | 0,0000297 | 2,42% | 0,622 | 0,646 | 0,02407 | 3,73% |
| FR214 | HAUTE-MARNE | 3,620 | 3,749 | 0,12947 | 3,45% | 0,002203 | 0,002230 | 0,0000268 | 1,20% | 0,978 | 0,998 | 0,02024 | 2,03% |
| FR221 | AISNE | 3,535 | 3,537 | 0,00225 | 0,06% | 0,001870 | 0,001829 | –0,0000412 | –2,25% | 0,800 | 0,799 | –0,00107 | –0,13% |
| FR222 | OISE | 3,846 | 3,803 | –0,04340 | –1,14% | 0,001773 | 0,001765 | –0,0000084 | –0,48% | 0,820 | 0,821 | 0,00071 | 0,09% |
| FR244 | INDRE-ET-LOIRE | 4,407 | 4,428 | 0,02080 | 0,47% | 0,002382 | 0,002352 | –0,0000303 | –1,29% | 1,052 | 1,070 | 0,01778 | 1,66% |
| FR245 | LOIR-ET-CHER | 4,024 | 4,062 | 0,03737 | 0,92% | 0,002036 | 0,002036 | 0,0000000 | 0,00% | 0,913 | 0,923 | 0,00976 | 1,06% |
| FR246 | LOIRET | 3,570 | 3,583 | 0,01273 | 0,36% | 0,001825 | 0,001722 | –0,0001031 | –5,99% | 0,808 | 0,764 | –0,04443 | –5,82% |
| FR261 | COTE-D'OR | 3,687 | 3,738 | 0,05158 | 1,38% | 0,002117 | 0,002117 | 0,0000000 | 0,00% | 0,915 | 0,917 | 0,00209 | 0,23% |
| FR264 | YONNE | 3,699 | 3,797 | 0,09818 | 2,59% | 0,002104 | 0,002118 | 0,0000140 | 0,66% | 0,841 | 0,853 | 0,01264 | 1,48% |
| FR301 | NORD | 3,171 | 3,202 | 0,03188 | 1,00% | 0,001589 | 0,001600 | 0,0000108 | 0,68% | 0,717 | 0,729 | 0,01158 | 1,59% |
| FR412 | MEUSE | 3,447 | 3,510 | 0,06294 | 1,79% | 0,001910 | 0,001953 | 0,0000425 | 2,18% | 0,962 | 1,000 | 0,03736 | 3,74% |
| **FR** | **AVERAGE** | 3,227 | 3,234 | 0,00791 | –0,44% | 0,001576 | 0,001570 | –0,0000063 | –0,87% | 0,727 | 0,724 | –0,00250 | –2,99% |
| | **MINIMUM** | 1,083 | 1,083 | –0,36688 | –21,86% | 0,000142 | 0,000142 | –0,0001031 | –16,46% | 0,052 | 0,052 | –0,11386 | –56,18% |
| | **MAXIMUM** | 4,407 | 4,428 | 0,13801 | 4,13% | 0,002382 | 0,002352 | 0,0000425 | 5,69% | 1,052 | 1,070 | 0,03736 | 3,74% |
| IE011 | BORDER | 3,343 | 3,782 | 0,43935 | 11,62% | 0,001371 | 0,001560 | 0,0001891 | 12,12% | 0,771 | 0,849 | 0,07730 | 9,11% |
| IE012 | MIDLAND | 3,601 | 3,698 | 0,09703 | 2,62% | 0,001458 | 0,001527 | 0,0000692 | 4,53% | 0,736 | 0,770 | 0,03398 | 4,42% |
| IE013 | WEST | 3,258 | 3,691 | 0,43222 | 11,71% | 0,001448 | 0,001668 | 0,0002207 | 13,23% | 0,776 | 0,871 | 0,09534 | 10,95% |
| IE021 | DUBLIN | 2,690 | 2,691 | 0,00101 | 0,04% | 0,001787 | 0,001878 | 0,0000901 | 4,80% | 0,722 | 0,747 | 0,02581 | 3,45% |
| IE022 | MID-EAST | 3,194 | 3,289 | 0,09534 | 2,90% | 0,001652 | 0,001772 | 0,0001199 | 6,77% | 0,711 | 0,775 | 0,06406 | 8,27% |
| IE023 | MID-WEST | 3,324 | 3,665 | 0,34063 | 9,29% | 0,001281 | 0,001489 | 0,0002079 | 13,97% | 0,692 | 0,793 | 0,10069 | 12,70% |
| IE024 | SOUTH-EAST | 3,171 | 3,226 | 0,05444 | 1,69% | 0,001834 | 0,001934 | 0,0000997 | 5,15% | 0,742 | 0,792 | 0,05077 | 6,41% |
| IE025 | SOUTH-WEST | 3,304 | 3,490 | 0,18644 | 5,34% | 0,001580 | 0,001719 | 0,0001388 | 8,07% | 0,784 | 0,858 | 0,07363 | 8,58% |
| **IE** | **AVERAGE** | 3,236 | 3,442 | 0,20581 | 5,65% | 0,001551 | 0,001693 | 0,0001419 | 8,58% | 0,742 | 0,807 | 0,06520 | 7,98% |
| | **MINIMUM** | 2,690 | 2,691 | 0,00101 | 0,04% | 0,001281 | 0,001489 | 0,0000692 | 4,53% | 0,692 | 0,747 | 0,02581 | 3,45% |
| | **MAXIMUM** | 3,601 | 3,782 | 0,43935 | 11,71% | 0,001834 | 0,001934 | 0,0002207 | 13,97% | 0,784 | 0,871 | 0,10069 | 12,70% |
| IT2 | LOMBARDIA | 3,153 | 3,160 | 0,00730 | 0,23% | 0,001508 | 0,001520 | 0,0000120 | 0,79% | 0,734 | 0,738 | 0,00438 | 0,59% |
| IT4 | EMILIA-ROMAGNA | 2,879 | 2,924 | 0,04499 | 1,54% | 0,001691 | 0,001697 | 0,0000064 | 0,38% | 0,754 | 0,765 | 0,01054 | 1,38% |
| IT6 | LAZIO | 4,416 | 4,431 | 0,01494 | 0,34% | 0,002105 | 0,002112 | 0,0000070 | 0,33% | 1,083 | 1,085 | 0,00183 | 0,17% |
| IT8 | CAMPANIA | 5,055 | 5,066 | 0,01093 | 0,22% | 0,002340 | 0,002360 | 0,0000200 | 0,85% | 1,158 | 1,161 | 0,00252 | 0,22% |
| IT11 | PIEMONTE | 3,819 | 3,759 | –0,05971 | –1,59% | 0,001812 | 0,001742 | –0,0000694 | –3,99% | 0,965 | 0,940 | –0,02555 | –2,72% |
| IT12 | VALLE D'AOSTA | 4,231 | 4,232 | 0,00089 | 0,02% | 0,001891 | 0,001887 | –0,0000041 | –0,22% | 1,033 | 1,050 | 0,01679 | 1,60% |
| IT13 | LIGURIA | 3,462 | 3,422 | –0,04046 | –1,18% | 0,001449 | 0,001403 | –0,0000454 | –3,24% | 0,802 | 0,766 | –0,03548 | –4,63% |
| IT31 | TRENTINO-ALTO ADIGE | 4,251 | 4,249 | –0,00111 | –0,03% | 0,001929 | 0,001930 | 0,0000006 | 0,03% | 0,972 | 0,973 | 0,00062 | 0,06% |
| IT32 | VENETO | 3,211 | 3,218 | 0,00736 | 0,23% | 0,001789 | 0,001797 | 0,0000078 | 0,43% | 0,773 | 0,777 | 0,00309 | 0,40% |
| IT33 | FRIULI-VENEZIA GIULIA | 3,572 | 3,558 | –0,01480 | –0,42% | 0,001856 | 0,001874 | 0,0000175 | 0,94% | 0,845 | 0,852 | 0,00690 | 0,81% |
| IT51 | TOSCANA | 4,371 | 4,349 | –0,02263 | –0,52% | 0,002335 | 0,002328 | –0,0000075 | –0,32% | 0,989 | 0,977 | –0,01163 | –1,19% |
| IT52 | UMBRIA | 4,918 | 4,938 | 0,02055 | 0,42% | 0,002972 | 0,002981 | 0,0000090 | 0,30% | 1,181 | 1,188 | 0,00746 | 0,63% |
| IT53 | MARCHE | 5,138 | 5,135 | –0,00277 | –0,05% | 0,003689 | 0,003689 | 0,0000000 | 0,00% | 1,227 | 1,231 | 0,00393 | 0,32% |
| IT71 | ABRUZZO | 4,207 | 4,241 | 0,03420 | 0,81% | 0,001895 | 0,001914 | 0,0000189 | 0,99% | 1,072 | 1,081 | 0,00945 | 0,87% |
| IT72 | MOLISE | 3,862 | 3,899 | 0,03774 | 0,97% | 0,001731 | 0,001740 | 0,0000085 | 0,49% | 1,036 | 1,047 | 0,01109 | 1,06% |
| IT91 | PUGLIA | 3,286 | 3,292 | 0,00564 | 0,17% | 0,001372 | 0,001373 | 0,0000006 | 0,04% | 0,836 | 0,836 | 0,00000 | 0,00% |
| IT92 | BASILICATA | 4,971 | 4,980 | 0,00900 | 0,18% | 0,002333 | 0,002344 | 0,0000110 | 0,47% | 1,149 | 1,154 | 0,00557 | 0,48% |
| IT93 | CALABRIA | 5,236 | 5,281 | 0,04484 | 0,85% | 0,002302 | 0,002327 | 0,0000252 | 1,08% | 1,144 | 1,154 | 0,00987 | 0,86% |
| ITA | SICILIA | 4,370 | 4,375 | 0,00464 | 0,11% | 0,001748 | 0,001747 | –0,0000006 | –0,04% | 1,071 | 1,073 | 0,00227 | 0,21% |
| ITB | SARDEGNA | 4,161 | 4,181 | 0,02095 | 0,50% | 0,001786 | 0,001783 | –0,0000033 | –0,18% | 1,037 | 1,032 | –0,00412 | –0,40% |
| **IT** | **AVERAGE** | 4,128 | 4,135 | 0,00612 | 0,14% | 0,002027 | 0,002027 | 0,0000007 | –0,04% | 0,993 | 0,994 | 0,00098 | 0,04% |
| | **MINIMUM** | 2,879 | 2,924 | –0,05971 | –1,59% | 0,001372 | 0,001373 | –0,0000694 | –3,99% | 0,734 | 0,738 | –0,03548 | –4,63% |
| | **MAXIMUM** | 5,236 | 5,281 | 0,04499 | 1,54% | 0,003689 | 0,003689 | 0,0000252 | 1,08% | 1,227 | 1,231 | 0,01679 | 1,60% |
| LU | LUXEMBOURG (GD-DUCHE) | 3,962 | 4,478 | 0,51513 | 11,50% | 0,002000 | 0,002300 | 0,0003000 | 13,04% | 1,055 | 1,111 | 0,05650 | 5,08% |
| LV001 | RIGA | 4,674 | 4,809 | 0,13541 | 2,82% | 0,002006 | 0,002225 | 0,0002188 | 9,84% | 1,058 | 1,098 | 0,04062 | 3,70% |
| LV002 | VIDZEME | 4,713 | 4,763 | 0,05030 | 1,06% | 0,002819 | 0,002952 | 0,0001330 | 4,51% | 1,182 | 1,220 | 0,03752 | 3,08% |
| LV003 | KURZEME | 4,455 | 4,563 | 0,10846 | 2,38% | 0,002265 | 0,002524 | 0,0002591 | 10,27% | 1,090 | 1,156 | 0,06582 | 5,69% |
| LV004 | ZEMGALE | 4,693 | 4,842 | 0,14917 | 3,08% | 0,002479 | 0,002690 | 0,0002107 | 7,83% | 1,184 | 1,231 | 0,04664 | 3,79% |
| LV005 | LATGALE | 5,161 | 5,232 | 0,07121 | 1,36% | 0,003064 | 0,003093 | 0,0000290 | 0,94% | 1,380 | 1,395 | 0,01555 | 1,11% |
| **LV** | **AVERAGE** | 4,739 | 4,842 | 0,10291 | 2,14% | 0,002527 | 0,002697 | 0,0001701 | 6,68% | 1,179 | 1,220 | 0,04123 | 3,47% |
| | **MINIMUM** | 4,455 | 4,563 | 0,05030 | 1,06% | 0,002006 | 0,002225 | 0,0000290 | 0,94% | 1,058 | 1,098 | 0,01555 | 1,11% |
| | **MAXIMUM** | 5,161 | 5,232 | 0,14917 | 3,08% | 0,003064 | 0,003093 | 0,0002591 | 10,27% | 1,380 | 1,395 | 0,06582 | 5,69% |
| NL11 | GRONINGEN | 1,984 | 2,062 | 0,07748 | 3,76% | 0,000713 | 0,000725 | 0,0000120 | 1,66% | 0,479 | 0,489 | 0,00975 | 2,00% |
| NL12 | FRIESLAND | 1,896 | 2,033 | 0,13716 | 6,75% | 0,000612 | 0,000660 | 0,0000480 | 7,27% | 0,409 | 0,436 | 0,02636 | 6,05% |
| NL13 | DRENTHE | 3,126 | 3,282 | 0,15592 | 4,75% | 0,000996 | 0,001066 | 0,0000700 | 6,57% | 0,739 | 0,769 | 0,02934 | 3,82% |
| NL21 | OVERIJSSEL | 3,228 | 3,304 | 0,07585 | 2,30% | 0,001128 | 0,001138 | 0,0000100 | 0,88% | 0,810 | 0,847 | 0,03693 | 4,36% |
| NL22 | GELDERLAND | 3,472 | 3,493 | 0,02136 | 0,61% | 0,001323 | 0,001342 | 0,0000190 | 1,42% | 0,892 | 0,903 | 0,01069 | 1,18% |
| NL23 | FLEVOLAND | 2,411 | 2,442 | 0,03038 | 1,24% | 0,000731 | 0,000762 | 0,0000310 | 4,07% | 0,588 | 0,622 | 0,03402 | 5,47% |
| NL31 | UTRECHT | 2,963 | 3,034 | 0,07152 | 2,36% | 0,001126 | 0,001172 | 0,0000460 | 3,93% | 0,717 | 0,757 | 0,03967 | 5,24% |
| NL32 | NOORD-HOLLAND | 2,641 | 2,661 | 0,01953 | 0,73% | 0,001026 | 0,000980 | –0,0000460 | –4,69% | 0,674 | 0,687 | 0,01324 | 1,93% |
| NL33 | ZUID-HOLLAND | 2,758 | 2,847 | 0,08878 | 3,12% | 0,001026 | 0,001013 | –0,0000135 | –1,33% | 0,679 | 0,687 | 0,00862 | 1,25% |
| NL34 | ZEELAND | 2,708 | 2,767 | 0,05880 | 2,13% | 0,000824 | 0,000829 | 0,0000045 | 0,54% | 0,623 | 0,644 | 0,02089 | 3,24% |
| NL41 | NOORD-BRABANT | 3,295 | 3,312 | 0,01676 | 0,51% | 0,001326 | 0,001313 | –0,0000130 | –0,99% | 0,828 | 0,845 | 0,01691 | 2,00% |

| NUTS | Name | Simple Diversity Index 1990 | 2000 | Diff. | Diff.(%) | Perimeter/Area Ratio 1990 | 2000 | Diff. | Diff.(%) | Shannon Index 1990 | 2000 | Diff. | Diff.(%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NL42 | LIMBURG (NL) | 3,812 | 3,747 | –0,06440 | –1,72% | 0,001508 | 0,001495 | –0,0000135 | –0,90% | 0,969 | 0,980 | 0,01135 | 1,16% |
| **NL** | **AVERAGE** | 2,858 | 2,915 | 0,05743 | 2,21% | 0,001028 | 0,001041 | 0,0000129 | 1,53% | 0,701 | 0,722 | 0,02148 | 3,14% |
| | **MINIMUM** | 1,896 | 2,033 | –0,06440 | –1,72% | 0,000612 | 0,000660 | –0,0000460 | –4,69% | 0,409 | 0,436 | 0,00862 | 1,16% |
| | **MAXIMUM** | 3,812 | 3,747 | 0,15592 | 6,75% | 0,001508 | 0,001495 | 0,0000700 | 7,27% | 0,969 | 0,980 | 0,03967 | 6,05% |
| PL021 | BYDGOSKI | 4,223 | 4,226 | 0,00253 | 0,06% | 0,002010 | 0,002012 | 0,0000022 | 0,11% | 0,961 | 0,961 | –0,00043 | –0,04% |
| PL022 | TORUNSKO-WLOCLAWSKI | 4,108 | 4,041 | –0,06752 | –1,67% | 0,002079 | 0,002045 | –0,0000342 | –1,67% | 1,069 | 1,062 | –0,00655 | –0,62% |
| PL041 | GORZOWSKI | 3,350 | 3,369 | 0,01859 | 0,55% | 0,001195 | 0,001195 | 0,0000000 | 0,00% | 0,654 | 0,660 | 0,00558 | 0,85% |
| PL071 | CIECHANOWSKO-PLOCKI | 4,412 | 4,415 | 0,00233 | 0,05% | 0,002420 | 0,002422 | 0,0000018 | 0,07% | 1,105 | 1,105 | 0,00000 | 0,00% |
| PL0B1 | SLUPSKI | 3,871 | 3,843 | –0,02849 | –0,74% | 0,001622 | 0,001598 | –0,0000237 | –1,49% | 0,846 | 0,844 | –0,00213 | –0,25% |
| PL0B2 | GDANSKI | 3,966 | 3,939 | –0,02677 | –0,68% | 0,001563 | 0,001562 | –0,0000002 | –0,01% | 0,822 | 0,824 | 0,00229 | 0,28% |
| PL0B3 | GDANSK-GDYNIA-SOPOT | 4,065 | 3,906 | –0,15897 | –4,07% | 0,001746 | 0,001673 | –0,0000733 | –4,38% | 0,931 | 0,934 | 0,00370 | 0,40% |
| PL0E1 | ELBLASKI | 4,188 | 4,204 | 0,01582 | 0,38% | 0,001832 | 0,001827 | –0,0000046 | –0,25% | 1,023 | 1,024 | 0,00150 | 0,15% |
| PL0E2 | OLSZTYNSKI | 4,253 | 4,249 | –0,00452 | –0,11% | 0,002084 | 0,002087 | 0,0000035 | 0,17% | 1,067 | 1,067 | 0,00000 | 0,00% |
| PL0E3 | ELCKI | 4,109 | 4,111 | 0,00220 | 0,05% | 0,001759 | 0,001749 | –0,0000102 | –0,58% | 0,991 | 0,990 | –0,00104 | –0,10% |
| PL0F1 | PILSKI | 4,045 | 4,029 | –0,01651 | –0,41% | 0,001834 | 0,001830 | –0,0000048 | –0,26% | 0,890 | 0,885 | –0,00471 | –0,53% |
| PL0F5 | M. POZNAN | 4,500 | 4,500 | 0,00000 | 0,00% | 0,001717 | 0,001717 | 0,0000000 | 0,00% | 1,090 | 1,090 | 0,00000 | 0,00% |
| PL0G1 | SZCZECINSKI | 3,602 | 3,585 | –0,01740 | –0,49% | 0,001439 | 0,001422 | –0,0000173 | –1,22% | 0,796 | 0,790 | –0,00673 | –0,85% |
| PL0G2 | KOSZALINSKI | 4,181 | 4,153 | –0,02755 | –0,66% | 0,001779 | 0,001775 | –0,0000036 | –0,20% | 0,909 | 0,906 | –0,00262 | –0,29% |
| **PL** | **AVERAGE** | 4,063 | 4,041 | –0,02188 | –0,55% | 0,001791 | 0,001779 | –0,0000117 | –0,69% | 0,940 | 0,939 | –0,00080 | –0,07% |
| | **MINIMUM** | 3,350 | 3,369 | –0,15897 | –4,07% | 0,001195 | 0,001195 | –0,0000733 | –4,38% | 0,654 | 0,660 | –0,00673 | –0,85% |
| | **MAXIMUM** | 4,500 | 4,500 | 0,01859 | 0,55% | 0,002420 | 0,002422 | 0,0000035 | 0,17% | 1,105 | 1,105 | 0,00558 | 0,85% |
| **TOT** | **AVERAGE** | **3,770** | **3,794** | **0,02376** | **0,57%** | **0,001885** | **0,001899** | **0,0000134** | **0,73%** | **0,905** | **0,914** | **0,00963** | **0,64%** |
| | **MINIMUM** | **1,083** | **1,083** | **–0,36688** | **–21,86%** | **0,000142** | **0,000142** | **–0,0001844** | **–16,46%** | **0,052** | **0,052** | **–0,11386** | **–56,18%** |
| | **MAXIMUM** | **5,434** | **5,402** | **0,51513** | **11,71%** | **0,003689** | **0,003689** | **0,0003000** | **13,97%** | **1,452** | **1,442** | **0,10069** | **12,70%** |

# Land use and land cover trands in the Netherlands and Ireland based on CORINE Land Cover

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## Introduction

The Cardiff Integration Process is the process launched by European heads of state and government at the meeting in Cardiff, in June 1998 requiring the different European Councils to integrate environmental considerations into their respective activities. At subsequent meetings in Vienna (December 1998) and Helsinki (December 1999), the European Council required the Commission to report on the integration of environmental concerns into Community sectoral policies. Agri-environmental indicators (AEI) have been adopted as a tool to contribute to meeting reporting requirements to monitor environmental integration into agricultural policy. A set of AEIs was identified in the Communication from the Commission to the Council and European Parliament, COM (2000) 20, and this set, and the statistics and other information needed to realise the indicators, was the subject of a further Commission Communication COM (2001) 144.

There are two land use and land cover indicators listed in the COM (2001) 144: “Land use: (topological) change” and “Land cover change”, which are Driving Force and State indicators, respectively.

Land use change relates to land development activities that have an important impact on the environment and landscape. Land developments reflect the wish to change the environment to cater for and facilitate human activity, and are linked to economic growth. While providing socio-economic benefits such development activities may have negative environmental impacts. Therefore land use change represents a driving force that requires monitoring.

There are many land development activities resulting in land use change away from agriculture: housing, services and recreation, industrial and commercial sites, transport (motorways, railways, etc.), mines and waste dump sites.

The impact of increased land development activities for the agricultural sector is the socio-economic consequences of greater competition for land between agriculture and other sectors (e.g. urban, industry, commerce, tourism), resulting in higher land prices and more restricted access to land. The environmental relevance of land developments in agricultural areas is the effects of soil sealing on the landscape and nature (e.g. restriction of animal movement, loss of biodiversity, increased water runoff and changes to agricultural landscapes).

Land cover change focuses on the relationship between agriculture and forest/semi-natural land, and internal land cover changes within agriculture. The expansion of agricultural land at the expense of forest and semi-natural land is not likely to take place in EU-15 countries, as there are strict planning restrictions to conserve forest and semi-natural land areas. The expansion of forest and semi-natural land areas onto agricultural land occurs where there is abandonment of agricultural land, the introduction of agro-forestry, expansion of forest plantations, or expansion of nature conservation schemes.

## Methods

The data sources for developing both indicators are the CORINE Land Cover (CLC) databases 1990 and 2000. CLC 1990 and 2000 are geographic land cover /land use databases encompassing most countries of the European Union, the majority of Eastern European countries and parts of the Maghreb. CLC describes land cover (and partly land use) according to a nomenclature of 44 classes organised hierarchically in three levels.

The IRENA operation (Indicator Reporting on the Integration of Environmental Concerns into Agriculture Policy), which is managed and coordinated by the European Environment Agency (EEA), has developed these two indicators further on the basis of using CLC 1990 and 2000.

IRENA 12 - land use change has a headline and a sub- indicator. The headline indicator is defined as the area of land use change from agriculture to artificial surfaces between 1990 and 2000. The sub-indicator is defined as the sector share of land converted from agriculture to artificial surfaces.

IRENA 24 - land cover change, also has a headline and a sub-indicator. The headline indicator is defined as the area of the entries and exits to and from agricultural and forest/semi-natural land between 1990 and 2000. The sub-indicator is defined as the net arable and permanent crop and pastureland cover changes between 1990 and 2000.

The Land and Ecosystems ACcounts (LEAC) method is used to produce both IRENA No. 12 and No. 24 indicators. LEAC is developed on the basis of studies carried out during the mid-1990s by the United Nations Economic Commission for Europe - UNECE (UNECE, 1995). The core accounts are intended to provide a foundation to the overall framework according to the chain: land cover change matrix – land cover flows – land use – industries/activities that generate pressure.

The concept underlying LEAC is that, rather than using the classical change matrix between different years based on land cover nomenclature (Figure 1 top left), land cover flows are identified that depict land cover change processes with opening

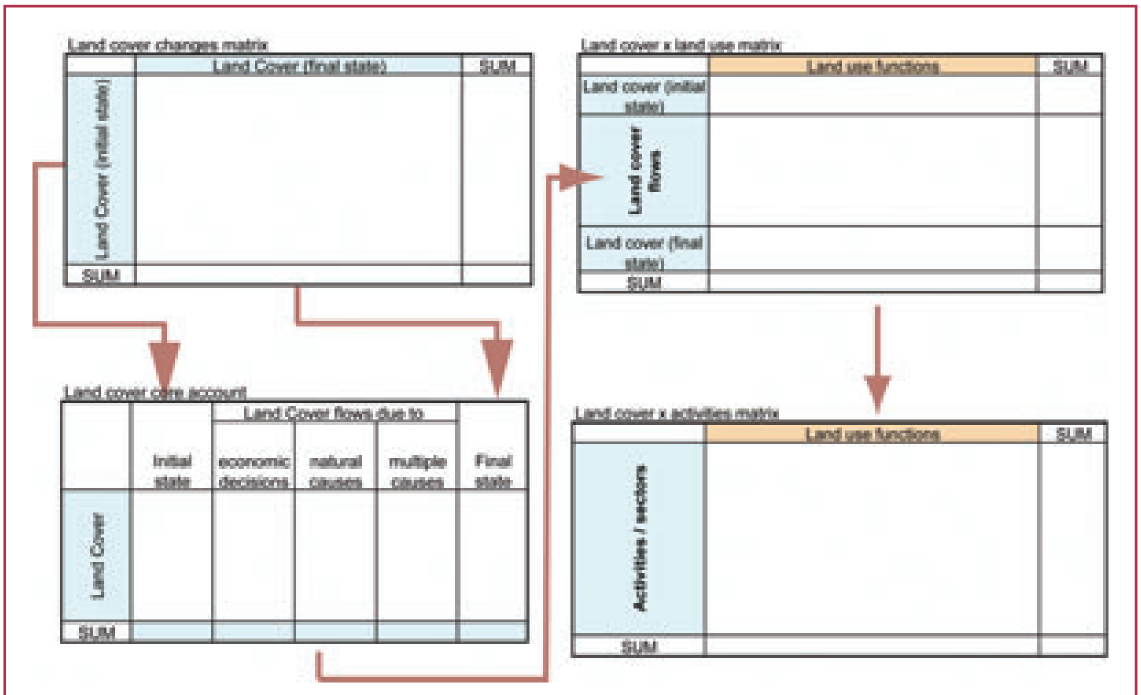


**Figure 1.** *Structure of the basic set of land cover/land use accounts*

and closing balances (Figure 1 bottom left). Land cover flows can be transformed to land use functions (Figure 1 top right), which in turn indicate the pressures generated by industries/activities (Figure 1 top right). Land cover flows relevant to IRENA 12 and 24 are used to produce indicators (i.e. making use of Figure 1 top and bottom left).

The current land use / land cover change database is developed on the basis of a 3 km by 3 km grid, which is superimposed on the CLC 2000 change database constructed on the basis of 5 ha land cover changes. The 3 km by 3 km generalisation results in inaccuracies in deriving area values for national and regional boundary regions, as well as the coastline. In the future a 1 km by 1 km generalisation will produce more precise accounts.

## Land use change

Artificial surfaces are subdivided into four sectors: housing, services and recreation; industrial & commercial sites; transport; and, mines and waste dumpsites. The land cover flows that are used to sum up the uptake of agricultural land by different sectors are listed in Table 1 with definitions. These land cover flows provide information of changes from CLC Class 2 – Agriculture to CLC Class 1 – Artificial surfaces.

**Table 1.** *Artificial surfaces broken down by sectors, with corresponding land cover flows*

| Sector | Land cover flow | Land cover flow definitions |
|---|---|---|
| Housing, services and recreation | LCF13 Development of green urban areas | Extension of green urban areas over developed land as well as, in the periphery of cities, over other types of land uses. |
| | LCF21 Urban contiguous residential sprawl | Conversion from non-urban land to continuous urban fabric (CLC 111). |
| | LCF22 Urban scattered residential sprawl | Conversion from non-urban land to discontinuous urban fabric (CLC 112). |
| | LCF38 Sprawl of sports and leisure facilities | Conversion from developed as well as non-urban land to sports and leisure facilities. |
| Industrial & commercial sites | LCF31 Sprawl of industrial & commercial sites | Conversion from non-urban land to industrial and commercial sites |
| | LCF37 Construction | Extension over non-urban land of areas under construction during the period (note: covers mainly construction of economic sites and infrastructures). |
| Transport | LCF32 Sprawl of transport networks | Conversion from non-urban land to transport networks (note that linear features narrower than 100 m are not monitored by CLC). |
| | LCF33 Sprawl of harbours | Conversion from non-urban land and sea to harbours. |
| Mines and waste dumpsites | LCF34 Sprawl of airports | Conversion from non-urban land and sea to airports |
| | LCF35 Sprawl of mines and quarrying areas | Conversion from non-urban land to mines and quarrying areas. |

## Land cover change

The land cover flows used to derive the area of the entries and exits to and from agricultural and forest/semi-natural land are listed in Table 2. The exits from agricultural to forest/semi-natural land are determined by a summation of the following land cover flows: LCF47, LCF511, LCF512, LCF521, LCF 522, and LCF53. The entries from forest/semi-natural land to agricultural land are determined by a summation of the following land cover flows: LCF61 LCF62 LCF72. The difference between "exits" and "entries" indicates the general land cover change flow direction between agricultural and forest/semi-natural land.

**Table 2.** *Land cover flows used to derive the area of the entries and exits to and from agricultural and forest/semi-natural land*

| Land cover flow | Land cover flow definitions |
|---|---|
| LCF47 Change of agricultural land to agro-forestry | Change of cultivated land and open pasture to agro-forestry systems such as dehesas (note: conversion from 243, where natural vegetation is important, is recorded under lcf522). |
| LCF511 Contiguous conversion from forest to agriculture | Deforestation, including agricultural conversion of transitional woodland shrub, for cultivation of annual and permanent crops (incl. in association, CLC241). |
| LCF512 Scattered conversion from forest to agriculture | Conversion from uniform forest to complex cultivation patterns, mosaic agricultural landscape and agro-forestry. Due to possible uncertainties in monitoring extension of pasture vs. recent fellings, conversion from forests to pasture land (CLC231) is recorded here. |
| LCF521 Contiguous land cover change from semi-natural land to agriculture | Land cover change from dry semi-natural land (except CLC324, grouped with forests) to annual crops, permanent crops and their association. |
| LCF522 Scattered land cover change from semi-natural land to agriculture | Scattered land cover change from dry semi-natural land (except CLC324, grouped with forests) to pasture and mixed agriculture with pasture. |
| LCF53 Land cover change from wetlands to agriculture | Land cover change from wetlands to any type of farmland (CLC2). |
| LCF61 Land cover change from agriculture land to forest and woodland (incl. Transitional woodland shrub) | Land cover change from agriculture land to forest and woodland (incl. transitional woodland shrub). |
| LCF62 Land cover change from agriculture land to non-seeded grasslands, heath and shrub land | Land cover change from agriculture land to non-seeded grasslands, heath and shrub land. |
| LCF72 Forest creation, afforestation | Forest creation and afforestation take place on all previously non-agricultural landscapes where new forests can be identified. Extension of transitional woodland shrub over non-agricultural land is recorded as afforestation. Conversion from transitional woodland to broadleaved, coniferous or mixed forests are not a creation of forest territory and are therefore registered separately (lcf71). |

The land cover flows used to derive net arable land and pasture land cover changes are listed in Table 3. Net pasture land cover change is derived by subtracting LCF46 (CLC 1990) from LCF41 (CLC2000), whereas net arable and permanent crop land cover change is derived by subtracting LCF41 (CLC 1990) from LCF46 (CLC 2000).

**Table 3.** *Land cover flows used to derive net arable and permanent cropland and pasture land cover changes*

| Land cover flow | Land cover flow definitions |
|---|---|
| LCF - 41 Extension of set-aside and pasture land | Land cover change from cropland to grassland as an agricultural rotation or for cattle husbandry. |
| LCF - 46 Change of pasture land to arable and permanent crop land | Land cover change from pasture to arable and permanent crops |

## Results and discussion

### IRENA 12 - area of land use change from agriculture to artificial surfaces between 1990 and 2000

In Ireland, the total area of land use change from agriculture to artificial surfaces between 1990 and 2000 was 31107 ha, which represents a percentage change from agriculture of 0.7%. Regional indicators show that the area of land use change from agriculture to artificial surfaces varies between administrative regions (Figure 2). The region with the largest relative area of land use change from agriculture to artificial surfaces is Dublin (IE021, 5542 ha, 11.2% of agricultural area). The land use change from agriculture to artificial surfaces, presented as a percentage of agricultural area, ranges from 0.4% (West, IE013) to 1.2% (Mid-East, IE022).

In the Netherlands, the total area of land use change from agriculture to artificial surfaces between 1986 and 2000 was 80807 ha, which represents a percentage change from agriculture of 4.3%. Regional indicators show that the area of land use change from agriculture to artificial surfaces varies between administrative regions (Figure 3). The regions with the largest relative area of land use change from agriculture to artificial surfaces are Utrecht (NL31, 5074 ha, 5.8% of agricultural area) and Zuid-Holland (NL33, 10396 ha, 5.4% of agricultural area). The regions with the smallest relative area of land use change from agriculture to artificial surfaces are Zeeland (NL34, 3018 ha and 2.0% of agricultural area), Friesland (NL12, 5928 ha and 2.4% of agricultural area) and Groningen (NL11, 3943 ha and 1.9% of agricultural area).

In general, there is relatively much more agricultural land lost to artificial surfaces in the Netherlands than in Ireland.

### IRENA 12 - the sector share of land converted from agriculture to artificial surfaces between 1990 and 2000

This sub-indicator shows that the two most important sectors encroaching on agricultural land in the Netherlands and Ireland are housing, services and recreation and industrial and commercial sites – totalling 96% and 90%, respectively.

In general the housing, services and recreation sector is more dominant in Ireland (Figure 2) than in the Netherlands (Figure 3) in comparison with the other three sectors identified. Industrial and commercial sites take a greater role in the Netherlands than in Ireland – 35% and 14%, respectively. On a regional basis the percentage share of the total area change from agriculture to artificial surfaces for the housing, services and recreation sector ranges from 50% (NL42 – Limburg) to 71% (NL13 – Drenthe) in the Netherlands, and from 68% (IE022 – Mid East) to 84% (IE013 – West) in Ireland. In terms of industrial and commercial sites, the percentage share of the total area change from agriculture to artificial surfaces ranges from 24% (NL13 – Drenthe) to 46% (NL42 – Limburg) in the Netherlands, and from 5% (IE013 – West) to 24% (IE021 – Dublin) in Ireland.

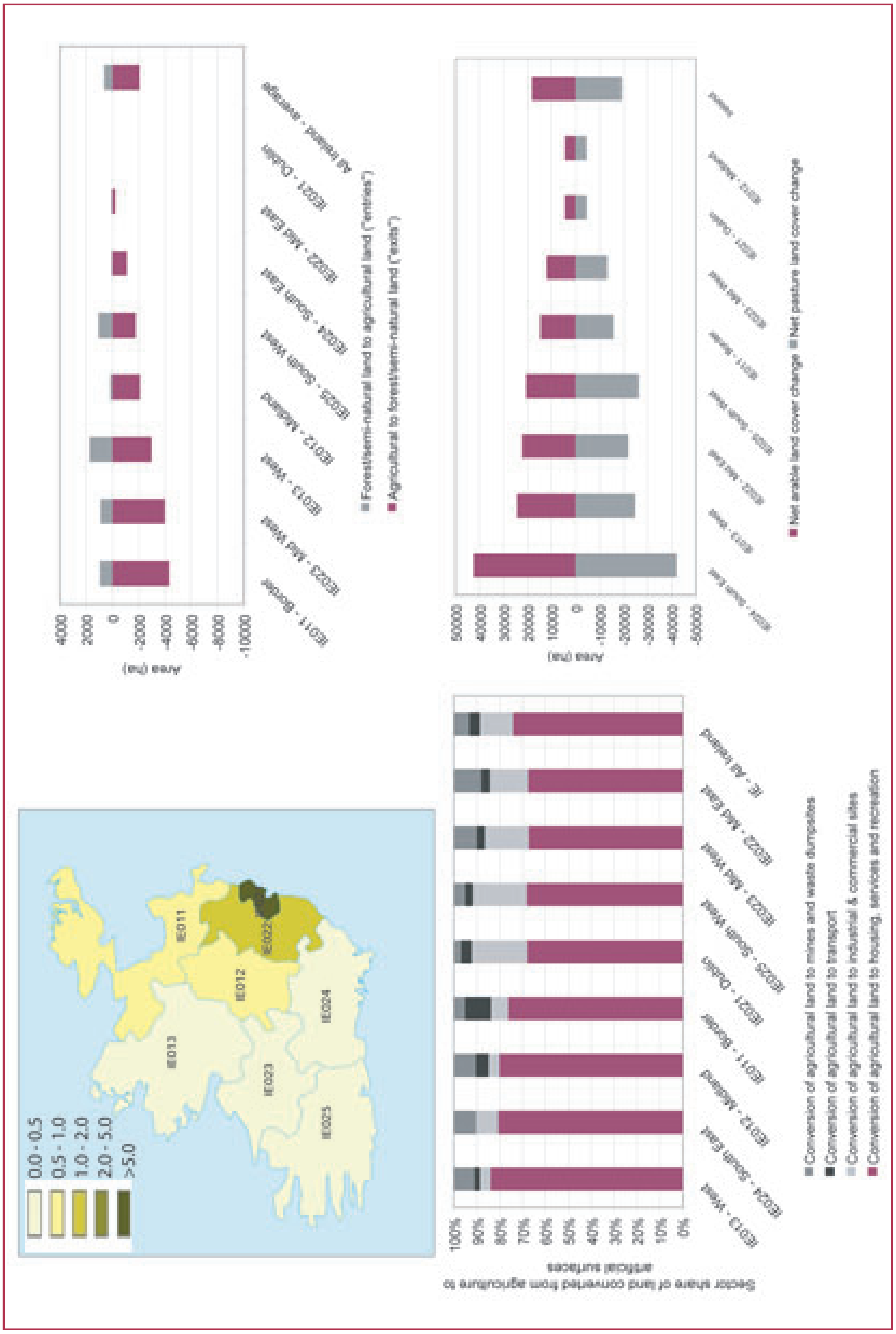


**Figure 2.** *Regional indicators for Ireland: Top Left - Regional map of the area of land use change from agriculture to artificial surfaces between 1990 and 2000, Bottom Left - Sector share of land converted from agriculture to artificial surfaces, Top Right - The area of the entries and exits to and from agricultural and forest/semi natural land between 1990 and 2000, Bottom right - Net arable land and pasture land cover changes between 1990 and 2000*

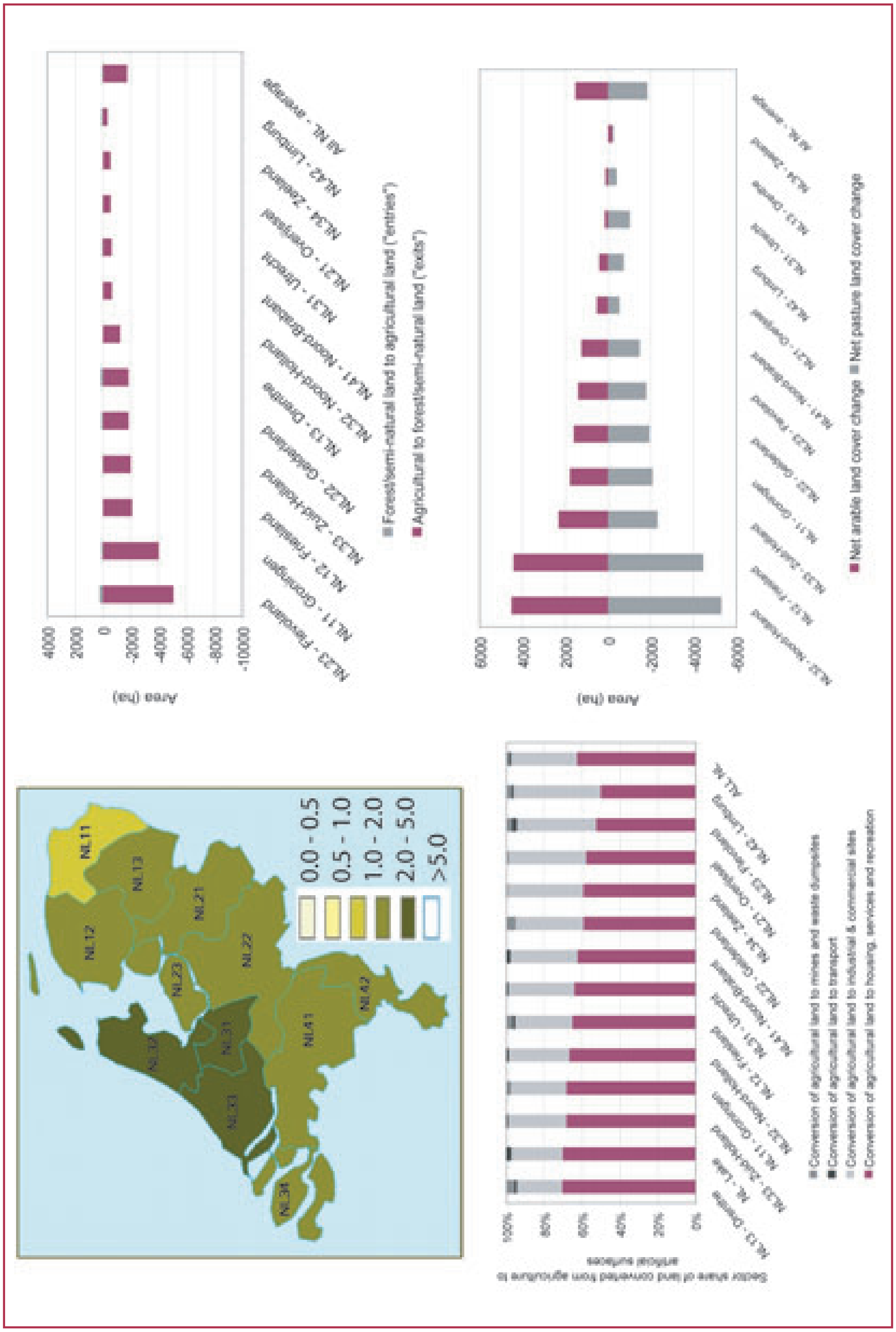


**Figure 3.** *Regional indicators for the Netherlands: Top Left - Regional map of the area of land use change from agriculture to artificial surfaces between 1990 and 2000, Bottom Left - Sector share of land converted from agriculture to artificial surfaces, Top Right - The area of the entries and exits to and from agricultural and forest/semi natural land between 1990 and 2000, Bottom right - Net arable land and pasture land cover changes between 1990 and 2000*

### IRENA 24 - the area of the entries and exits to and from agricultural and forest/semi-natural land between 1990 and 2000

In Ireland, the change in land cover results in a clear flow from agricultural to forest and semi-natural land between 1990 and 2000. In all regions, apart from Dublin (IE021), more forest/semi-natural land has developed on agricultural land between 1990 and 2000, than the other way round. However, there are major regional differences. The Border (IE011) region has seen the largest expansion of forest/semi-natural land onto agricultural land (4318 ha forest/semi-natural to agricultural land, 945 ha agricultural to forest/semi-natural land). On the other hand, the Mid East (IE022) region has seen the smallest expansion (220 ha forest/semi-natural to agricultural land, 51 ha agricultural to forest/semi-natural land). In Dublin (IE021), there is no detected entries or exits to and from agricultural and forest/semi-natural land.

In the Netherlands, the change in land cover results in a clear flow from agricultural to forest and semi-natural land between 1986 and 2000. In all regions more forest/semi-natural land has developed on agricultural land between 1986 and 2000, than the other way round. However, there are major regional differences. The Flevoland (NL23) region has seen the largest expansion of forest/semi-natural land onto agricultural land (5057 ha forest/semi-natural to agricultural land, 237 ha agricultural to forest/semi-natural land). On the other hand, the Limburg (NL42) region has seen the smallest expansion (318 ha forest/semi-natural to agricultural land, 104 ha agricultural to forest/semi-natural land).

### IRENA 24 - the net arable and permanent crop and pastureland cover changes between 1990 and 2000

In Ireland, the total net arable and permanent cropland cover change between 1990 and 2000 is 145,448 hectares and the total net pastureland cover change is –152,951 hectares. So there is a net increase in arable and permanent cropland and a net decrease in pastureland. There are considerable regional differences: the largest change is detected in South East (IE024, net arable and permanent crop land cover change is 42,487 hectares, net pasture land cover change is –42,206 hectares), whereas the smallest change is detected in Midland (IE012, net arable and permanent crop land cover change is 4,402 hectares, net pasture land cover change is –4,470 hectares).

The ploughing up of permanent grassland for arable production during the 1990s is supported by Farm Structure Survey data, which indicates that the arable area has increased by 535,330 ha. Although the absolute are values are different, it is clearly shown that satellite information can be used to identify general land cover trends.

In the Netherlands, the total net arable and permanent cropland cover change between 1986 and 2000 is 18,249 hectares and the net pastureland cover change is –22,007 hectares. So there is a small net increase in arable and permanent cropland and a small net decrease in pastureland.

## Conclusions

In the Netherlands, the total area of land use change from agriculture to artificial surfaces between 1986 and 2000 was 80,807 ha, which represents a percentage change from agriculture of 3.2%. In Ireland, the total area of land use change from agriculture to artificial surfaces between 1990 and 2000 was 31107 ha, which represents a percentage change from agriculture of 0.7%. Regional indicators show that the area of land use change from agriculture to artificial surfaces varies between administrative regions. Administrative regions with large conurbations tend to have larger areas of land that have been converted from agriculture to artificial surfaces than more rural regions.

The housing, services and recreation sector is the highest and industrial and commercial sites are the second highest sector share of land converted from agriculture to artificial surfaces. There are regional variations of this indicator with industrial and commercial sites taking a more prominent role in regions with large conurbations. In general, mines and waste dump sites take a more dominant role in Ireland than in the Netherlands.

In Ireland and the Netherlands the change in land cover results in a strong flow from agricultural to forest/semi-natural land between 1990 and 2000. Regional differences are quite pronounced in both Ireland and the Netherlands. In regard to internal land cover changes within agriculture there are larger net arable and permanent crop and pasture land cover changes in Ireland than in the Netherlands. In Ireland there is a strong net increase in arable and permanent cropland and a net decrease in pastureland.

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# The effect of the delineation as Natura 2000 region on land cover change

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## 1. Introduction

The NATURA 2000 network is one of the main instruments of the European Union to implement a coherent nature conservation policy in the Member States. The network has been built gradually over the last 10 years and will contain at the end at least 25.000 sites, covering more than 15% of the territory. These so called NATURA 2000 sites can be of two different types: the Special Protection Areas (SPA's) for protection of wild birds as defined in the Birds Directive[1], and the Sites of Community Importance (SCI's) for the conservation of natural habitats and wild fauna and flora as defined by the Habitats directive[2]. The SPA's are designated by the Member States; the SCI's are proposed by the Member States and must be approved by the Commission after a scientific evaluation in the respective Bio-geographical Committees.

The 15 'old' Member States (already a member before 2004 May 1$^{st}$) proposed until now 15.724 Sites of Community Importance covering some 45,78 million ha[3]. Within 6 years of the adoption of the SCI's, each Member State must take the necessary measures to protect and manage them. From then on, the SCI's will become Special Areas of Conservation (SAC's). They must be monitored to be able to detect timely the evolution of the conservation status of the values for which the site has been designated. For each of the individual sites information is gathered regarding their status: species to be found, natural habitats covering the area, activities in or around the site affecting it, etc. This information is stored in a descriptive database, managed by the European Topic Centre for Nature Protection and Biodiversity in Paris.

Information about the Land Cover and Land Use are very important elements to monitor sites. The EC has launched a program to monitor land cover in the EU at a regular basis (every 10 years): Corine Land Cover (CLC). In this article, the CLC datasets of 1990 and 2000 will be used to evaluate land cover change in- and outside Natura2000 regions. The basic idea is that the majority of the Natura2000 sites is delineated in the period 1990-2000 and that the changes between 1990 and 2000 in- and outside Natura2000 regions will give an indication of the influence of the protection of the Natura2000 regions on land cover change.

In most EU(15) - countries, the majority of the Natura2000 sites were delineated between 1990 and 2000, but a part of the sites was delineated after 2000. The land cover change in these sites can of course not be assigned to the protection of the region in the framework of Natura2000. Since the area compiled after 2000 is rather limited, all sites were included in this pilot study, irrespective their compilation date.



[1] Birds Directive: Council Directive 79/409/EEC on the conservation of wild birds.

[2] Habitats Directive: Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora.

[3] Data based on the descriptive database version December 2003.

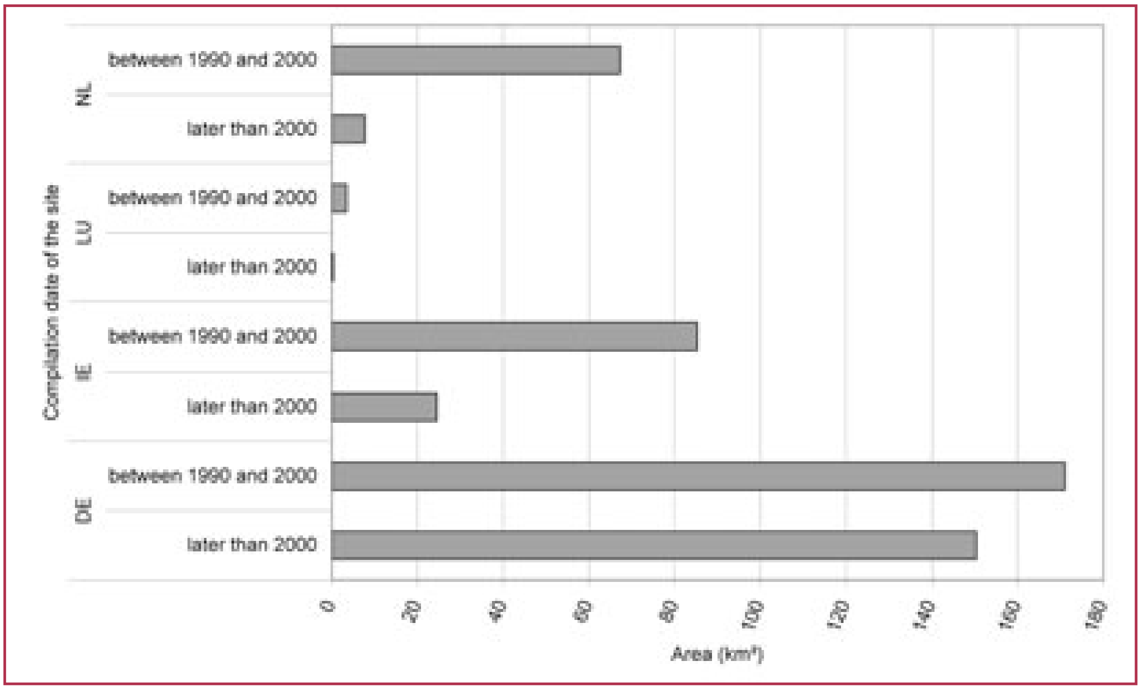



**Figure 1.** *Compilation date of the Natura2000 sites in the different countries*





Figure 1 shows which area of Natura2000 sites was delineated in which year for the 4 different countries used in this pilot study. In Germany, a considerable part of the total Natura2000 – area was compilated in (and after) 2000. In Ireland, Luxembourg and the Netherlands, the majority of the sites is delineated between 1990 and 2000. It should be underlined that the NATURA 2000 data used are not yet validated, nor are they approved by the Commission. The results can therefore only be seen as results from an exploratory exercise.

The CLC 1990 and 2000 are not based on Land cover data of exactly the years 1990 and 2000. The date of image acquisition varies between countries. Table 1 gives an overview of the acquisition period for the satellite data used for the CLC1990 inventory in the different countries. CLC2000 is based on the Image2000 images. This coverage consists mainly of images from the summer period of year 2000, complemented with images from 1999 and 2001 where needed.

**Table 1.** *Acquisition period for the satellite data used for the CLC1990 inventory*

| Country | Acquisition period for the satellite data used for the CLC inventory |
|---|---|
| DE | Mainly 1989, 1990. Along Eastern border1991. To fill gaps: 1992. |
| IE | 1989 (May), 1990 (April, May) |
| LU | 1989 |
| NL | 1986 |

## 2. Objective and Problem statement

The objective of this article was to analyze the impact of the delineation of Natura2000 sites on the land cover change between 1990 and 2000. For this article, we explored the land cover change inside and outside the Natura2000 sites of Ireland, the Netherlands, Luxembourg and the 6 Länder in the eastern part of Germany (Berlin, Mecklenburg-Vorpommern, Sachsen, Sachsen-Anhalt, Thüringen and Brandenburg). These countries/regions were first of all selected because they are the only ones where

NATURA 2000 sites and Corine Land Cover data from 1990 and 2000 are available at the time of writing (June 2004). CLC2000 is also available for some new Member States, but it is not useful to look at the influence of NATURA 2000 sites on the Land Cover change in these 'new' member states because the NATURA 2000 sites were not delineated yet between 1990 and 2000.

When relating information from different data sources, i.e. NATURA 2000 database and Corine Land Cover, we should pay attention to the different nature and scale of these databases. The NATURA 2000 sites were defined at a scale level of 1/100.000. There are some exceptions: very large sites were sometimes defined at scales 1/250.000 or 1/500.000, while very small sites and the most recent sites/datasets were often defined at scales 1/25.000 and even 1/10.000. The resolution will be in general around 100 meter. In general, the NATURA 2000 database is reliable and quite accurate.

The delineation of the Natura2000 sites used in this article is not the final one. In most countries, the designation process is still ongoing; new sites are still added and existing ones are changing.

# 3. Land Cover change inside and outside Natura2000 sites

## 3.1 Method

### 3.1.1. *Aggregation of classes CLC*

The Corine Land Cover distinguishes 43 land cover classes. In the framework of this explorative study concerning the evolution of land cover inside and outside NATURA 2000 sites, these 43 land cover classes were aggregated into 21 classes (Willems et al, 2002). Artificial surfaces and agricultural areas were aggregated to level 1 (no sub-classes); for forests, (semi)-natural areas and continental waters, the most detailed subclasses of CLC are used (level 3). Marine waters are left out from the classification. The 21 land cover classes used in this study are shown in Table 2.

**Table 2.** *Aggregated Land Cover classes as used in this study*

| Aggregated Land Cover classes | | | |
|---|---|---|---|
| 1. | Artificial surfaces | 4. | *Wetlands* |
| 2. | Agricultural Areas | 4.1.1. | Inland marshes |
| 3. | *Forest and semi-natural areas* | 4.1.2. | Peat bogs |
| 3.1.1. | Broad-leaved forest | 4.2.1. | Salt marshes |
| 3.1.2. | Coniferous forest | 4.2.2. | Salines |
| 3.1.3. | Mixed forest | 4.2.3. | Intertidal flats |
| 3.2.1. | Natural grassland | 5. | *Inland waters* |
| 3.2.2. | Moors and heathland | 5.1.1. | Water coarses |
| 3.2.3. | Sclerophyllous vegetation | 5.1.2. | Lakes |
| 3.2.4. | Transitional woodland shrub | | |
| 3.3.1. | Beaches, dunes and sand plains | | |
| 3.3.2. | Bare rock | | |
| 3.3.3. | Sparsely vegetated areas | | |
| 3.3.4. | Burnt areas | | |
| 3.3.5. | Glaciers and perpetual snow | | |

### 3.1.2. *Size of Natura2000 sites*

The threshold for delineation of separate Corine Land Cover units is 25 ha. This is a rather large area, compared to the area of some NATURA 2000 sites. Although some sites have an area smaller than the reference unit of CLC (25 ha) we did not exclude those sites. Many Natura2000 sites are bordering each other, resulting in a larger area than described by the official area values of the individual sites. Furthermore some so called large sites are composed of many small polygons. Also rivers with a very irregular shape would need special attention. Considering all this in detail would lead to very time consuming research resulting in a negligible improvement of precision considering the large mapping units of the CLC.

### 3.1.3. *Reference grid*

Similarly to the methodology used by Willems et al (2002), we defined a reference grid composed of small uniform squares of 3 by 3 km, thus with an area value of 9 $km^3$ and a perimeter of 12 km. For each square of the reference grid, four land cover change indicators were calculated (cfr infra).

### 3.1.4. *Reference squares at the border*

A difficulty to be conquered concerned the squares of the reference grid at the border of the country. At the border, not the whole area of the reference units is covered by CLC polygons, meaning that using a reference area value of 9 $km^2$ and/or reference perimeter of 12 km would be incorrect. Therefore the real reference area and real reference perimeter is calculated for the “border reference units”.

In Figure 2 an overlay is shown of the grid and the surface (total CLC area) of Ireland. Figure 3 shows an enlargement of the marked black rectangle on Figure 2.

### 3.1.5. *Whole country versus Natura2000 sites only*

All indicators have been calculated twice: for the whole country and for the Natura2000 sites only. The intersections of the different layers are drawn schematically below.

**Figure 2.** *Overlay of the grid and the total CLC area of Ireland. An enlargement of the marked rectangle is shown in the figure on the right*

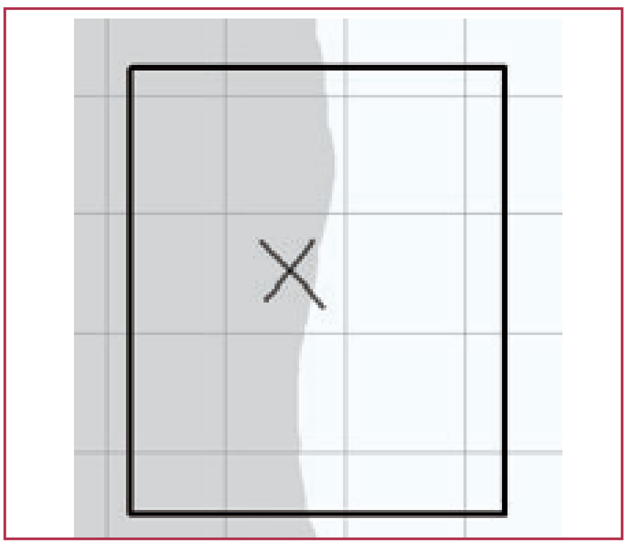


**Figure 3.** *Enlargement of some border reference squares. The square marked by “x” is not completely covered by CLC area (marked by the light grey background). The real reference values here are: for the area 6,8 $km^3$ and for the perimeter 10,6 km.*

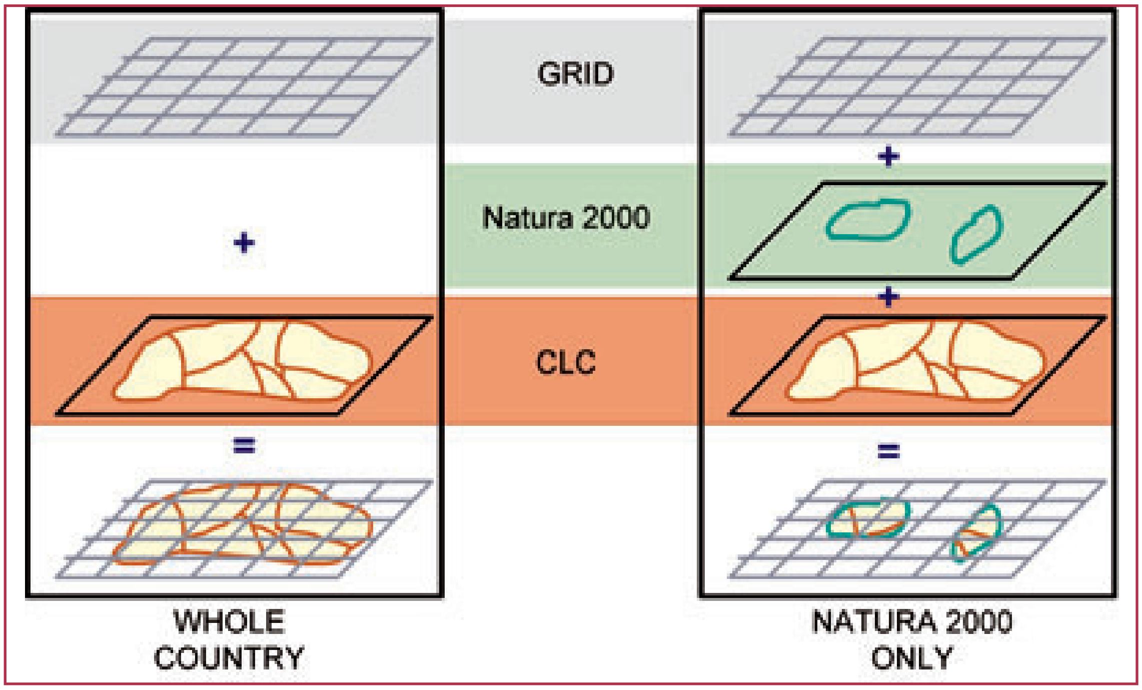



**Figure 4.** *Schematic overview of the combined layers for the calculation of indicators for the whole country (left) versus the Natura2000 sites only (right)*

We made an intersection of the total CLC area and the Natura2000 sites, resulting in reduced reference areas for the Natura2000 sites (compare Figure 5 and Figure 7).

If no intersection between a cell of the reference grid and a Natura2000 area was found, all indicator values for that cell were set equal to “-1”.

### 3.1.6. *Land cover change indicators*

The indicators used to assess land cover change between 1990 and 2000 are:

- total area (share) per land cover class (see §3.2.1)
- number of land cover classes (see §3.2.2)
- Shannon Diversity Index (see §3.2.2)
- Perimeter Area Ratio or Edge Density (see §3.2.2)

**Figure 5.** *Detailed view of the reference squares as used for the whole country*

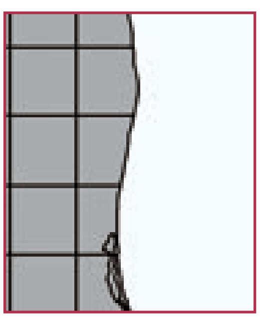


**Figure 6.** *Detailed view of the aggregated CLC classes within the reference reference squares of the whole country*

**WHOLE COUNTRY**

**Figure 7.** *Detailed view of the reduced (Natura2000 only) reference areas*

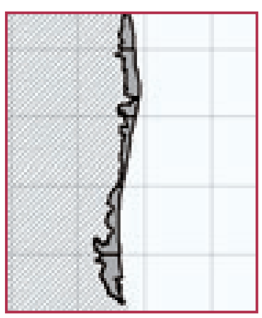
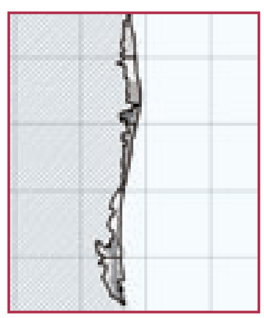


**Figure 8.** *Detailed view of the aggregated CLC classes within the reference areas of the Natura2000 area*



**NATURA2000 SITES ONLY**

### 3.1.7. *Software*

The spatial analysis was elaborated using ArcGis 8.3. The algorithms program code is written in VBA including the ArcObjects library (ESRI ©).

## 3.2. Results

The first way to assess land cover changes is simply by looking at the total area share per land cover class in 1990 and 2000. The percentage taken by each (aggregated) land cover class is given in Table 3 (Ireland), Table 5 (Germany), Table 8 (the Netherlands) and Table 11 (Luxembourg). The evolution of the area share per land cover class is graphically shown in Figure 9 (Ireland), Figure 10 (Germany), Figure 11 (Netherlands) and Figure 12 (Luxembourg). The different figures show a different behaviour of the land cover change in NATURA 2000 sites compared to the overall evolutions in land cover in the region/country.

### 3.2.1 *Changes in area share per land cover class*

#### 3.2.1.1 Ireland

The (evolution of) the area share per aggregated land cover class in Ireland is given in Table 3 and Figure 9.

**Table 3.** *Area share per land cover class in Ireland*

| Aggregated land cover class | | Ireland | | | | | |
|---|---|---|---|---|---|---|---|
| | | Total 1990 (%) | Total 2000 (%) | Evolution Total (%) | N2k sites 1990 (%) | N2k sites 2000 (%) | Evolution N2k sites (%) |
| 100 | Artificial surfaces | 1,46 | 1,92 | 0,45 | 0,33 | 0,42 | 0,08 |
| 200 | Agricultural Areas | 67,79 | 67,17 | -0,62 | 11,49 | 11,43 | -0,05 |
| 311 | Broad-leaved forest | 0,44 | 0,44 | 0,00 | 0,99 | 1,02 | 0,03 |
| 312 | Coniferous forest | 3,53 | 3,44 | -0,09 | 1,27 | 1,28 | 0,00 |
| 313 | Mixed forest | 0,33 | 0,32 | -0,02 | 0,53 | 0,50 | -0,03 |
| 321 | Natural grassland | 1,33 | 1,32 | -0,01 | 5,96 | 6,09 | 0,13 |
| 322 | Moors and heath land | 0,84 | 0,83 | -0,01 | 1,80 | 1,79 | 0,00 |
| 324 | Transition Woodland shrub | 3,06 | 4,83 | 1,77 | 1,82 | 2,38 | 0,56 |
| 331 | Beaches, dunes and sand plains | 0,20 | 0,20 | 0,00 | 1,46 | 1,43 | -0,03 |
| 332 | Bare rock | 0,24 | 0,24 | 0,00 | 2,16 | 2,16 | 0,00 |
| 333 | Sparsely vegetated areas | 0,29 | 0,29 | 0,00 | 2,16 | 2,16 | 0,00 |
| 334 | Burnt areas | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| 411 | Inland marshes | 0,26 | 0,25 | -0,01 | 0,87 | 0,83 | -0,04 |
| 412 | Peat bogs | 17,65 | 16,20 | -1,45 | 50,35 | 49,79 | -0,56 |
| 421 | Salt marshes | 0,04 | 0,04 | 0,00 | 0,31 | 0,31 | 0,00 |
| 423 | Intertidal flats | 0,64 | 0,64 | 0,00 | 5,04 | 5,05 | 0,00 |
| 511 | Water courses | 0,14 | 0,14 | 0,00 | 0,81 | 0,81 | 0,00 |
| 512 | Lakes | 1,75 | 1,74 | -0,02 | 12,65 | 12,55 | -0,10 |

No values for land cover classes 323, 335 and 422.

The most important land cover changes that are shown in this table and picture are the increase of artificial area, the decrease of agricultural land, the increase in transitional woodland shrub and the decrease in peat bogs. These changes occur over the

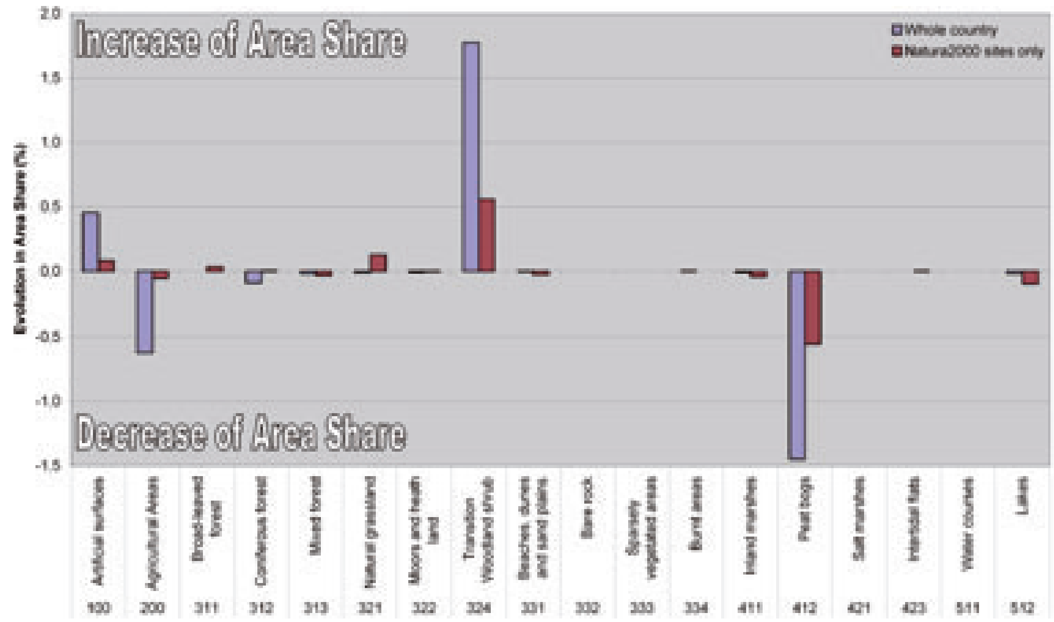



**Figure 9.** *Evolution of area share per land cover class in Ireland*

whole country as well as in the Natura2000 regions, but the evolutions are less pronounced in the Natura2000 regions. The Natura2000 regions seem to perform a buffer effect.

Table 4 shows the evolutions from one land cover class into another between 1990 and 2000. From this table it is clear that the decrease in agricultural land is in favour of

**Table 4.** *Changes from one land cover class into another in Ireland*

| Area (km²) | Land Cover class 2000 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| LC class 1990 | 100 | 200 | 311 | 312 | 313 | 321 | 324 | 334 | 411 | 423 | 512 | *Total* |
| 200 | 31304 | | 119 | 5175 | 186 | 0 | 10019 | 0 | 0 | 15 | 0 | *46819* |
| 311 | 65 | 58 | | 0 | 0 | 0 | 748 | 0 | 0 | 0 | 0 | *870* |
| 312 | 59 | 10 | 0 | | 0 | 0 | 66582 | 0 | 0 | 0 | 37 | *66688* |
| 313 | 0 | 15 | 0 | 0 | | 0 | 2098 | 0 | 0 | 0 | 0 | *2112* |
| 321 | 28 | 225 | 0 | 418 | 0 | | 2197 | 0 | 0 | 0 | 0 | *2868* |
| 322 | 0 | 38 | 37 | 116 | 0 | 0 | 477 | 0 | 0 | 0 | 7 | *676* |
| 324 | 249 | 488 | 630 | 30350 | 733 | 134 | | 0 | 0 | 0 | 14 | *32600* |
| 331 | 191 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *191* |
| 334 | 0 | 0 | 0 | 0 | 0 | 0 | 31 | | 0 | 0 | 0 | *31* |
| 411 | 0 | 37 | 0 | 26 | 0 | 488 | 29 | 0 | | 0 | 0 | *579* |
| 412 | 222 | 1923 | 41 | 24208 | 41 | 0 | 75908 | 90 | 0 | 0 | 99 | *102532* |
| 421 | 0 | 44 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *44* |
| 512 | 0 | 0 | 0 | 0 | 0 | 1263 | 26 | 0 | 42 | 0 | | *1332* |
| 523 | 41 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *41* |
| *Total* | *32159* | *2839* | *826* | *60294* | *959* | *1885* | *158115* | *90* | *42* | *15* | *157* | *257382* |

artificial areas (67%), transition woodland shrub (21%) and coniferous forest (11%). The increase in artificial areas is almost completely caused by the conversion of arable land into artificial area. The increase in 'transition woodland shrub' is particularly due to the decrease of peat bogs (48%), coniferous forest (42%) and arable land (6%). The peat bogs are converted into transition woodland shrub (74%) and coniferous forest (24%).

### 3.2.1.2 Germany

The (evolution of) the area share per aggregated land cover class in the 6 Bundesländer in the eastern part of Germany is given in Table 5 and Figure 10.

In the 6 Bundesländer in the eastern part of Germany, the land cover changes inside Natura2000 sites are in general stronger than over the whole area. An exception is the artificial area, where we see an overall increase, but a decrease in the Natura2000 area. The decrease of the agricultural area is weaker in the Natura2000 area than in the country as a whole.

Table 6 and Table 7 show the evolutions from one land cover class into another for the whole region (Table 6) and for the Natura2000 sites (Table 7) between 1990 and 2000.

The overall increase of the artificial areas is due to the conversion of agricultural area (88%), coniferous forest (5%) and natural grassland (3%) into artificial land. In the Natura2000 areas, there is a decrease of the artificial area; the artificial area is converted into sparsely vegetated areas (52%), transition woodland shrub (20%) and lakes (16%).



**Table 5.** *Area share per land cover class in Germany (6 Bundesländer)*

| Aggregated land cover class | | Germany (6 Bundesländer) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Total 1990 (%) | Total 2000 (%) | Evolution Total (%) | N2k sites 1990 (%) | N2k sites 2000 (%) | Evolution N2k sites (%) |
| 100 | Artificial surfaces | 7,14 | 7,49 | 0,35 | 1,89 | 1,67 | -0,22 |
| 200 | Agricultural Areas | 62,48 | 61,68 | -0,80 | 38,25 | 37,97 | -0,28 |
| 311 | Broad-leaved forest | 5,17 | 5,17 | 0,00 | 21,64 | 21,71 | 0,07 |
| 312 | Coniferous forest | 19,06 | 19,17 | 0,11 | 17,91 | 18,12 | 0,21 |
| 313 | Mixed forest | 2,91 | 2,95 | 0,05 | 6,87 | 7,03 | 0,16 |
| 321 | Natural grassland | 0,77 | 0,59 | -0,18 | 3,63 | 2,64 | -0,99 |
| 322 | Moors and heath land | 0,21 | 0,09 | -0,12 | 0,94 | 0,25 | -0,70 |
| 324 | Transition Woodland shrub | 0,32 | 0,73 | 0,41 | 1,41 | 3,05 | 1,64 |
| 331 | Beaches, dunes and sand plains | 0,01 | 0,01 | -0,01 | 0,02 | 0,01 | -0,01 |
| 332 | Bare rock | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| 333 | Sparsely vegetated areas | 0,17 | 0,24 | 0,07 | 0,36 | 0,30 | -0,06 |
| 334 | Burnt areas | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| 411 | Inland marshes | 0,23 | 0,23 | 0,00 | 1,36 | 1,38 | 0,02 |
| 412 | Peat bogs | 0,00 | 0,00 | 0,00 | 0,01 | 0,01 | 0,00 |
| 511 | Water courses | 0,12 | 0,12 | 0,00 | 0,88 | 0,88 | 0,00 |
| 512 | Lakes | 1,40 | 1,50 | 0,10 | 4,82 | 4,96 | 0,14 |

No values for land cover classes 323, 335, 421, 422 and 423.

The agricultural areas decrease. If the whole region is taken into account, the agricultural areas are particularly converted into artificial areas (73%) and coniferous forest (12%). In the Natura2000 areas, agricultural areas are converted into artificial areas (47%), coniferous forest (11%), natural grassland (9%) and various other land cover

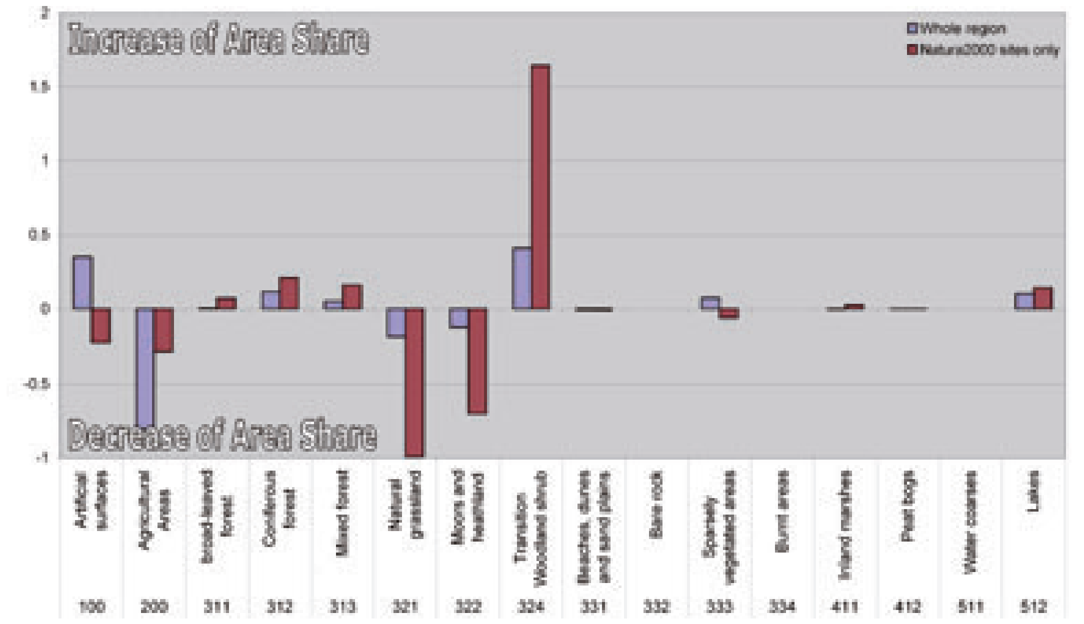



**Figure 10.** *Evolution of area share per land cover class in the 6 studied Bundesländer*

classes (32%). The decrease in agricultural areas is less in the Natura2000 areas than in the entire region.

The loss of natural grassland and moors/heathland is almost completely converted into 'transition woodland shrub'. This evolution is more explicit in the Natura2000 regions than in the whole country.

**Table 6.** *Changes from one land cover class into another in Germany (6 studied Bundesländer)*

| Area (km²) | Land Cover class 2000 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LC class 1990 | 100 | 200 | 311 | 312 | 313 | 321 | 322 | 324 | 333 | 411 | 412 | 512 | *Total* |
| 100 | | 3798 | 160 | 1273 | 241 | 2194 | 0 | 9098 | 15139 | 32 | 0 | 7618 | *39554* |
| 200 | 71999 | | 2878 | 12179 | 2634 | 1952 | 35 | 2088 | 988 | 1013 | 43 | 2555 | *98365* |
| 311 | 457 | 567 | | 205 | 0 | 573 | 0 | 3621 | 40 | 507 | 7 | 121 | *6100* |
| 312 | 4231 | 1545 | 310 | | 724 | 81 | 0 | 3256 | 195 | 48 | 0 | 247 | *10638* |
| 313 | 516 | 222 | 262 | 200 | | 0 | 0 | 415 | 216 | 0 | 0 | 103 | *1934* |
| 321 | 2984 | 637 | 1030 | 3075 | 227 | | 239 | 21171 | 1533 | 0 | 31 | 420 | *31349* |
| 322 | 611 | 22 | 334 | 1277 | 308 | 121 | | 9876 | 107 | 0 | 0 | 41 | *12697* |
| 324 | 411 | 8 | 1740 | 4422 | 2597 | 0 | 0 | | 52 | 0 | 0 | 26 | *9254* |
| 331 | 0 | 70 | 0 | 49 | 0 | 128 | 0 | 172 | 137 | 0 | 0 | 0 | *555* |
| 333 | 295 | 514 | 13 | 544 | 38 | 6339 | 0 | 3203 | | 0 | 0 | 182 | *11129* |
| 334 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 82 | 0 | 0 | 0 | 0 | *82* |
| 411 | 90 | 861 | 194 | 83 | 0 | 0 | 0 | 130 | 59 | | 0 | 526 | *1943* |
| 412 | 0 | 0 | 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | *21* |
| 512 | 67 | 208 | 20 | 0 | 0 | 65 | 0 | 27 | 146 | 251 | 0 | | *784* |
| 521 | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *25* |
| 523 | 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *19* |
| *Total* | *81705* | *8451* | *6963* | *23308* | *6769* | *11452* | *274* | *53138* | *18613* | *1852* | *81* | *11840* | *224447* |

**Table 7.** *Changes from one land cover class into another in the Natura2000 sites of Germany (6 studied Bundesländer)*

| Area (km²) | Land Cover class 2000 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LC class 1990 | 100 | 200 | 311 | 312 | 313 | 321 | 322 | 324 | 333 | 411 | 412 | 512 | *Total* |
| 100 | | 336 | 44 | 23 | 0 | 409 | 0 | 1305 | 3478 | 26 | 0 | 1074 | *6694* |
| 200 | 5150 | | 808 | 1243 | 581 | 1022 | 0 | 718 | 574 | 478 | 0 | 315 | *10890* |
| 311 | 47 | 308 | | 49 | 0 | 297 | 0 | 440 | 0 | 440 | 7 | 0 | *1590* |
| 312 | 341 | 277 | 109 | | 359 | 7 | 0 | 41 | 0 | 48 | 0 | 47 | *1228* |
| 313 | 90 | 64 | 250 | 114 | | 0 | 0 | 10 | 169 | 0 | 0 | 14 | *711* |
| 321 | 380 | 293 | 640 | 672 | 105 | | 10 | 12710 | 159 | 0 | 0 | 126 | *15096* |
| 322 | 21 | 22 | 140 | 653 | 106 | 121 | | 6656 | 66 | 0 | 0 | 0 | *7784* |
| 324 | 283 | 8 | 581 | 1631 | 1348 | 0 | 0 | | 0 | 0 | 0 | 0 | *3851* |
| 331 | 0 | 0 | 0 | 14 | 0 | 71 | 0 | 0 | 43 | 0 | 0 | 0 | *128* |
| 333 | 0 | 35 | 0 | 252 | 0 | 1540 | 0 | 403 | | 0 | 0 | 138 | *2369* |
| 411 | 85 | 417 | 158 | 83 | 0 | 0 | 0 | 19 | 37 | | 0 | 371 | *1170* |
| 512 | 7 | 95 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 19 | 0 | | *129* |
| *Total* | *6404* | *1854* | *2731* | *4734* | *2499* | *3465* | *10* | *22303* | *4536* | *1010* | *7* | *2086* | *51639* |

### 3.2.1.3 The Netherlands

The (evolution of) the area share per aggregated land cover class in the Netherlands is given in Table 8 and Figure 11.

**Table 8.** *Area share per land cover class in the Netherlands*

| Aggregated land cover class | | The Netherlands | | | | | |
|---|---|---|---|---|---|---|---|
| | | Total 1990 (%) | Total 2000 (%) | Evolution Total (%) | N2k sites 1990 (%) | N2k sites 2000 (%) | Evolution N2k sites (%) |
| 100 | Artificial surfaces | 7,14 | 7,49 | 0,35 | 1,89 | 1,67 | -0,22 |
| 100 | Artificial surfaces | 9,20 | 11,27 | 2,08 | 1,68 | 1,97 | 0,29 |
| 200 | Agricultural Areas | 66,32 | 63,75 | -2,57 | 16,04 | 15,20 | -0,84 |
| 311 | Broad-leaved forest | 1,27 | 1,48 | 0,21 | 2,61 | 2,69 | 0,08 |
| 312 | Coniferous forest | 4,23 | 4,21 | -0,02 | 11,80 | 11,79 | -0,02 |
| 313 | Mixed forest | 2,39 | 2,40 | 0,01 | 4,88 | 4,88 | -0,01 |
| 321 | Natural grassland | 0,64 | 0,79 | 0,15 | 4,01 | 4,32 | 0,32 |
| 322 | Moors and heath land | 0,95 | 0,95 | 0,00 | 4,86 | 4,89 | 0,02 |
| 324 | Transition Woodland shrub | 0,01 | 0,04 | 0,02 | 0,04 | 0,07 | 0,03 |
| 331 | Beaches, dunes and sand plains | 0,46 | 0,41 | -0,06 | 2,49 | 2,14 | -0,35 |
| 411 | Inland marshes | 0,73 | 0,83 | 0,10 | 2,72 | 2,92 | 0,20 |
| 412 | Peat bogs | 0,20 | 0,20 | 0,01 | 1,05 | 1,07 | 0,02 |
| 421 | Salt marshes | 0,23 | 0,24 | 0,00 | 1,48 | 1,52 | 0,04 |
| 423 | Intertidal flats | 5,70 | 5,67 | -0,03 | 38,93 | 38,89 | -0,04 |
| 511 | Water courses | 1,15 | 1,15 | 0,00 | 2,16 | 2,16 | 0,01 |
| 512 | Lakes | 6,51 | 6,60 | 0,09 | 5,21 | 5,47 | 0,26 |

No values for 323, 332, 333, 334, 335 and 422.

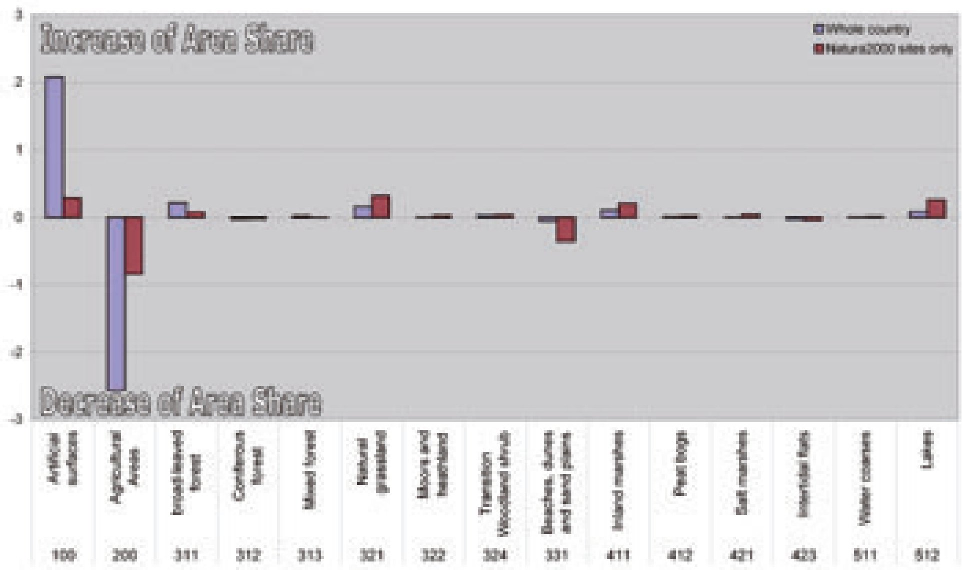



**Figure 11.** *Evolution of area share per land cover class in the Netherlands*

In the Netherlands, there are very few changes in land cover in the natural vegetation. Almost all changes occur in the artificial and agricultural area. The changes in these land cover classes are smaller in the Natura2000 areas than in the whole country.

The changes in natural land covers are in general larger in the Natura2000 sites. The total area of beaches, dunes and sand plains decreases in favour of natural grassland, inland marshes and lakes.

Table 9 and Table 10 show the evolutions from one land cover class into another for the whole country (Table 9) and for the Natura2000 sites (Table 10) between 1990 and 2000. From these tables is becomes clear that dunes and beaches are partially converted into

**Table 9.** *Changes from one land cover class into another in the Netherlands*

| Area ($km^2$) | Land Cover class 2000 | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LC class 1990 | 100 | 200 | 311 | 312 | 313 | 321 | 322 | 324 | 331 | 411 | 412 | 421 | 423 | 511 | 512 | 522 | 523 | *Total* |
| 100 | | 369 | 228 | 7 | 0 | 725 | 147 | 0 | 0 | 255 | 0 | 43 | 0 | 150 | 256 | 63 | 0 | *2683* |
| 200 | 82181 | | 8122 | 185 | 1014 | 4258 | 365 | 1004 | 112 | 3640 | 435 | 621 | 0 | 148 | 3235 | 45 | 0 | *105753* |
| 311 | 725 | 122 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *847* |
| 312 | 969 | 39 | 21 | | 17 | 162 | 748 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 71 | 0 | 0 | *2046* |
| 313 | 306 | 144 | 0 | 0 | | 64 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 34 | 0 | 0 | *559* |
| 321 | 216 | 0 | 0 | 0 | 0 | | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *217* |
| 322 | 279 | 5 | 90 | 632 | 60 | 0 | | 0 | 0 | 0 | 77 | 0 | 0 | 0 | 71 | 0 | 0 | *1270* |
| 324 | 0 | 0 | 301 | 224 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *526* |
| 331 | 286 | 0 | 0 | 0 | 0 | 289 | 86 | 0 | | 0 | 0 | 57 | 1938 | 0 | 61 | 0 | 1156 | *3874* |
| 411 | 264 | 85 | 597 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 30 | 0 | 0 | *976* |
| 412 | 0 | 274 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | *274* |
| 421 | 0 | 0 | 0 | 0 | 0 | 170 | 0 | 502 | 21 | 0 | 0 | | 9 | 0 | 0 | 0 | 0 | *702* |
| 423 | 6 | 0 | 0 | 0 | 0 | 782 | 0 | 0 | 1021 | 627 | 0 | 126 | | 0 | 1270 | 0 | 717 | *4549* |
| 511 | 136 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 13 | 0 | 0 | *149* |
| 512 | 704 | 288 | 0 | 0 | 0 | 17 | 0 | 0 | 0 | 679 | 0 | 0 | 0 | 16 | | 0 | 0 | *1715* |
| 522 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | *12* |
| 523 | 147 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 482 | 0 | 0 | 0 | 1409 | 0 | 205 | 0 | | *2244* |
| *Total* | *86232* | *1327* | *9360* | *1048* | *1091* | *6467* | *1357* | *1524* | *1637* | *5202* | *511* | *847* | *3357* | *314* | *5246* | *108* | *1872* | *128395* |

**Table 10.** *Changes from one land cover class into another in the Natura2000 sites of the Netherlands*

| Area (km²) | Land Cover class 2000 | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LC class 1990 | 100 | 200 | 311 | 312 | 313 | 321 | 322 | 324 | 331 | 411 | 412 | 421 | 423 | 511 | 512 | 522 | 523 | *Total* |
| 100 | | 82 | 0 | 0 | 0 | 446 | 32 | 0 | 0 | 23 | 0 | 43 | 0 | 0 | 0 | 33 | 0 | *1059* |
| 200 | 3035 | | 485 | 53 | 69 | 969 | 295 | 150 | 41 | 1615 | 178 | 621 | 0 | 64 | 593 | 45 | 0 | *8245* |
| 311 | 35 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *35* |
| 312 | 77 | 0 | 0 | | 17 | 162 | 583 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 71 | 0 | 0 | *910* |
| 313 | 8 | 33 | 0 | 0 | | 64 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *106* |
| 321 | 216 | 0 | 0 | 0 | 0 | | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *217* |
| 322 | 91 | 0 | 0 | 490 | 60 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 71 | 0 | 0 | *768* |
| 324 | 0 | 0 | 0 | 224 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *224* |
| 331 | 33 | 0 | 0 | 0 | 0 | 289 | 42 | 0 | | 0 | 0 | 57 | 1917 | 0 | 61 | 0 | 1156 | *3555* |
| 411 | 149 | 0 | 350 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *498* |
| 412 | 0 | 145 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | *145* |
| 421 | 0 | 0 | 0 | 0 | 0 | 170 | 0 | 502 | 21 | 0 | 0 | | 9 | 0 | 0 | 0 | 0 | *702* |
| 423 | 6 | 0 | 0 | 0 | 0 | 500 | 0 | 0 | 1021 | 442 | 0 | 126 | | 0 | 931 | 0 | 717 | *3742* |
| 511 | 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | *23* |
| 512 | 29 | 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | *69* |
| 523 | 147 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 454 | 0 | 0 | 0 | 1395 | 0 | 205 | 0 | | *2202* |
| *Total* | *3849* | *290* | *835* | *768* | *146* | *2599* | *952* | *652* | *1538* | *2080* | *178* | *847* | *3322* | *64* | *1932* | *78* | *1872* | *22501* |

intertidal flats and sea. The increase in artificial area and the decrease in agricultural area is almost completely due to the conversion of agricultural land into artificial areas.

### 3.2.1.4 Luxembourg

The (evolution of) the area share per aggregated land cover class in the Netherlands is given in Table 11 and Figure 12.

In Luxembourg, the changes in land cover between 1990 and 2000 are very small (<1%). The changes occur predominantly in artificial areas (increase), agricultural areas (decrease), forests (decrease) and transition woodland shrub (increase). The changes in these land cover classes are smaller in the Natura2000 areas than in the whole country.

**Table 11.** *Area share per land cover class in Luxembourg*

| Aggregated land cover class | | Luxembourg | | | | | |
|---|---|---|---|---|---|---|---|
| | | Total 1990 (%) | Total 2000 (%) | Evolution Total (%) | N2k sites 1990 (%) | N2k sites 2000 (%) | Evolution N2k sites (%) |
| 100 | Artificial surfaces | 8,02 | 8,69 | 0,67 | 3,55 | 3,64 | 0,09 |
| 200 | Agricultural Areas | 55,45 | 54,84 | -0,61 | 46,82 | 46,73 | -0,09 |
| 311 | Broad-leaved forest | 24,71 | 24,41 | -0,30 | 14,42 | 14,42 | 0,00 |
| 312 | Coniferous forest | 4,95 | 4,63 | -0,32 | 3,76 | 3,57 | -0,20 |
| 313 | Mixed forest | 6,16 | 5,94 | -0,22 | 26,75 | 26,75 | 0,00 |
| 321 | Natural grassland | 0,07 | 0,07 | 0,00 | 0,57 | 0,57 | 0,00 |
| 324 | Transition woodland shrub | 0,18 | 0,96 | 0,78 | 0,47 | 0,66 | 0,20 |
| 511 | Water courses | 0,18 | 0,18 | 0,00 | 0,05 | 0,05 | 0,00 |
| 512 | Lakes | 0,27 | 0,27 | 0,00 | 3,62 | 3,62 | 0,00 |

No values for the classes 322, 323, 331, 332, 333, 334, 335, 411, 412, 421, 422 and 423.

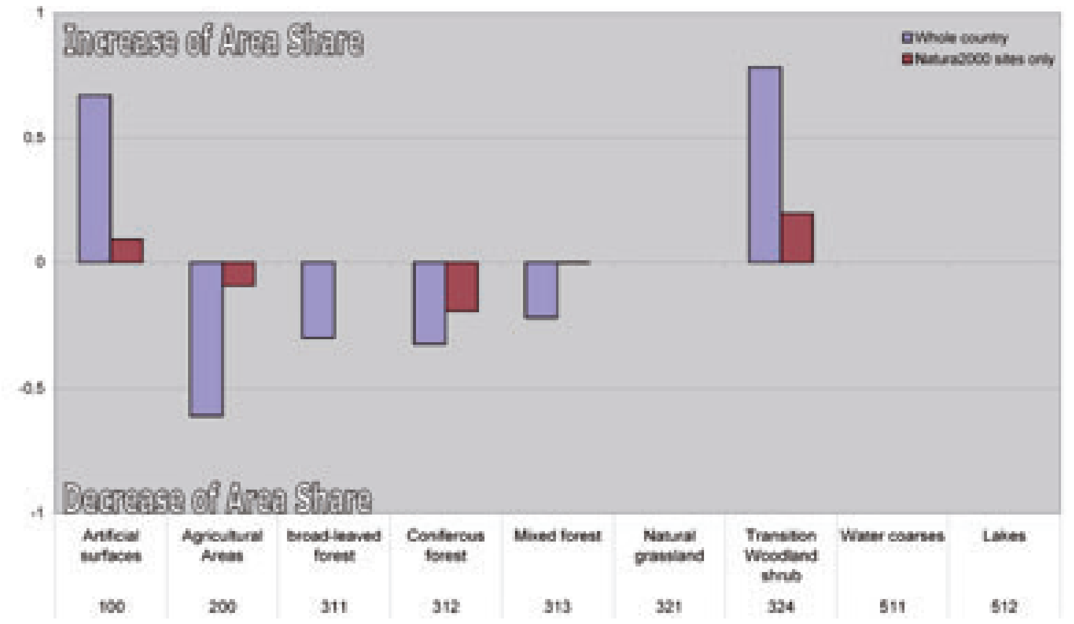



**Figure 12.** *Evolution of area share per land cover class in Luxembourg*

Table 12 and Table 13 show the evolutions from one land cover class into another for the whole country (Table 12) and for the Natura2000 sites (Table 13) between 1990 and 2000. From these tables it becomes clear that the increase in artificial area is almost completely due to the conversion of agricultural area into artificial area. The forest is converted into transition woodland shrub (deforestation?). The evolutions in the Natura2000 areas are identical, but less explicit than in the whole country.

**Table 12.** *Changes from one land cover class into another in Luxembourg*

| Area (km$^2$) | Land Cover class 2000 | | | |
|---|---|---|---|---|
| **LC class 1990** | **100** | **200** | **324** | ***Total*** |
| 100 | | 23 | 0 | *23* |
| 200 | 1609 | | 17 | *1625* |
| 311 | 89 | 38 | 604 | *731* |
| 312 | 16 | 9 | 810 | *835* |
| 313 | 20 | 0 | 540 | *560* |
| *Total* | *1733* | *70* | *1971* | *3774* |

**Table 13.** *Changes from one land cover class into another in the Natura2000 sites of Luxembourg*

| Area (km$^2$) | Land Cover class 2000 | | |
|---|---|---|---|
| **LC class 1990** | **100** | **324** | ***Grand Total*** |
| 200 | 12,98 | 0,08 | *13,06* |
| 312 | 0 | 27,32 | *27,32* |
| 313 | 0 | 0,09 | *0,09* |
| 511 | 0,01 | 0 | *0,01* |
| *Grand Total* | *12,99* | *27,49* | *40,48* |

### 3.2.2 *Indices reflecting land cover diversity*

Besides the (evolution of) area share of the different land cover classes inside and outside the NATURA2000 sites, some indices are calculated reflecting land cover diversity per square of 3 by 3 kilometers: (1) the number of classes per grid cell, (2), the Shannon Diversity Index and (3) the Perimeter Area Ratio.

The first index calculated is the ***number of land cover classes*** per grid cell. The simplest way of capturing the diversity of the earth's surface is to count the number of different categories, in our case land cover classes in a unit area. The more classes there are the more diverse or rich the area is. The advantage of this index is that it can be calculated and interpreted easily. But, as in all richness measures, the result might be misleading, because the area covered by each class and thus its importance is not considered. Even if a certain class covers only the smallest possible area, it is counted.

The second index used is the ***Shannon Diversity Index (SDI)***. The Shannon diversity index is an index that is commonly used to characterize diversity. Shannon's index accounts for both richness and evenness of the land cover classes present. Richness refers to the number of patch types (compositional component) and evenness to the area distribution of classes (structural component). The proportion of land cover ***i*** relative to the total number of land cover classes (***pi***) is calculated, and then multiplied by the natural logarithm of this proportion (ln***pi***). The resulting product is summed across the different land covers, and multiplied by –1:

$$SHDI = -\sum_{i=1}^{m}\left(Pi * \ln Pi\right)$$

*m = number of patch types*
$P_i$ *= proportion of area covered by patch type (land cover class) i*



The Shannon Diversity Index increases as the number of different patch types (= classes) increases and/or the proportional distribution of the area among patch types becomes more equitable. For a given number of classes, the maximum value of the Shannon Index is reached when all classes have the same area.

The third index used is the ***Edge Density (ED) or Perimeter/Area Ratio (PAR).*** An edge refers to the border between two different classes. Edge density (in m/ha) or alternatively Perimeter/Area Ratio equals the length (in m) of all borders between different patch types (classes) in a reference area divided by the total area of the reference unit. The index is calculated as:

$$ED = \frac{E}{A}$$

*E = total edge (m)*
*A = total area (ha)*

In contrast to patch density, edge density takes the shape and the complexity of the patches into account. Edge density is a measurement of the complexity of the shapes of patches and, similar to patch density an expression of the spatial heterogeneity of a landscape mosaic. Like patch density, edge density is a function of the size of the smallest mapping unit defined (grain size): the smaller the mapping unit the better the spatial delineation is measured, resulting in an increase of the edge length.

#### 3.2.2.1 Number of classes

The evolution of the number of land cover classes in the different case study areas is given in Table 14.

**Table 14.** *Average Number of Land Cover classes per grid cell (3 × 3 km)*

| Number of classes | Ireland | | Germany (6 studied Bundesländer) | | Netherlands | | Luxembourg | |
|---|---|---|---|---|---|---|---|---|
| | 1990 | 2000 | 1990 | 2000 | 1990 | 2000 | 1990 | 2000 |
| Country | 2.93 | 3.05 | 3.36 | 3.41 | 2.69 | 2.78 | 3.49 | 3.57 |
| Natura2000 sites | 2.69 | 2.79 | 2.66 | 2.68 | 2.52 | 2.56 | 2.58 | 2.54 |

In Ireland (see also Figure 13) there is an overall increase of the number of land cover classes; the average number of classes per grid cell increases from 2.93 in 1990 to 3.05 in 2000. If only Natura2000 sites are studied, there is also a general increase of the average number of land cover classes (2.69 in 1990 to 2.79 in 2000).

From Figure 13 it becomes clear in which spots there is an increase in the number of land cover classes and in which places there is a decrease. The map with the location of the Natura2000 sites is shown separately (right part of the figure) and as a basic layer in the left part of the figure (to make it more easy to compare the location of the Natura2000 sites and the spots with increases/decreases in the number of land cover classes).

In Germany (6 studied Bundesländer) there is an overall increase of the number of land cover classes from 3.36 (1990) to 3.41 (2000). Inside Natura2000 sites, there is also an increase of land cover diversity (from 2.66 in 1990 to 2.68 in 2000). The number of classes is significantly lower in Natura2000 sites than in the whole area. From Figure 14 it becomes clear in which spots there is an increase in the number of land cover classes and in which places there is a decrease.

In the Netherlands there is also an overall increase of the number of land cover classes (from 2.69 (1990) to 2.78 (2000). Inside Natura2000 sites, there is only a small increase of land cover diversity (from 2.66 in 1990 to 2.68 in 2000). The number of classes is lower in Natura2000 sites than in the whole area. From Figure 15 it becomes

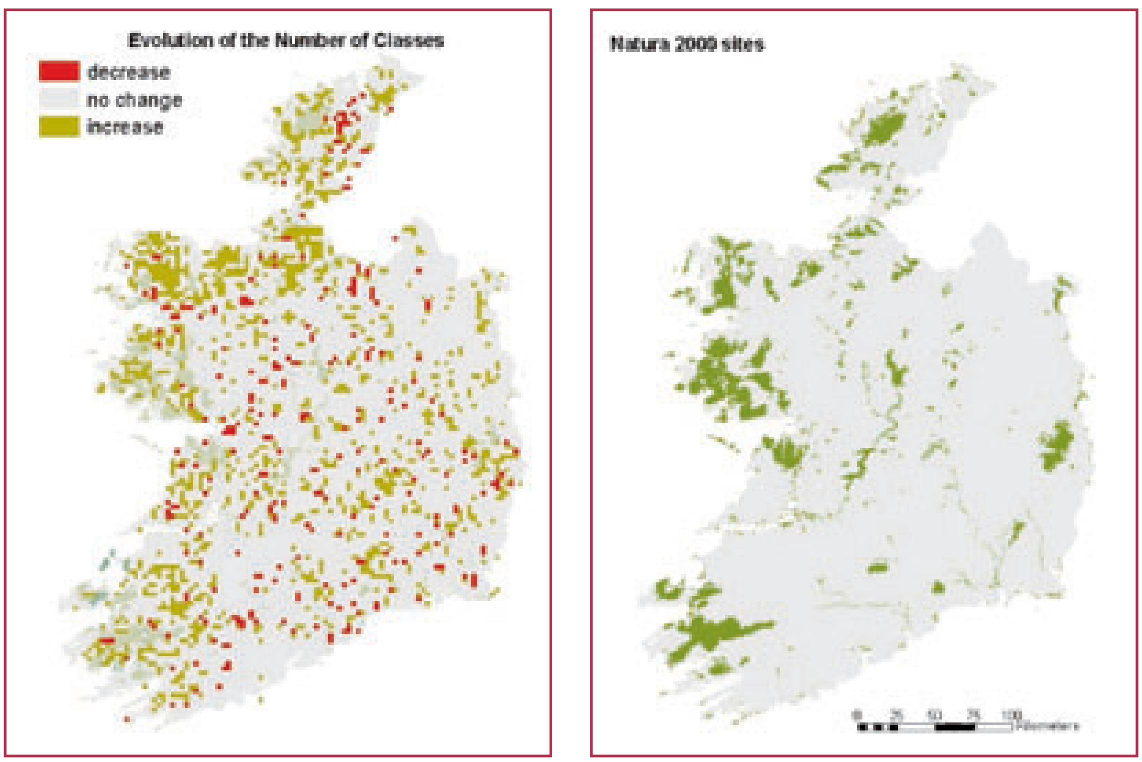



**Figure 13.** *Evolution of the number of land cover classes in Ireland between 1990 and 2000*

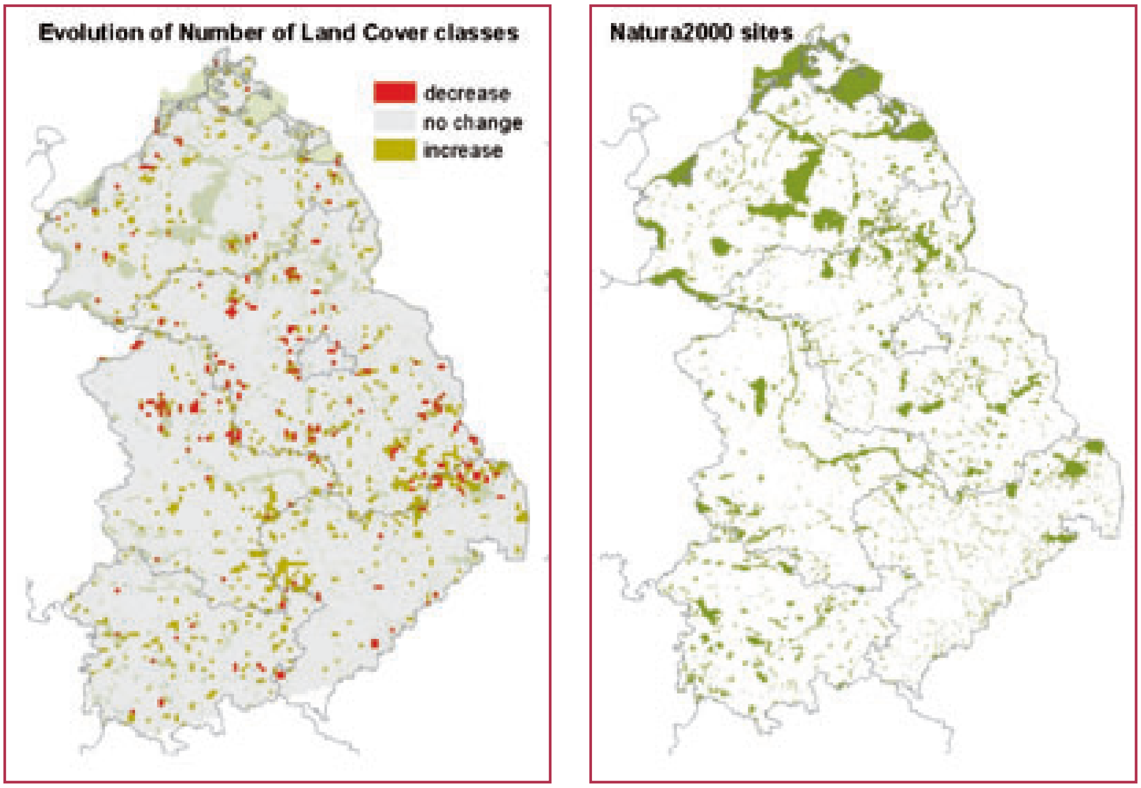



**Figure 14.** *Evolution of the number of land cover classes in the 6 studied Bundesländer of Germany between 1990 and 2000*

clear in which spots there is an increase in the number of land cover classes and in which places there is a decrease.

In Luxembourg, the number of land cover classes increased between 1990 and 2000 from 3.49 to 3.57. In Natura2000 sites, the number of land cover classes is generally lower, and even decreased slightly between 1990 and 2000 (from 2.58 to 2.54).

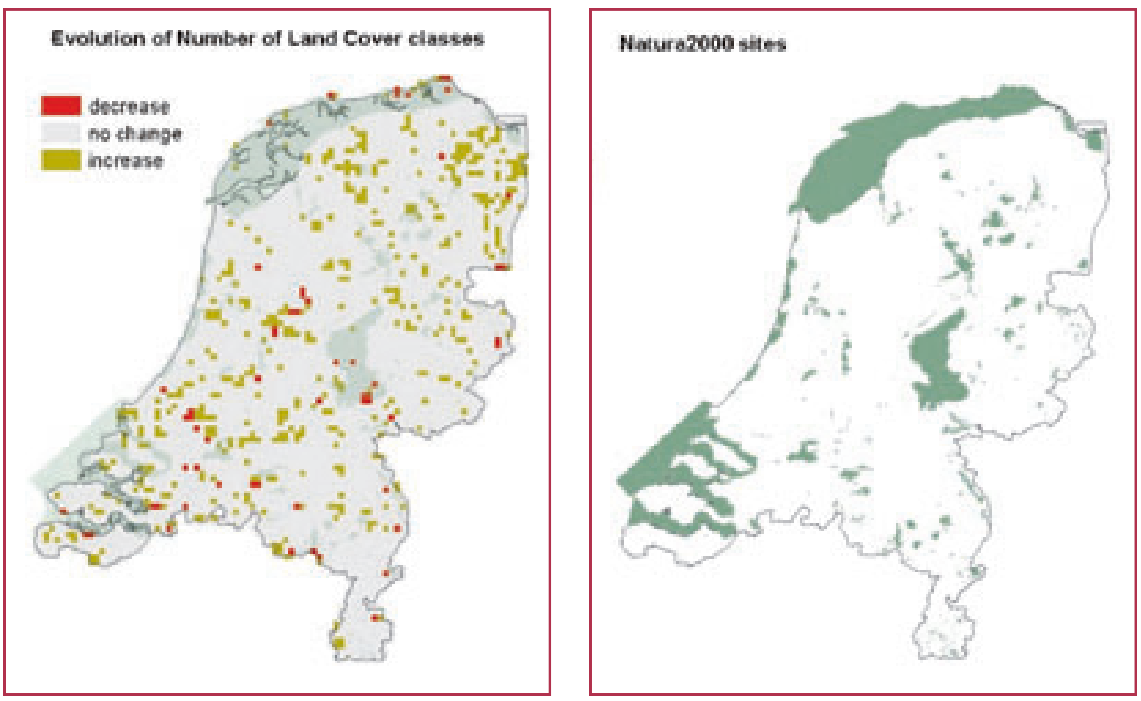



**Figure 15.** *Evolution of the number of land cover classes in the Netherlands between 1990 and 2000*

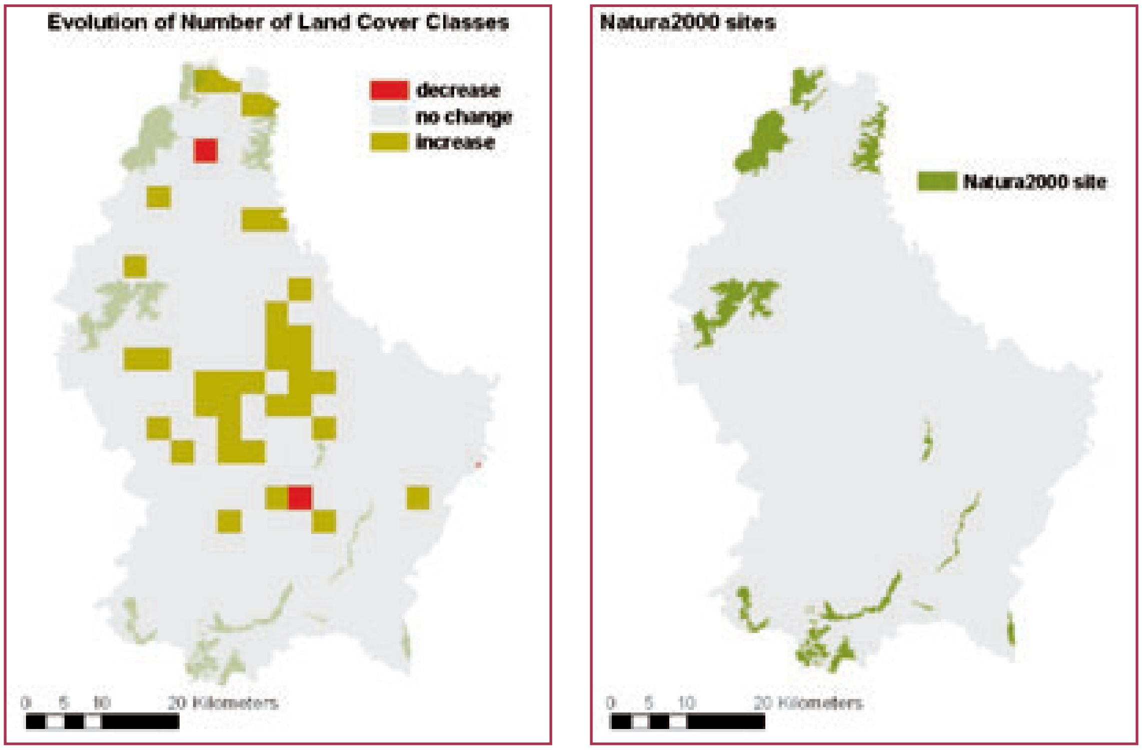



**Figure 16.** *Evolution of the number of land cover classes in Luxembourg between 1990 and 2000*

From Figure 16 it becomes clear in which spots there is an increase in the number of land cover classes and in which places there is a decrease.

### 3.2.2.2 Shannon Diversity Index

In all studied countries, the overall Shannon Diversity Index has increased between 1990 and 2000 (Table 15), indicating that overall land cover diversity has increased.

**Table 15.** *Average Shannon Diversity Index per grid cell (3 × 3 km)*

| SDI | Ireland | | Germany | | Netherlands | | Luxembourg | |
|---|---|---|---|---|---|---|---|---|
| | 1990 | 2000 | 1990 | 2000 | 1990 | 2000 | 1990 | 2000 |
| Country | 0.50 | 0.53 | 0.63 | 0.65 | 0.46 | 0.49 | 0.79 | 0.80 |
| Natura2000 sites | 0.40 | 0.41 | 0.45 | 0.45 | 0.46 | 0.47 | 0.40 | 0.38 |

In Ireland, the SDI is lower in the Natura2000 sites than in the whole country. The increase in the SDI inside the Natura2000 sites is smaller than in the whole country.

In Germany, the SDI is also lower in Natura2000 sites the whole country. While an increase of the SDI is observed in the whole country, there is no change in the SDI in the Natura2000 sites. The landscape structure seems to be very stable here.

In the Netherlands, the SDI 1990 is the same in the Natura2000 sites as in the whole country. In 2000, the SDI has increased in the Natura2000 areas and in the whole country, but in the Natura2000 sites, the increase is small.

In Luxembourg there is a slight increase in the SDI from 0.79 to 0.80. In Natura2000 sites, the SDI is much lower than in the whole country and there is a decrease in the SDI between 1990 and 2000.

In the following figures is shown in which spots there is an increase in the number of land cover classes and in which places there is a decrease (Ireland: Figure 17, Germany: Figure 18, the Netherlands: Figure 19, Luxembourg: Figure 20).

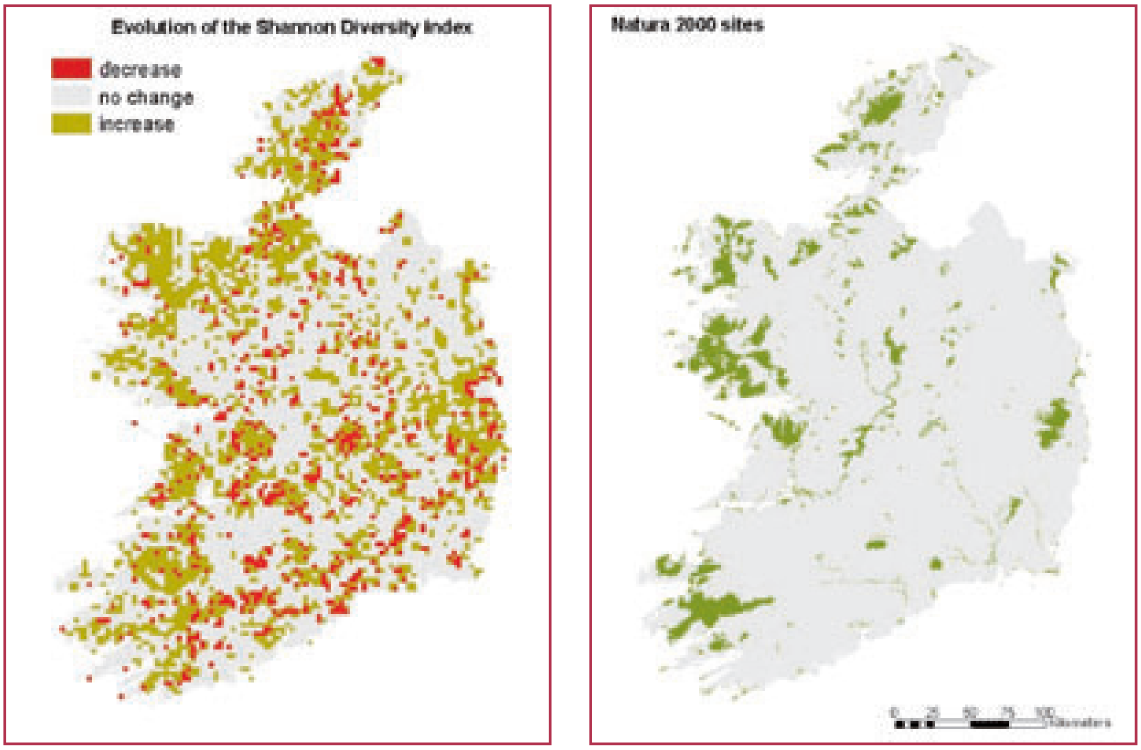



**Figure 17.** *Evolution of the SDI in Ireland between 1990 and 2000*

### 3.2.2.3 Perimeter Area Ratio

The Perimeter Area Ratio (PAR) in the studied countries and the Natura2000 sites of these countries is given in Table 16. In all studied countries, the overall PAR has increased between 1990 and 2000, indicating an increase in the complexity of the shape of patches.

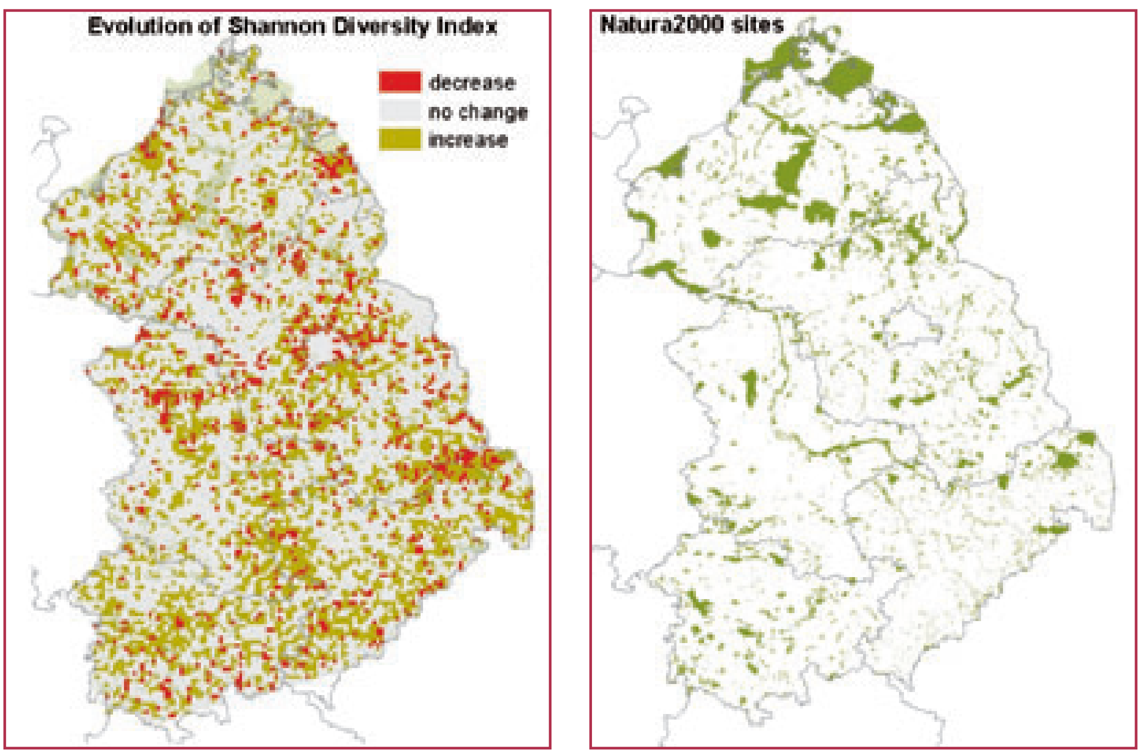



**Figure 18.** *Evolution of the SDI in the 6 studied Bundesländer of Germany between 1990 and 2000*

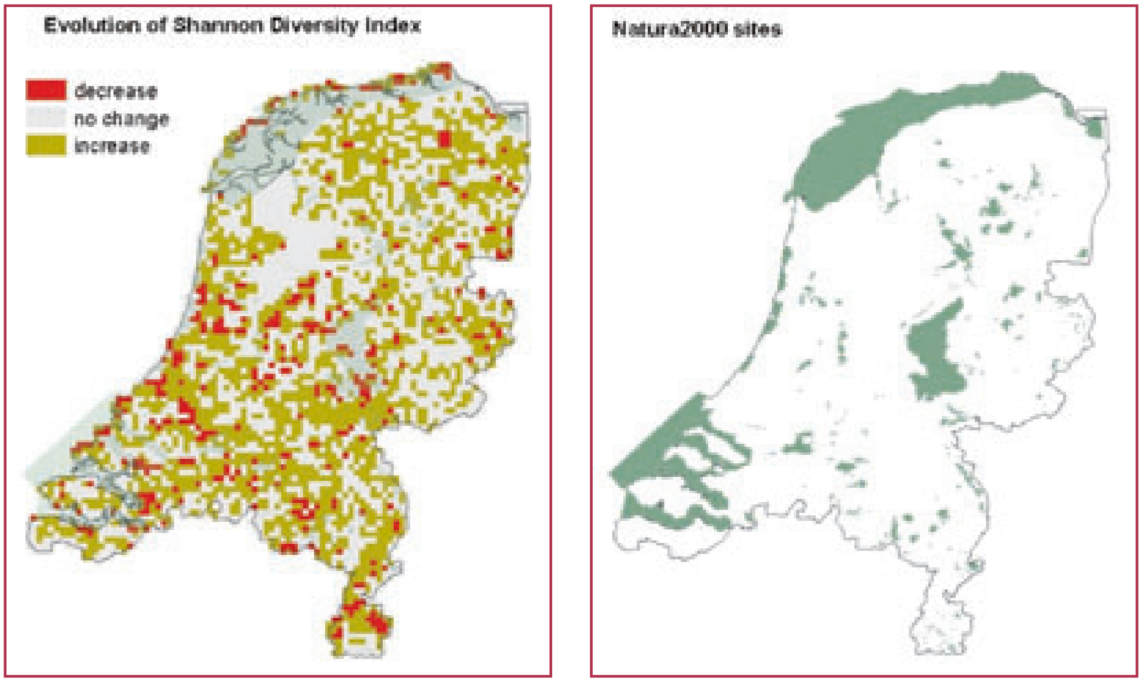



**Figure 19.** *Evolution of the SDI in the Netherlands between 1990 and 2000*

**Table 16.** *Average Perimeter Area Ratio per grid cell (3 × 3 km)*

| SDI | Ireland | | Germany | | Netherlands | | Luxembourg | |
|---|---|---|---|---|---|---|---|---|
| | 1990 | 2000 | 1990 | 2000 | 1990 | 2000 | 1990 | 2000 |
| Country | 0.00096 | 0.00102 | 0.001205 | 0.001235 | 0.000781 | 0.000820 | 0.001975 | 0.002000 |
| Natura2000 sites | 0.00159 | 0.00164 | 0.002089 | 0.002107 | 0.001301 | 0.001335 | 0.002733 | 0.002571 |

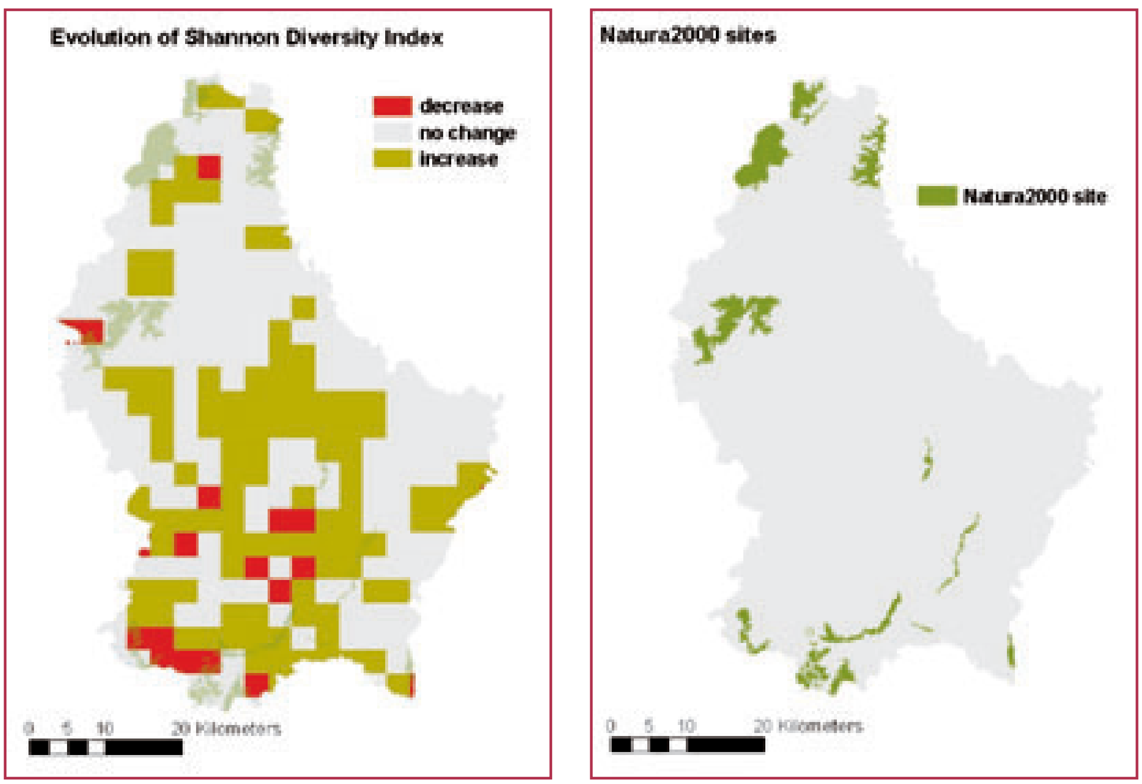



**Figure 20.** *Evolution of the SDI in Luxembourg between 1990 and 2000*

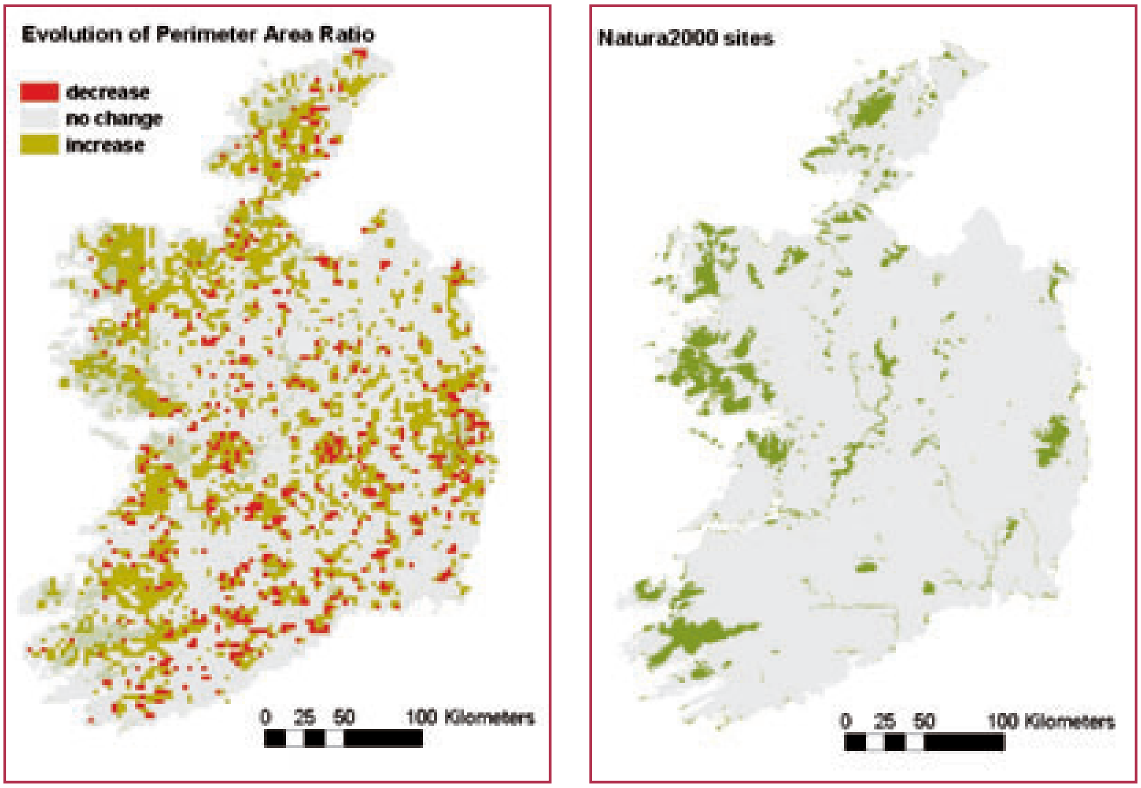



**Figure 21.** *Evolution of the PAR in Ireland between 1990 and 2000*

The exact location of the grid cells where an increase/decrease of the PAR occurs, is given in Figure 21 (Ireland), Figure 22 (Germany), Figure 23 (Netherlands) and Figure 24 (Luxembourg). In the Natura2000 sites, the PAR is in general higher than in the whole country. In all studied countries, except Luxembourg, the PAR has increased

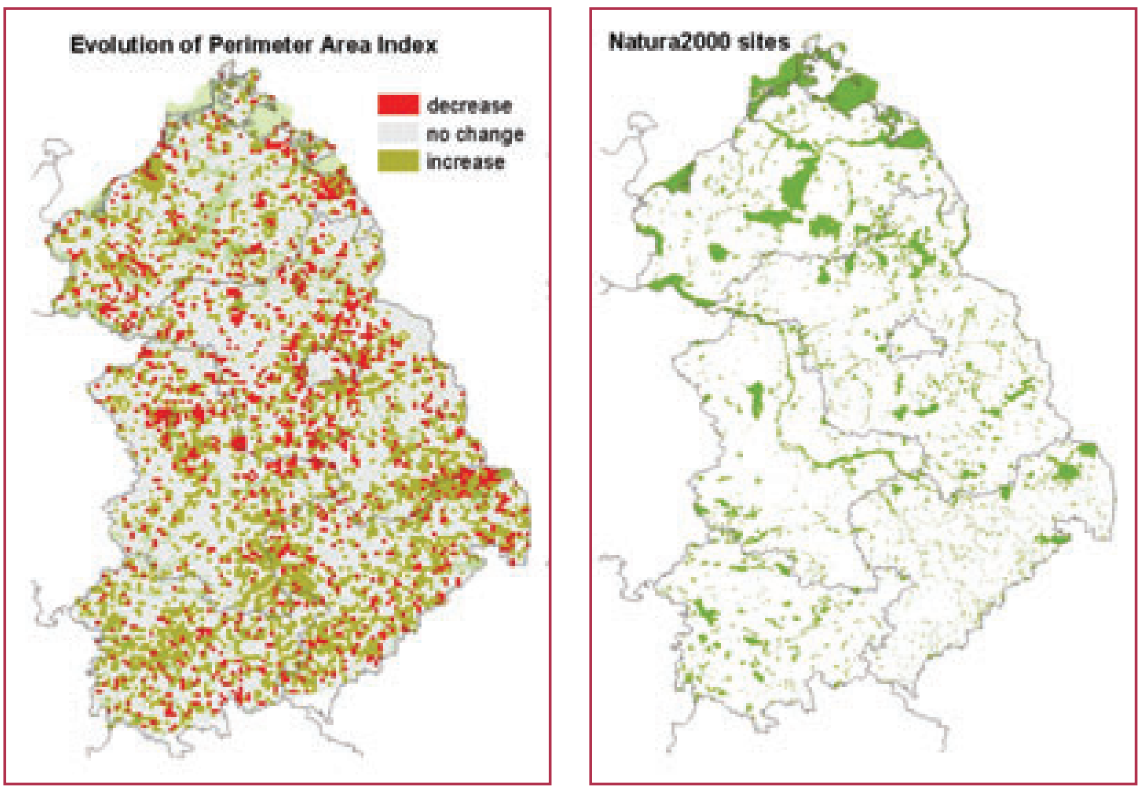



**Figure 22.** *Evolution of the PAR in Germany between 1990 and 2000*

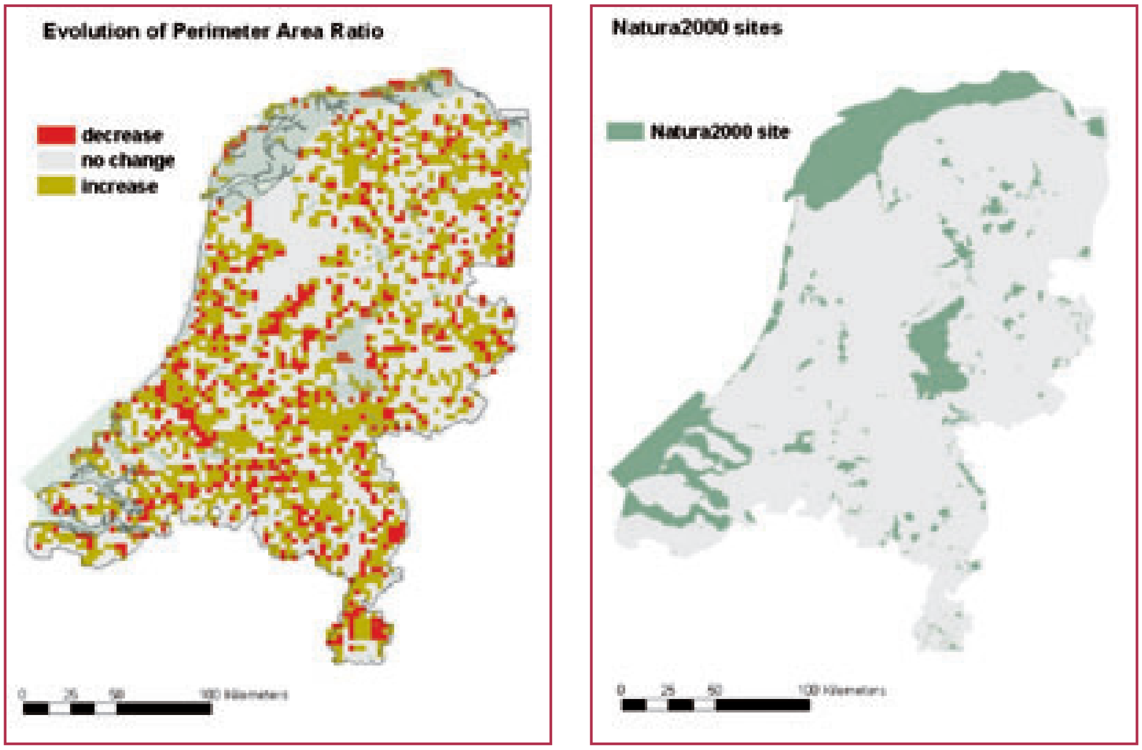



**Figure 23.** *Evolution of the PAR in the Netherlands between 1990 and 2000*

between 1990 and 2000. The increase is a little bit lower than outside the Natura2000 sites, resulting in a slightly decreasing difference in PAR between the Natura2000 sites and the whole country.



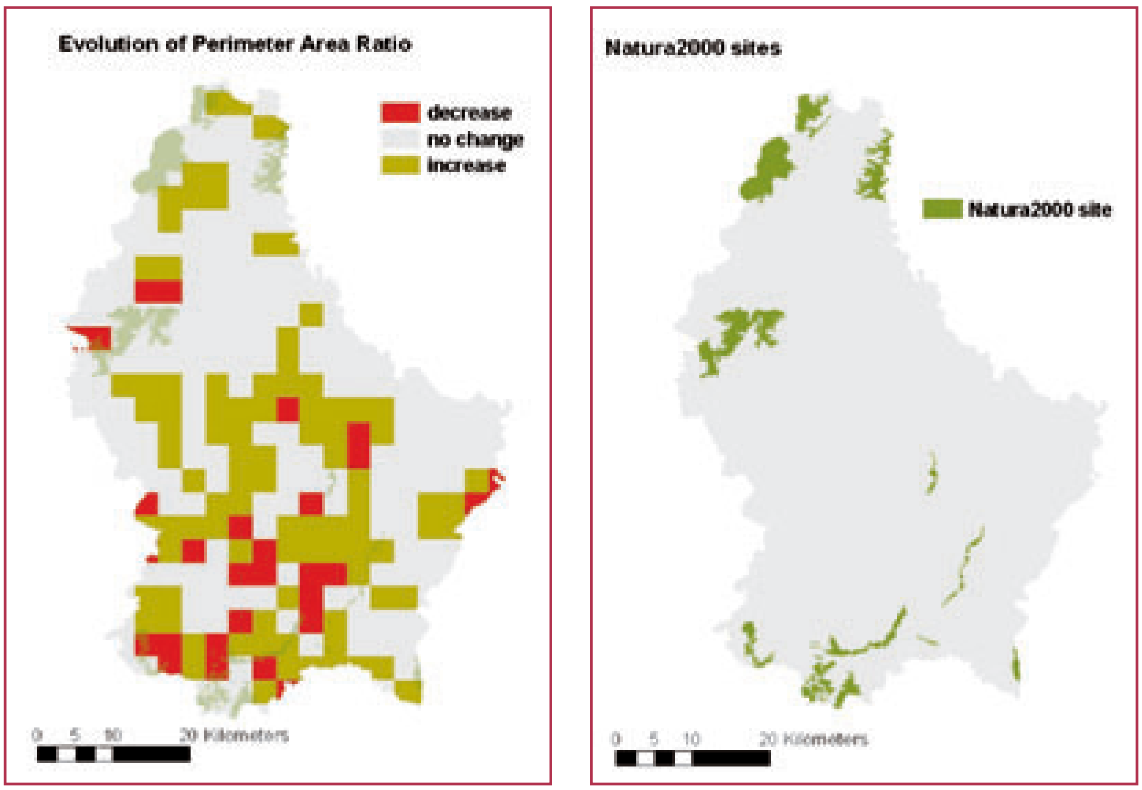



**Figure 24.** *Evolution of the PAR in Luxembourg between 1990 and 2000*

## 4. Résumé and Conclusions

For this article, we explored the land cover change inside and outside the Natura2000 sites of Ireland, the Netherlands, Luxembourg and the 6 Länder in the eastern part of Germany with the objective to assess the influence of the delineation of Natura2000 sites on the land cover change. These 4 countries/regions were selected because they are the only ones where NATURA 2000 sites and Corine Land Cover data from 1990 and 2000 are available at the time of writing. CLC2000 is also available for some 'new' Member States (member since May 1st 2004), but it is not possible to look at the influence of NATURA 2000 sites on the Land Cover change in these 'new' member states because the NATURA 2000 sites were not delineated yet in these countries between 1990 and 2000.

When relating information from the NATURA 2000 database and Corine Land Cover, we combine information from datasets with a different nature and scale. The Natura2000 sites are often delineated at a very detailed scale, while the threshold for delineation of separate Corine Land Cover units is 25 ha. This is a large area compared to the area of some NATURA 2000 sites. Land cover changes in small sites, cannot be monitored using CLC. The success of evaluating land cover based on CLC inside NATURA 2000 sites is highly dependant on the size of the sites.

When comparing the land cover change indicators of the different countries, one can conclude that more data are needed (more countries and longer time series) to draw conclusions on the impact of the Natura2000 sites on land cover change. In Ireland, the land cover change in the Natura2000 sites shows the same tendency as in the whole country, but less pronounced. N2k regions seem to perform a buffer function. In Germany, the land cover changes are sometimes opposite in the Natura2000 sites and in the whole region; some evolutions are similar in Natura2000 areas and in the whole country; changes can be even more pronounced in Natura2000 sites (e.g. decrease of natural grasslands and moors and heathland decrease in favorite of woodland and forest). In the Netherlands, the increase in artificial area and the decrease in agricultural area is less pronounced in the Natura2000 sites than in the whole country. To the contrary, the changes in natural land cover classes are stronger in the Natura2000 sites. In Luxemburg, the trend is similar as in Ireland: the Natura2000 sites seem to perform a buffer function. The land cover changes are similar as in the whole country, but less pronounced.

It can be expected that the effect of the delineation of Natura2000 sites on land cover (changes) can only be observed in the long term. The limited number of countries studied in this article and the limited time period (10 years) do not allow drawing clear conclusions. Longer time series and more case study areas will be necessary to draw conclusions concerning the effect of Natura2000 sites on land cover (change).

Nevertheless, the method presented in this article is very useful since we developed an automatic way to monitor the land cover inside Natura2000 sites. In the future, the method can be fine-tuned if more land cover data for more countries and complete Natura2000 datasets become available. The method can be used to make global assessments at EU-level, making use of existing data. It will be possible then to monitor and compare the nature of land cover changes in different geographical regions etc.

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# Land Cover Changes Observed Inside and Outside Natura 2000 Sites: Examples from Belgium

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## Introduction

BIOPRESS aims at providing decision makers with quantitative information on how past changes in land cover and land use has affected the environment and biodiversity in Europe. The project is currently producing consistent and coherent sets of historical (1950-1990-2000) land cover change information in and around 75 Natura 2000 sites sampled from the boreal to the Mediterranean, and from the Atlantic to the continental regions of Europe. The total area covered will be 67,500 km$^2$ in the form of 75 30 km × 30 km windows (Figure 1). The next stage will be to convert the land cover change statistics into assessments of pressures on biodiversity.

The information produced has a twofold aim:

– as part of the GMES initiative, it is aimed at the EU-user community concerned with the impact of land cover and land use changes on the environment and biodiversity. The project's main stakeholder is the European Environment Agency and its topic centres (ETC-NPB and ETC-TE). Other users are DG Environment, the GMES project LADAMER, National conservation agencies and Regional and local authorities responsible for Natura2000 sites;
– as a contribution to EU Research programme on environment it will serve as input to develop knowledge and modelling on the relationships between land cover changes and biodiversity.

BIOPRESS uses Aerial photography of the 1950'ies to backdate CORINE Land Cover 1990 (and 2000 when available) and relies on information from the Natura 2000 database to ensure the sample of Natura 2000 sites is representative of the main biogeographical regions of Europe. This report shows some preliminary land cover change results observed inside and outside the Natura2000 sites present in three 30 km × 30 km windows located in Belgium. The windows in other EU countries will be analysed in the same way as soon as Natura 2000 boundary data is made available by DG Environment.

## Site description

In the case of Belgium, Natura 2000 site-boundary data is available to the public from the website http://www.gisvlaanderen.be/geo-vlaanderen/natura2000/ which is maintained by the 'Ondersteunend Centrum GIS Vlaanderen' of the 'Vlaamse Land Maatschappy'. Three of the six Belgian BIOPRESS sites were selected for this preliminary study. Figure 2 shows the location of the six Belgian 30 km × 30 km windows. The windows selected are window F, 209 and 210.


**Figure 1.** *Spatial Distribution of the selected windows relative to the Biogeographical Regions Map of Europe (note, Geographic Projection distorts 30 km windows in higher latitudes)*

## Window F

This window includes the “Zwin” which is a very important nature conservation area along the Belgian coast and contains some important polder grasslands. Possible pressures in this area are from industry, tourism and agriculture. The main area of industrial pressure present in this window is the harbour of Zeebrugge which has been expanding considerably over the study period. Another interesting aspect in this area of the coast is that the borders between agriculture and nature conservation areas have been established during the period 1950-2000.

The following table gives an overview of the Natura2000 sites and major habitat types for window F. Table 2 gives the habitat type description for the codes listed in table 1 and the following tables 3, 4 and 5.

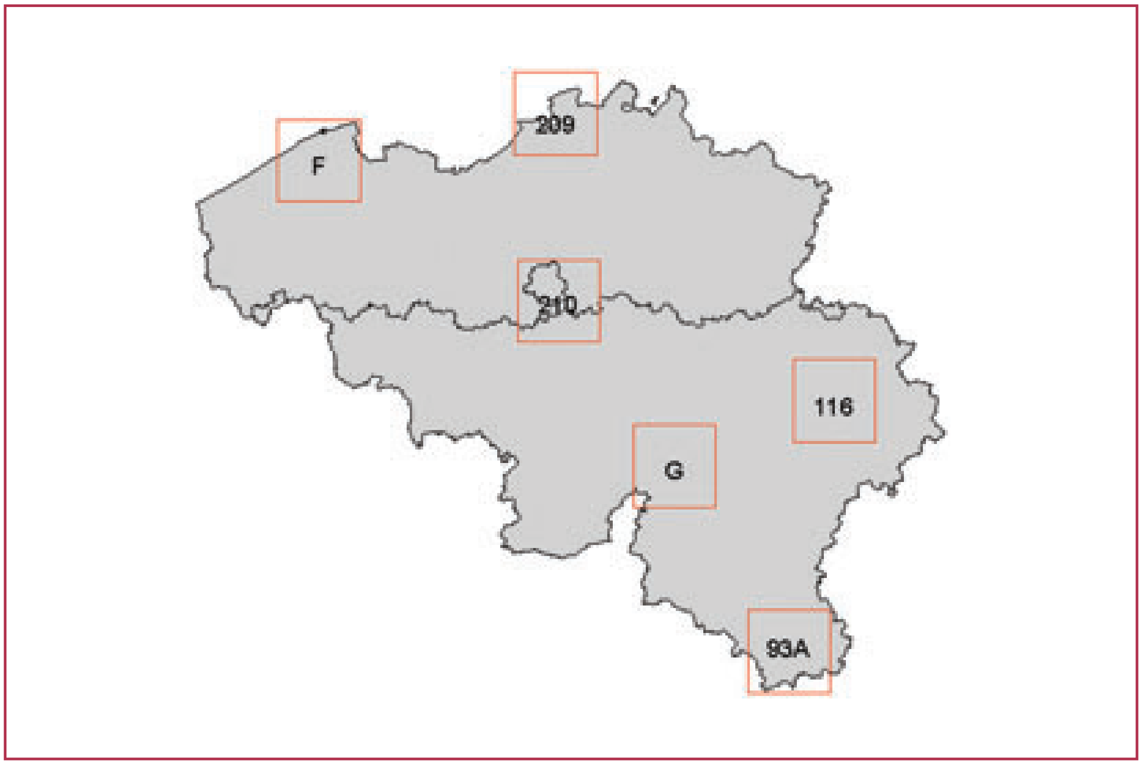


**Figure 2.** *The location of the six Belgian 30 km × 30 km BIOPRESS windows*

**Table 1.** *Natura2000 sites and major habitats in window F*

| Window # | Site names | Site codes | Major habitat | % | Represen-tativity |
|---|---|---|---|---|---|
| F | Duingebieden inclusief Ijzermonding en Zwin | BE2500001 | 2130 | 21 | A |
| | | | 2160 | 17 | A |
| | | | 2180 | 17 | C |
| | Polders | BE2500002 | 1330 | 12 | B |

**Table 2.** *Habitat type description*

| Habitat code | Habitat description |
|---|---|
| 1130 | Estuaries |
| 2130 | Fixed dunes with herbaceous vegetation ("grey dunes") |
| 2160 | Dunes with Hippophae rhamnoides |
| 2180 | Wooded dunes of the Atlantic coast |
| 2310 | Dry sandy heaths with Calluna and Genista |
| 91E0 | Alluvial forests with Alnus glutinosa and Fraxinus excelsior (Alno-Padion, Alnion incanae, Salicion albae) |

## Window 209

The centre of this window is the Natura2000 site "Kalmthoutse heide" which is part of a transborder nature area called De Zoom-Kalmthoutse heide. The nature park contains the heath habitats 4030 and 4010. Table 3 shows the different habitat types that are represented in the window.

**Table 3.** *Natura2000 sites and major habitat types in window 209*

| Window # | Site names | Site codes | Major habitat | % | Represen-tativity |
|---|---|---|---|---|---|
| 209 | Kalmthoutse heide | BE2100015 | 4030 | 28 | A |
| | Klein en Groot schietveld | BE2100016 | 4010<br>4030 | 12<br>12 | A<br>A |
| | Schelde en Durme estuarium | BE2300006 | 1130 | 10 | A |
| | Ossendrecht | NL54 | 2310 | | |

## Window 210

The centre point of window 210 falls in the Zoniën-Soignes forest that is situated very close to Brussels (also called the green lung of Brussels). It is also a Natura2000 site that is situated partly in the Brussels, Flemish and Walloon regions. Table 4 lists the habitat types contained in this window.

**Table 4.** *Natura2000 sites and major habitat types in window 210*

| Window # | Site names | Site codes | Major habitat | % | Represen-tativity |
|---|---|---|---|---|---|
| 210 | Zonienwoud | BE2400008 | 9120 | 80 | A |
| | Hallerbos | BE2400009 | 9130 | 27 | A |
| | Valleien van de Dijle, Laan en Ijse | BE2400011 | 9120 | 33 | B |
| | Valleigebied Melsbroek | BE2400010 | 91E0 | 18 | A |
| | Affluents brabançons de la Senne | BE31001 | 9130 | 54.4 | B |
| | Vallée de l'Argentine | BE31002 | 9120 | 64.6 | B |
| | Vallée de la Lasne | BE31003 | 9120 | 37.7 | A |
| | Vallée de la Dyle en aval d'Archennes | BE31004 | 4030 | 33.3 | B |



# Method and Results

The land cover change information was produced by backdating the CORINE Land Cover 1990 map (classification level 3) with black and white aerial photographs of the 1950'ies (Figure 3). This was carried out through manual interpretation by a team of experts in GISAT (Prague, Czech Republic). The Natura2000 site boundary data from Flanders and Brussels were used to split the windows into areas inside and outside the Natura2000 sites and land cover change matrices were produced accordingly. Table 5 lists the CORINE Land Cover level 3 classes to which the class numbers in the change matrices refer. The change results were presented to local experts and their comments included.

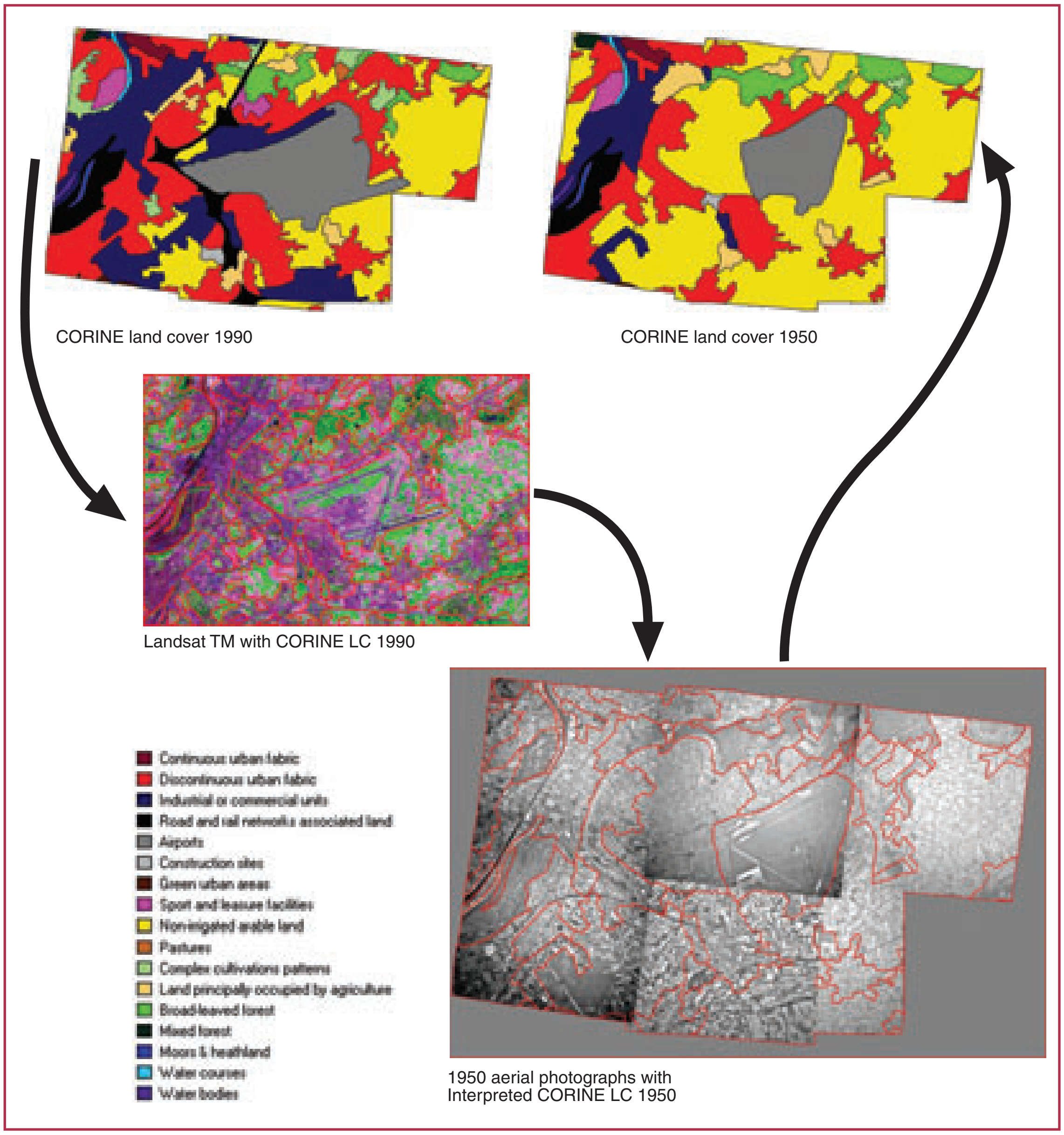


**Figure 3.** *A schematic overview of the CORINE backdating method*

**Table 5.** *CORINE Land Cover level 3 classes*

| CORINE Land Cover - level 3 classes | |
|---|---|
| 1.1.1. Continuous urban fabric | 3.1.1. Broad-leaved forest |
| 1.1.2. Discontinuous urban fabric | 3.1.2. Coniferous forest |
| 1.2.1. Industrial or commercial units | 3.1.3. Mixed forest |
| 1.2.2. Road and rail networks and associated land | 3.2.1. Natural grassland |
| 1.2.3. Port areas | 3.2.2. Moors and heathland |
| 1.2.4. Airports | 3.2.3. Sclerophyllous vegetation |
| 1.3.1. Mineral extraction sites | 3.2.4. Transitional woodland/shrub |
| 1.3.2. Dump sites | 3.3.1. Beaches, dunes, and sand plains |
| 1.3.3. Construction sites | 3.3.2. Bare rock |
| 1.4.1. Green urban areas | 3.3.3. Sparsely vegetated areas |
| 1.4.2. Sport and leisure facilities | 3.3.4. Burnt areas |
| 2.1.1. Non-irrigated arable land | 3.3.5. Glaciers and perpetual snow |
| 2.1.2. Permanently irrigated land | 4.1.1. Inland marshes |
| 2.1.3. Rice fields | 4.1.2. Peatbogs |

| | | | |
|---|---|---|---|
| 2.2.1. | Vineyards | 4.2.1. | Salt marshes |
| 2.2.2. | Fruit trees and berry plantations | 4.2.2. | Salines |
| 2.2.3. | Olive groves | 4.2.3. | Intertidal flats |
| 2.3.1. | Pastures | 5.1.1. | Water courses |
| 2.4. | Heterogeneous agricultural areas | 5.1.2. | Water bodies |
| 2.4.1. | Annual crops associated with permanent crops | 5.2.1. | Coastal lagoons |
| 2.4.2. | Complex cultivation | 5.2.2. | Estuaries |
| 2.4.3. | Land principally occupied by agriculture, with significant areas of natural vegetation | 5.2.3. | Sea and ocean |
| 2.4.4. | Agro-forestry areas | | |

## Window F

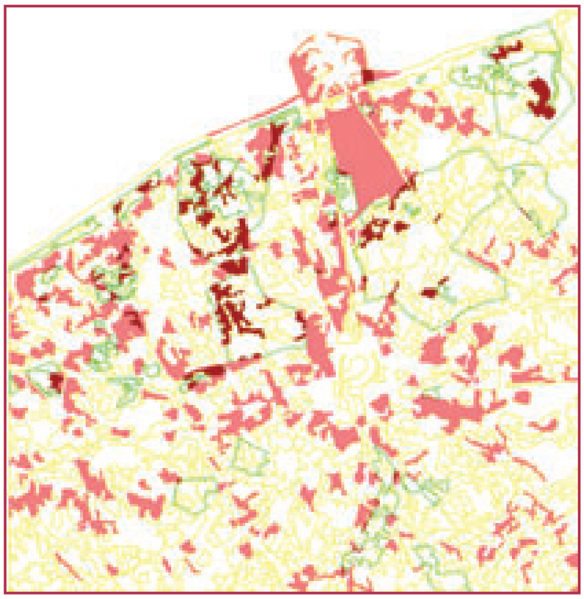

**Figure 4.** *LCC inside window F, lighter red are the changes outside the Natura2000 areas, darker red the changes inside; yellow is CLC90; green are Natura2000 sites*

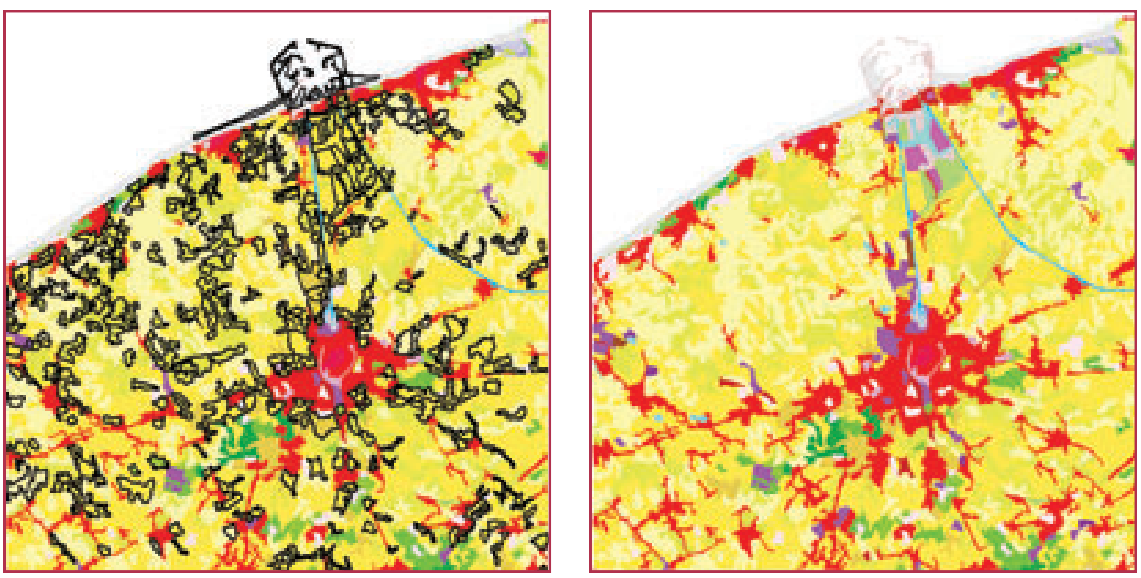

**Figure 5.** *LCC inside window F. right 1990 and left status 1950; area that changes from 1950 to 1990 are marked with a black outline in the 1950ties pictures*

**Table 6.** *The Land cover change matrix calculated for window F for the area inside the Natura2000 sites*

| 1950 \ 1990 | 1.1.2. Discontinous urban fabric | 1.2.1. Industrial or commercial units | 1.2.2. Road nd rail networks and associated land | 1.2.3. Port areas | 1.3.1. Mineral extraction sites | 1.3.3. Construction sites | 1.4.2. Sport and leisure facilities | 2.1.1. Non-irrigated arable land | 2.3.1. Pastures | 2.4.2. Complex cultivation | 3.1.2. Coniferous forest | 3.1.3. Mixed forest | 3.3.1. Beaches, dunes, and sand plains | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.1.1. Non-irrigated arable land | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.81 | 0.06 | 0.00 | 0.00 | 0.00 | 1.87 |
| 2.3.1. Pastures | 0.17 | 0.00 | 0.21 | 0.00 | 0.26 | 0.00 | 0.69 | 26.28 | 0.00 | 39.01 | 0.00 | 0.00 | 0.00 | 66.83 |
| 2.4.2. Complex cultivation | 5.39 | 0.00 | 0.00 | 0.00 | 0.00 | 0.58 | 0.03 | 5.61 | 9.14 | 0.00 | 0.00 | 0.27 | 0.00 | 21.01 |
| 2.4.3. Land principally occupied by agriculture, with significante areas of natural vegetation | 0.02 | 0.15 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.18 |
| 3.2.4. Transitional woodland/shrub | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 8.50 | 0.16 | 0.00 | 8.66 |
| 5.2.3. Sea and ocean | 0.00 | 0.00 | 0.00 | 0.40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.26 | 1.65 |
| **Total** | 5.58 | 0.15 | 0.21 | 0.40 | 0.26 | 0.58 | 0.72 | 31.88 | 10.95 | 39.07 | 8.50 | 0.43 | 1.26 | 100.00 |

**Table 7.** *The Land cover change matrix calculated for window F for the area outside the Natura2000 sites*

| 1950 \ 1990 | 1.1.2. Discontinous urban fabric | 1.2.1. Industrial or commercial units | 1.2.2. Road and rail networks and associated land | 1.2.3. Port areas | 1.3.1. Mineral extraction sites | 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 | 2.4.2. Complex cultivation | 2.4.3. Land principally occupied by agriculture, with significant areas of natural vegetation | 3.1.1. Broad-leaved forest | 3.1.2. Coniferous forest | 3.1.3. Mixed forest | 3.2.2. Moors and heathland | 3.3.1. Beaches, dunes, and sand plains | 5.1.2. Water bodies | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.2.1. Industrial or commercial units | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.12 |
| 1.2.3. Port areas | 0.00 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 | 0.14 |
| 1.4.2. Sport and leisure facilities | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.09 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.09 |
| 2.1.1. Non-irrigated arable land | 1.58 | 0.51 | 0.00 | 0.00 | 0.31 | 0.00 | 0.00 | 0.00 | 0.00 | 1.88 | 3.22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.30 | 7.79 |
| 2.2.2. Fruit trees and berry plantations | 0.18 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.18 |
| 2.3.1. Pastures | 1.06 | 0.22 | 0.57 | 0.69 | 0.11 | 0.12 | 1.07 | 0.39 | 4.25 | 0.00 | 19.94 | 0.00 | 0.00 | 0.00 | 0.00 | 1.68 | 0.00 | 0.57 | 30.68 |
| 2.4.2. Complex cultivation | 21.89 | 2.88 | 0.86 | 1.03 | 0.42 | 0.37 | 1.31 | 2.72 | 5.81 | 10.51 | 0.00 | 1.01 | 0.00 | 0.00 | 0.50 | 1.11 | 0.00 | 1.47 | 51.89 |
| 2.4.3. Land principally occupied by agriculture, with significant areas of natural vegetation | 1.77 | 1.42 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.30 |
| 3.2.2. Moors and heathland | 0.00 | 0.00 | 0.00 | 0.15 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 | 0.19 |
| 3.2.4. Transitional woodland/shrub | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.27 | 0.99 | 0.34 | 0.00 | 0.00 | 0.00 | 1.60 |
| 3.3.1. Beaches, dunes, and sand plains | 0.00 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 |
| 5.1.1. Water courses | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.14 | 0.14 |
| 5.2.3. Sea and ocean | 0.00 | 0.00 | 0.05 | 1.65 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.08 | 0.00 | 3.78 |
| **Total** | 26.47 | 5.14 | 1.48 | 3.61 | 0.84 | 0.60 | 2.38 | 3.11 | 10.06 | 12.58 | 23.17 | 1.01 | 0.27 | 0.99 | 0.84 | 2.79 | 2.08 | 2.56 | 100.00 |

The expansion of the Zeebrugge harbour is the most important phenomenon in this window. The gain of water bodies (512) is also due to harbour expansion. Part of the expansion happened within the Natura 2000 sites. The areas lost were probably parts of the salt meadows in the polder area.

In the agricultural areas there is a strong decrease in pastures (231) in favour or arable land (211), which is a general tendency in the Flanders.

The transition of 324 towards 312 is strange; not much coniferous forest was planted in this period and certainly not at the cost of other woodlands. There is a small increase in beaches and dunes. Probably this can be explained by dune formation near the salt meadow area 'Het Zwin' and at the 'Baai van Heist', two sand accretion zones. Loss of dunes in this area is prevented by coastal defence measures.

## Window 209

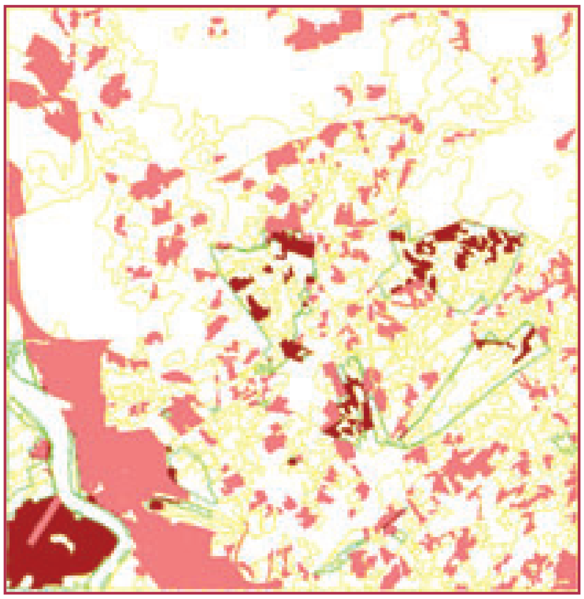

**Figure 6.** *LCC inside window 209, lighter red are the changes outside the Natura2000 areas, darker red the changes inside; yellow is CLC90; green are Natura2000 sites*

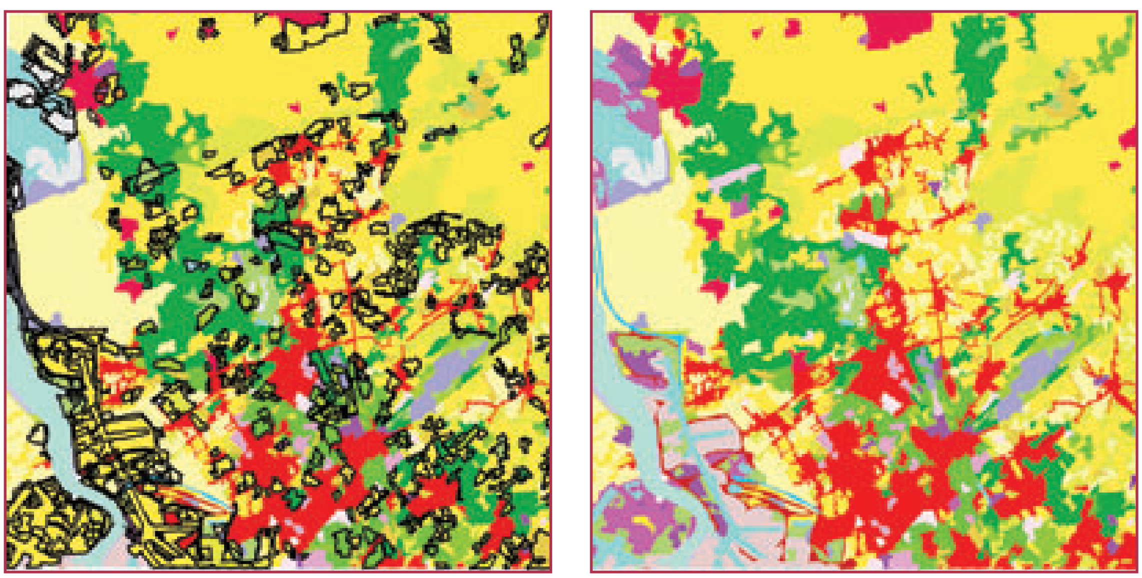

**Figure 7.** *LCC inside window 209. right 1990 and left status 1950. area that changes from 1950 to 1990 are marked with a black outline in the 1950ties pictures*

The two most important driving forces for the changes visible in window 209 are the expansion of the Antwerp harbour and the overall evolution of the agriculture in Flanders. The conversion of class 242 (Complex cultivation) to 133 (Construction site) is mainly due to the industrial expansion on the left bank (a Natura 2000 site) and the right bank of 'De Schelde' river. Changes from 242 to 512 (water bodies) are related to the creation of 'Het Kanaal Dok', a new harbour dock. Outside the Natura 2000 areas a more general urbanisation process can be observed, but this is expected to have a smaller impact than the harbour expansion. A large number of pastures (231) were converted into arable land (211 and 242), which in this particular area is dominated by an expansion of maize as crop.

Other visible but small changes are: the conversion of part of a forest (Transitional woodland shrub, 324) to a landing strip (124) in the Dutch part of the window and the changes from 'Transitional woodland shrub' (324) to Conifer (312) and mixed woodland (313). The latter requires further exploration of the polygons in question, however a possible explanation is that a natural succession of heath land into forest started before 1950 and has continued during the period of observation: spontaneous scrub and young plantations are now grown up forests.

The overall changes observed inside and outside Natura 2000 sites are very similar. For 'outside Natura 2000' a more scattered pattern can be observed in the matrices: the classes of 1950'ies are converted to a wider range of 1990 classes. The question is if this is a real difference or if it is just caused by the 'outside Natura 2000' covering a larger area than the 'inside Natura 2000'.





The implementation of Natura 2000 has just very recently started to have influence on the overall processes. It is therefore logical that the differences outside and inside are comparable. In this respect the Flemish situation is different to other regions. In a large number of countries the Natura 2000 network consist mainly of nature parks, nature reserves, which have a long tradition of nature conservation. In this window, this is also true for Kalmthoutse heath area, and more or less for the 2 military regions (although we see in the latter a lot of spontaneous successions due to lack of management). The Natura 2000 site in the north east is an intensively used agricultural area, declared special protection area due to bird populations typical for pastures (only a smaller marshy area is nature reserve). In the whole polder and harbour area at the left bank of 'De Schelde' river only very small parts are nature reserve.

**Table 8.** *The Land cover change matrix calculated for window 209 for the area inside the Natura2000 sites*

| 1950 \ 1990 | 1.1.2. Discontinous urban fabric | 1.2.1. Industrial or commercial units | 1.2.2. Road and rail networks and associated land | 1.2.3. Port areas | 1.2.4. Airports | 1.3.3. Construction sites | 1.4.2. Sport and leisure facilities | 1.4.2. Sport and leisure facilities | 1.4.2. Sport and leisure facilities | 3.1.2. Coniferous forest | 3.1.3. Mixed forest | 3.1.3. Mixed forest | 5.1.2. Water bodies | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.54 | 0.00 | 0.00 | 0.00 | 1.54 |
| 1.1.2. Discontinous urban fabric | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 |
| 1.3.3. Construction sites | 0.00 | 0.35 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.35 |
| 2.1.1. Non-irrigated arable land | 0.16 | 0.48 | 0.15 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.79 |
| 2.3.1. Pastures | 0.00 | 1.73 | 0.00 | 0.00 | 0.00 | 0.91 | 0.00 | 13.73 | 3.55 | 0.00 | 0.00 | 5.97 | 0.00 | 25.89 |
| 2.4.2. Complex cultivation | 0.69 | 0.66 | 0.95 | 0.00 | 0.00 | 24.19 | 0.00 | 1.66 | 0.00 | 0.00 | 0.14 | 7.07 | 13.50 | 48.86 |
| 2.4.3. Land principally occupied by agriculture, with significant areas of natural vegetation | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.27 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.27 |
| 3.1.2. Coniferous forest | 0.98 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.51 | 0.00 | 0.00 | 0.00 | 0.00 | 0.62 | 0.00 | 5.11 |
| 3.1.3. Mixed forest | 0.44 | 0.35 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.85 |
| 3.2.2. Moors and heathland | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.04 | 0.00 | 0.00 | 0.04 | 0.42 | 0.00 | 0.00 | 0.61 | 1.12 |
| 3.2.4. Transitional woodland/shrub | 0.11 | 0.00 | 0.00 | 0.00 | 1.37 | 0.00 | 0.00 | 0.00 | 0.00 | 6.09 | 5.77 | 0.59 | 0.78 | 14.72 |
| 4.1.1. Inland marshes | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.44 | 0.00 | 0.00 | 0.00 | 0.44 |
| 5.1.1. Waer courses | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 |
| **Total** | 2.38 | 3.55 | 1.14 | 0.01 | 1.37 | 25.18 | 3.51 | 15.73 | 3.58 | 8.48 | 5.91 | 14.25 | 14.89 | 100.00 |

**Table 9.** *The Land cover change matrix calculated for window 209 for the area outside the Natura2000 sites*

| 1950 \ 1990 | 1.1.1. Continous urban fabric | 1.1.2. Discontinous urban fabric | 1.2.1. Industrial or commercial units | 1.2.2. Road and rail networks and associated landa | 1.2.3. Port areas | 1.2.4. Airports | 1.3.1. Mineral extraction sites | 1.3.3. Construction sites | 1.4.1. Green urban areas | 1.4.2. Sport and leisure facilities | 2.1.1. Non-irrigated arable land | 2.3.1. Pastures | 2.4.2. Complex cultivation | 3.1.1. Broad-leaved forest | 3.1.2. Coniferous forest | 3.1.3. Mixed forest | 3.2.1. Natural grassland | 3.2.2. Moors and heathland | 3.2.4. Transitional woodland/shrub | 3.3.1. Beaches, dunes, and sand plains | 5.1.1. Water courses | 5.1.2. Water bodies | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.96 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.96 |
| 1.1.2. Discontinous urban fabric | 0.18 | 0.00 | 0.03 | 0.09 | 0.70 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.06 | 0.09 |
| 1.3.2. Dump sites | 0.00 | 0.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.13 |
| 1.3.3. Construction sites | 0.11 | 0.00 | 0.29 | 0.08 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.62 |
| 1.4.1. Green urban areas | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 |
| 2.1.1. Non-irrigated arable land | 0.28 | 0.24 | 1.49 | 0.04 | 0.00 | 0.00 | 0.00 | 0.59 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.40 | 0.10 | 0.00 | 0.23 | 0.24 | 3.64 |
| 2.2.2. Fruit trees and berry plantations | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.15 |
| 2.3.1. Pastures | 0.00 | 1.78 | 0.06 | 0.65 | 1.42 | 0.00 | 0.00 | 0.63 | 0.01 | 0.00 | 4.80 | 0.00 | 3.77 | 0.06 | 0.05 | 0.07 | 0.00 | 0.85 | 0.00 | 0.00 | 0.00 | 0.18 | 14.31 |
| 2.4.2. Complex cultivation | 4.04 | 5.46 | 1.80 | 2.25 | 5.57 | 0.07 | 0.11 | 17.40 | 0.00 | 0.33 | 3.98 | 0.00 | 0.00 | 0.00 | 0.43 | 1.21 | 0.23 | 2.77 | 0.00 | 0.00 | 0.41 | 5.64 | 51.68 |
| 2.4.3. Land principally occupied by agriculture, with significant areas of natural | 0.00 | 1.36 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.55 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.47 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.53 |
| 3.1.1. Broad-leaved forest | 0.00 | 0.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.15 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.28 |
| 3.1.2. Coniferous forest | 0.04 | 3.53 | 0.00 | 0.04 | 0.00 | 0.44 | 0.00 | 0.06 | 0.00 | 0.58 | 0.16 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.09 | 0.10 | 0.00 | 0.00 | 5.08 |
| 3.1.3. Mixed forest | 0.04 | 3.06 | 0.17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.00 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.10 | 3.61 |
| 3.2.2. Moors and heathland | 0.00 | 0.00 | 0.00 | 0.25 | 0.59 | 0.36 | 0.00 | 0.61 | 0.00 | 0.00 | 0.00 | 0.04 | 0.07 | 0.00 | 0.40 | 0.49 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 2.93 |
| 3.2.4. Transitional woodland/shrub | 0.00 | 0.81 | 0.00 | 0.07 | 0.00 | 0.23 | 0.00 | 0.00 | 0.00 | 0.12 | 0.00 | 0.13 | 0.00 | 0.00 | 3.01 | 2.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.62 |
| 3.3.1. Beaches, dunes, and sand plains | 0.00 | 0.00 | 0.30 | 0.00 | 0.29 | 0.00 | 0.00 | 2.81 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.23 | 3.62 |
| 4.1.1. Inland marshes | 0.00 | 0.00 | 0.00 | 0.00 | 0.07 | 0.00 | 0.00 | 0.15 | 0.00 | 0.00 | 0.91 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 | 0.00 | 0.00 | 0.00 | 0.61 | 0.00 | 1.80 |
| 5.1.1. Water courses | 0.00 | 0.00 | 0.03 | 0.02 | 0.04 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.00 | 0.07 | 0.20 |
| 5.1.2. Water bodies | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.47 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.70 |
| **Total** | 4.71 | 16.51 | 4.26 | 3.51 | 8.70 | 1.09 | 0.11 | 22.74 | 0.11 | 1.72 | 10.04 | 0.22 | 3.84 | 0.06 | 4.98 | 4.50 | 0.29 | 4.30 | 0.23 | 0.10 | 1.25 | 6.72 | 100.00 |

## Window 210

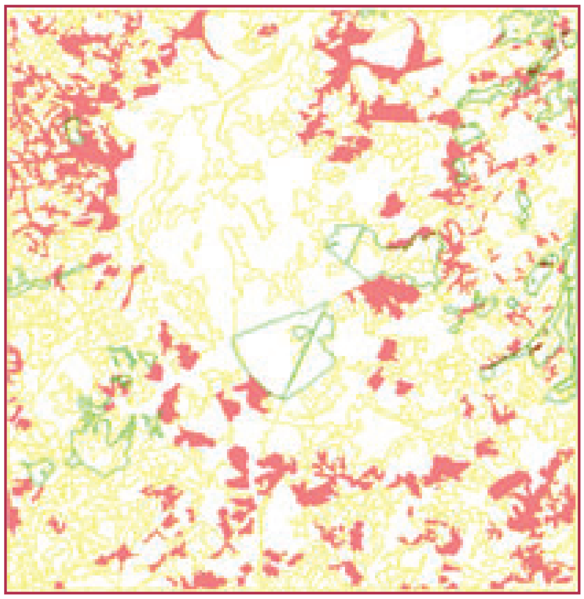

**Figure 8.** *LCC inside window 210, lighter red are the changes outside the Natura2000 areas, darker red the changes inside; yellow is CLC90; green are Natura2000 sites*

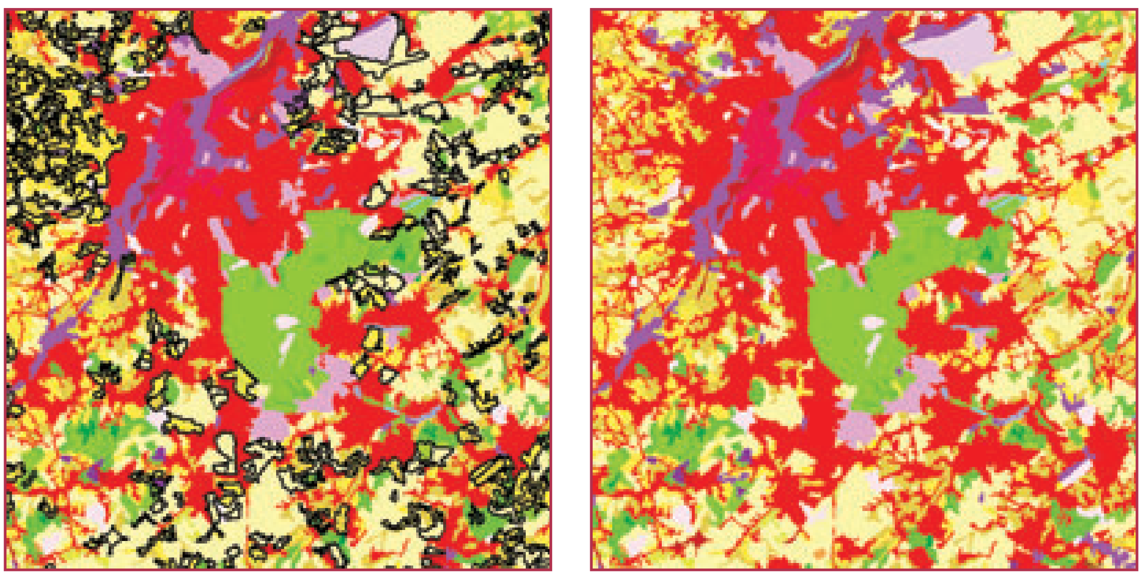

**Figure 9.** *LCC inside window 210 right 1990 and left status 1950. area that changes from 1950 to 1990 are marked with a black outline in the 1950ties pictures*

The main changes are due to the urbanisation and traffic expansion in and around the Brussels area. Also the airport of Zaventem has expanded. Very few of the changes have affected the nature conservation areas present in this window.

**Table 10.** *The Land cover change matrix calculated for window 210 for the area inside the Natura2000 sites*

| 1950 \ 1990 | 1.1.2. Discontinous urban fabric | 1.2.2. Road and rail networks and associated land | 1.3.1. Mineral extraction sites | 2.1.1. Non-irrigated arable land | 2.3.1. Pastures | 3.1.1. Broad-leaved forest | 5.1.2. Water bodies | **Total** |
|---|---|---|---|---|---|---|---|---|
| 2.1.2. Permanently irrigated land | 7.34 | 0.02 | 1.30 | 0.00 | 1.01 | 0.00 | 0.00 | 9.66 |
| 2.3.1. Pastures | 1.63 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.63 |
| 2.4.2. Complex cultivation | 28.61 | 0.00 | 0.00 | 0.74 | 0.65 | 4.00 | 0.00 | 34.00 |
| 2.4.3. Land principally occupied by agriculture, with significant areas of natural vegetation | 36.11 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.00 | 36.21 |
| 3.1.1. Broad-leaved forest | 6.57 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 9.12 | 15.69 |
| 3.1.3. Mixed forest | 2.80 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.80 |
| **Total** | 83.07 | 0.02 | 1.30 | 0.84 | 1.66 | 4.00 | 9.12 | 100.00 |

**Table 11.** *The Land cover change matrix calculated for window 210 for the area outside the Natura2000 sites*

| 1950 \ 1990 | 1.1.2. Discontinous urban fabric | 1.2.1. Industrial or commercial units | 1.2.2. Road and rail networks and associated land | 1.2.4. Airports | 1.3.1. Mineral extraction sites | 1.3.2. Dump sites | 1.4.1. Green urban areas | 1.4.2. Sport and leisure facilities | 2.1.1. Non-irrigated arable land | 2.2.2. Fruit trees and berry plantations | 2.3.1. Pastures | 2.4.2. Complex cultivation | 2.4.3. Land principally occupied by agriculture, with significant areas of natural vegetation | 3.1.1. Broad-leaved forest | 3.1.2. Coniferous forest | 3.1.3. Mixed forest | 5.1.2. Water bodies | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.1.2. Discontinous urban fabric | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 |
| 1.2.1. Industrial or commercial units | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.14 | 0.00 | 0.21 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.34 |
| 1.3.1. Mineral extrction sites | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.30 | 0.00 | 0.00 | 0.00 | 0.30 |
| 1.4.1. Green urban areas | 0.00 | 0.00 | 0.17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.17 |
| 1.4.2. Sport and leisure facilities | 0.05 | 0.00 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 |
| 2.1.1. Non-irrigated arable land | 23.59 | 5.74 | 3.06 | 3.40 | 0.26 | 0.00 | 0.15 | 1.92 | 0.00 | 0.21 | 0.38 | 0.51 | 0.11 | 0.03 | 0.00 | 0.00 | 0.00 | 39.35 |
| 2.1.2. Permanently irrigated land | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 |
| 2.2.2. Fruit trees and berry plantations | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.13 | 0.00 | 0.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.25 |
| 2.3.1. Pastures | 1.72 | 0.18 | 0.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.28 | 0.00 | 0.00 | 0.39 | 0.19 | 0.00 | 0.00 | 0.02 | 0.00 | 3.03 |
| 2.4.2. Complex cultivation | 31.03 | 3.30 | 0.71 | 0.00 | 0.11 | 0.00 | 0.00 | 0.49 | 0.48 | 0.00 | 0.07 | 0.00 | 0.03 | 0.06 | 0.00 | 0.19 | 0.00 | 36.47 |
| 2.4.3. Land principally occupied by agriculture, with significant areas of natural vegetation | 11.65 | 1.39 | 0.71 | 0.00 | 0.00 | 0.18 | 0.00 | 0.77 | 0.18 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.00 | 14.98 |
| 3.1.1. Broad-leaved forest | 1.07 | 0.00 | 0.00 | 0.00 | 0.14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 1.23 |
| 3.1.3. Mixed forest | 1.68 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.76 | 0.00 | 0.00 | 0.00 | 0.00 | 2.54 |
| 3.2.4. Transitional woodland/shrub | 0.94 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.14 | 0.00 | 0.00 | 1.14 |
| **Total** | 71.78 | 10.67 | 5.00 | 3.40 | 0.51 | 0.18 | 0.29 | 3.28 | 1.27 | 0.21 | 0.58 | 0.90 | 1.09 | 0.38 | 0.14 | 0.31 | 0.02 | 100.00 |

Table 12 compares the area and proportion of area outside Natura2000 sites that has undergone change with area and proportion area inside Natura2000 that has undergone change. However, the BIOPRESS research team has not yet initiated the detailed analysis of the changes and of their significance in terms of pressure on biodiversity. This will be done with the support of specialists aware of the local situations.

**Table 12.** *Comparison between area and % area change observed inside and outside Natura2000 sites.*

| | A | | B | |
|---|---|---|---|---|
| **Window** | **$Km^2$** | **%** | **$Km^2$** | **%** |
| **F** | 21.0 | 14.47 | 143 | 23.99 |
| **209** | 33.3 | 31.07 | 212 | 26.79 |
| **210** | 1.6 | 2.71 | 122 | 14.54 |

*A Area and % Area inside Natura2000 sites that has undergone changes*
*B Area and % Area outside Natura2000 sites that has undergone changes*

# Estimation of land cover change matrices. Use of ground surveys and photo-interpretation

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## Summary

Major land cover changes between two reference dates can be estimated from a sample of geographical units. Basic information can be obtained from ground visits or by photo-interpretation. This paper analyses two options: point surveys and photo-interpretation of satellite images. We present the approach followed in a pilot test for estimation of land cover change matrices with visual photo-interpretation of SPOT images on a site of 40 × 40 km in the area of Arles (South-East France). Some difficulties for such operations are underlined:

a) Risk of bias due to mislocation. Some comments are also given on the use of ground surveys on an area frame of points for the same purpose. In particular we analyse the possible consequences of providing or not providing the ground surveyor with the point observations in the previous visits. Such considerations could be useful for the possible application in LUCAS.
b) Need to regroup cells of the legend matrix.
c) Severe over-estimation of changes if comparison of classified images is applied.



## 1. Introduction: Land cover change statistics

Comparing traditional land cover or land use statistics we get information on the evolution of total area of arable land, permanent crops or grassland. For example from Table 1 we can say that the area of arable land increased between 1991 and 2001 in the Benelux, Italy, Ireland or France, and decreased in the Scandinavian countries, Greece, Spain, Austria, the UK, and a surprisingly strong decrease in Portugal (785,000 ha, i.e. 33%). On the other hand Portugal saw a major increase of grassland according to these figures (62%, i.e. 533,000 ha).

A first question to be asked is if such figures correspond to a real land cover change or part of it is due to a change in the way of applying the nomenclature (for example a change in the criterion to classify pastures into permanent or temporary). A second question is whether there has been 533,000 ha that have changed from arable into pasture or there has been a more complex process involving changes from arable to other classes and from other classes into pastures.

Each of these evolution figures is the aggregated result of several components, but we do not have information on the single components or on the spatial patterns of land cover change, although in some cases we can make a good guess. The example of change from arable to grassland in Portugal is probably in this category, assuming that there has been no change in the nomenclature criteria.

In other cases, it can be less clear. For example a stable figure for arable land might be due to very little changes in arable land, but from the information in the table we cannot exclude that it results from changes from grassland to arable land compensated with changes from arable land to forest or to urban.

Understanding land cover change processes requires estimations of the area flow between each pair of classes in a nomenclature. It is also important to have some knowledge on the location of each type of change in order to analyse links with soil, climate or topography. One of the goals of this study is testing the use of satellite images to estimate the area of land cover changes between two reference dates and some ways to combine them with other data, such as ground surveys or aerial photographs.

**Table 1.** *Area evolution for some land cover classes from REGIO data base (in 1000 ha)*

| | Arable | | Permanent crops | | Grassland | | Forest | |
|---|---|---|---|---|---|---|---|---|
| | 2001* | 1991 | 2001* | 1991 | 2001* | 1991 | 2001* | 1991 |
| Be | 846 | 776 | 21 | 17 | 521 | 556 | 607 | 617 |
| Dk | 2,498 | 2,563 | 12 | 10 | 184 | 212 | 493 | 493 |
| De | 11,813 | 11,559 | 208 | 218 | 5,013 | 5,330 | 10,531 | 10,433 |
| Gr | 2,213 | 2,334 | 1,130 | 1,075 | 1,789 | 1,789 | 2,940 | 2,940 |
| Es | 13,608 | 15,258 | 4,904 | 4,831 | 6,825 | 6,535 | 16,408 | 15,859 |
| Fr | 18,271 | 17,801 | 1,139 | 1,206 | 10,046 | 11,104 | 15,375 | 14,899 |
| Ie | 799 | 755 | 2 | 2 | 3,220 | 3,687 | 327 | 327 |
| It | 8,450 | 8,125 | 2,722 | 2,902 | 4,365 | 4,521 | 6,855 | 6,764 |
| Lu | 61 | 55 | 1 | 2 | 65 | 69 | 89 | 89 |
| Nl | 1,005 | 912 | 31 | 33 | 881 | 1,044 | 336 | 330 |
| At | 1,380 | 1,427 | 71 | 79 | 1,917 | 1,953 | 3,260 | 3,229 |
| Pt | 1,589 | 2,374 | 767 | 787 | 1,390 | 857 | 3,465 | 3,108 |
| Fi | 2,192 | 2,521 | 4 | 3 | 25 | 15 | 23,186 | 23,186 |
| Se | 2,694 | 2,789 | 4 | 4 | 366 | 576 | 23,633 | 22,535 |
| Uk | 6,452 | 6,545 | 51 | 56 | 10,019 | 11,174 | 2,486 | 2,410 |

* or latest date available before 2001

## 2. Estimating land cover change matrices

Here we use the expression "land cover change matrix" for the matrix that represents the area that has changed from land cover type *c* to land cover type *c'* for all *c* and *c'* in a given nomenclature. When we speak of "land cover change estimation" we refer rather to the aggregated information, as given in Table 1.

There are several possible ways to collect data to estimate land cover change matrices and analyse their spatial patterns. Similar approaches can be based on georeferenced observations on an area frame sample: ground surveys or photo-interpretation of aerial photographs and satellite images.

Ground surveys on a stable sample generally give more detailed information. They can allow the computation of backwards estimates in some countries that have been running such area frame surveys, such as France (Gay and Porchier, 1998), Spain (FAO, 1998, Ambrosio, 1993), Italy (Consorzio ITA, 1987), or Greece (Mimidis, 1992)., but some care is needed because changes could be dramatically over-estimated if the interpretation of the nomenclature has not been identical in different years, for example if there has been a wrong application of the nomenclature in one of the two years. On the other hand a posteriori quality checks of historical ground observations are difficult. A partial check is possible if surveys are combined with aerial photographs or satellite image acquisition. Additionally we discuss the possible bias of estimated land cover change matrices when there is location inaccuracy on repeated ground surveys with a permanent sample of points.

Land cover change matrices can be obtained by photo-interpretation of full coverages of satellite images at a relatively coarse scale. This is the approach followed by CORINE Land Cover 2000 (CLC2000): there is no sampling error because the whole territory is mapped in principle, but there are other potential sources of error linked with the scale (minimum mapping unit) and photo-interpretation errors.

A number of issues need to be addressed to tackle land cover change estimation from satellite images:

a) Which types of land cover change can be estimated by visual photo-interpretation of satellite images? For example distinguishing cropland and grass may be difficult, and change estimates from cropland to grass or vice versa may be unreliable.
b) Which ones require also aerial photographs and/or ground surveys?
c) How can we use automatic classification of satellite images for this purpose?
d) Are usual image classification techniques useful for land cover change estimation? or is there a need for specific algorithms for automatic change detection?
e) To which extent sampling error may be larger/smaller than bias due to coarse scale?
f) Which sampling scheme can be efficient for land cover change estimation?
g) How to combine fine-scale, approximately unbiased, information on a sample (e.g. LUCAS) with exhaustive coarse-scale information (CLC)?





## 2.1 Bias in land cover change matrices from area frame surveys

Ground surveys on an area sampling frame of points (for example LUCAS or TER-UTI) are an ideal tool for the estimation of land cover change matrices: the most reliable way to state that the land cover type has changed in a given point between year *t* and year *t'* is visiting the point in both dates. However this approach is not free of bias and some caution is necessary to keep the potential bias at a low level. The comments below are mainly referred to surveys with visit on the ground, but can be adapted to surveys by photo-interpretation.

We assume that a ground survey has been carried out in year *t* and in year *t'*. For both dates the same sample of points has been visited. We call

$Y_{i,t,c}$ = Observed land cover in point *i* and year *t* (0-1 variable for a land cover *c*).

$Z_{i,t,c}$ = True land cover in point *i* and year *t*. (also 0-1 variable for *c*)

The difference between $Y_{i,t,c}$ and $Z_{i,t,c}$ is due to location and observation inaccuracy (including interpretation of a class in the nomenclature):

$$Y_{i,t,c} - Z_{i,t,c} = \varepsilon_{i,t,c} = \varphi_{i,t,c} = \psi_{i,t,c}$$

$\varphi_{i,t,c}$ = location error with possible values –1, 0, and 1. It may be considered approximately unbiased, i.e. the probability that a point in class *c* is wrongly located in a different class *c'* is the same as the probability of the opposite event:

$$p(\varphi_{i,t,c} = -1) \cong p(\varphi_{i,t,c} = 1).$$

$\psi_{i,t,c}$ = difference between the interpretation of the nomenclature of a hypothetical perfect surveyor and the real surveyor. This includes real mistakes (e.g. recording wheat in a field of barley) and subjective interpretation of a fuzzy nomenclature (e.g. woodland, shrub). $\psi_{i,t,c}$ is usually biased, but it might be considered as approximately unbiased if the "perfect" surveyor is assimilated with an "average" surveyor.

We are interested on the estimation of a change. Assuming an equal probability sampling, the true change matrix $\Lambda$ is estimated by $A$ with elements:

$$A_{c,c'} = k\sum_i Y_{i,t,c} \times Y_{i,t',c'}$$

$A$ has two sources of error: sampling and differences between $Z_{i,t,c}$ and $Y_{i,t,c}$. Sampling error is generally unbiased, but the differences between $Z_{i,t,c}$ and $Y_{i,t,c}$ may originate a bias. It is important to notice that, if $\varphi_{i,t,c}$ and $\varphi_{i,t,c}$ are both unbiased, the area estimate of class $c$ in year $t$ $A_{c,t} = k\sum_i Y_{i,t,c} \times Y_{i,t',c'}$ is unbiased, but the area change estimate $A_{c,c'}$ from class $c$ to class $c'$ can be strongly biased. The possible situations contributing to bias $A_{c,c'}$ $c \neq c'$ are:

1. There is no change but class $c$ is observed in year $t$ and class $c'$ in year $t'$ (one of them or both because of observation error).
2. There is a change from $c''$ to $c'''$, interpreted as change from $c$ to $c'$ because of location or observation errors.
3. There is a change from $c$ to $c'$, but because of errors, it appears as "no change" or a different change type.

Situations 1 and 2 contribute to overestimation while situation 3 contributes to underestimation:

Compensation of causes of over and underestimation of $A_{c,c'}$ is unlikely, since most of the territory usually does not change land cover type in a few years with the type of nomenclature considered in table 1. Therefore the first cause of overestimation is by far the most likely to happen among the possible sources of bias.

We can think of two ways of organising the survey for the estimation of land cover change:

1. Surveys in both years are independent: The surveyor in year $t'$ does not know which land cover type has been observed for the same point in year $t$. The errors $\varepsilon_{i,t}$ and $\varepsilon_{i,t'}$ are independent, $A_{c,t}$ and $A_{c,t'}$ may be unbiased, (or have the same bias), but $A_{c,c'}$ $c \neq c'$ can be strongly overestimated, because it includes changes in $\varepsilon$. The heavy overestimation of change when the errors $\varepsilon_{i,t}$ and $\varepsilon_{i,t'}$ are independent is well known in remote sensing (Fuller et al, 2003). We come back later to this point.
2. Trying to oblige $\varepsilon_{i,t'}$ to coincide with $\varepsilon_{i,t}$ to eliminate the bias in change estimation. This can be better achieved if the surveyor in year $t'$ has the observation in year $t$ and is asked to write a comment if there are signs of change (new buildings, young trees or abandoned agricultural). In this way if there is an error in year $t$, the same error will appear in year $t'$. Before recording a change the surveyor will only if there is some indication of change: land no forest in the neighbourhood when forest had been recorded in year $t$. With this approach there is a small risk of underestimation of change because the surveyor may push $Y_{i,t',c}$ to coincide with $Y_{i,t,c}$ instead of pushing $\varepsilon_{i,t'}$ to coincide with $\varepsilon_{i,t}$. This may happen for example if an abandoned pasture is progressively invaded by woodland or shrub and this phenomenon escapes to the attention of the surveyor. It would be good to validate the instructions to surveyors that minimize this risk.

# 3. Photo-interpreting for change area estimation

One of the activities of the MARS Project (Meyer-Roux and Vossen, 1994, Gallego, 1999) was the so-called "Rapid crop area change estimation at European level" that used a set 60 sites of 40 km × 40 km located across Europe. We consider here one of these sites, located in the area of Arles, in SE France (Figure 1), combining visual photo-interpretation of a systematic subsample with automatically classified images in order to evaluate the economic feasibility of this approach for area change estimation.

## 3.1 General description of the test site

The site is located in the South of France (Region: Provence-Alpes-Côte d'Azur), in a complex, traditional agricultural area corresponding to the western part of the "Départment Bouches du Rhône". The site was mainly selected as a pilot test area due to its diversity in terms of land-use, landscape units, topography, soil, and agricultural management practices.

Within the site, a large range of annual and permanent crops can be observed: cereals (rice, wheat and maize), industrial crops, vegetables, permanent crops (fruit trees, olive trees and vineyards), pastures and natural grassland (livestock). Despite a productive and intensive agricultural system (located within extensive irrigation possibilities), agricultural activities are continually confronted with an important urban pressure (Montpellier, Avignon and Marseille) and a constant increase in infrastructures.

We used SPOT-XS and Landsat-TM images (Figure 2) that have been radiometrically calibrated and atmospherically and geometrically corrected within the MARS project. The resolution (pixel size) of SPOT-XS images is 20 meters. Landsat TM images have a resolution of 30 m, but they have been resampled to 20 m for homogeneity.



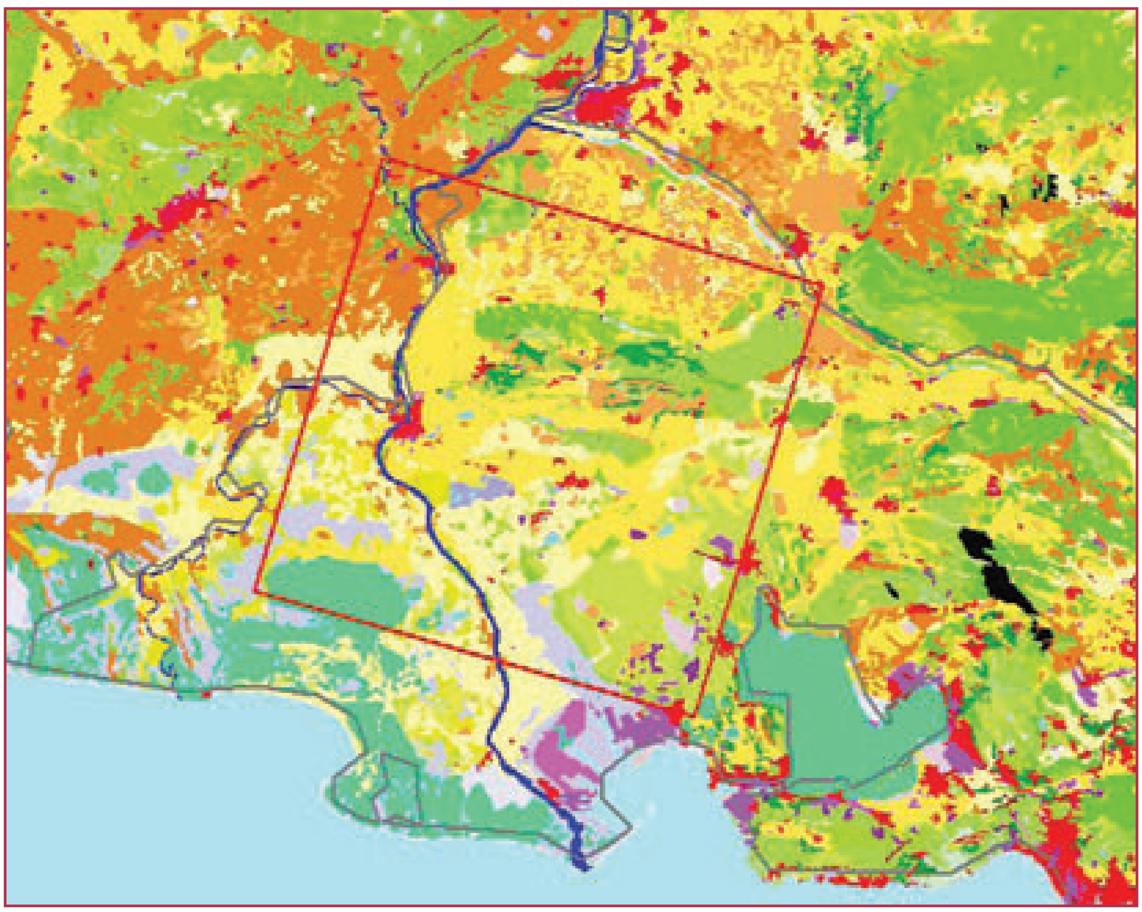

**Figure 1.** *Test site with CORINE Land Cover*

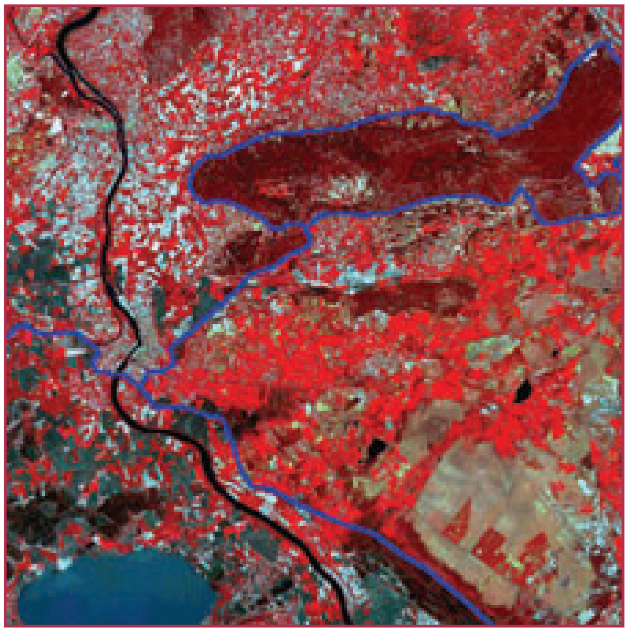

**Figure 2.** *Arles site and main landscape units*

The overall location accuracy of the geocoded images is within 1 pixel. Multi-temporal data sets were used in order to cover the different phenological stages of the main crops of interest, and in particular to differentiate pastures and permanent crops.

**Table 2.** *Images for the site Arles*

| | 1. | 2. | 3. | 4. |
|---|---|---|---|---|
| 1991 | TM: 28.03.91 | TM: 15.05.91 | XS: 05.07.91 | TM: 04.09.91 |
| 1998 | XS: 02.03.98 | XS: 10.05.98 | TM: 05.07.98 | XS: 09.09.98 |

### *Other data*

Ground survey data have been used, as well as topographic maps at scale 1/25.000 and 1:50.000, agronomic data, Digital Elevation Models (DEM) and CORINE Land Cover, a land cover map with common specifications in most European countries (CEC, 1993, Perdigão and Annoni, 1997). A few additional ground visits have been made, but they do not have the value of a proper ground survey for quality assessment, because no suitable data for 1991/92 were available.

## 3.2 Naïf change estimation using automatic image classification

From 1991 to 1998 satellite images for these sites were classified in the MARS project (Action 4 and Activity B) following a multi-step approach, which combines mono-temporal clustering analysis, manual labelling of classes by visual photo-interpretation and classification results of the previous year. The results of the classification were further processed and used as input together with other data sources in an extrapolation module and final figures were obtained for inter-annual crop area change (Hiederer et al., 1993, Genovese et al 1999), although the contribution of satellite images to the quality of the estimates is not clear (Gallego, 1999).

A first approach to the problem of land cover change matrix estimation would be based on pixel counting on automatically classified images. The area of pixels classified as class *c* in 1991 and class *c'* in 1998 would be an estimate of the area that changed from *c* to *c'*. If we apply this criterion to the final classifications of the site, we get Table

3. The figures in the off-diagonal cells are the result of accumulating real changes, classification errors and effects of location inaccuracy (including border effects).

In this table we can see that some unlikely changes appear to be far from zero, such as artificial area or water in 1991 becoming permanent crops or natural grassland in 1998. In most cases these unlikely cells report rather low figures, although there are some exceptions, such as "permanent crops" becoming "natural grassland" (more than 3000 ha reported).

Some other changes reported look too high to be acceptable. For example it is unlikely that more than 11000 ha changed from permanent crops to other land cover types (nearly 40% of the area under permanent crops) and another 9000 ha changed from other land cover types to permanent crops. According to this matrix, a total of 38000 ha have changed land cover type, i.e. 24% of the site.

**Table 3.** *Naïf land cover change matrix estimated by pixel counting on automatically classified images in the Arles site (in hectares)*

| | | 1998 | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | | Artificial | Arable | Perm. Crops | Pastures | Wood | Natural grass | Water | Mask | Total |
| 1991 | Artificial | **5679** | 29 | 84 | 37 | 17 | 85 | 4 | 7 | 5943 |
| | Arable | 705 | **24625** | 3141 | 8703 | 179 | 733 | 253 | 24 | 38363 |
| | Perm. crops | 689 | 3459 | **17005** | 3117 | 565 | 3141 | 296 | 27 | 28300 |
| | Pastures | 187 | 3388 | 3074 | **12018** | 103 | 651 | 12 | 7 | 19439 |
| | Wood | 41 | 111 | 473 | 195 | **4316** | 383 | 76 | 14 | 5609 |
| | Nat. grass | 423 | 348 | 2092 | 346 | 245 | **18254** | 325 | 21 | 22054 |
| | Water | 39 | 44 | 58 | 54 | 26 | 44 | **3156** | 3 | 3424 |
| | Mask | 2 | 36 | 18 | 17 | 7 | 26 | 7 | **36423** | 36537 |
| | Non identif. | 1 | 4 | 18 | 4 | 3 | 34 | 186 | 1 | 252 |
| | Total | 7764 | 32044 | 25962 | 24492 | 5463 | 23352 | 4316 | 36527 | |

## 3.3 Regrouping land cover change types.

The land cover change matrices with a simplified nomenclature (7 classes) contain 49 classes (cells of the table). For the purpose of mapping or for using classified images as covariables, we have grouped them into a smaller number of types.

Table 4 gives the groups used for the site of Arles.

**Table 4.** *Groups of land cover change categories*

| | | 1998 | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | | Artificial | Arable | Perm. Crops | Pastures | Wood | Natural grass | Water |
| 1991 | Artificial | 0 | 6 | 6 | 6 | 6 | 6 | 6 |
| | Arable | 1 | 0 | 7 | 5 | 3 | 3 | 6 |
| | Perm. Crops | 1 | 7 | 0 | 7 | 3 | 3 | 6 |
| | Pastures | 1 | 4 | 7 | 0 | 3 | 3 | 6 |
| | Wood | 1 | 2 | 2 | 2 | 0 | 7 | 6 |
| | Nat. grass | 1 | 2 | 2 | 2 | 7 | 0 | 6 |
| | Water | 1 | 6 | 6 | 6 | 6 | 6 | 0 |

0: no change
1: New artificial (urban expansion)
2: From natural vegetation to agricultural (agricultural expansion)
3: Abandoned agricultural land
4: From pastures to arable
5: From arable to pastures
6: Unlikely (but not impossible)
7: Other changes

## 3.4 Photo-interpretation

Visual photo-interpretation was carried out for a sample of segments in the site of Arles. The definition of nomenclature was based on CORINE Land Cover. The photo-interpreter is asked to avoid as much as possible the use of labels of mixed land cover (CORINE class 2.4.*, "heterogeneous").

| | |
|---|---|
| 1. | Artificial surfaces |
| 2.1. | Arable land |
| 2.2. | Permanent crops |
| | Fruit trees |
| | Olive trees |
| | Vineyards |
| 2.3. | Pastures |
| 2.4.1. | Annual crops associated with permanent crops |
| 2.4.2. | Complex cultivation patterns |
| 2.4.3. | Agriculture, with natural vegetation |
| 2.4.4. | Agro-forestry areas |
| 3.1.1. | Broad-leaved forest |
| 3.1.2. | Coniferous forest |
| 3.1.3 | Mixed forest |
| 3.2. | Shrub and/or herbaceous vegetation associations |
| 3.2.1. | Natural grassland |
| 3.3. | Open spaces with little or no vegetation |
| 4.1. | Inland wetlands |
| 4.2. | Coastal wetlands |
| 5.1. | Inland waters |
| 5.2. | Marine waters |

## 3.5 Photo-interpretation by polygons

The minimum cartographic unit for this study was defined to be 1 hectare. In some areas the minimum cartographic unit of 1 ha did not correspond to the complexity of agricultural pattern and the visual interpretation based on a pixel size of 20 meters was not sufficient to distinguish different types of agricultural land use.

For the visual image interpretation the software Co-Pilot (CORINE Photo-Interpretation Land cover Oriented Tool) was used. The Co-Pilot software is an integrated geographic information system, developed regarding the updating of CLC database. Within the Co-Pilot system, it is possible to integrate satellite images together with other multi-data layers (vector or raster data) in order to perform visual image interpretation.

Photo-interpretation of the whole site with this level of detail was considered too cumbersome. Therefore a systematic sample of 36 segments with a size 2 km × 2 km was selected. The segments were first photo-interpreted on the basis of the 1991 images. The resulting polygones of this photo-interpretation were then overlaid on the 1998 images to identify and digitise changes (Figure 3). The size threshold (1 ha) was affordable (workload) for the sampling plan and sufficient to distinguish main land cover and identification of land cover changes.

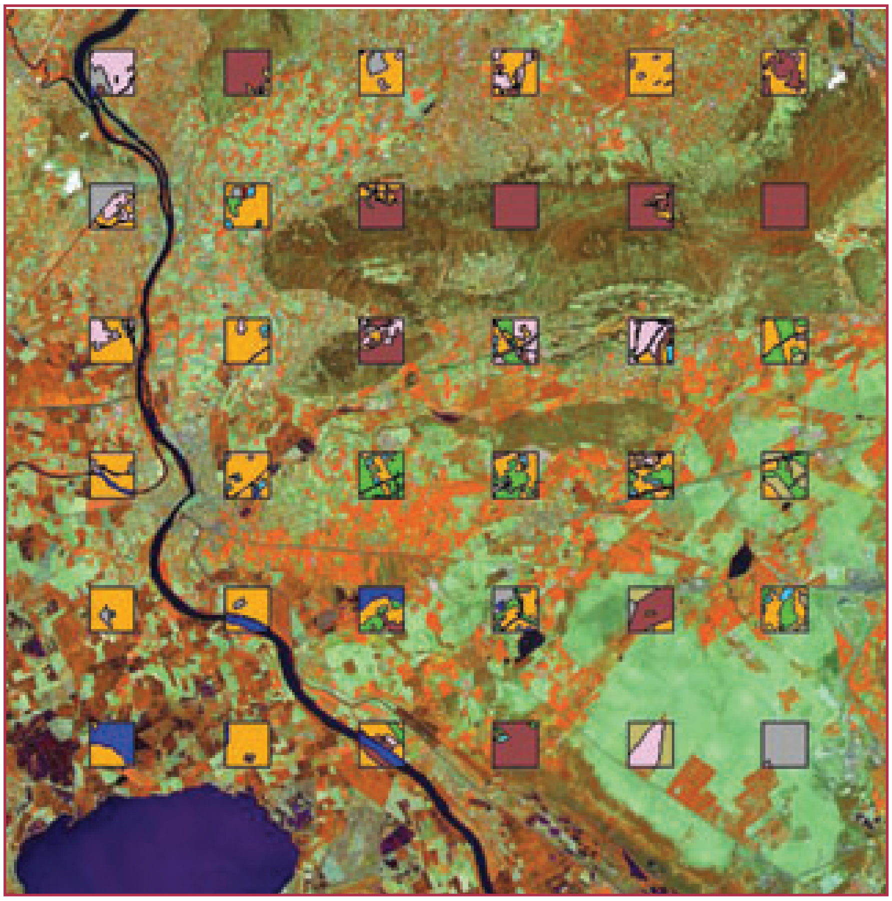

**Figure 3.** *Polygon photo-interpretation*

## 3.4 Photo-interpretation

A systematic sample of 81 points was selected within each segment of 2 km ×2 km, in a grid of 200 meters. Compared with the polygon approach, the point approach gives additional information: changes can be identified for units smaller than the minimum cartographic unit of 1 ha. However identifying smaller changes was difficult and its reliability is often debatable when spectral contrast is insufficient (this often happens with permanent crops). The point approach adds a variance component to the estimates.

If we look at the land cover area estimated at each date (total of rows and columns in Table 5 and Table 6) the main difference between point and polygon approach is that the point approach gives a higher area of artificial surfaces and a lower area of arable land. This seems to happen because isolated buildings or small built areas are missed by the polygon approach

Concerning land cover changes, point and polygon approaches give quite consistent results, with some differences due to the variability introduced with the point sub-sampling, in particular for forest, that seem to have a slight decrease in the polygon approach while the point approach estimates a minor increase. The total area involved on land cover change is estimated to be 5240 ha (5050 ha by point photo-interpretation), compared with the 38000 obtained with the naïf estimator. For the other classes we notice:

- Increase of artificial area (more moderate with the point approach)
- Decrease of arable land
- Permanent crops are unchanged
- Increase of pastures
- Slight decrease in surfaces under natural grassland

**Table 5.** *Land cover change matrix between 1991 and 1998 estimated by polygon photo-interpretation*

| | 1998 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | *in hectares* | Artificial | Arable | Perm. Crops | Pastures | Wood | Natural grass | Water | Total |
| 1991 | Artificial | 11319 | 0 | 0 | 0 | 0 | 0 | 0 | 11319 |
| | Arable | 917 | 66059 | 0 | 2720 | 0 | 0 | 0 | 69696 |
| | Perm. Crops | 0 | 0 | 16196 | 0 | 0 | 0 | 0 | 16196 |
| | Pastures | 162 | 839 | 0 | 12809 | 0 | 0 | 0 | 13810 |
| | Wood | 0 | 152 | 0 | 125 | 35041 | 0 | 0 | 35319 |
| | Nat. grass | 0 | 292 | 0 | 0 | 0 | 5537 | 0 | 5829 |
| | Water | 0 | 0 | 0 | 0 | 0 | 0 | 7833 | 7833 |
| | Total | 12398 | 67342 | 16196 | 15654 | 35041 | 5537 | 7833 | |

**Table 6.** *Land cover change matrix between 1991 and 1998 estimated by point photo-interpretation*

| | 1998 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | *in hectares* | Artificial | Arable | Perm. Crops | Pastures | Wood | Natural grass | Water | Total |
| 1991 | Artificial | 14321 | 0 | 0 | 0 | 0 | 0 | 0 | 14321 |
| | Arable | 274 | 61893 | 0 | 2743 | 55 | 0 | 0 | 64966 |
| | Perm. crops | 0 | 55 | 16571 | 0 | 0 | 0 | 0 | 16626 |
| | Pastures | 219 | 384 | 0 | 12565 | 0 | 0 | 0 | 13169 |
| | Wood | 55 | 329 | 0 | 274 | 36708 | 0 | 0 | 37366 |
| | Nat. grass | 0 | 219 | 0 | 0 | 0 | 4993 | 0 | 5213 |
| | Water | 0 | 0 | 0 | 0 | 0 | 0 | 8340 | 8340 |
| | Total | 14869 | 62880 | 16571 | 15583 | 36763 | 4993 | 8340 | |

## *Classified images as proxy variables*

The problem of estimating land cover change matrices is similar to the problem of estimating land cover area for a particular year (Gallego, 2004). The main difference is that location errors of individual observations are usually not dramatic for area estimation, but become a major problem for land cover change matrices. In both problems we can apply the principle of combining accurate information on a sample and less accurate (but cheaper) information covering the whole population or a large sample. Less accurate information is often called “proxy variable” or “covariable”.

We can consider two options to acquire accurate information on a sample:

– ground surveys.
– visual photo-interpretation of aerial photos and/or satellite images.

Both ground surveys and visual photo-interpretation can be made by points or by polygons.

We have used as covariable available image classifications from the European rapid estimates of the MARS Project. Proxy variables can be used in two ways:

– a posteriori correction of estimators or
– to improve the sample of units to be visited or photo-interpreted.

*Combining land cover change from photo-interpretation and from image classification*

For the 36 photo-interpreted segments, we can link the main land cover change categories (groups defined in Table 4) identified by photo-interpretation and by the classified images from MARS activity B. Table 7 shows the total area identified as land cover change for each group. For categories 1, 2, 4 and 5 there is a disagreement in the order of magnitude, but classified images can be useful as covariable if there is a good correlation between both sources, i.e. if segments for which a higher change has been identified from photo-interpretation tend to have also a higher rate of change from image classification.

The strongest correlation (r=0.46) appears for the change from arable to pastures. This means that the possible land cover change identified from classified images in activity B can be used as covariable to improve the estimate of land cover change reducing the variance by a factor that is approximately $(1 - r^2)$, i.e. about 20% reduction. However the same correlation is found between photo-interpreted land cover change and CORINE Land Cover, even if the CORINE Land Cover data do not refer to a change. CORINE Land Cover data have the advantage of being available nearly everywhere.

**Table 7.** *Area identified as land cover change in a sample of 36 segments in the site of Arles (in hectares)*

| code | change category | classified image | photo-interpretation | correlation Δ Activity B - Δ photoint | correlation Δ photoint CLC |
|---|---|---|---|---|---|
| 0 | No change | 11667 | 13931 | 0.32 | –0.31 |
| 1 | New artificial | 234 | 97 | 0.20 | 0.15 |
| 2 | Natural to agriculture | 185 | 51 | –0.08 | –0.13 |
| 3 | Abandoned agricultural | 193 | 0 | n.a. | n.a. |
| 4 | Pastures to arable | 392 | 76 | 0.12 | 0.16 |
| 5 | Arable to pastures | 1067 | 245 | 0.46 | 0.46 |
| 6 | Unlikely | 13 | 0 | –0.07 | 0.15 |
| 7 | Other | 650 | 0 | n.a. | n.a. |
| total | | 14400 | 14400 | | |

## 4. Conclusions

From the tests reported in this paper, some conclusions can be drawn on the combination of photo-interpretation of satellite images or aerial photographs and classified images.

### 4.1 Automatic classification techniques

Standard image classification techniques provide land cover maps for a given year with a moderate accuracy. They are relatively fast to process a large area. It is well known that land cover area estimates by pixel counting are generally biased (Czaplewski, 1992), but can be acceptable for land cover types for which the classification is very good. For land cover change identification, most of the pixels identified as "change" with usual classification techniques in two different years correspond in fact to classification errors. Pixel counting give a strong overestimation of land cover change area.

Classifications from Activity B of the MARS Project were not adapted to be used as proxy variables for the estimation of transition matrices. New algorithms must be assessed to provide efficient proxy variables for the estimation of land cover change matrices.

## 4.2 Visual photo-interpretation: polygons and points

A detailed satellite image photo-interpretation is more reliable, but more expensive than automatic classification. For area estimates at a reasonable cost it should be performed on a sample.

No clear conclusion could be reached on the cost-efficiency comparison between point and polygon photo-interpretation. Points can detect changes in areas smaller than 1 ha (polygon size threshold), but points oblige the photo-interpreter to take a decision for each point to provide more detailed information. Point photo-interpretation adds a variance component.

However there are important limitations: It is nearly impossible to identify permanent crops using only SPOT and TM satellite data with a resolution of 10 to 30 m. Other sources of information, such as aerial photographs, preferably ortho-rectified, are needed. The minimum mapping unit (1 ha in this test) depends on the used data and complexity of the zone. It is very difficult to go below 1 ha with SPOT or TM images. Identification of some types of change, such as arable land to pastures or pastures to arable land, is very difficult. Suitable ground data are needed for these checks.





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# Analysis of territory diversity and of its evolution. Tools and methods of the National Forest Inventory (France)

JEAN-GUY BOUREAU, CLAUDE VIDAL

## 1. The landscape concept

### 1.1. The landscape: a system

The landscape concept, such as it is conceived today, can not be reduced to the study of only the physical elements of the countryside and to traces of human activity. In addition to this is a subjective element represented by the perspective that the observer overlooks the environment which surrounds him. The landscape is consequently at the same time a physical object and the view observed by the observer over the countryside is to some extent "physical space and mental representation" [8].

The landscape, which calls upon a visual perception of reality, is the place in which several overlapping *components* [16], centred around two poles, interact: a concrete space developed by man and an observer with his actual experiences and his cultural and emotional references.



– The first one of these components, also called physical space, is made up of the natural biotic or non-biotic elements that are present in the countryside: relief, rocks, water or vegetation, whatever the aspect or the development stage of these elements.
– A second component corresponds to the influence of man on his surroundings. Economic activity will indeed shape these physical elements or impress its marks on them: forest management, farming, dwellings, communication networks, industries, etc.
– Finally, the third component of the landscape lies in its cultural density, i.e. in what everyone feels when observing a given picture. The observer's actual experiences, his feelings or even his culture in the broad sense of the term, play a contributing factor. There is a transition from the quantitative to the qualitative here.

Thus, between the material components that the physical elements and the traces of human activity, which form the observable reality are either object-landscape, and the cultural component, or the manner in which the visible landscape is perceived [18]. It is nothing but the portion of the object-landscape as seen from the place where the observer is located.

Analysing such a "system" will tackle in first place, the object-landscape, which is easier to describe and quantify than the perceived landscape. Thus, land occupation indicators could be defined from area frame survey data, concerning the whole territory like TERUTI [13] or LUCAS.

The appraisal of the perceived or observed landscape is more delicate. It requires the establishment of a value scale, likely to reflect the quality of a landscape and which relies amongst others, on the expectations of the society [8].

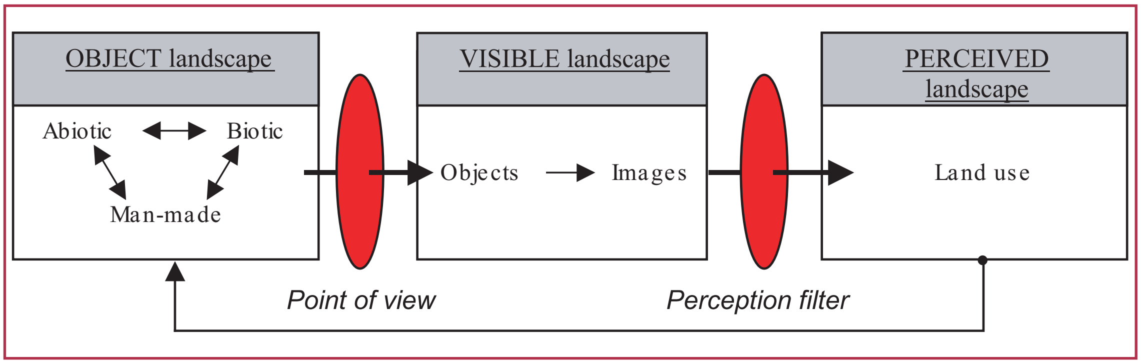


**Figure 1.** *The components of the "system" landscape.*
According to Eurostat, Statistics in short: Agriculture, 1998. *European landscapes: more than half of the territory maintained by the farmers*. Adapted of Wieber JC, 1985. *The visible landscape, a necessary concept*. In: Berdoulay V, and Phipps Mr, *Landscape and system*. Ottawa University Press.

**Aerial photography and landscape**

The vertical aerial photograph is a technical picture, primarily descriptive, even if it can have an artistic or aesthetic dimension.
The landscape is an emotional relationship between man and his countryside [9] which, necessarily, leads to the symbolic. The emblematical illustration of that is the horizon, which creates a link with the imaginary beyond, the dream of each one. To consider the country up to its horizon, the observer has, inevitably, got to have his feet on the ground.
Speaking about "landscape" from vertical photographs constitutes therefore a semantic abuse. However, we will allow ourselves this presentation of the potential offered by the aerial view within the framework of landscape analyses.




## 1.2. Countryside diversity and methods of apprehension

A territory is characterised by its heterogeneity and by its dynamics impelled, to some extent, by human activities. When analysing this diversity, the number of objects present and their relative abundance must be taken into account, in order to compare different landscapes or two states of the same landscape at different times. Therefore, it becomes necessary to identify the elements of this mosaic in addition to their size, form and space pattern, within each one of the main categories of land cover and of land use. In other words, all aspects that can vary with the observation scale.

Those elements, natural or man-made, are of various natures. They are mostly area objects (wooded patches or agricultural plots), connected sometimes by linear elements or corridors.

A summary classification of the elements relating to the agricultural landscapes was proposed by the European authorities and Working Parties of the OECD [14]. It revolves around four major types of objects:

- Pin-point elements, characterised by their low surface, irrespective of their nature,
- Linear elements, hedges, brooks or paths, but also walls or canals,
- Area elements, woods, fields, vines, orchards or meadows,
- Characteristic elements of a region, rice plantations or wooded patches, for example.

With regards to the methods of perception of the diversity of a countryside, they relate either to the environment or to man or to both of them. Therefore, so-called objective or subjective approaches, i.e. putting the object of study or the observer in first place, or even economy-based approaches, have been developed. Other methods

**Figure 2.** *Bocage landscape in the Champagnole region (French Jura)*

**Figure 3.** *Mixed agriculture and forest landscape near the Northern border of the Limousin plateau (Haute-Vienne)*

stress the existence of links between object and subject. In this case they use sociological surveys or traditional ground photographs as an active survey tool [8]. Those photographs are not, however, used as completely objective tools, since they are subject to the subjectivity of the investigator who analyses them.

At least during the first approach, only the analysis of the object-landscape and its evolution will be considered. The landscape will therefore be captured, by focusing on its physical components and on the traces of the human activity that can be deduced from them. The analysis of the composition (nature, number, specific diversity, frequency) or of the spatial structure of the objects, present on a territory (organisation of what is present), represent two possible and interdependent angles of versatile approach.

With respect to the data available for this type of analysis, they are of statistical or cartographic nature, or represented by the various existing or available pictures: aerial photographs and satellite pictures. Only a bird's eye-view makes it possible to perceive a landscape "in all its entirety and its variety [7]". However, if these pictures are a source of considerable information, it can only be acquired by the performance of the eye-brain system. Interactions and inter-relationships between the elements existing in a picture, are still difficult to automate, but are defined in a simple and natural way by a visual analysis.

Complementary to the statistical and cartographic approaches, and without claiming to quantify the entire perceived landscape, the contribution of these pictures to a more complete apprehension of the landscapes will be analysed.

## 2. Countryside evolution indicators

Here, the aim is to compare the levels of heterogeneity of different sites, or those of the same site at different times. The overall heterogeneity of a site or its evolution in time, can be represented with its two components, which determine the diversity of the elements which it constitutes and the degree of complexity of their spatial relations.

Indicators, generally quantitative, simple or more elaborate variables, allow a description of this heterogeneity, enables quantification and the apprehension of its evolution.

Those indicators can be classified in three major types, according to whether they are:

- Of statistical nature and resulting from a sampling of the territory to be analysed, the "*département*" (NUTS 3) or a natural entity like the forest region. It is a first level of general characterisation of the landscapes. This generally involves data pertaining to land occupation (forest areas, heath land or farmland) or to its evolution (afforestation rate evolution rate). The territory is then characterised on a scale smaller than the one on which local observers would perceive it. Surface measurements, frequency analysis, Shannon indexes [3], which measures diversity as a result of the number of species and the regularity of their distribution, or co-occurrence matrixes [12] are some tools to build this category of indicators.
- Of cartographic nature, i.e. pertaining to the spatial organisation of categorised, individualised and in general geo-coded objects. The aim is to apprehend the organisation of the landscape and the fitting of the elements characterised by each class of the classification, and to determine as to whether they are of specific, linear or area nature. The characterisation of the fragmentation of a field, the compactness? index, the importance of the edges or contour density, space connectivity or relations between the spots or the intermingling and juxtaposition index are some indicators enabling the apprehension of the heterogeneity of the space of a territory or its evolution.
- Results from pictures (aerial photographs, satellite or virtual pictures), are two- or three-dimensional, or relative to their ground resolution. If no specific "standardised" indicator relates to these pictures, they however contain complete information, individualised and in a historical prospective. Therefore, they are likely to aid in the analysis of the object-landscape, as well as for understanding more objectively and consensually the perceived-landscape and its evolution according to present actions and decisions.

## 3. National Forest Inventory data

### 3.1. Mission and objectives

The National Forest Inventory (IFN) is responsible for carrying out "the continuous survey of the national forest resources, independent of any question of ownership". Therefore, a permanent statistical inventory of the French forests has been undertaken since 1960, within the geographical framework of the *départements* and at intervals of 12 to 15 years.

The aims of the IFN [4] are in first place, the estimation of the surfaces pertaining to the main categories of land use, and in second place, the estimation of the available wood resources in production forests: volumes and yield, by species, stand types and product categories. A third objective complies with environmental concerns. This resulted in the collection of data about stands and flora, which allowed IFN to contribute to national and regional studies of typology of the forest stations, of asset evaluation or of sustainable management indicator assessment.

### 3.2. Tools and method

Adapted to the specific character of the French forest, the method implemented by IFN relies on an extensive use of aerial photographs. Each one of the 95 metropolitan *départements* is the target of a complete aerial cover, renewed approximately every 12 years. The IFN photographic library, built from the beginning of the 1960s until today. It thus hosts more than 400,000 pictures representing almost 3.5 times the total area of France.

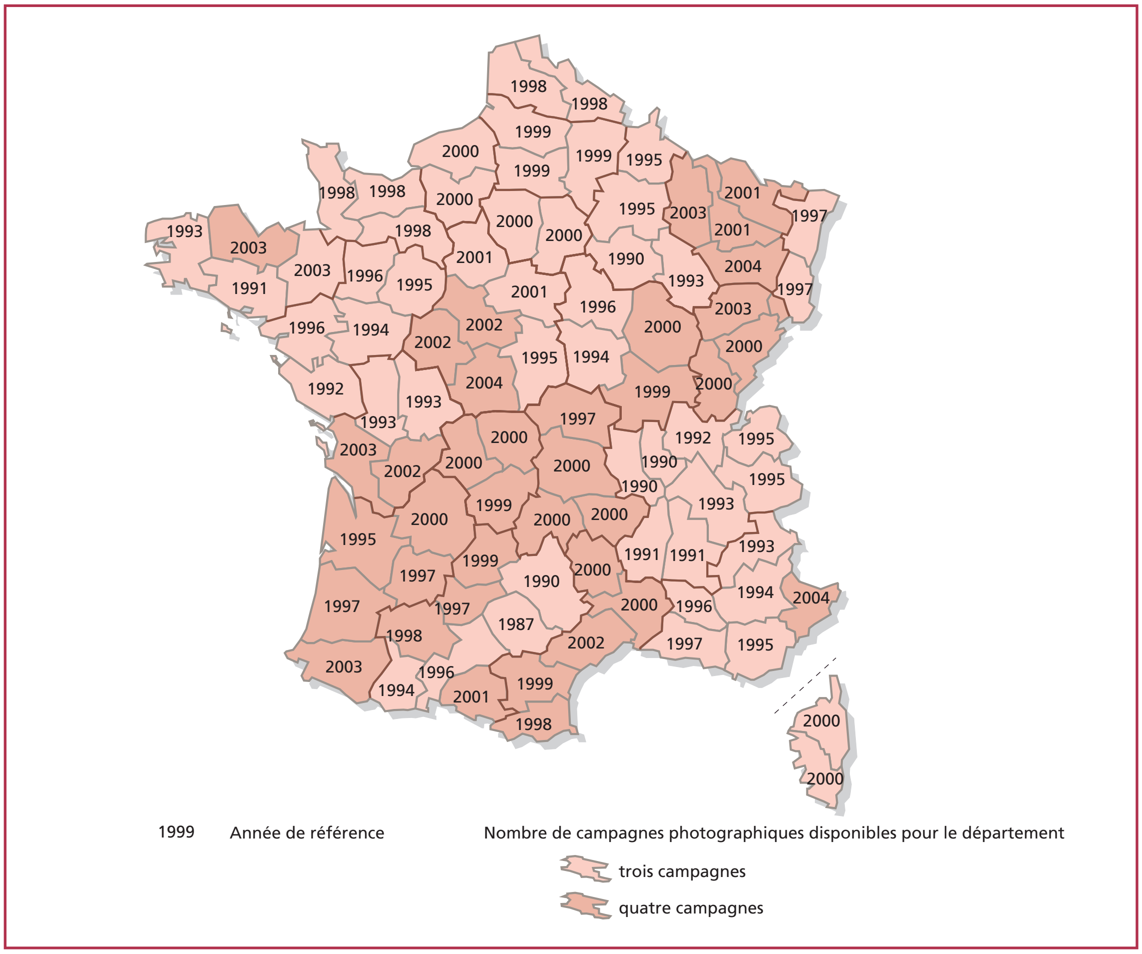


**Figure 4.** *The aerial photograph covers [15]*

## 3.2.1. *The aerial photographs: characteristics*

They are always carried out in infrared film, an emulsion much richer in information for vegetation study than natural colour. Land cover and land use, vegetation species nature and health or certain environment factors are much easier to apprehend on a colour infrared film than using any other composite.

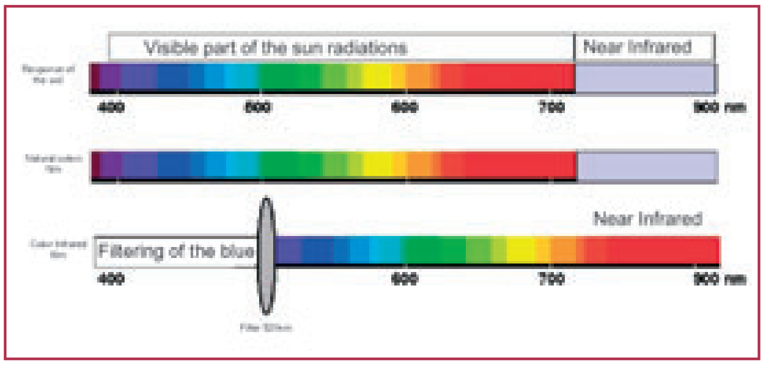


**Figure 5.** *Colour infrared [15]*

Almost three quarters of the territory are photographed in colour infrared today.

The scale of the photographs which, from one county to the other, can vary from 1/15,000 to 1/25,000, is generally around 1/20,000, thus making it possible to, at the same time, apprehend tree individually and forest in a synthetical way.

The photographs are taken between June and September. This choice is justified by generally favourable weather conditions in summer, a maximum height of the sun above the horizon, which limits the casting of shadows and the period of full chlorophyll activity for all plant species.

As a result, these stereoscopic images, enable the observation in three dimensions, enabling a perspective of each portion of the landscape. They have also been subject, since 1999, to systematic digitisation followed by an orthorectification and by a geo-referencing, enabling their overlay with any other picture or vector map. This also enables, on a given site, the creation of three dimensional pictures.

### 3.2.2. *Photography, a basic mapping tool*

The production of a forest map, on a scale of 1/25,000, is the first step of the procedure, implemented by the IFN. This map is made up of three layers of information:

– National forest regions (309 in France)
– State-owned forests or state-managed forests and private forests,
– Vegetation types, resulting from photo-interpretation.

A vegetation type [4] is, dependant on land cover:

- A forest stand type, when the cover of the trees is equal or higher than 10%,
- A heath land type, when this cover is less than 10%, the remainder of the ground being covered with non-cultivated plants (woody species or not),
- A poplar plantation type, when the cover of cultivated poplars is equal or higher than 75%.

These vegetation types are delimited on-screen, where an orthorectified and geo-coded picture is displayed, with, if necessary, backup of the traditional stereoscopic vision of silver film. The various vector plans composed by this method are then inserted into a cartographic database. Two successive maps exist today, covering almost half the country.

The other vegetation types, farmland in particular, and the other types of land cover or of land use (built up areas, transport infrastructures, areas without vegetation, water bodies, etc.) are not distinguished on the map but are joined into a single class.

**Department forest stand types**

– AA: oak high forest
– EY: young Douglas' fir high forest
– EV: young spruce high forest
– ER: young high forest of other softwoods
– HF: mixed hardwood high forest and coppice
– MR2: mixed softwood high forest and coppice
– PR2: resinous plantation in stripes in coppice
– QE: chestnut coppice
– QF: mixed hardwood coppice


**Figure 6.** *Forest map of Aude département - 1999*

| Ten national vegetation types | |
|---|---|
| Broadleaf high forest | Coppice |
| Conifer high forest | Open forest |
| Mixed high forest | Heathland |
| Mixed broadleaf high forest and coppice | Poplar plantation |
| Mixed conifer high forest and coppice | Other (crops, water, land without vegetation) |

## 3.2.3. *Photography, support for sampling*

The second step of the method implemented by the IFN is a statistical sampling method. After the mapping has been completed, the aerial photographs are still widely used to collect further information from a sample point sample, made up of 20-are plots, laid out in a systematic way on the photographs. The interpretation of this sample (one plot for 30 ha approximately i.e. more than 1.5 million throughout the country) initiates an on-the-ground survey at these areas, for which a maximum of precision is required.

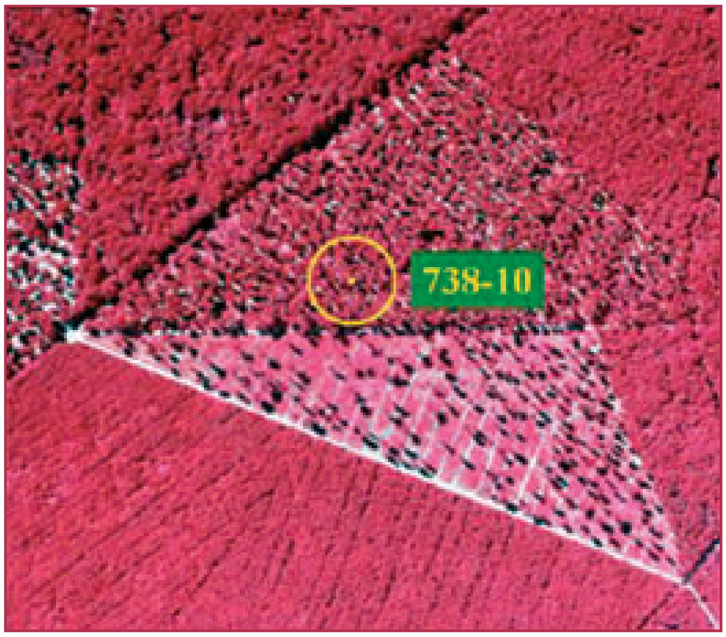


**Figure 7.** *Photography, support of the sample*

In addition to the three already mapped criteria, the main information collected on these plots is the land cover: open or closed forest, heathland, poplar plantation, farmland, ground without vegetation and water. Additional information on the local characteristics of the forest patches is also collected, such as for example the broad-leaved or resinous composition, three volume per hectare classes or the presence of hedges, tree lines or scattered trees.

On the ground, for a number of those plots, other information is collected, dimensional or environmental in particular, such as cover, diameters, heights, ages or increments in the tree species present. This data is supplemented by a floristic survey and by the notation of the principal natural conditions: slope, exposition, soil type, depth, humidity, stoniness, etc.

## 3.2.4. *In short…*

Four major types of tool, corresponding to varied observation scales, enable the IFN to apprehend at the same time, the general diversity of the land and more specifically, the forest massifs and other woodlands. This involves:

- Systematic and stereoscopic infrared aerial photographs of the territory at a scale of 1/20,000. The resolution of these pictures is markedly lower than one metre.
- Digitised maps of the land cover and of the main species and forest structures at a scale of 1/25,000. The minimum mapped surface is 2.25 ha (25 ha for the Corine Land Cover survey).
- Sample plots on the ground covering the whole territory (more than 110,000 plots every inventory cycle). The average surface of which it is possible to deduce a landscape characteristic is a few ten of thousand hectares.
- Satellite pictures, within the framework of specific or located needs. The resolution is here 20 m (Spot 1 to 4) or of the order of one metre (Ikonos, Spot 5, etc.).

The temporal scale required to analyse the evolutions using IFN data, is of the order of half-century. The first infrared aerial covers and the first ground inventories date back, indeed to the end of the 1950s.

# 4. Showing territory diversity and evolution

## 4.1. By analysis of land use statistical data

The diversity connected with the occupation of the soil, as well as its evolution, can be apprehended using the same 110,000 sampling plots, covering the whole country where ground measurements have been carried out. In these 2000-m² plots, land use and land cover is documented. When they are located in forest, the dimensional, ecological and floristic data gives a detailed description of the forest vegetation and of its evolution.

### 4.1.1. *Distribution of land use*

The main categories of land cover and land use play a leading role in the perception that we have of a landscape. The above maps show the dominance, in some regions, either of forest (Landes, Vosges, Southern Alps massifs, etc.) or of agricultural production, large cereal plains or areas of intensive stock breeding of the North, the North-West and the West of the country, without forgetting the Aquitaine plains. Heath land, on the other hand, characterises the regions under Mediterranean influence, as well as the high mountains (the Alps, the Pyrenees and Corsica), but also regions with poor ground such as Brittany. Regarding the unproductive areas, they mostly represent the

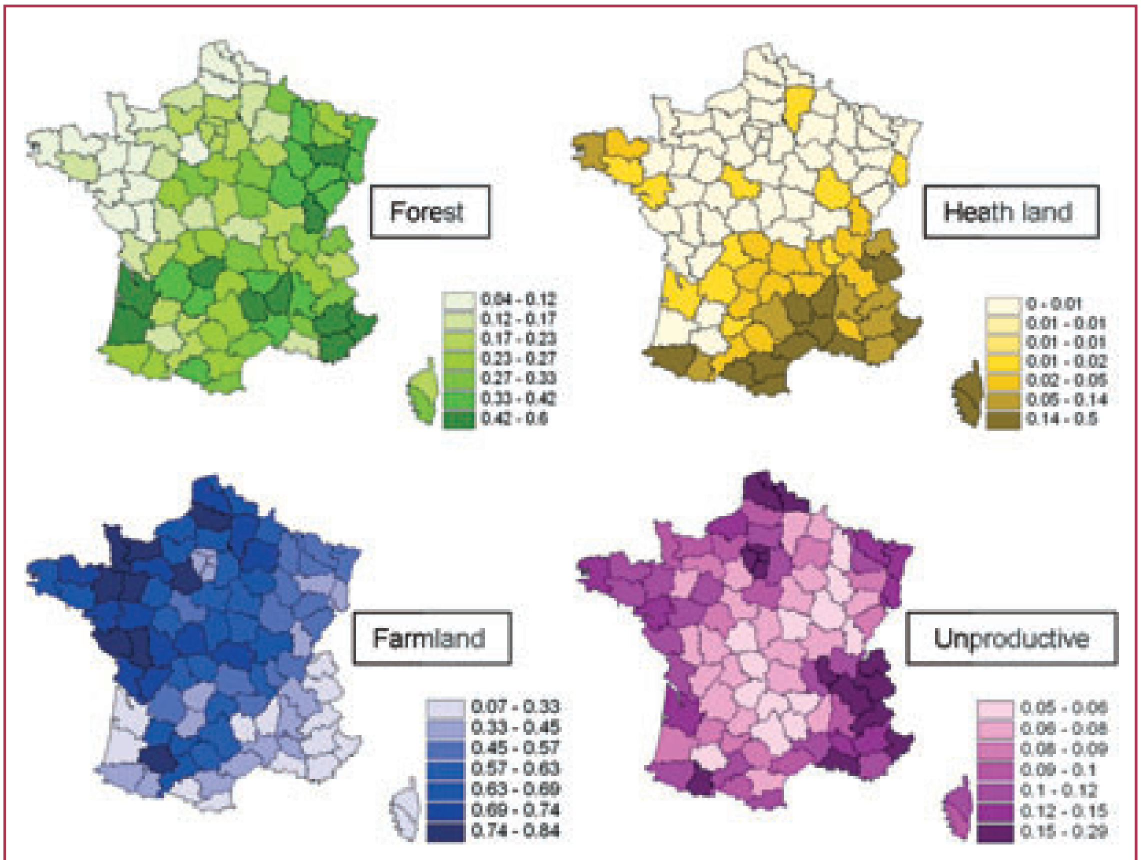


**Figure 8.** *Land cover of forest, heathland, farmland and land without crops. Frequencies by département.*
*Forest: the wooded state is acquired when the cover of forest is equal to or higher than 10%.*
*Heath land: heath land is a site carrying non cultivated woody plants, i.e. heath land in the usual definition for, fallow and vacant land.*
*Farmland: areas covered by non-woody cultivated plants or by non-forest woody plants.*
*Unproductive: Without crops or not covered by inland water.*

densely populated regions, major urban and industrial centres or areas developed for mass tourism such as the Atlantic and Mediterranean coasts. In the high mountains, the naturally unproductive ground dominates. Considering the space distribution and the relative importance of unproductive land, is important information in, for example, the evaluation of the hydrological risk.

**Unproductive**

IFN classify as "unproductive", land lacking in vegetation cover and that is not covered by permanent water. It is unproductive from the agricultural and forestry point of view. It can be naturally unproductive (naked rock, glaciers, dune, marshes, etc.) or artificially unproductive (roads, railways, buildings, etc).

Unproductive by nature (natural spaces) or by vocation (result of the development of a site): this class intersects therefore the concepts of land cover and land use

If the sequential analysis of the elements which makes up a landscape, brings useful information as to the characterisation of the environments present, it is insufficient with respect to the overall approach that is perceived by a landscape, connected with its visual perception.

### 4.1.2. *Land occupation diversity*

The Shannon index, here calculated by *département*, the value of which increases with the number of classes and/or that these will be distributed more evenly, is a first step towards overall apprehension of land occupation diversity of a territory.

A good North-West quarter of France, except for Brittany, appears thus slightly diversified, while the opposite case occurs in the Alps, the Pyrenees and all the Mediterranean region that present maximum diversity such as in Île-de-France, in Alsace or in Aquitaine, for example. The Massif Central on the other hand, sparsely populated and poorly industrialised, presents high diversity, connected at the same time to the variety of the natural conditions, to the methods of land utilisation (fields, livestock, forest) and to the economic changes of the last century.

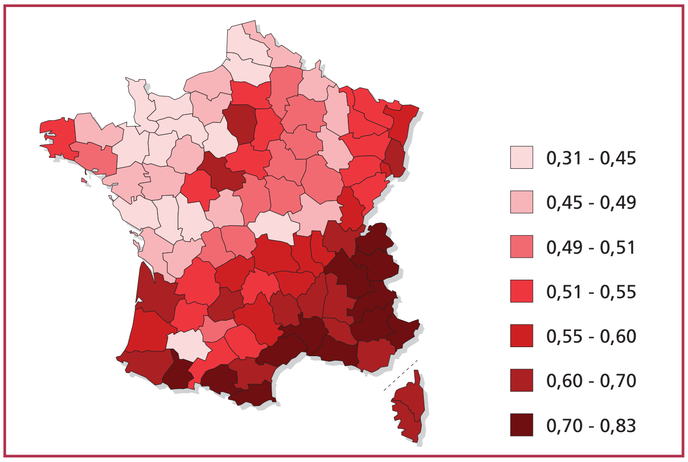


**Figure 9.** *Shannon index of land occupation diversity*

The diversity thus demonstrated, depends initially on the criteria contained in the database. Moreover, certain care has to be taken, in view of this data only, regarding the establishment of bi-univocal relations between a high value of the Shannon index and high landscape quality or high biological diversity.

### 4.1.3. *Annual variation of the afforestation rate*

France forest cover was 24.7% at the end of the 1960s. It is presently 27.1% i.e. a current forest area of almost 15 million ha.

This increase in woodland, which measures up to almost 1.3 million ha, is a major component of landscape evolution. It is, however, very unequally distributed on the territory and benefits especially the Mediterranean region, the South-East, the West of the Massif central, the main Loire valley or Brittany.

In France the main part of the wooded areas is in the south of a line connecting

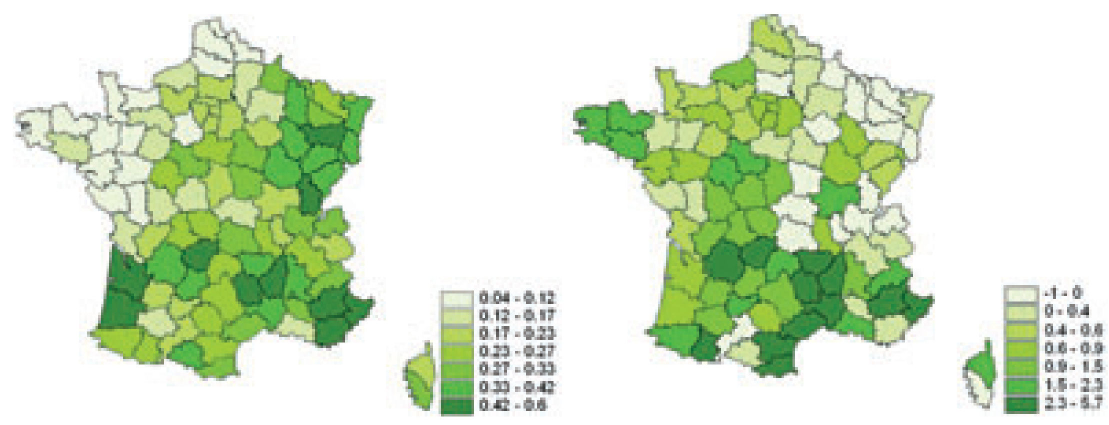


**Figure 10.** *Forest cover (on the left) and average annual variation of the afforestation (on the right)*

Strasbourg to the Landes coast. The strongest rates of increase in forest area are at the south of a line connecting Brittany to the Southern Alps.

This established fact is explained as much by historical considerations and the evolution of society as by the constraints connected with the natural conditions. The policy of major afforestation, especially in the Southern Alps and the Pyrenees, continued until a very recent date. The abandonment of subsistence agriculture on upland or on the poorest land or grants for afforestation or for the improvement of forest stands are further explanatory factors. One can also refer to the decisions made at the beginning of the 1990s within the framework of the Common Agricultural Policy to freeze farmlands or to afforest them. All this resulted in certain closure of the environment with abandonment of the most barren land and of the least productive pastures, the former as well as the latter being afforested or by natural succession to woodland.

This extension of the French forest goes on today at a rate of 0.5% a year on average.



**Reference years of ground measurements**

Ground measurements are carried out at a rate of six to seven departments a year, i.e. a complete cycle throughout the country in 12 to 15 years. Thus, the data presented above results from the measurements concerning the last inventory of each department, spread out from 1988 to 2003.

## 4.2. By analysis of cartographic data

Another way of apprehending the diversity of the elements which make up a landscape consists of space indicators, applied to cartographic data, in analysing the fragmentation of the landscape, number, form, dimension and space distribution of the patches [3]. Evolution with time can also be represented by analysing the variation of these same indexes between two dates.

This cartographic approach will not be dealt with here. It is the subject however of a separate paper "Mapping landscape changes with French national forest inventory aerial photographs". Cartographic comparisons and corresponding index computations (number of classes and average area, fragmentation, compactness, frequency, Shannon index, etc.) are presented and are analysed through examples relating to forests, heath lands, fallow land and wetlands.

## 4.3. By comparison of aerial photographs

The systematic and periodic photographic aerial coverages of a landscape are exhaustive space representations of physical or man-made environments. Using these pictures to analyse countryside diversity can appear a priori quite natural. This is however not how it's done.

The aerial photograph, often orthorectified and geo-coded, is today used either as a simple plan, with the addition of picture semantics, or as, for instance a database, reflecting reality as seen from a certain point of view. IFN, for example, uses the vertical aerial photographs at the same time as a data source for vegetation mapping, but also as a support for positioning sample plots on the ground.

Analysis of these pictures, to extract from them all underlying information concerning the topic of interest intervenes, generally, at the beginning of the work chain. It can also intervene at the end, the image being used as a visualisation, communication and decision-making tool.

### 4.3.1. *Multiple approaches of countryside diversity and of its evolution*

Aerial photographs are not only useful to describe a present state (according to the photograph shooting date) but also to put it back in an evolutionary process by analysing, on other photographic sets, previous situations.

Let us note, however, that a vertical aerial photograph is a document which refers to the projection in space of a map and not to the tangential space of the view [13]. If the observation point concept, to perceive a landscape loses much of its interest, if the enumeration and the organisation in space of the objects can be apprehended in a more complete way than on the ground. On the other hand, the screen concept which, on the ground, stops the glance, is here completely absent. The visual impact of the surface components and of the "vertical" elements, is very different in the aerial view than that seen from the ground. Does a correct apprehension of landscape reality not lie then in the complementarity of both approaches?

These various methods of use of the pictures (simple semantic support or source of information of a current or historical nature) are implemented, to differing degree, by IFN to respond to specific needs.



### 4.3.2. *Visual comparisons of pictures*

The *département* aerial photographs, taken at intervals from 12 to 15 years for forest inventory, represent three complete covers of the territory and a fourth one already covers almost half the country. An analysis of this time series of pictures makes it possible to grasp the evolution of any type of landscape over nearly half a century. The evolution problems already approached by IFN, by compared analysis of these pictures, relate to land cover and land use, wetlands or tree cover evolution or mapping of damage to the forests. These problems can also concern the evolution of forestry practices with, for example, conversion of coppices with standards into high forests, and the evolution of the bocage landscape or the impact of big roads, railways, industrial or urban infrastructures.

Pictures of a given situation at a precise moment, are irreplaceable tools for analysis and co-operation, helping to visualise and therefore to better apprehend and understand landscape changes, whether their origin is natural or man-induced.

#### ✦ **Forest Management**

Forest management: road building, tree harvesting, forest regeneration periodically modify the aspect of certain parts of a wooded area. We see here where the forest roads radiate from a star crossroad revealing, in particular, the aristocratic past of this forest connected with hunting. The current forest lot delimitation rests on this old network as numerous rectilinear limits between lots as the different composition, density or age attest.

Ripe oaks and Scots pines, which made up this forest in 1975 were harvested in a number of lots. These clearings are progressive as some trees, isolated or in clumps,

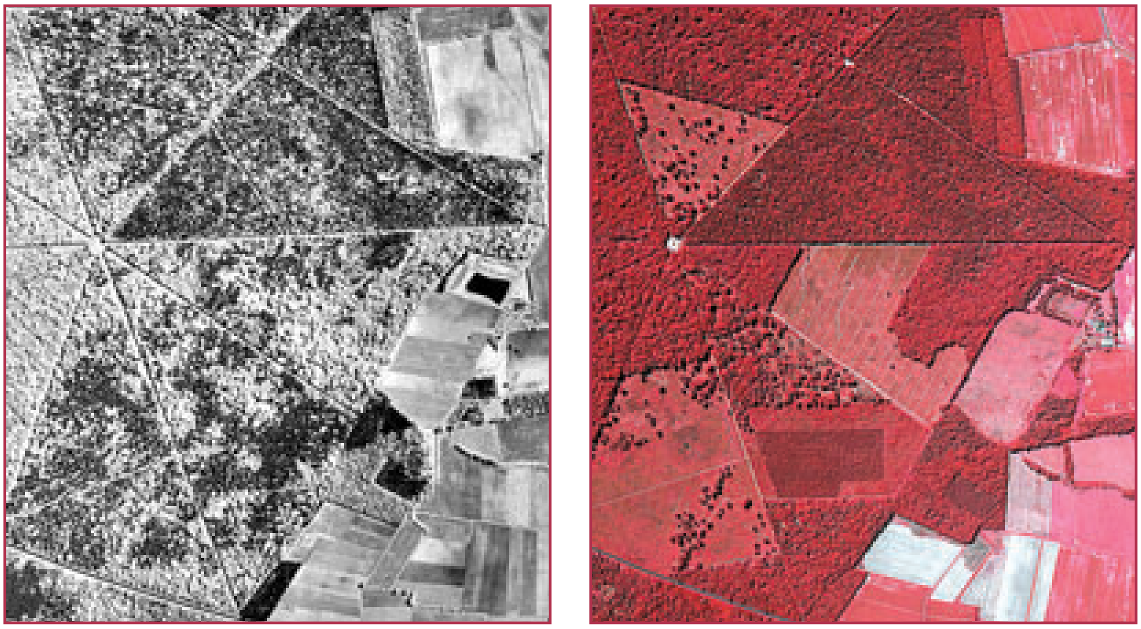

**Figure 11.** *Forest felling and management*
Location: Loiret *département*, Fay-aux-Loges, in the east of Orleans
Years of film shootings: 1975 and 2001
Emulsions, scales: IRNB 1/25,000 and IRC 1/20,000





standing in these clearings, under regeneration, testify. The removal of the last large trees, seed-bearers, takes place only when a young forest has completely replaced the old clearing. The forester's work consists then in "educating" these young trees, as soon as they begin to grow, in particular by systematic thinning in parallel strips, as can be observed in the centre of the picture.

### ✦ Regional planning

In the example presented below, a wetland and ripisylve landscape, near Dôle in the French Jura, has undergone deep modifications in connection with complete reworking of the site. The beds of the Doubs and Loue rivers have been modified, a motorway has been created and land use has compleatlycompletely changed: renewed farming on some plots, creation of a golf course, poplar plantation, etc.

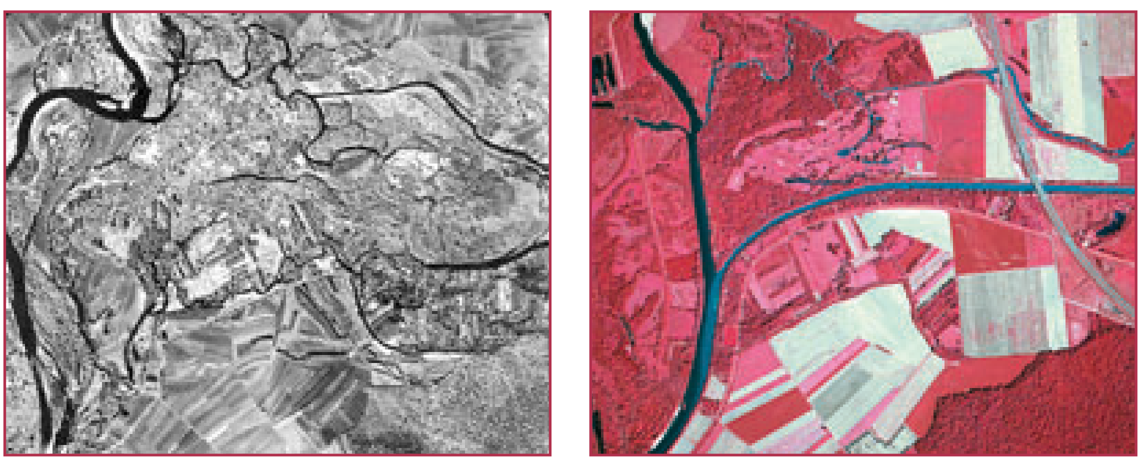

**Figure 12.** *Road and hydraulic installations in the south of the town of Dôle.*
Location: Jura *département*, confluence of the Doubs and Loue rivers.
Years of film shootings: 1969; 2000.
Emulsion, scale: IRNB 1/15,000; IRC 1/17,000

### ✦ Grazing recession

In 1967, erosion traces connected with the over-grazing, which prevailed in the Cévennes mountains until the first half of the XX century, are very important. Of the forest, only some wooded beech patches are left. Thirty-four years later, in the area located on the right side of the road, erosion traces have almost entirely disappeared. These lands are obviously no longer grazed, bushes have colonised the last grassy patches

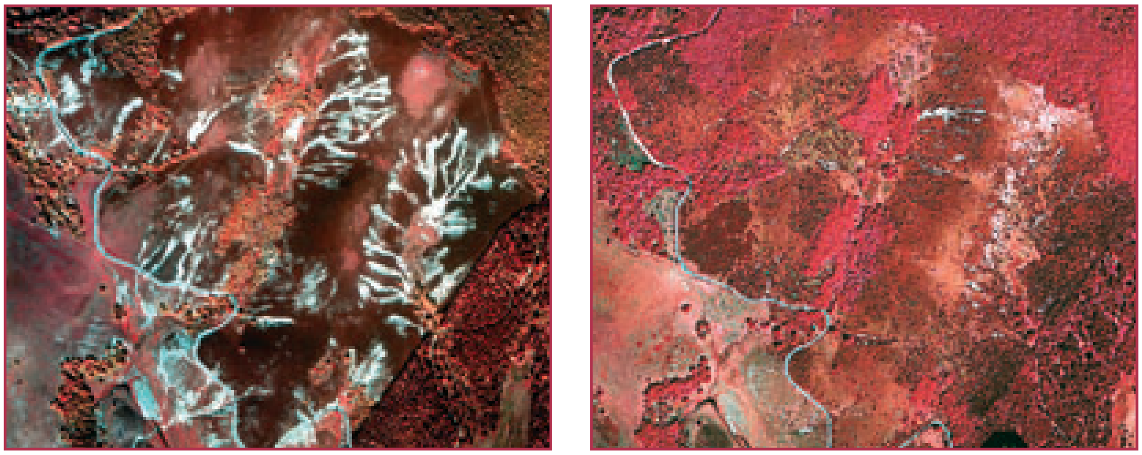

**Figure 13.** *Healing of bad lands following a phenomenon of grazing recession.*
Location: Gard *département*, Cévennes massif, Minier pass, 1 264 m above sea level.
Years of film shootings: autumn 1967; summer 2001
Emulsion, scale: IRC 1/17,000

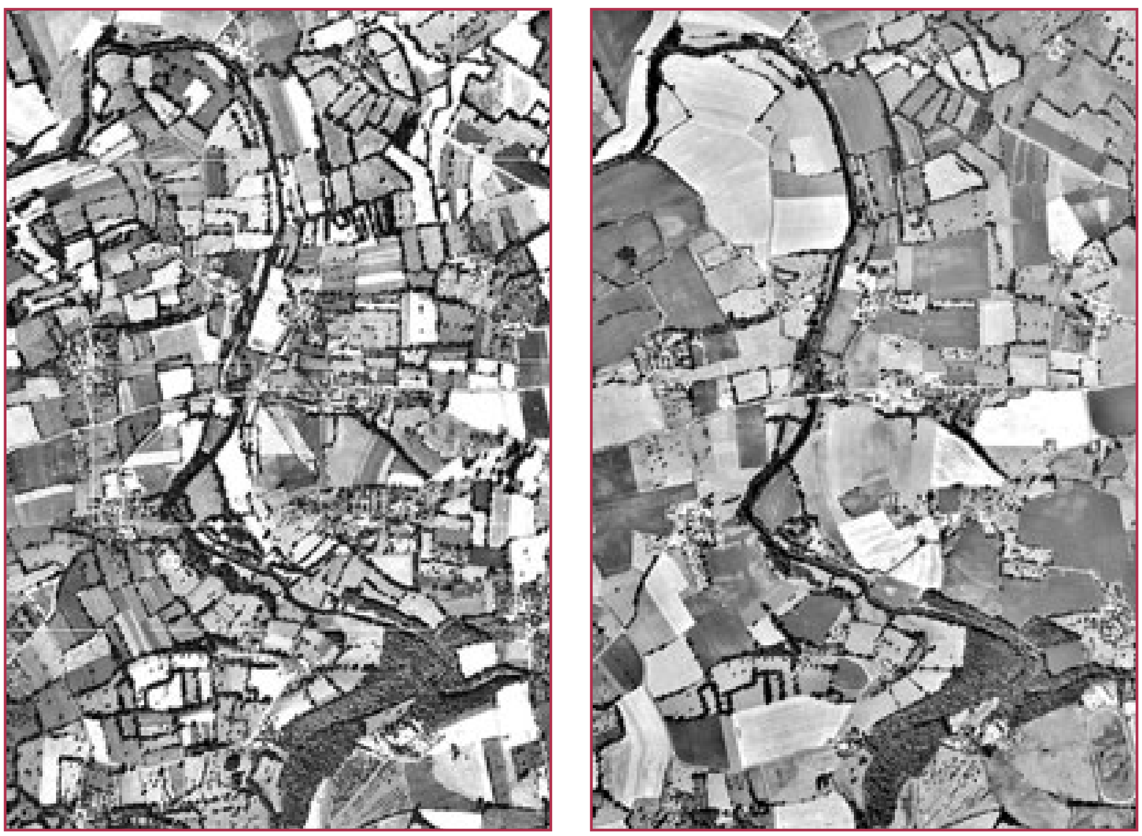

**Figure 14.** *Evolution of a bocage landscape.*
Location: Border the Orne and Mayenne départements, higher course of the Mayenne river.
Years of film shootings: 1972; 1998
Emulsion, scale: panchro 1/25,000 et panchro 1/20,000

and forest has settled again. The few beech patches present in 1967, have grown and mostly conifer trees colonise naturally these nowadays abandoned areas. However, on the left side of the road, if erosion traces have disappeared, a light grazing remains as shown by the prevalence of grass.

## ✦ Bocage landscape evolution

This part of the high valley of the Mayenne rivers, at the border between the Maine province and the Normandy hills, underwent considerable landscape evolution connected with the removal of the majority of the hedges. If the bocage landscape has not completely disappeared, the average size of the plots increased from 1 or 2 ha up to more than twice, sometimes even three times. Orchard area has also decreased. On the other hand, few evolutions have occured with regard to the dwellings, that are rather scattered, or the road network. The trees which underline the course of the Mayenne or the small scattered wooded copses, within the farm plots, were not suppressed and are even prone to extend, as some small agricultural plots are no longer cultivated.

The region passed from a type of land utilisation to another, without changing land cover or land use.

## ✦ Land reform

The Beauce, a quintessentially large cereal plain, was also subjected to an important land regrouping, which resulted in a very substantial increase in the average size of the plots. This change is much more visible, and in any case, easier to apprehend,

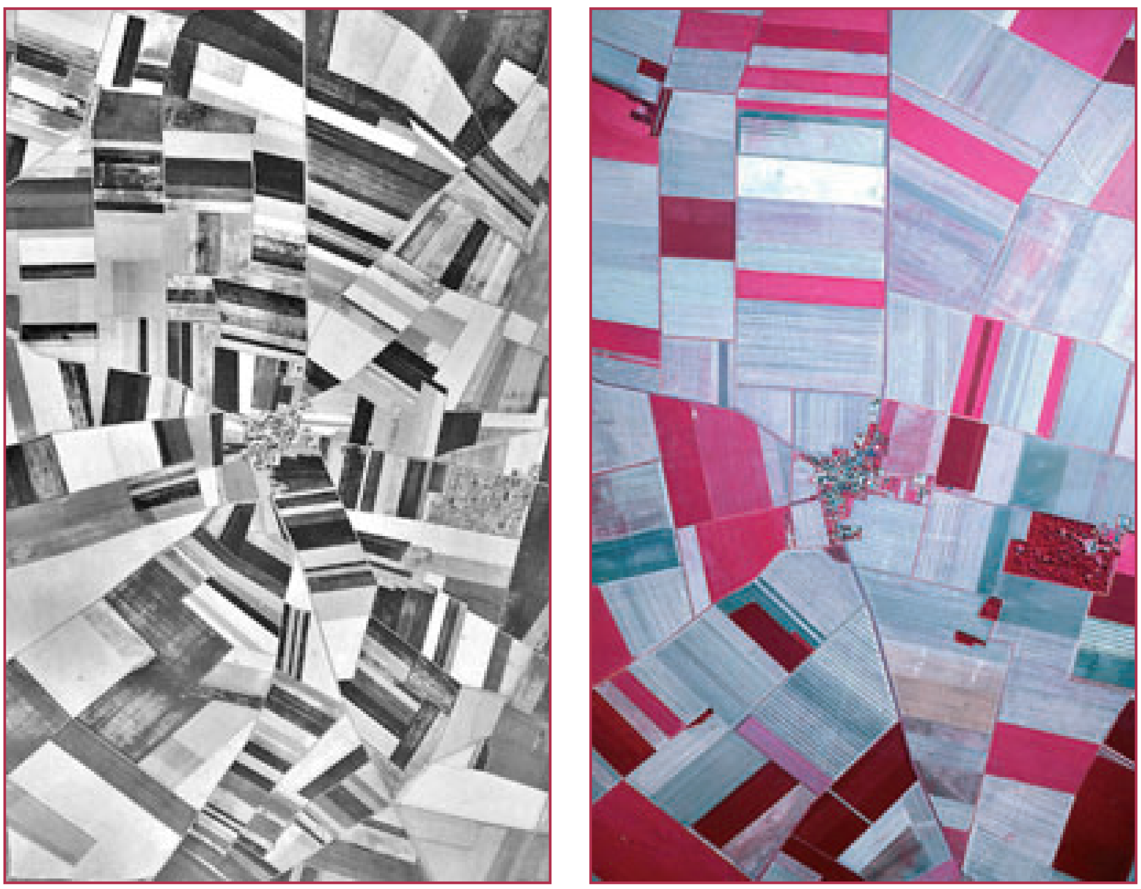

**Figure 15.** *Land reform in a large cereal plain.*
Location: Loiret *département*, Beauce plain in the north of Pithiviers
Years of film shootings: 1975; 2001
Emulsion, scale: IRNB 1/25,000 et IRC 1/20,000

with a birds-eye view than on the ground in a region with a traditionally very open landscape, with only some scattered small woods or large grain silos to block ones view. These vertical elements, which, on the ground, attract and prevent visual perception (woods or buildings) are as few today that they were in 1975. Only some additional buildings were made around the village, while the rare wooded plots are still present. It seems, on the other hand, that if the major road network remained the same, the network of ways to access the plots underwent marked changes.

### ✦ Urbanisation

While the plateau, in the south of the Oise valley, was entirely cultivated in 1976, twenty-four years later, the landscape has changed radically. Urbanisation made up mostly of family houses or small apartment-buildings, has conquered a major part of this plateau, without infringing on the forest patches inclined to grow in the area. Woodland areas therefore seem to resist urbanisation much better than farmland. Along the river Oise, where housing of a suburban type existed, few major changes are noted, to some extent a slow densification. On the other hand, in the Oise bend, the industrial gravel pits and their inevitable increase of the water table disappeared to the benefit of the installation of a major recreation area, known as Cergy-Pontoise.

**Figure 16.** *Progression of urbanisation to the detriment of agricultural land.*
Location: Val d'Oise *département*, bend of the Oise river in Cergy-Pontoise near Paris.
Years of film shootings: 1976 and 2000
Emulsions, scales: Panchro 1/25,000 et IRC 1/20,000

### 4.3.3. *Automated comparisons*

Beyond the simple visual comparison of documents, automated approaches (picture segmentation and object-oriented classification) are being used by the IFN. Their aim is to take into account contextual information, in addition to spectral information, in addition to automatic delimitation of patches whose space pattern or even time evolution can then be analysed – if the analysis is carried out with a time series of pictures.

## 4.4. By automatic comparison of satellite pictures

Automatic high-resolution image (aerial photographs) comparisons and change detection of using satellite images, with a decametric resolution and by automatisable procedures are advancing. Territory evolution analysis, however, evolutions on the scale of a farmland or woodland plot, are therefore possible. This technique is implemented periodically by IFN to answer specific or local needs such as monitoring clear-cuts on Landes massif or mapping of storm damages in some regions.

### 4.4.1. *Annual mapping of clear-cuts in the Aquitaine massif*

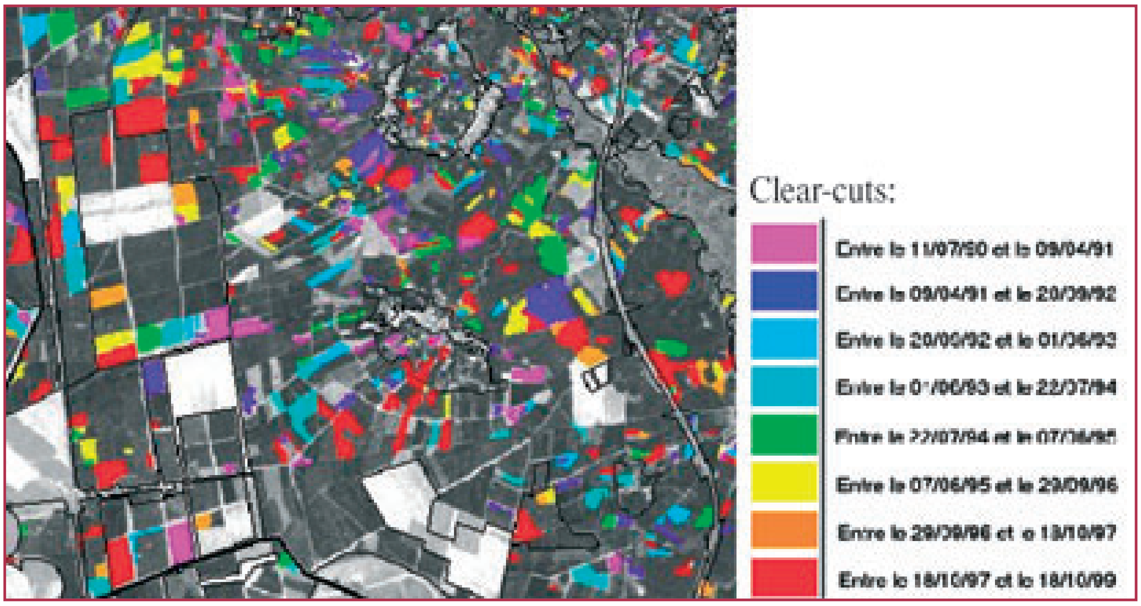


**Figure 17.** *Annual mapping of clear-cuts in the Aquitaine maritime pine massif*

The aim here is the annual mapping of clear-cuts from 1990 to 1999 on the Aquitaine maritime pine massif. The two-fold aim of updating the inventory of two cycles gives better knowledge of the clearings and model the future evolution of the forest resource [5]. This annual mapping of the clear-cuts over almost one million hectares, led on the long term to a map of the age classes of the forest patches. This is not simple at a reasonable cost, by any other method than the digital processing of satellite pictures.

The approach developed here is based on the use of time series of Landsat-TM pictures (30 m ground resolution) on which clearings of maritime pine are represented in the medium infra-red reflection regions, as an intense reflectance change. Their detection is then obtained, after picture standardisation, by comparison of radiometry's between two successive scenes, taken at approximately a one year interval.

The precision of the results obtained is about 95%, taking into account the fact that the clearing's smaller than 1 ha, which account for 10% of the total on the mass, could not be detected due to the 30 m space resolution of the Landsat-TM pictures. A breakdown of the cleared areas, by age group, can also be obtained combining the clearing map, with the sampling ground carried out by IFN within the framework of the traditional inventory.

### 4.4.2. *Mapping storm damage in the Vosges* département

The damage to some forest patches, caused by the December 1999 storms were mapped, (Gascony Landes or Vosges plain) using Landsat or Spot [6] satellite pictures.

In the Vosges lowlands, three SPOT pictures recorded before the storm and tree pictures following the storm[1], were acquired in order to detect and automatically delineate the damage patches. Minimum surface chosen is 1 ha with four damage intensity classes (0-10%; 10-50%; 50-90%; 90-100%).

[1] Dates of the images: 7-08-98; 27-05-99; 25-07-99; 8-06-00; 27-06-00; 23-08-00.

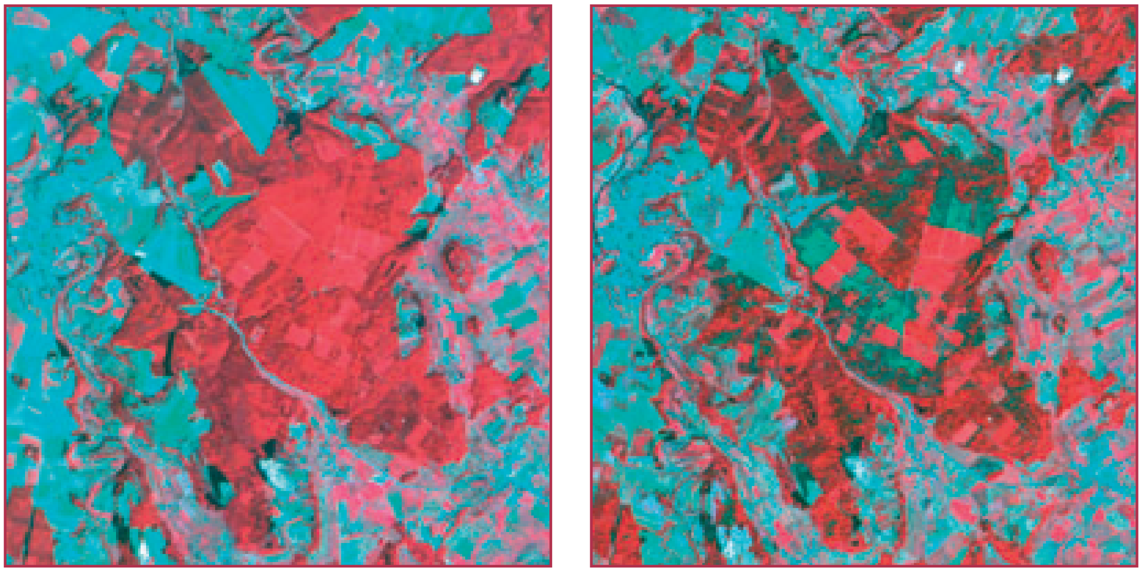

**Figure 18.** *Vosges lowlands, Spot-4 pictures before and after the storm*

The method implemented includes:

- Detection of changes between pictures before and after storm, making it possible to produce pixel classifications of damage (total, partial damage or absence of damage);
- Automatic segmentation of the picture taken after storm, making it possible to define “plots” bigger than one pixel (from 1 to a few hectares);
- After integration of both results, a simple model makes it possible to assign an overall damage intensity to each one of those “plots”, according to the number of pixels of each class that it contains.

Very good results were thus obtained using summer Spot-4 pictures. Damages caused by a cataclysmic phenomenon, such as a wind storm, leading to a brutal modification of the forest landscape can therefore, as in the previous example, quickly be apprehended and mapped on the scale of one hectare and in a context of plain forests.

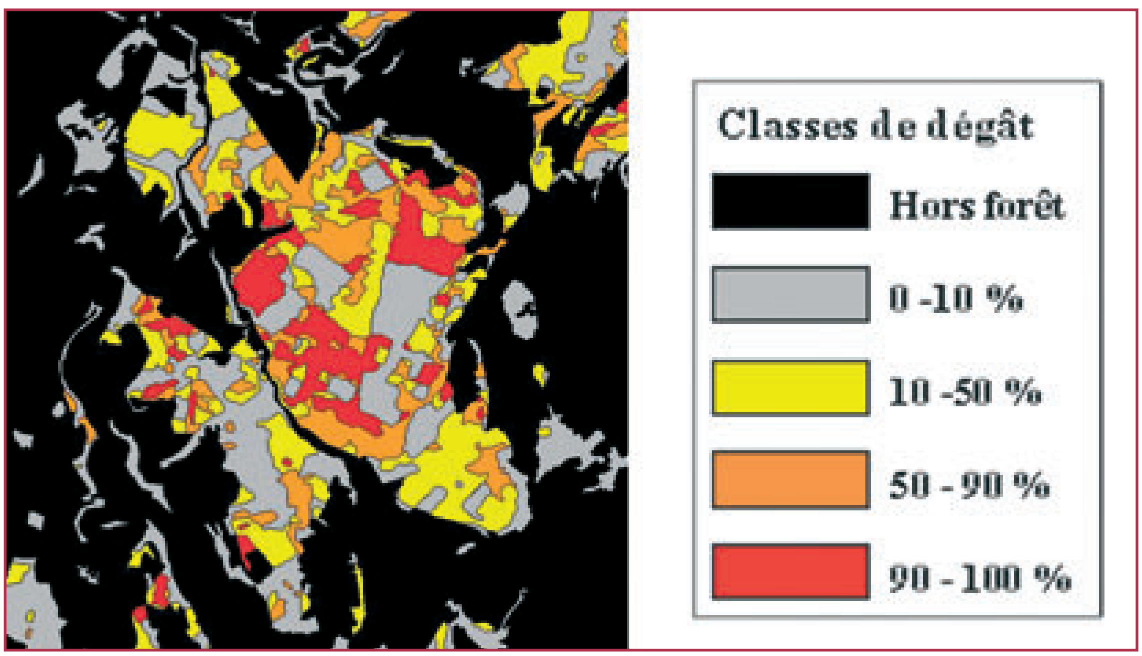


**Figure 19.** *Map of storm damage of established by automatic comparison of Spot4 pictures*

## 5. Conclusion

The tools and methods implemented by the IFN to map and characterise French forests proof particularly fitted to the analysis of a territory, seen as a whole, its diversity and its evolution, and this irrespective of the observation scale.

The statistical data resulting from ground sampling makes it possible, at the same time, to apprehend the general diversity of a territory (land cover and land use) on units of several thousand hectares but also, at a larger scale, the specific diversity of the forest patches and other wooded landscapes. Three complete inventories of the country make it possible today, to apprehend and quantify any type of evolution within French forests.

The digitised map of the main forest species and structures, as well as of heath land and large grazing ranges, at a scale of 1/25,000, also appears to be a first order tool for analysing territories, in particular thanks to the 2.25 ha minimum representation area. Its periodical updating, which intervenes every 12 to 15 years, allows local monitoring of forest evolution, in general, and of its composition in particular.

But the most adapted tool remains the infra-red aerial photography which, by the wealth of the information that it brings, allows an exhaustive and unconstrained spatial apprehension of landscapes. Current background documents for forest mapping, and systematic and stereoscopic aerial covers are also the reflection of disappearing or extensively modified landscapes. A tool for analysing the object landscape and its evolution with time, they are also a support for communication, if not of consensus, for the joint analysis of a site or of its development.

Satellite pictures and their automated analysis enable cartographic monitoring of the evolution of a site, as far as this is on the scale of the forest or agricultural plot and not on the scale of an isolated object, such as a tree for example. This is also the case for the monitoring of forestry operations, of forest damage assessments or of any other compartment-sized evolution. New approaches on digitised very high resolution pictures are being developed and should enable a better understanding of automated procedures of landscape evolution.





## Acknowledgements

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# Mapping landscape changes with French national forest inventory aerial photographs

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## Introduction

The purpose of the French National Forest Inventory (NFI) is to continuously provide up-to-date information about the state of the French forests.

During the last forty years, the French NFI has constituted a database unique in Europe composed of aerial images, detailed data about land covers, tree measurements and environmental information like description of the vegetation by strata and soil features.

Using aerial images captured approximately every ten years on NUTS 3 extent, the French NFI has developed competencies and skills in aerial interpretation. These competencies were enlarged by mapping land cover evolutions with the aim of characterising landscape changes.

The French NFI has been involved in the study of several topics like:

– The evolution of Mediterranean abandoned fields in relation to fire risks,
– The evolution of production chestnut forests in Corsica,
– The changes from wetlands into agricultural fields and poplar groves in the Loire Valley.



Methodologies defined about digitising techniques, changes detection and calculation of indexes in order to quantify the changes are illustrated by several examples developed in this paper.

## 1. The French NFI Aerial Photography Archive: a Source of Land Cover Information

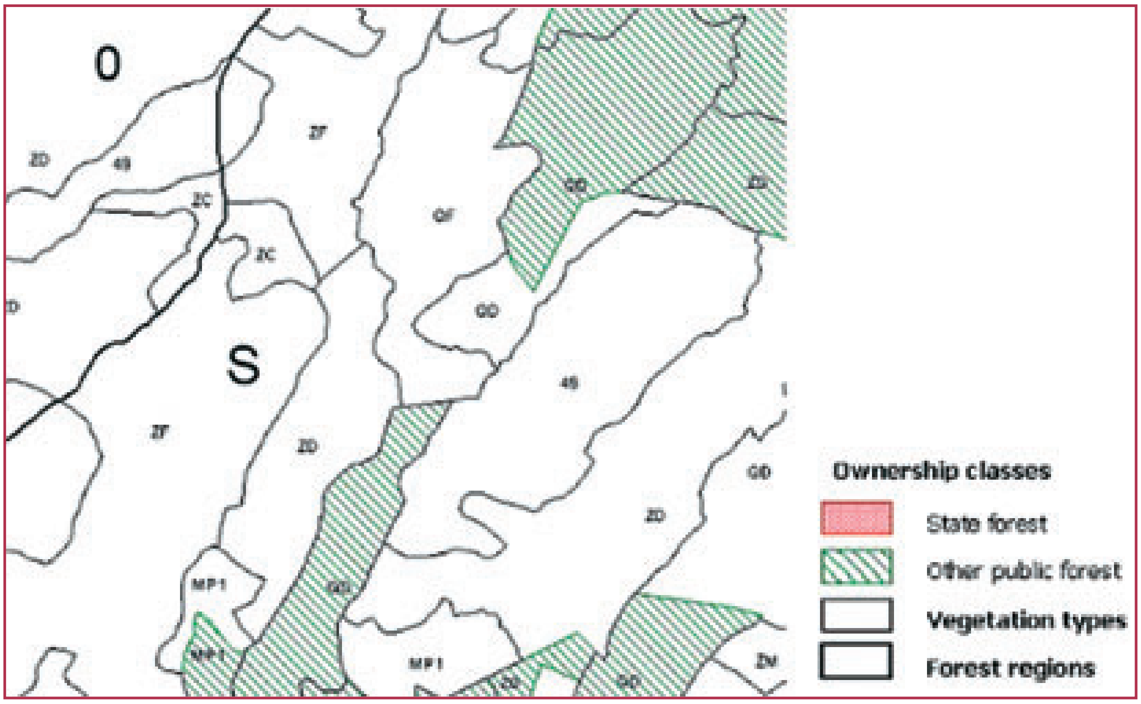
### 1.1. The French NFI: a Tool for Mapping Land Cover and Quantifying Forest Resources

In order to accomplish its mission, the French NFI must base its work on data derived from aerial photography and on field surveys.

First and foremost, forest regions and ownership classes are delineated on the aerial photographs, and the type of vegetation is allocated by means of visual interpretation and field trips in order to derive a forest map.

Then, NFI uses a method based on a grid of sampling points.

For these points (almost 15,000 for one French "département" NUTS 3), photo-interpreters identify several characteristics such as land cover and land use within a 50-meter diameter circle around the point. Forest ownership, specific composition of stands, standing volume are documented if the land cover is forest. In addition, in the presence of more than one inventory cycle of images, an increase or decrease in forest cover can also be identified.




**Map 1.** *Example of a derived NFI coverage – three coverages are derived: vegetation types, ownership classes and forest regions*

The second stage of the forest inventory consists of stratification based on photo plot attributes with varying intensity among the strata.

During a ground survey on a sample area (almost 1,500 points for one NUTS 3), the wood volumes are estimated and phytoecological data are collected (soil features, list of botanical species on the plot, local topography…).

In addition, using aerial image interpretation and statistical sampling, other formations such as heathland, poplar forests, hedgerows, rows of trees and scattered trees are documented.

## 1.2. Using Aerial Infrared Photography

Every 12 years, a full coverage of aerial images is completed for each NUTS 3 extent on a scale between 1:15,000 and 1:20,000.

Most of these coverages, in particular in composite landscapes (e.g. Mediterranean and mountainous regions), are captured as coloured infrared composites. The other regions are covered by black and white infrared or panchromatic composites.

Using aerial coloured infrared composites, broad-leaved and coniferous forests and, in most cases different species can be identified.

## 1.3. Large Inventory of Aerial Photographs to define Spatial and Temporal Dimensions

Aerial images on NUTS 3 extent are captured approximately every ten years, under the supervision of the five inter-regional NFI units.

These images are taken during the summer months, when climatic and technical conditions are optimum (sun near the zenith, no shadows). These aerial images have the following applications:

- To identify the different categories of land cover,
- Area estimates can be made and the classification of wooded areas, with the aim of drawing up a field inventory woodland areas,

- Derivation of land cover maps,
- Identification of sampling units for field surveys.

During the last forty years, the French national inventory has compiled a very representative picture of land cover information using these aerial photographs. Consequently, the French NFI photo-archive has become an important reference tool for resource managers. NFI remote sensing experts also have the ability to relate spectral reflectances to land cover classes.



# 2. Methodology used for Mapping Landscape Changes

The NFI has developed expert competence and skills in aerial image interpretation, with special emphasis on land cover mapping, change detection and digitising techniques. Well-defined methodologies can be illustrated by numerous successes and results.

## 2.1. Procedure

### 2.1.1. *Delimiting a Study Area*

The first step of the study is to define the extent of the study area.

These extents are usually determined on a digital map (SCAN25 of National geographical institute). The study area is often enclosed in a single NUTS 3 in order to obtain a full coverage on a specific date.

### 2.1.2. *Establishing a Land Cover Class Nomenclature*

With aerial image colour-infrared composites, deciduous and coniferous forests and, in most cases, different tree species can be distinguished. These composites are commonly used when mapping Mediterranean and mountainous vegetation regions. The derivation of the nomenclature is determined according to the scale of the area and the image composite used. According to the request of the client, several options are proposed.

The measurements obtainable from a stereoscopic aerial image analysis are length, width, area and height of an object, perimeter of a polygon containing the same feature (tone, colour, and texture of a surface).

The nomenclature of the land cover classes is derived according to these criteria.

### 2.1.3. *Establishing Technical Specifications of Coverages*

The minimal mapping unit area depends on the scale of the aerial photograph acquisition mission. The smallest area that can be defined (i.e.; measured and mapped) is half a hectare. The minimum mapping unit width is fifty or seventy five meters.

## 2.2. Interpreting Aerial Photography

Aerial photographs are vertical (camera optical axis < 10° off vertical). The vertical overlap between two photographs is sixty percent. The horizontal overlap between two axes is twenty percent. These technical specifications enable stereoscopic viewing. A visual interpretation using hard copy (photographs and transparencies) is conducted.

## 2.3. Digitising

Photogrammetry enables accurate measurements and good planimetric precision for digital coverages.

Two different methods are used for digitising patches. The first method digitises limits directly of the aerial photograph. The second technique, the orthophoto method, constitutes scanning an aerial photograph and then rectifying the resulting image using conventional remote sensing techniques.

The orthophoto method is carried out on each pixel of the image as opposed to the first method, where only specific points and digitised features are rectified.

Hence, the orthophoto technique is a raster based technique, whereas the first method is a vector based technique.

### 2.3.1. *Using digitisation on analogical photography*

Digitisation on analogical photography or "Photo Digitisation" is a method of digitising points or features traced on (or superimposed on) photographs, which are then automatically converted to geographical extents by algorithms.

The process is accomplished by measuring photo coordinates and mathematically transforming them into geographical coordinates. It takes into account the camera tilt on the x, y, z axes, the digital elevation model (DEM), the camera's technical specifications and the flight parameters.

The calculation is carried out by application of the reverse transformation of the quasi-conical projection using the parameters of flight, the technical specifications of the optics and the altimetry data of the scene.

By using photogrammetry, the photo coordinates are transformed into map coordinates and can be integrated in a GIS.



### 2.3.2. *Using Orthophotography*

Due to the variation of the scale across the image, aerial photographs contain distortion. Distortion in aerial photographs is removed by eliminating in ERDAS Imagine® the effects of relief and the perspective projection of the camera and by adjusting the image to a particular map projection.

The result is a digital photo that is spatially accurate and measurable. Orthophoto is an "image map" that has a uniform scale and a known accuracy. Sets of aerial photographs are then processed in Orthovista® in order to generate a mosaic of orthophotos called an "orthophotomap". The operator can now use this orthophotomap to interpret and digitise the types of vegetation.

It is also necessary to control the planimetric precision of digitising. Planimetric precision can be quantified by the average quadratic error ($\Delta$D). Corresponding control points have to be found on ortho images and on the ground. The ground coordinates are compared to the orthophotograph coordinates.

Orthophotographs can be integrated with other geographic information and become the geographic reference for digitising work.

## 2.4. Calculation of the Results

### 2.4.1. *Sum of the surface areas, number of patches, average of patch surface areas, frequency*

For each coverage, the following informations in the form of spreadsheets can be provided with the following characteristics:

- Sum of the areas of each category of land cover,
- Number of patches for each category of land cover,
- Average of the patch surface areas for each category of land cover,
- Frequency (sum of the areas for each category of land cover divided by the area of the whole study area).

### 2.4.2. *Fragmentation and division qualification*

The most efficient way to characterise fragmentation is to edit the histogram of the surface areas for each category of land cover and then to calculate the evolution index between the two dates.

The second way to qualify the division is to calculate the compactness index. This index corresponds to the ratio of the surface to the perimeter and is calculated for each category of land cover. For the same area, when the index decreases, the perimeter increases and the coverage edges are more pronounced.

### 2.4.3. *Diversity Indices*

A diversity index is a mathematical measure of species diversity in a community. Such indexes are usually calculated for ecological studies. This process can be applied to cartographic data in vector format. Comparing diversity between two dates allows an objective evaluation of the main changes in the study area. There is an abundance of examples of publications of the European Commission such as:

- "Landscape and land cover diversity index", article from EC/DG AGRI, included in the report "From land cover to landscape diversity in the European Union" or
- "Geographical use of statistical data" in the topic report "Building agro environment indicators" written in collaboration between several services of the European Commission.

To qualify the diversity, NFI uses three indicators: the number of classes, the Shannon index and the Simpson index. A brief description is available in the glossary.

### 2.4.4. *Differences' Coverage Calculation*

By performing a spatial analysis on two vector coverages of different dates, a numeric coverage representing the differences between these can be defined. The resulting output is a polygon coverage that quantifies the differences in land cover between the two vector coverages. In addition, a visual interpretation can be performed. The results, in other words, the type of changes and their area, are represented in a spreadsheet.

In order to quantify the quality of the classification of the raster image, a transition matrix is often created.

A transition matrix evaluates the actual classification and in addition, adds a hypothetical factor of a predicted classification, thereby objectively evaluating the classification.

This approach can be applied in order to quantify the evolution of the land cover between two dates. The first entry corresponds to the sum of the area of the recent coverage interpretation, and the second contains the information of the former one.

Other criteria can be calculated such as the stability index for each land cover class. For a given land cover class X of date Y, the index corresponds to the division of the area of all polygons that have the same land cover type X on both dates, with the area of the land cover class X at date Y. If the stability index is equal to 1 (or 100%), that means that all the patches mapped at the second date were already present at the first date.

## 3. Application Examples

The following examples illustrate various applications of the method in order to qualify landscape changes.

## 3.1. Mapping the Evolution of Mediterranean Abandoned Fields between two Dates

Forest fires constitute one of the most significant hazards to Mediterranean forests. It is generally accepted that the risk increases with the increase of areas of abandoned fields, i.e. abandoned agricultural plots. The flammability of the vegetation of such areas is very high. Moreover, the risk is also linked to the added difficulty of access roads to these holdings.

The French NFI has been involved in the following related study:

- To determine, for several study areas, in the Mediterranean zone, the extent of these abandoned fields;
- To determine the nature of changes which occur (increase in abandoned fields by abandonment of agricultural practices, or deforestation, or land use change to urban settlements or tourist installations);
- To compare the spatial distribution of abandoned fields, in order to quantify the redistribution of land use.

### 3.1.1. *Study's Area Selection*

The project was supported by Environment and Territorial Planning Minister, the natural risks services and local authorities.

The first zone (11,700 ha in Pyrénées-Orientales) was limited by the Tech River on the western and northern NUTS 3 boundaries and on the east by the Mediterranean Sea. In the south, the parallel of latitude 42°31'17" was chosen.

An area of 14,400 ha (Alpes-de-Haute-Provence) was delimited by the boundaries of the communes of Redortiers, la Rochegiron, Two polygons (8,600 ha and 9,900 ha in Var) included the commune of Entrecasteaux and Solliès-Pont (North of Toulon) respectively. The total surface area was almost 44,700 ha.

### 3.1.2. *Aerial Photographs Used*

Colour-infrared composites supplied by the NFI photography archive were used to characterise the initial land cover state. The 1982 Alpes-de-Haute-Provence 1983 Var and 1988 Pyrénées-Orientales events taken with a 1:17,000 scale were chosen. The horizontal and vertical overlaps were in accordance to technical stereoscopic specifications. To quantify the final state, a special aerial mission was taken during the summer of 1998 with the same characteristics and a scale of 1:15,000.

### 3.1.3. *Type of Land Cover Nomenclature*

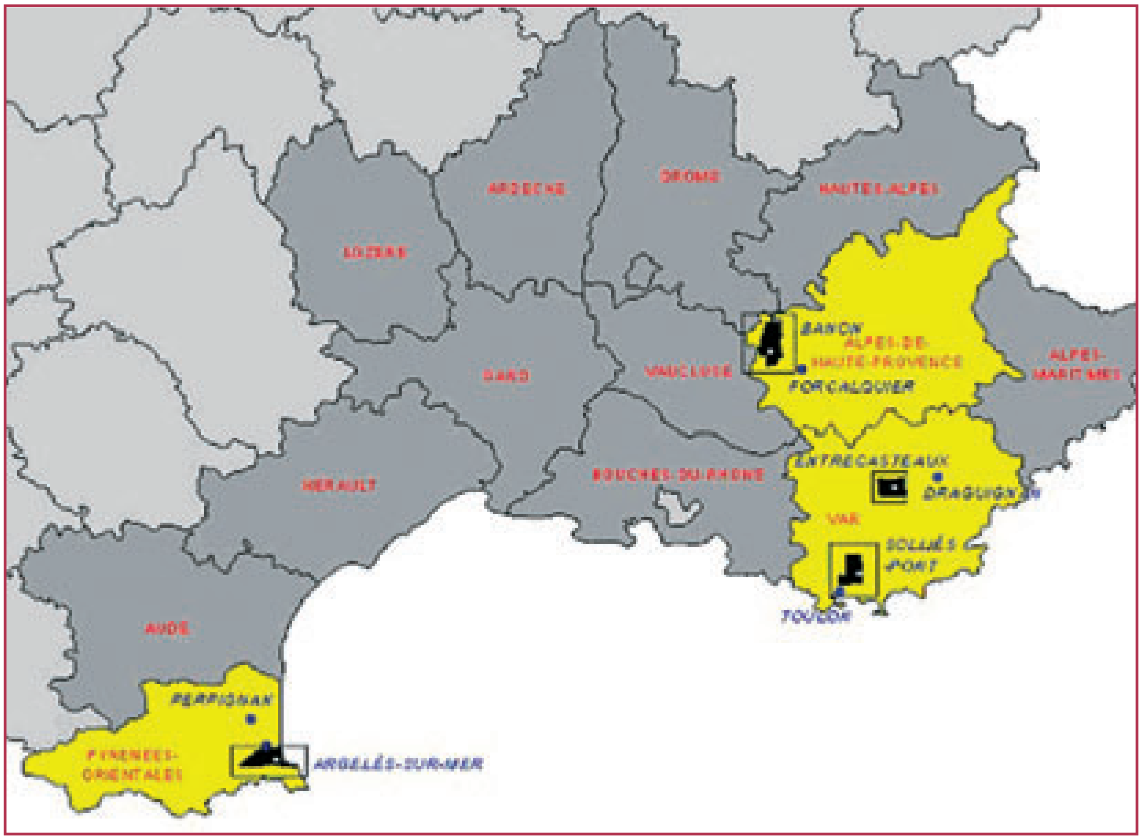
The nomenclature used for this study is composed by four essential types of land covers.

The first class, including all **forest types**, is defined by forest tree cover of at least 10% or by young trees with a density of at least 500 shoots per hectare.

Two subdivisions of forest classes were proposed: **woodland** (forest with a forest tree cover between 10 and 40%) and **closed forest** (forest with a forest tree cover of 40% or more). Then, the map is derived by distinction of hardwood forest, mixed forests and conifer (or softwood) forests. The forest patches with a majority of Aleppo Pine were represented as an own class because of their sensitivity to forest fires.

The second type of land cover defined for this study corresponds to **heathland**. This class is defined by vegetation with a forest tree cover of less than 10% (a density of less than 500 young tree shoots per hectare) but at least 25% of woody or semi-woody plants such as ferns, room, gorse, heather…

Heathland includes abandoned field with traces of agricultural uses (abandoned fields). Agricultural fields were mapped but with a distinction to permanent pasture.




**Map 2.** *Study areas*





For the remaining types of vegetation, urban or tourist area and soil with outcropping rock and water were defined.

The following classes were used:

**Table 1.** *Classes of land cover nomenclature*

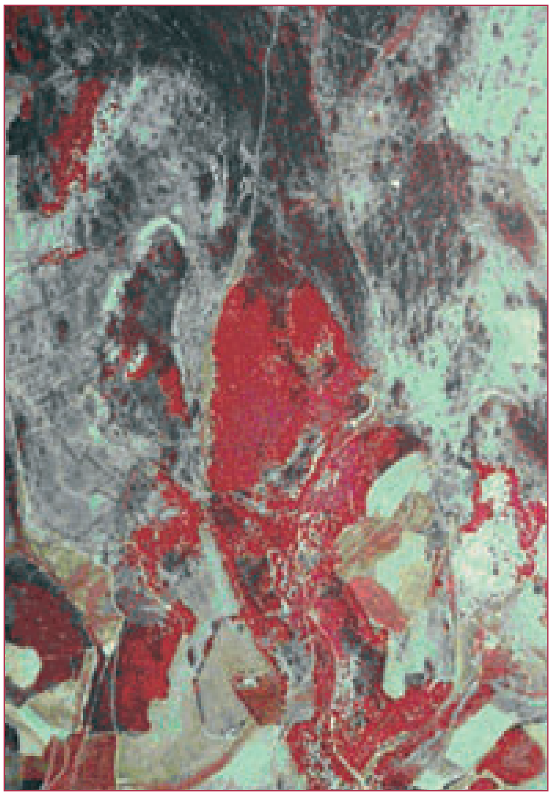
| LAND COVER CLASS | DEFINITION | VALUE |
|---|---|---|
| FOREST TYPES | Formations with an apparent forest tree cover of 10% or more or a density of at least 500 future shoots per hectare for young trees | |
| • WOODLAND: Forest with a forest tree cover between 10 and 40% of the patch area: | | |
| • Hardwood forest | At least 75% of hardwoods | Ø |
| • Mixed forest | Cover of hardwoods between 25 and 75% | |
| Mainly of Aleppo pine | The conifers cover is composed at least of 50% of Aleppo pines | 1 |
| Mainly of other species in patch | The conifers cover is composed of less than 50% of Aleppo pines | 2 |
| • Conifer forest | Less than 25% of hardwoods | |
| Mainly of Aleppo pine | The conifers cover is composed at least of 50% of Aleppo pines | 3 |
| Mainly of other species in stand | The conifers cover is composed of less than 50% of Aleppo pines | 4 |

| LAND COVER CLASS | DEFINITION | VALUE |
|---|---|---|
| • CLOSED FOREST: Forest with a forest tree cover of 40% or more of the patch area: | | |
| • Hardwood forest | At least 75% of hardwoods | 5 |
| • Mixed forest | Cover of the hardwoods between 25 and 75% | |
| Mainly of Aleppo pine | The conifers cover is composed at least of 50% of Aleppo pines | 6 |
| Mainly of other species in patch | The conifers cover is composed of less than 50% of Aleppo pines | 7 |
| • Conifer forest | Less than 25% of hardwoods | |
| Mainly of Aleppo pine | The conifers cover is composed at least of 50% of Aleppo pines | 8 |
| Mainly of other species in stand | The conifers cover is composed of less than 50% of Aleppo pines | 9 |
| HEATHLAND TYPES | Formations with an apparent forest tree cover of less than 10% or more or a density of 500 future shoots per hectare for young trees and at least 25% of woody of semi-woody plants such a ferns, room, gorse, heather… | |
| • Abandoned fields | | |
| Abandoned lavender fields | Some lavender plants still present | L |
| Abandoned vineyards | Some vine still present | V |
| Abandoned olive groves | Unkept and overgrown olive groves | O |
| Abandoned orchards | Unkept and overgrown olive orchards | F |
| Abandoned agricultural fields | Traces of agricultural practices | C |
| • Other heathland | No traces of agricultural practices | |
| Holm oak vegetation | Semi-woody or woody vegetation containing holm oak | Y |
| Pubescent oak vegetation | Semi-woody or woody vegetation containing pubescent oak | B |
| PERMANENT PASTURE | Covered by less than 10% forest and less than 25% of woody or semi-woody vegetation – herbaceous vegetation | P |
| OTHER TYPES | Covered by less than 10% forest and less than 25% of woody or semi-woody vegetation – non-herbaceous vegetation | |
| Agriculture field | | A |
| Urban or tourist area | | U |
| Soil with outcropping rock, water | | I |

### 3.1.4. *Aerial Photo Interpretation*

The limits of the forest patches were first delimited on 1998 aerial photographs and were then directly digitised on those photographs by digitisation on analogical photography method. The first photo interpretation was carried out on the 1998 pictures, which was then taken as the reference coverage. The minimal mapping unit area used was 0.5 ha. Thereafter, the changes between the 1998 and 1982 were established.

The infrared aerial photograph presented below is situated in the north of Alpes-de-Haute-Provence study area.

|  |  |
|---|---|
| **Coloured infrared composite**<br>Alpes-de-Haute-Provence, 1982 | **Coloured infrared composite**<br>Alpes-de-Haute-Provence, 1998 |

**Example 1.** *1st stage - Infrared aerial photographs, NFI Library*

### 3.1.5. *Digitisation*

The 1998 photographs were digitised first. By interpretation of the 1982 coverage, new forest areas were identified and digitised.

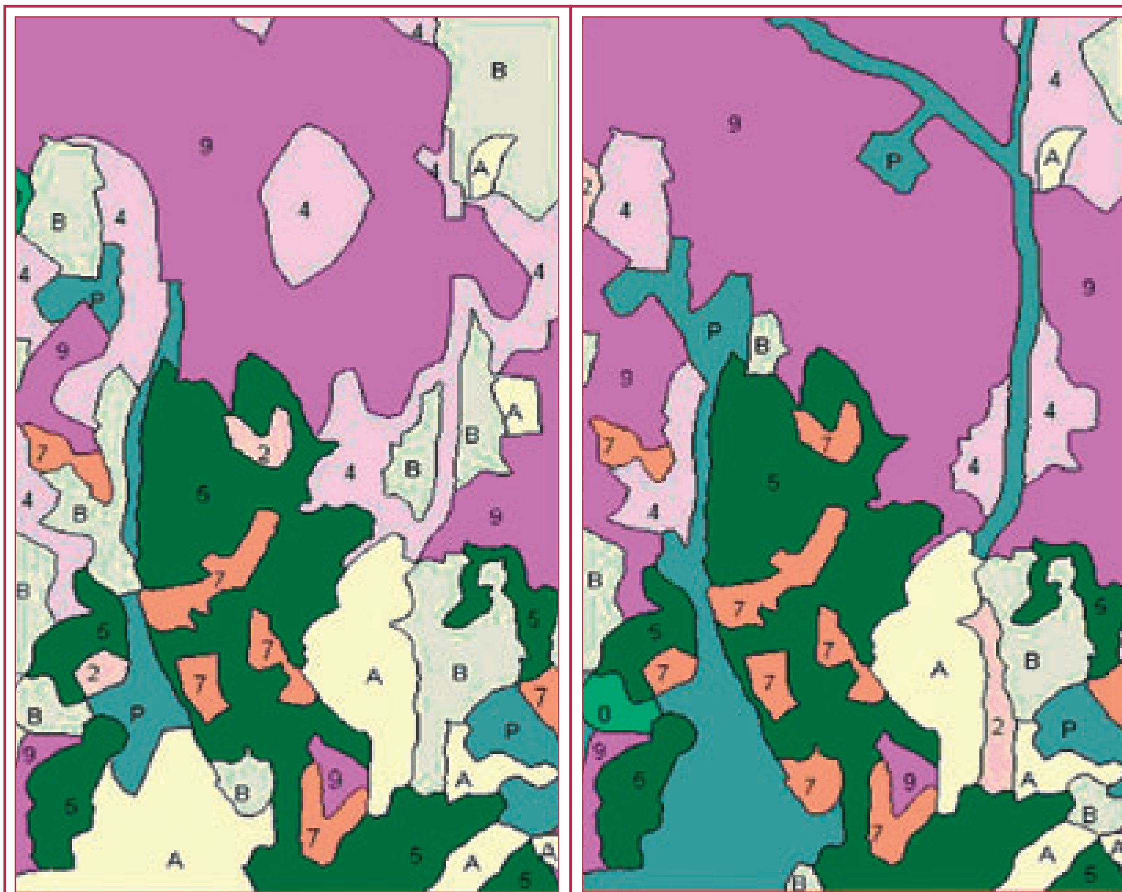
The mapping result of this operation is shown in the following example.

### 3.1.6. *Results concerning adjoining types to urban and tourist areas*

Table 4 contains the reclassification based on the edges' length adjoined to urban and tourist zones. There is an important decrease in borders between urban and tourist zones and heathlands, but an important increase with forests types. Agricultural fields are however the most significant bordering areas.

**Table 2.** *Alpes-de-Haute-Provence – Variation of the length of land cover types near urban and tourist areas*

| LAND COVER TYPES NEAR URBAN OR TOURIST AREAS | Edge length in 1982 (m) | Edge length in 1998 (m) | Difference (m) |
|---|---|---|---|
| Hardwoods woodlands | 604 | 1,302 | +698 |
| Mixed woodlands | | 88 | +88 |
| Conifers woodland | 64 | 64 | +0 |
| Hardwoods closed forests | 1,046 | 1,739 | +693 |
| Abandoned agricultural fields | 1,318 | 1,814 | +496 |
| Heathland with pubescent oak vegetation | 1,577 | 509 | –1,069 |
| Permanent pasture | 954 | 714 | –240 |
| Agriculture fields | 12,959 | 12,752 | –206 |



Alpes-de-Haute-Provence, 1982 | Alpes-de-Haute-Provence, 1998

**Example 2.** *2nd stage - Mapping land cover limits*

### 3.1.7. *Evolution and diversity index*

On the study extent, by comparison of the list of land cover classes found in each coverage, two types of category of land cover disappeared:

- In the woodland class: the mixed forest with a majority of Aleppo pine (representing by one patch in 1982) became a conifer closed forest where Aleppo pine is not preponderant.
- In the heathland class: heathland with holm oak have been transformed into heathland with pubescent oak vegetation and abandoned agricultural field (one part has been cultivated between 1982 and 1998).

However, in order to establish evolution tendencies, several indexes can be calculated. The first indicator is the evolution index.

**Table 3.** *Alpes-de-Haute-Provence – Evolution index between 1982 and 1998*

| Class | Surface area in 1982 (ha) | Surface area in 1998 (ha) | Difference (ha) | Evolution index (%) |
|---|---|---|---|---|
| Mixed forest with a majority of other species (woodland) | 231.83 | 365.44 | +133.61 | +57.6% |
| Hardwoods closed forest | 5,892.36 | 6,049.76 | +157.40 | +2.7% |
| Mixed closed forest | 733.23 | 898.18 | +164.95 | +22.5% |
| Conifers closed forest | 1,040.94 | 1,338.62 | +297.68 | +28.6% |
| Heathland with pubescent oak | 1,413.20 | 901.09 | –512.11 | –36.2% |
| Permanent pasture | 447.49 | 642.42 | +194.93 | +43.6% |

| Class | Surface area in 1982 (ha) | Surface area in 1998 (ha) | Difference (ha) | Evolution index (%) |
|---|---|---|---|---|
| Agricultural fields | 3,157.30 | 2,772.95 | –384.35 | –12.2% |
| Urban or tourist area | 60.44 | 68.66 | +8.22 | +13.6% |
| Other classes | 1,460.10 | 1,399.77 | +60.33 | +0.95 |

The main evolution corresponds to the decrease of heathlands areas and the increase of permanent pasture areas.

Others indicators are the diversity indexes.

For the 1982 stage, the following results have been found:

– The number of classes is 16 on a maximum of 21;
– The Shannon index is 0.343;
– The Simpson index is 0.895.

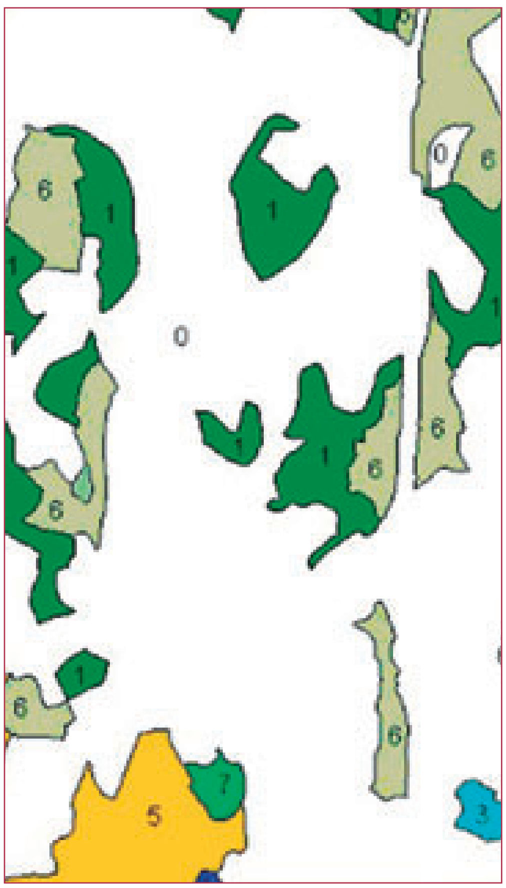
The diversity indicators show the important diversity in this area.

However, in 1998, the diversity has decreased:

– The number of types is 14;
– The Shannon index is 0.340;
– The Simpson index is 0.896.

### 3.1.8. *Evolution map*

The following map was derived from the interpretation of two extracts of aerial photograph described above.



Map of differences between two dates
1982 and 1998 - Alpes-de-Haute-Provence

**CODE 1: FOREST CHANGES**
Change from woodlands (with a majority of other species in stand) into closed forests (with almost the same composition) is shown on this example (cf. patch with attribute 1).

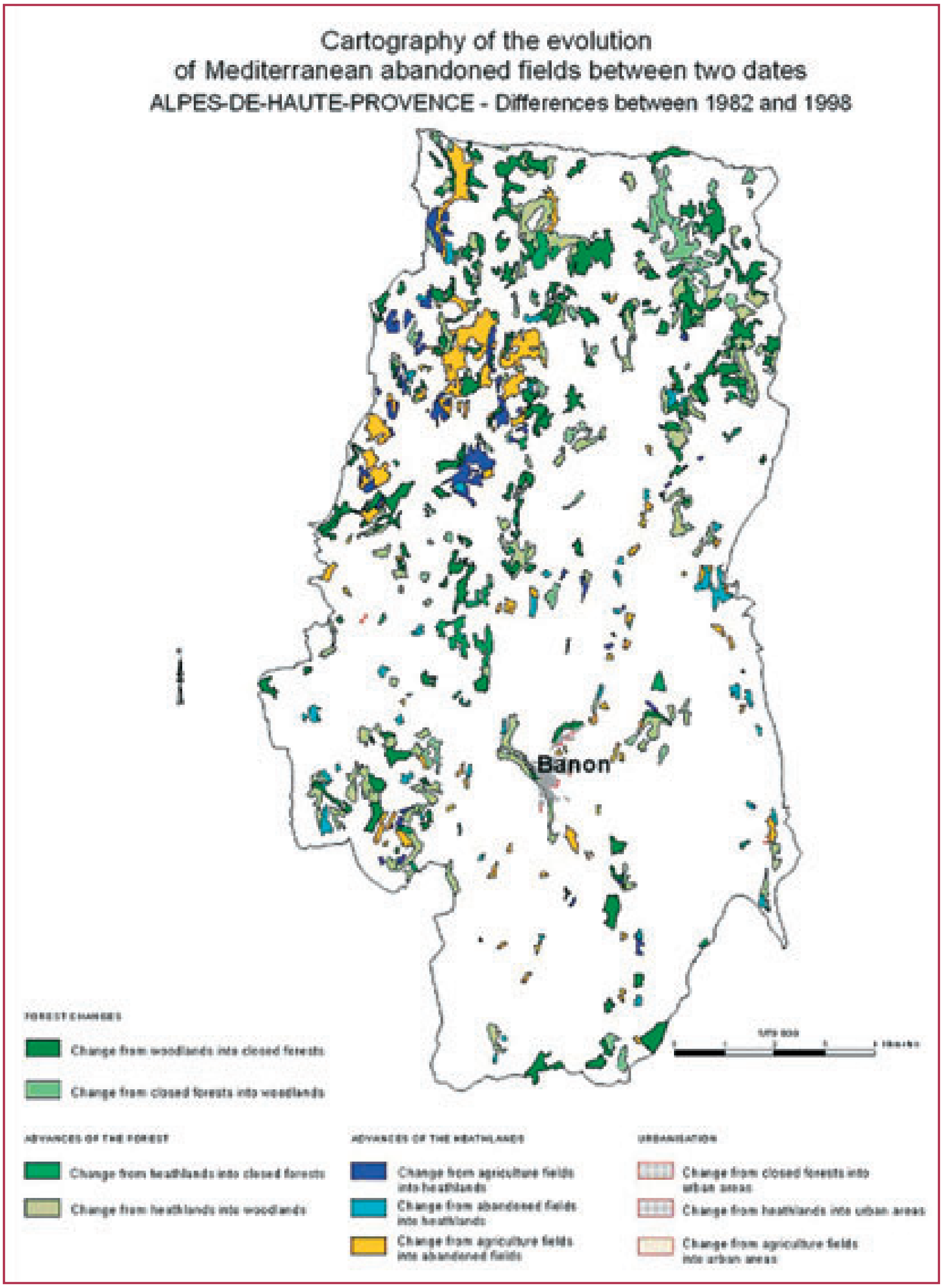
**CODE 6: ADVANCES OF THE FOREST**
Change from heathland with pubescent oak vegetation into woodland composed by conifers and hardwoods is characterised by the attribute 6.

**CODE 3: ADVANCE OF THE HEATHLANDS**
The blue patch with attribute equal to 3 is permanent pasture that changed to heathland with pubescent oak vegetation.

**CODE 5: CHANGE OF AGRICULTURAL PRACTICE**
The patch with code 5 in the south of this map corresponds to an agriculture field, which changed to permanent pasture.

**Map 3.** *Alpes-de-Haute-Provence – Evolution map on the aerial photograph presented on the example 1.*

The principal changes in this area are:
- Change from woodlands into closed forests and vice versa,
- Change from heathlands into closed forests or into woodlands,
- Change from agriculture fields into heathlands, transformation of abandoned fields into heathland and transformation of agriculture fields into abandoned fields,
- Urbanisation: transformation of dense forest, heathland, and agriculture fields into urban area.




**Map 4.** *Map of the evolution between 1982 and 1998*

### 3.1.9. *Transition Matrix*

A transition matrix was used to quantify changes, based on the information of the coverages.

The first entry corresponds to the sums of the area of the recent coverage (1982) and the second contains the information of the 1998 coverage. The following matrix represents the surfaces of 1998 in relation to the state of 1982 and grouped by land cover types.

**Table 4.** *Alpes-de-Haute-Provence - Transition matrix (relative surfaces in relation to the final state by elementary type)*

| 1998 state / 1982 state | Wood-lands | Closed forests | Aban-doned fields | Heath lands | Perma-nent pasture | Agri-culture fields | Urban or tourist areas | Out-cropping rock-water | Total |
|---|---|---|---|---|---|---|---|---|---|
| Woodlands | 47.4% | 50.5% | | 0.5% | 1.1% | 0.5% | | | 100.0% |
| Closed Forests | 2.5% | 96.1% | 0.0% | 0.9% | 0.3% | 0.2% | | 0.0% | 100.0% |
| Abandoned Fields | 13.1% | 5.9% | 32.3% | 29.3% | 5.4% | 13.1% | 0.9% | | 100.0% |
| Heathlands | 39.4% | 8.1% | 0.4% | 39.5% | 3.6% | 9.0% | | | 100.0% |
| Permanent pasture | 17.4% | 2.2% | 1.6% | 11.4% | 59.8% | 7.6% | | | 100.0% |
| Agriculture fields | 1.1% | 1.5% | 2.8% | 4.7% | 8.7% | 81.0% | 0.2% | | 100.0% |
| Urban zone or tourist zone | 1.6% | | | | | | 98.4% | | 100.0% |
| Outcropping rock-water | | | | 27.3% | 9.1% | | | 63.6% | 100.0% |

The most significant change corresponds to the decrease of heathlands (these decreased by almost 500 ha, hence more than a third of their area (cf. Evolution index - Table 3). Agriculture field areas decreased and in part changed to permanent pasture land cover. The stages of abandoned fields and heathlands are transitory.

The results of the last two population censuses indicate a continuation in rural migration. The perimeter common to urban and tourist zones and agricultural zones is reduced to a limited extent.

It should however be noted that 16 years separate the two coverages of aerial photographs and that the intermediate states are not known.

The zone is dominated by the forest; agriculture fields still hold on an important place in the landscape.

However, we can notice that the agriculture field area has regressed. The state of abandoned fields is often followed by the installation of pastures, which seems to be itself a transitory state. Closed forest areas have increased.

As a conclusion, fire risks for urban and tourist areas do not seem to be increased due to the important place of agriculture fields which represent the most significant urban bordering areas (cf. table 2), the reduced urbanisation (cf. table 4) and the rural migration.

## 3.2. Cartography of the Evolution of Areas of Production Chestnut Forests in Corsica

Forest and wood service of regional agriculture and forest administration of Corsica wanted to qualify the evolution of chestnut forests between 1975 and now. The aerial image coverage of the first NFI cycle (1975) and the coverage of the last cycle (2000) on the whole island were used.

### 3.2.1. *Nomenclature*

Three classes of production chestnut forests were used.

The first one corresponds to the well-kept production chestnut forests, the second one to the production chestnut forests with a dense vegetation layer composed by woody or semi-woody plants such as ferns, gorse, and heather. The last one corresponds to forests with a dense vegetation layer composed by woody or semi-woody vegetation such as holm oak or pubescent oak and indicates neglect. A minimal mapping unit area of 1 hectare and a minimal mapping unit length of 50 meters were applied. On those patches, if 75% of the cover in the area was represented by chestnuts, the limits of the patch were digitised and an attribute of the level of upkeep was documented.

### 3.2.2. *Aerial Image Interpretation*

The extents of patches are first delineated on aerial photographs and then converted to orthophotos made with the 2000 aerial coverage.

### 3.2.3. *Digitisation*

The last coverage of aerial photographs was scanned and orthophotos were used as a reference map for digitising the information from 1975 and 2000.

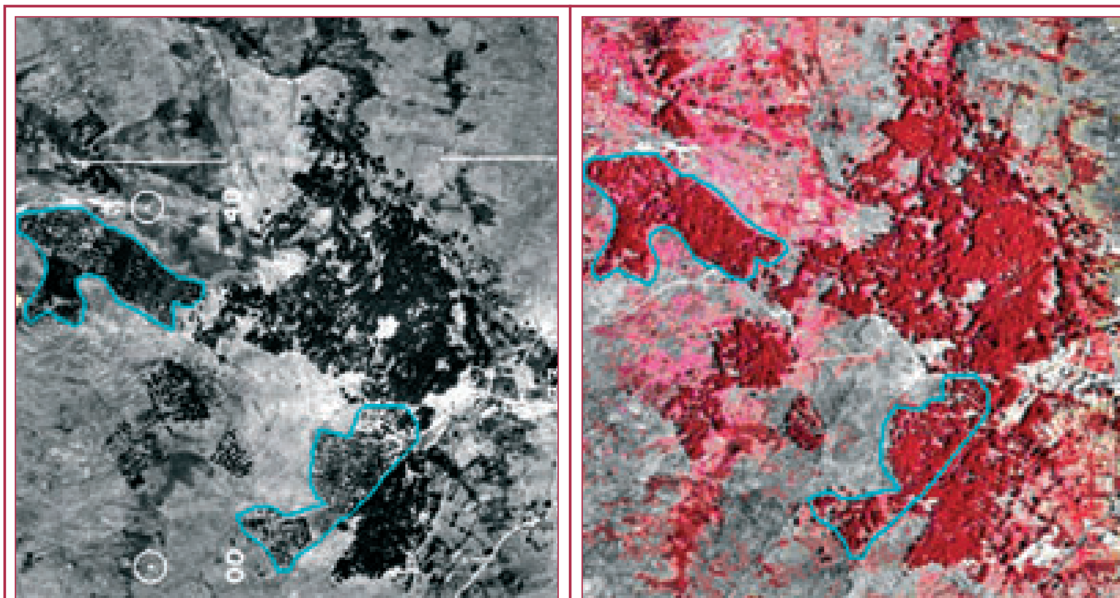
Users of this numeric coverage are mainly forest administrative and management services.





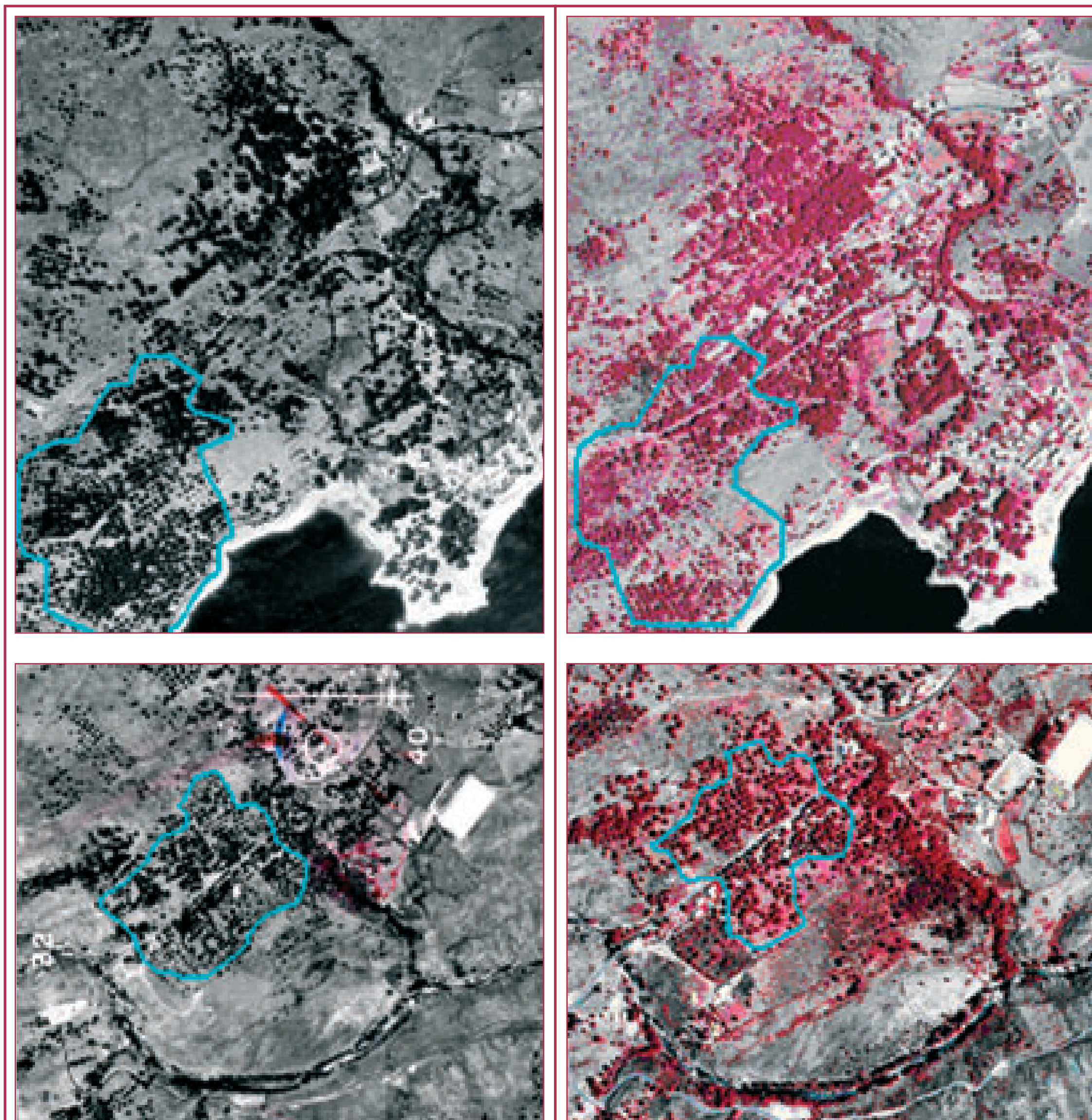
## 3.3. Cartography of the Evolution of the Wetlands in the Loire Valley

The general objective of this study was to determine the thread of intensive single-crop farming (mainly corn and poplar) which would threaten the biodiversity of rare areas. The French NFI mission was to determine and quantify changes over the time of



| **Black and white panchromatic composite** | **Coloured Infrared composite** |
|---|---|
| Well-kept production chestnut forests<br>Corsica, 1975 | Chestnut forests with vegetation layers composed<br>by woody or semi-woody plants - Corsica, 2000 |

**Example 3.** *Cartography on black and white composite and infrared aerial photographs, NFI Library*




**Black and white panchromatic composite**
Well-kept production chestnut forests
Corsica, 1975

**Coloured infrared composite**
Chestnut forests with vegetation layers composed by woody or semi-woody plants
Corsica, 2000

**Example 4.** *Cartography on black and white composite and infrared aerial photographs, NFI Library*

land cover and land use of meadows, cultures and poplar groves in an environment of wetlands.

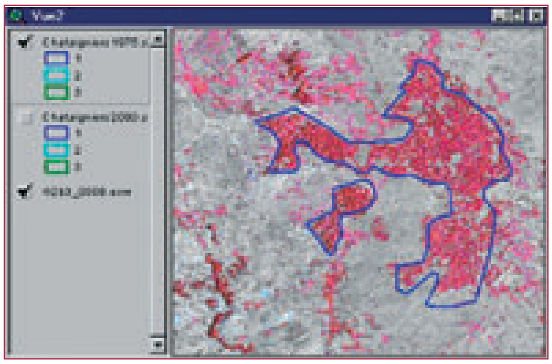
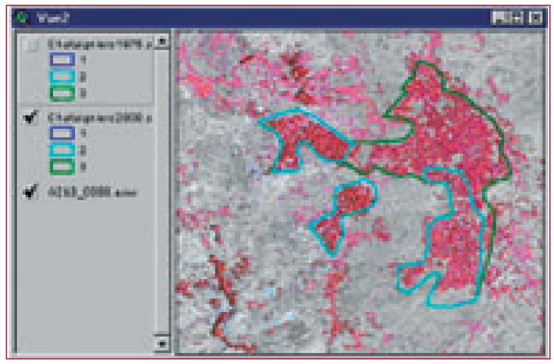
This study was commissioned by the French ministry for agriculture.

### 3.3.1. *Study's Area Selection*

The selected area surface is about 50,000 hectares and is situated in the NUTS 3 "Maine-et-Loire".

This zone covers:

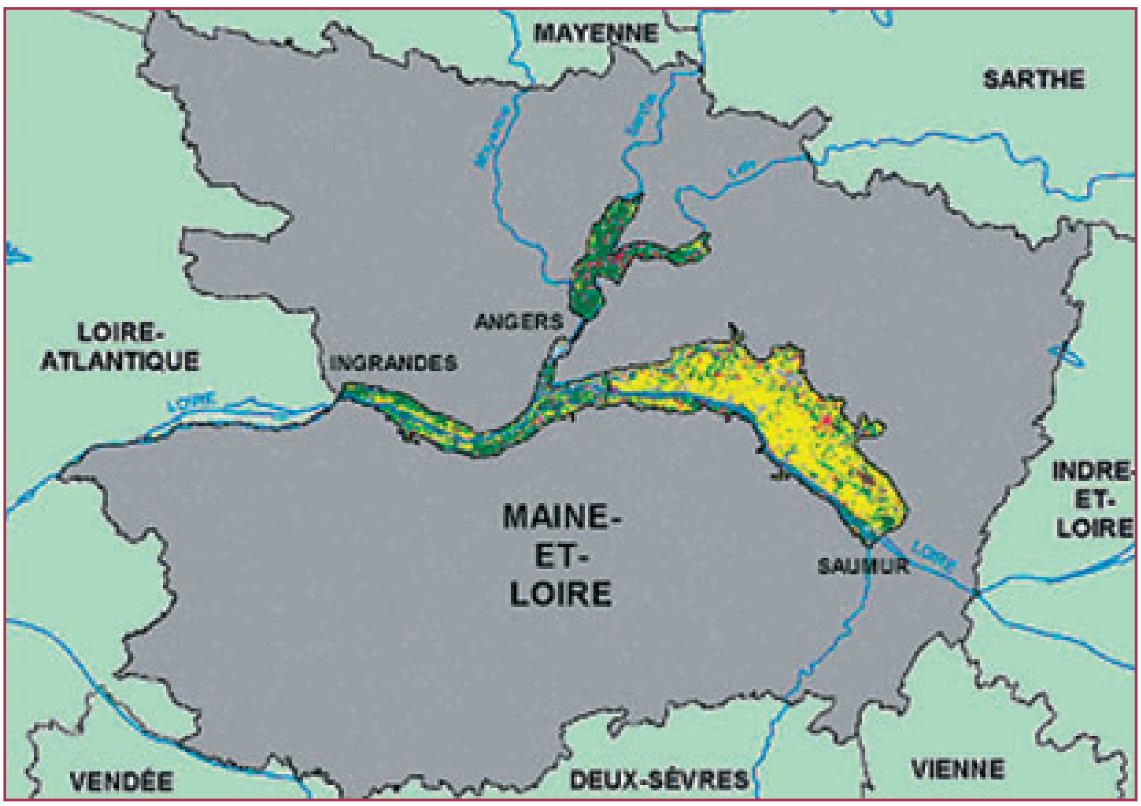
– Alluvial zone of the Loire from Saumur up to the departmental limit,
– Flooding areas in the valleys of Angers (junction of the Sarthe and the Loir Rivers) and the valley of Maine.

|  |  |
|---|---|
| **Coverage of 1975**<br>– In dark blue, well-kept production chestnut forest | **Coverage of 2000**<br>– In dark blue, well-kept production chestnut forest<br>– In light blue, production chestnut forest with low vegetation layer composed by woody or semi-woody plants<br>– In green, production chestnut forest with high vegetation layer composed by woody or semi-woody plants |

**Example 5.** *Digitisation on orthophotomap*

### 3.3.2. *Classes of land cover*

Two classes of forest land cover have been distinguished: closed forest and woodland. Four classes of heathlands, four classes of agricultural land cover (including permanent and rotation pasture) and two classes of poplar groves (young and adult) have been mapped. Gravel and sand extractions areas were also identified.




**Map 5.** *Map of the study areas*

**Table 5.** *Type of land cover nomenclature*

| Code | Wording | Definition |
|---|---|---|
| FF | **Closed forest** | Forest with an forest tree cover of 40% or more |
| FO | **Woodland** | Forest with an forest tree cover between 10 and 40% |
| | **Heathland** | Formations with an forest cover of less than 10% or more or a density of 500 shoots per hectare of young trees and at least 25% of woody of semi-woody plants |
| LF | Forest heathland | More than 50% of the perimeter adjoins to dense forests or woodlands |
| LP | Poplar heathland | Some scattered poplar or poplar sprout<br>More than 50% of the perimeter adjoins poplar groves |
| LA | Agricultural heathland | More than 50% of the perimeter adjoins agriculture fields |
| LX | Other heathland | |
| | **Poplar grove** | |
| PB | Young poplar grove | Fields with a poplar cover of 10% or more<br>Crown height less than 10 meters |
| PH | Adult poplar grove | Fields with an poplar cover of 10% or more<br>Crown height of 10 meters or more |
| | **Other vegetal land cover** | |
| PP | Permanent pasture | Area covered by grass (grazing or reaped area) |
| PT | Rotation pasture | Area temporarily covered by grass (grazing or reaped area) |
| CJ | Agricultural field or fallow land | Non-woody cultivated vegetation, except grassland |
| AP | Orchard or tree nursery or vineyard | Vines, fruit trees, cultivated shrubs |
| CO | **Soil with outcropping rock, urban area or artificial area** | |
| | **Continental water** | |
| GS | Gravel extraction or sand extraction | Water with extraction of materials like sand or gravel |
| EA | Other continental water | Other continental water |

## 3.3.3. *Aerial photographs interpretation*

Digitisation was used for the 1998 image cover. The minimal mapping unit was 1 hectare. The minimal mapping unit width was 50 meters.

## 3.3.4. *Example on Chalonnes-Ingrandes*

Several indexes have been calculated. The first indicator is the change in the number of patches and the edge length between 1968 and 1998.

Differences between 1968 and 1998 on black and white panchromatic composite - near Cantenay-Épinard (North of the study area):
– Black patches: no changes
– Red patches: evolution

Differences between 1968 and 1998 on infra-red coloured composite - near Briollay (North of the study area):
– Black patches: no changes
– Red patches: evolution (height of poplar groves and land covers)

**Example 6.** *Interpretation of land covers on aerial photographs*





**Table 7.** *Results calculated on vector converages - number of patches and edge lencht*

| | |
|---|---|
| Surface area (ha) | 11,127 |
| Number of patches 1968 | 492 |
| Number of patches 1998 | 628 |
| Edge lenght 1988 | 1,292 |
| Edge legnth 1998 | 99 |

The index of compactness K helps us to quantify the shape of the mapped patches. The closer the index is to 1, the denser the patches are. Conversely, when K is low, the

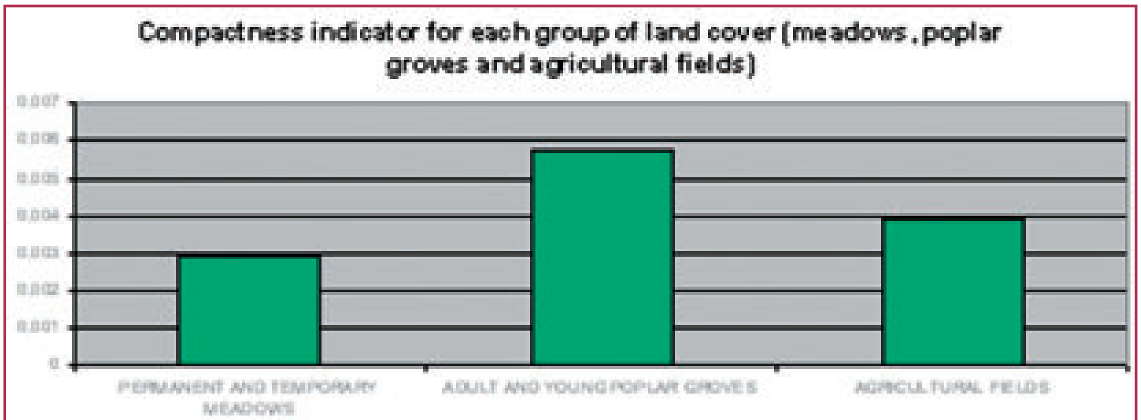



**Table 8.** *Compactness index for each group of land cover*

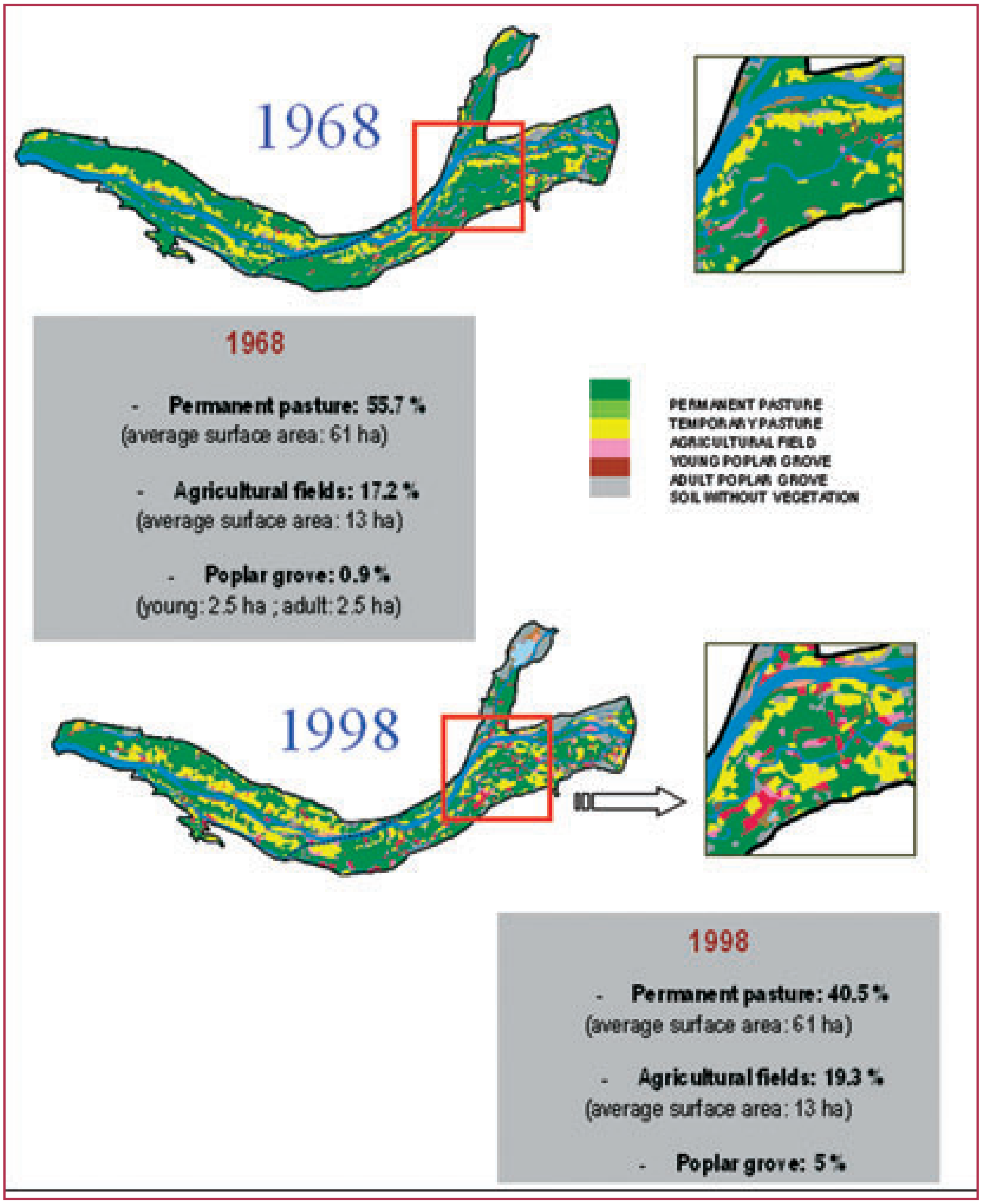
extents of the patches are smaller. By calculating the differences of the compactness index between two dates, the change in landscape can be quantified.

An increase in the index of compactness, relating to young poplar groves and gravel or sand extractions, and a moderate increase in of the adult poplar groves and orchards compactness, was observed.

The same index is calculated by regrouping classes of land cover, according to the objectives of the study.

This graph shows that the patches of "poplar groves" (young and adult plantations) are more compact than the patches of the meadows (permanent and temporary) and than the faces of the agricultural fields.

The evolution map can complete the analysis. In this particular area, poplar groves' area increases and permanent pasture area decreases.




**Map 6.** *Evolution of land covers on Chalonnes-Angers*

## 4. Conclusion

The importance of the changes occurred over several decades in the land cover within a particular zone often justify an objective and precise approach.

These types of projects started six years ago with the study of abandoned fields in the in the NUTS 3 *"Cantal"*. That was the first time NFI used the technique of digitising on analogical aerial photographs.

However, this technique is not currently used, because no software, compatible to Windows NT station, is available. So far, digitising techniques in NFI services have been investigated and gave good precision results.

As a matter of fact, this first evaluation of Photo digitisation enabled the creation and use of orthophotos. Currently, the technique of orthophoto production is being improved by using higher resolution scanning and GPS checking points.

Nowadays, the orthophoto map integrated in a GIS has become the digitising reference for NFI cartographic coverage production and land cover evolution studies.

From the thematic point of view, the cartographic method used by NFI based on the analysis of aerial photographs taken on various dates allows the establishment of detailed cartographic coverages. The French NFI aerial photographs specifications permit a precise cartography with a high level of precision linked to the minimal surface of representation (up to half a hectare).

Production of precise and objective data completed by the calculation of evolution indexes often contributed to solve problems that remained complex in the absence of objective data.




## 5. Glossary

### Compactness index

The compactness index corresponds to the ratio of the surface and the perimeter and it is calculated for each category of land cover.

$$K = \frac{4\Pi S}{P^2}$$

This index qualifies the shape of the patches. For the same area, when the index decreases, the perimeter increases and the coverage edges are more pronounced.

### Number of classes

This diversity indicator is the number of classes found. This criterion is really simple to calculate but hard to analyse.

As a matter of fact, the image obtained by the indicator can be false because the population can be represented by a lot of categories of land covers but, for most of them, with a low surface area.

### Planimetric precision of digitising

The planimetric precision can be qualified by the average quadratic error ($\Delta$D). Control points have to be found on Orthophotos and on the ground. The ground coordinates ($x_{gps}$ and $y_{gps}$) are compared to the orthophotos coordinates ($x_{ortho}$ and $y_{ortho}$) by calculation of the following index:

$$\Delta D = \sqrt{\left(x_{gps} - x_{ortho}\right)^2 + \left(y_{gps} - y_{ortho}\right)^2}$$

The same process can be used with the coverage created by photo digitisation technique.

## Shannon index

The Shannon diversity $I_1$ index is commonly used to characterise species diversity in a community.

$$I_1 = -\sum_{i=1}^{n} p_i Logp_i$$

$p_i$ represents the relative proportion of individuals in group i.

The proportion of species i relative to the total number of species ($p_i$) is calculated, and then multiplied by the logarithm of this proportion (Log$p_i$). The resulting product is summarised by the sample and multiplied by –1.

## Simpson index

The Simpson index $I_2$ increases the correction done by the Shannon index. As a matter of fact, this index uses the sum of the relative frequencies of the couple i-j.

$$I_2 = \sum_{i=1}^{n} \sum_{j \neq i}^{n} p_i p_j$$

n represents the total number of patches in the categories of land cover we are considering, and $n_i$ represents the number of patches in group i. $p_i$ therefore represents the relative proportion of individuals in group i.

The Index ranges from 0 to 1. More the index is closer to 1 the less diverse is the community.

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# Potential use of Rural Development Policy databases to derive Agri-Environmental Indicators

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## 1. Introduction: the Rural Development Policy

### 1.1 Context, history and legal basis

Rural areas cover about 90% of the (enlarged) EU's territory and are home to approximately a quarter of its population. A sound Rural Development Policy is therefore an absolute necessity to guarantee the viability of those rural areas and their sustainable development.

In the early nineties, the process of the "greening" of the Common Agricultural Policy (CAP) entailed in the first instance including environmental aspects in the agricultural policy, thus focussing on the protection of the natural environment in the rural areas [1]. Efforts were made to make farming and forestry more viable activities through the so-called "accompanying measures". With Agenda2000, the rural development policy (since then called the "second pillar" of the CAP) became a more solid component of the CAP and widened its scope, looking at the entire context of the rural areas [2]. Apart from strengthening the instruments to protect the rural environment, also the rural heritage was now given its due importance. The multifunctional character of agriculture and forestry was highlighted and the need to improve also the competitiveness of other sectors in the rural areas was recognised. The CAP reform of 2003 introduces the concept of a more sustainable development of the rural areas and reinforces the reallocation of funds from the first to the second pillar [3]. Recently, the European Commission adopted a proposal to go even further. It proposes that in the future, aspects such as – consumer driven – demands related to food quality and animal health come into play, as well as the means to improve the viability of the rural areas to avoid the exodus of the younger population and to increase the attractiveness of the rural area for tourists.

The Rural Development Policy is co-financed from the European Agricultural Guidance and Guarantee Fund (EAGGF). The total expenditure – including the Leader + programmes and Objective 1 and Objective 2 programmes with RD measures – is estimated at 52.5 billion € for the full period. About 10% of the CAP Guarantee budget available for the current programming phase (2000-2006) is consumed by Rural Development.

In the context of the European Rural Development Policy, Member States are obliged to set up a Rural Development Plan (RDP) [4] at national level or at regional level. These plans describe in detail how each Member State will implement the policy, what the concrete objectives are for the country or region concerned and how they plan to achieve them, including the definition of the measures and distribution of the available funds.

### 1.2 Rural Development Measures

The various measures included in the Rural Development Plans are grouped under 11 chapters and 27 titles (a, b, c,… to aa) [3]. There are three main groups of measures[1]: 1) a series of structural measures and measures focussing on competitiveness, 2) measures related to the natural environment and land management and 3) measures focussing on the rural economy and the rural communities.

Only part of the measures concerns the relation between agriculture and forestry on the one hand and the environment on the other, and thus involves the use of geographic information. These are the measures for the Less Favoured Areas (LFA) and areas with environmental restrictions (e), the agri-environmental measures (f), measures for afforestation of agricultural land (h), part of the other forestry measures (i) and some of the measures for implementing demanding standards (x).

In the context of the present article, our interest mainly focuses on the agri-environmental measures (AEMs). They consume the lion's share of the RDP budget with an estimated expenditure of 13480 million € (or 27.5% of the total available) for entire programming period.

### 1.3 Process of payment of the support for Rural Development

At the initial stage of the implementation of the agro-environmental measures, the Administration makes a "contract" with the farmers who, on a voluntary basis, enter in the schemes provided in the national or regional plan. At this point in time, the eligibility of the objects under contract is verified and a check is carried out whether the farmer adheres to the usual good farming practices of the region. The contract specifies which measures the farmer will implement and exactly which commitments those measures entail. It is generally established for a duration of 5 years.

The support consists of an annual payment for compensation of income foregone.

To receive the support and to apply for the actual payment, the farmers normally have to submit a declaration every year, giving details on their objects under commitment. Some Member States only require an annual declaration in case the contracted objects have changed.

Before proceeding to the actual payment of the support to the farmers, Member States have the obligation to control on a yearly basis a sample of the applications whether the farmer fulfils the commitments made in the initial contract. Reductions and /or sanctions of the payment amounts are foreseen in case irregularities are detected during this control exercise, for the yearly payment (with possible retro-active effects).

The practical management and control of RD claims are based on the generic principles and functions of the IACS (Integrated Administration and control system of the 1st pillar), including a proper land parcel identification system (LPIS).

### 1.4 Evaluation

Besides the compulsory annual control activity, annual monitoring, a mid-term and ex-post evaluation of the implementation of the Rural Development Plan is stipulated in the regulations.

Member States report to the EC, who makes an overall evaluation of the RDP implementation in terms of level and distribution of uptake of measures, use of available funds, infringements, achievement of the objectives set forward in the RDP, problems encountered and solutions found/proposed,….

## 2. Monitoring policy impact on the environment

In order to study the impact of policy measures (and of human activity in general), the state of the (rural) environment has to be monitored. Based on observations made

[1] Regulation 1257/1999 specified 22 titles grouped into 9 chapters; Regulation 1783/2003 added two chapters and 5 titles.

at various points in time, trends can be derived and used as input for policy makers to reinforce or re-direct current legislation.

Of particular interest here is the integration of environmental concerns into the agricultural policy of the EU. To this purpose, the EC has set up a list of features that are considered to be good indicators of the success of this policy and its impact on the natural environment [5], [6]. The main challenge now lies in the development of such indicators, and in determining if and which existing databases can be used and how.

## 3. Databases in the context of RDP/AEM implementation

For the implementation of the Rural Development Policy several databases are created, which contain a set of administrative and textual data and some geographic information.

In the context of this article, we focus on agri-environemental measures (AEMs) on objects with a geographic component – i.e. area features, linear features and point objects. Issues related to animals, structural measures and measures directed to the rural community as a whole are not touched upon here.

### 3.1 Macro-level: eligibility zones

In the initial stage of the programming period, each Member State studies environmental problems occurring on their territory. Based on this assessment, objectives for the programme are set and the Administration defines the most appropriate measures to mitigate the negative impact of agriculture on the natural environment.

To address specific problems, target zones can be defined and Member States can draw up a map of eligibility zones that determines where farmers are eligible for the related AEM schemes. It should be noted that this "map" can be defined in various ways, such as in terms of socio-economic parameters of administrative units (list of provinces, communes,…)[2], through GIS data layers describing topological characteristics of the territory (e.g. altitude, slope, river basin,…), through characteristics of the territory derived through spatial analysis (any combination of socio-economic parameters and topological features).

For the RDP in general but in particular in relation to the AEMs, the status of the natural environment at this initial point in time should be well-known because it is of major importance for long-term evaluation on macro-scale, constituting the reference with which to compare the impact of the policy implementation. However, there are little cases were an objective inventory of the initial "$T_0$" situation is available, either based on a statistical survey or on a detailed mapping of the whole area of interest.

### 3.2 Micro-level: inventory at farm level

#### 3.2.1 *Initial situation on the holding*

As stated above, at the entry of the farmer in the programme, a contract is made. This contract contains a detailed description of the measures the farmer will implement and on what part of his holding the farmer will implement them. The period for which the various measures included in the contract are valid is stipulated as well as the value of the subsidies resulting of the commitments. Usually a map of the holding is made, on which the objects under commitment are indicated. As mentioned before, a unique parcel identification system is used, fully compatible with the digital LPIS of the 1st Pillar of the CAP.

Having information on the status of the environment on the farmer's holding at $T_0$ will enable the Member State to assess at a later stage if the farmer has fulfilled his commitments and support annual or short-term control at micro-level.

[2] This is for instance the case of most of the EU15 "Less favoured areas".

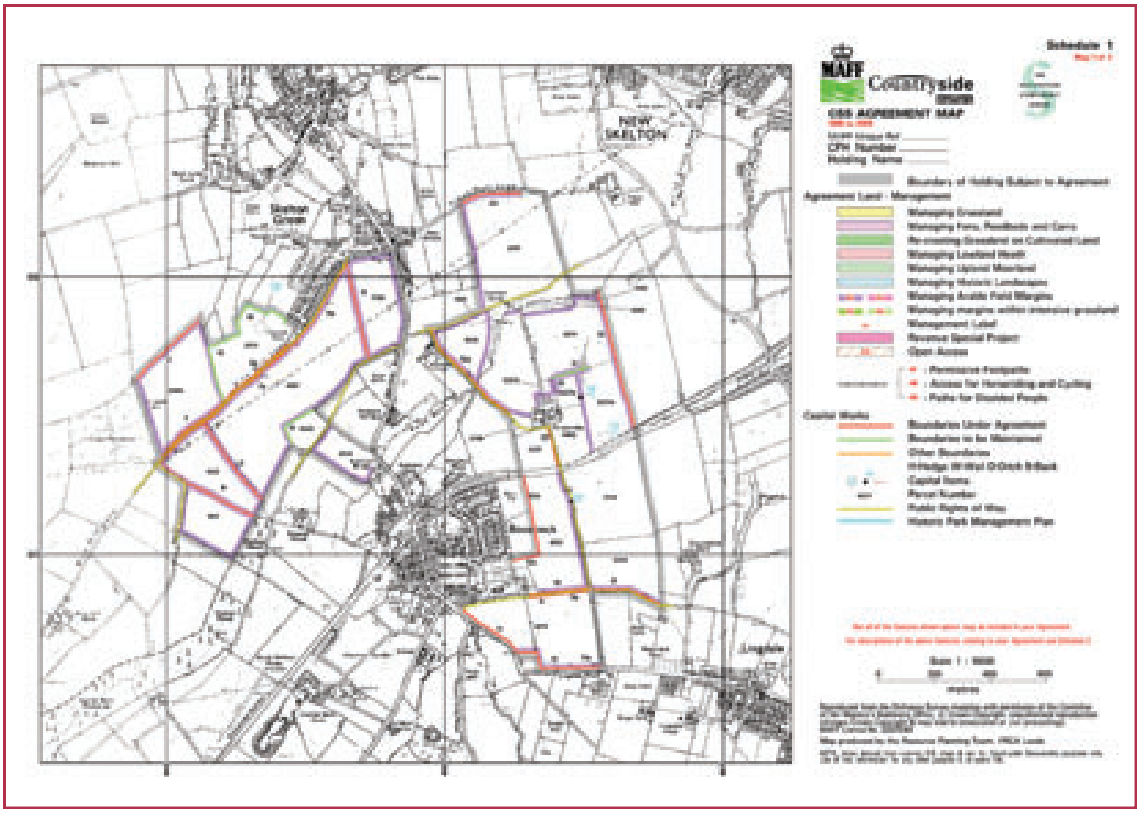



**Figure 1.** *Extract of an agreement map depicting the contents of the contract with the farmer - used in England (source: ADAS/MAFF)*

### 3.2.2 *Annual data through declaration database*

Annually farmers make an application, to claim payment for the commitment(s) they made at their entry in the programme. For some measures this means a confirmation of the information provided in the previous year(s). For other measures, new information is required e.g. specification of parcels and related crops in a measure including crop rotation.

In any case, farmers are obliged to declare individually all parcels of their holding, including the ones where no AEM is implemented. The information provided includes the parcel ID, its area, the crop grown on it and the measure(s) applied. All objects that are included in the commitment, such as linear and point features, are indicated and where appropriate linked to the parcels declared.

All information contained in the annual subsidy applications is recorded into a dedicated database that is managed by the Administration at an appropriate regional or central level. It comprises both alpha-numerical data and geographic data, but also rather important paper/document archives (ancillary information etc).

The databases established and maintained in the framework of the direct payments of the first pillar of the CAP (for the Integrated Administration and Control System - IACS) are used for parcel and farmer identification purposes, and for administrative cross-checks. As for IACS the geographic data established and collected in the context of RD will be obligatory in a computerised GIS system as of 1/1/2005.

Even if not compulsorily in the IACS regulation, all the 25 Member States included into their digital LPIS a regularly updated ortho-imagery. The digital LPIS and this detailed information provide a crucial support for the management and control of the RD applications. Ortho-imagery for instance allows preliminary checks on eligibility and location of the elements contracted (at the initial instruction phase of the contract).

### 3.2.3 *Annual data from control activities*

Each year, all the subsidy applications lodged by farmers are controlled. This control consists of two major parts: An administrative control on 100% of the applications and the so-called "on-the-spot" checks on a sample of minimum 5%, selected through risk analysis procedures.

Administrative controls range from simple data-format related checks (e.g. fields that are compulsory should not be empty; name of farmer should be an alpha-numerical string; bank account number should be conform the national standard;…) to more complex cross-checks of the claims with external databases or between themselves (e.g. are the parcel IDs are existing in the LPIS; the parcels are eligible for the aid requested from an administrative point of view; if aid for more than one measure/scheme is requested on a given parcel, does it concern cumulative measures/schemes – the latter including cross-checks with the applications for arable direct payments;…). All the findings of these controls are recorded in the database and trigger different administrative procedures.

On-the-spot (OTS) checks can be done completely through a physical visit in the field or partially by means of remote sensing, completed by a field visit. The information contained in the applications is verified, the results of the checks are recorded and a control report is made.

In the first instance, the existence and eligibility of the land use of the objects under commitment is investigated: agricultural parcels, pastures, hedges, ponds, creeks, grass strips, etc. This is traditionally done during a field visit, but can also be done using aerial photography or satellite imagery with the appropriate resolution. For the identification of many features, the required resolution is better or equal to 1 meter because of their small size (in one or two dimensions). However a lower resolution remains sufficient for the identification of agricultural parcels only.

Secondly, the exact dimension of the objects (area, length or diameter) or their number and density (for trees) have to be determined if there are the base for the payment. This can be done in the field using traditional analogue measuring devices but more and more the Member States tend to make use of GPS for their measurements. Alternatively, length or diameter measurement can be done using aerial or VHR ortho-imagery, which are becoming more easily available.

The resulting geographical information is stored in a GIS database and if relevant used for the update of the reference system in use.

Finally, the Administration verifies the detailed compliance with the specific commitments for the measures contracted by the farmer. They check if the farmer has carried out all the actions that make up the corresponding commitments as stipulated in the rural development plan. More generally, the Administration has to ensure the farmer did respect the "Good Agricultural Practices", i.e. a list of regional standards which are compulsorily for the eligibility of the whole application.

Due to the complexity of the measures, it is sometimes difficult for the Administration to verify all elements of the commitments: this would for instance require several inspections during the year, would be time consuming and not very cost-efficient. Therefore, Member States' Administrations can define a control strategy combining risk analysis on the various commitments and the calendar / specificity of the controls, the control obligation covers all elements that can be verified at the time of the OTS checks.

The timing of the OTS checks is determined by the crop calendar and the critical dates related to the obligations and/or prohibitions linked to the measure implemented. For some measures controls are needed at various points in time (e.g. extended flooding period of rice fields for promotion of bird population). The economic aspect of the elements to be controlled is also taken into account when setting up this calendar.

Traditionally the control of the commitments is done through a classical field visit. This is mainly due to the complexity of the definitions of the commitments but the nature of the actions itself also plays an important role here. For example all obligations related to documentation (e.g. invoices of seed purchase) can only be verified physically at the farm.

In the recent past, some studies have been carried out by various instances to investigate the potential use of remote sensing (spatial and airborne) in the control of AEMs. It is difficult to draw general conclusions on this issue, because of the heterogeneity of the measures that are implemented in the various Member States and their regions. However, based on the studies carried out under coordination of the MARS project of the JRC in UK, IT, ES, FR and DE, some issues became apparent. The said studies focussed on the control of a number of AEMs related to practices at field level and some pertaining to landscape elements. A general observation was that satellite imagery can be used for the control of a) practices at field level that relate to absence of presence of a certain crop type and to certain conditions of the field at a certain point(s) in time and b) absence or presence of landscape elements and up to a certain point of their condition. The type of imagery to be used for reliable control and the timing of the image acquisition are however crucial points and especially the latter can cause serious problems for the timely and complete execution of the control campaign. For many measures, the traditional field visit is still required to ensure completeness of the control.

### 3.2.4 *Data on changes of the holding*

Farmers have the obligation to report any changes to the situation of their holding to the Member State's Administration. These may consist of transfers of the holding – in whole or in part –, reparceling due to major public works, expansion, etc. The existing commitments are to be maintained wherever possible or to be replaced by new ones that are at least equivalent in terms of environmental impact.



# 4. Suitability of RDP databases to derive Agri-Environmental Indicators

## 4.1 General requirements for databases to derive Agri-Environmental Indicators

Agri-environmental indicators serve to assess the impact on the environment of the integration of the environmental concerns in the agricultural policy. Their objective is to collect statistical information, to allow the setting up of territory-covering inventories for drawing valid conclusions at macro-level.

Such inventories can consist of or be based on mapping approaches, i.e. on data that are exhaustive at a given scale, as for instance CLC, as was investigated in earlier publications [7], [8], [9].

Alternatively, if no exhaustive coverage of the territory can be made due to time or resources constraints, or if the objects to measure or assess are not identified at the former scale, statistical surveys are carried out on a sample-basis are aggregated at regional level, as for example done in the LUCAS survey, Farm Structure survey and many others. These statistical approaches present the need for a well-thought sampling method that ensures efficient and representative samples of the population in order to obtain reliable and non-biased estimators at a regional or national level. Homogeneity of the sampling approach and of the observation methodology throughout the Member States is an absolute requirement to produce comparable and homogeneous data that can be used to make assessments at an EU-wide level.

In term of environment and agriculture, area frame surveys, based on a geographic sampling plan, have demonstrated their interest and capacity for this purpose. Nevertheless, the data should preferably, be collected at a reasonably narrow interval in time, especially in case the aim is to study changes over time and to make comparisons between various territorial entities.

## 4.2 Characteristics of RDP databases

The information about the contracts and the annual subsidy applications lodged by the farmers is stored in two databases: an alpha-numerical database is created with the textual data about the farmers, their holdings and parcels, about the contracted elements and the declarations made by the farmers on an annual basis. This database is linked to a GIS database that contains the objects under contract and the description of their status at the various points in time, as well as the geo-data gathered for the control (satellite images, aerial photography, other GIS baseline data). It can be either fully integrated with the LPIS GIS database or linked to it.

It should be kept in mind that the databases implemented for the RDP are built and managed for administrative purposes, with as main objective the management of aid payments of the CAP. This has some important consequences for the contents and accessibility of the data contained in them.

### 4.2.1 *Contents*

The objects that are included in the databases for the RDP implementation are determined by the Rural Development Plans. Looking at the AEMs, we see that it concerns on the one hand information about parcels on which certain environmentally-friendly agricultural practices are applied or on which abstinence of certain types of harmful agricultural practices is guaranteed. On the other hand there are a number of landscape elements included in the AEMs, for which a series of actions to be executed are defined. The information related to the objects in the databases focuses on the actions/practices themselves, rather than on the effect they may really have on the environment.

However, especially for the landscape elements, the indication of the presence of the landscape element as such and some information on their status could be a valuable source of information (see below).

### 4.2.2 *Representativity*

The data recorded in the frame of the RDP implementation are individual data: they result from the declarations farmers make to the Administration. Their main purpose is to truly reflect the actual situation on the farmer's holding.

The uptake of the measures varies strongly from country to country, and even from region to region. In addition, some measures are implemented by a high percentage of farmers, whilst for others the uptake is rather low.

This heterogeneity can be linked to historical reasons (long pre-existence of national schemes transferred in EU RDP) but also to the dissemination and appropriate definition of the RDP in the Member States. The latter plays an important role in the suitability for implementation and therefore a good uptake of the measures.

More fundamentally, the representativeness of the RDP administrative databases faces the following problems:

- Farmers participate in the RDP and AEM on a voluntary basis, which definitely constitutes a bias for any extrapolation to the whole population;
- The eligible area for a given AEM may not fully correspond to the administrative unit for which indicators have to be produced. (further complexity may be generated by geographic intersections between the fragmented areas of the various AEM).

- Agri-environmental measures are justifying extra payments because they require extra commitments that are not part of the usual good farming practices. They will de facto address only a specific part of the farmers in the area of interest and not the whole population.

In consequence, Administrative statistics from the RDP should be used very carefully and appropriate analysis should be made on the feasibility to correct them through a range of ancillary information data sources. The situation of the RDP in this regard is dramatically different from the one of the Arable sector (1st pillar) where, according to EU Member States[3], farmers' declarations registered in the IACS cover an agricultural area bigger than 85% of the utilised agricultural area. Consequently, several Member States have studied or developed statistical information or indicators based on their IACS databases.

The most recent consolidated figures available on RDP implementation are for the EU15 for the year 2003[4]: A total of 1.5 million contracts were established with farmers participated in the AEM programme, applying for subsidy for slightly over 27.5 million hectares[5], for a total budget of 2,516 million €. These figures have to be compared with the total number of farmers that reached almost 6.8 million and the total UAA that amounted to over 100 million hectares[6]. A total of roughly 3 million farmers participate in the arable direct payments scheme, which consumes a budget of around 25 billion on a yearly basis (EU15). Although the rate of participation in AEM could represent a very large sample, the major problem is the very irregular geographic distribution of the participating farmers, which cannot be influenced in the present RDP implementation.



**Table 1.** *1998 uptake of AEMs in Lombardia (source DG Agricoltura - Regione Lombardia)*

| Measure | N° of uptakes | Surface in ha |
|---|---|---|
| Input reduction | 2243 | 36651 |
| Organic farming | 450 | 5055 |
| Arable to grassland reversion | 8168 | 116740 |
| Reduction of livestock density | 3 | 156 |
| Farmland conservation | 8165 | 133379 |
| Breeding of endangered local species | 444 | |
| Maintenance of abandoned land | 1478 | 7702 |
| Set-aside of arable land | 10 | 149 |
| Management of land for public access and leisure | 24 | 734 |
| Training | 23 | |
| TOTAL | 21008 | 300566 |

[3] Data provided to the JRC by Member States. Data not available for part of Spain, part of UK, Greece, Sweden and part of Germany.

[4] Data provided to EC DG AGRI; figures for all Member States, excluding Sweden (no data available at time of writing). Note that one farmer may establish more than one contract.

[5] Some areas are double counted because of the possibility to cumulate more than one AEM on an agricultural parcel. Also, double counting of areas under measures of Reg. 2087/92 and 1257/1999 occurs. No exact information is at hand to exclude the double counting at EU level.

[6] Data from EUROSTAT; data for Greece and United Kingdom missing.

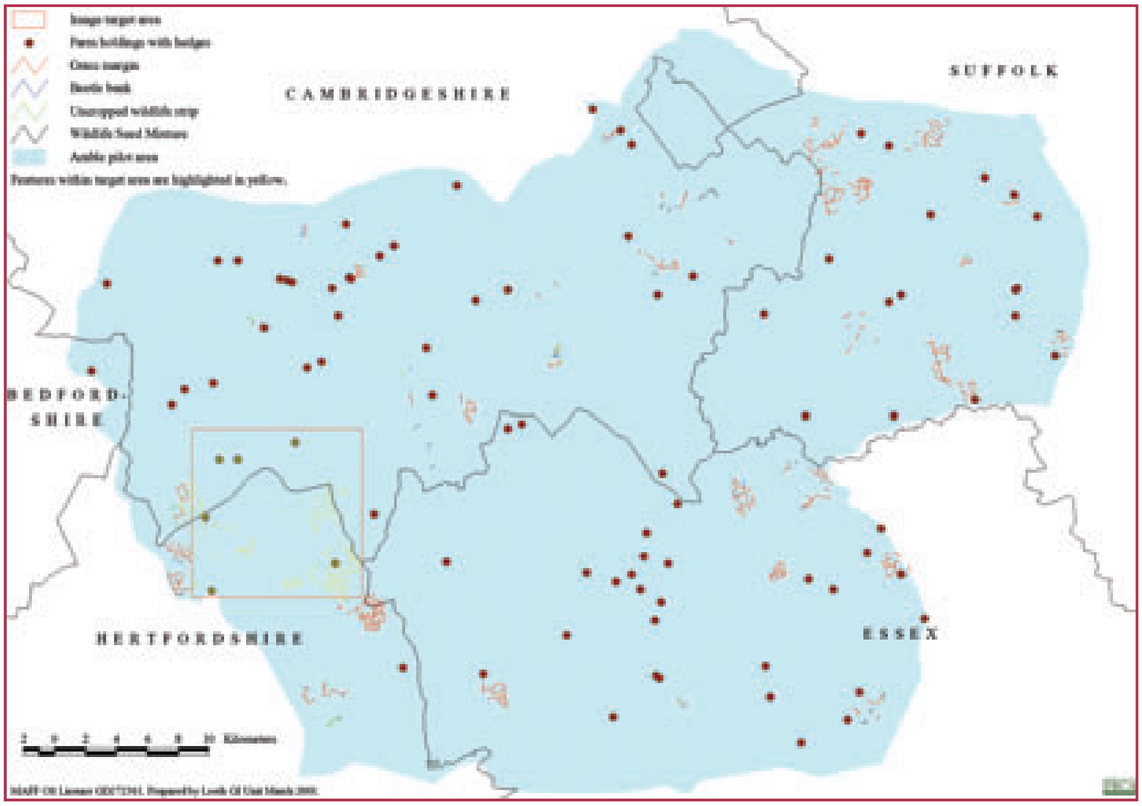



**Figure 2.** *UK: uptake of field margins and hedging options in East Anglia Arable Stewardship (source: ADAS/MAFF)*

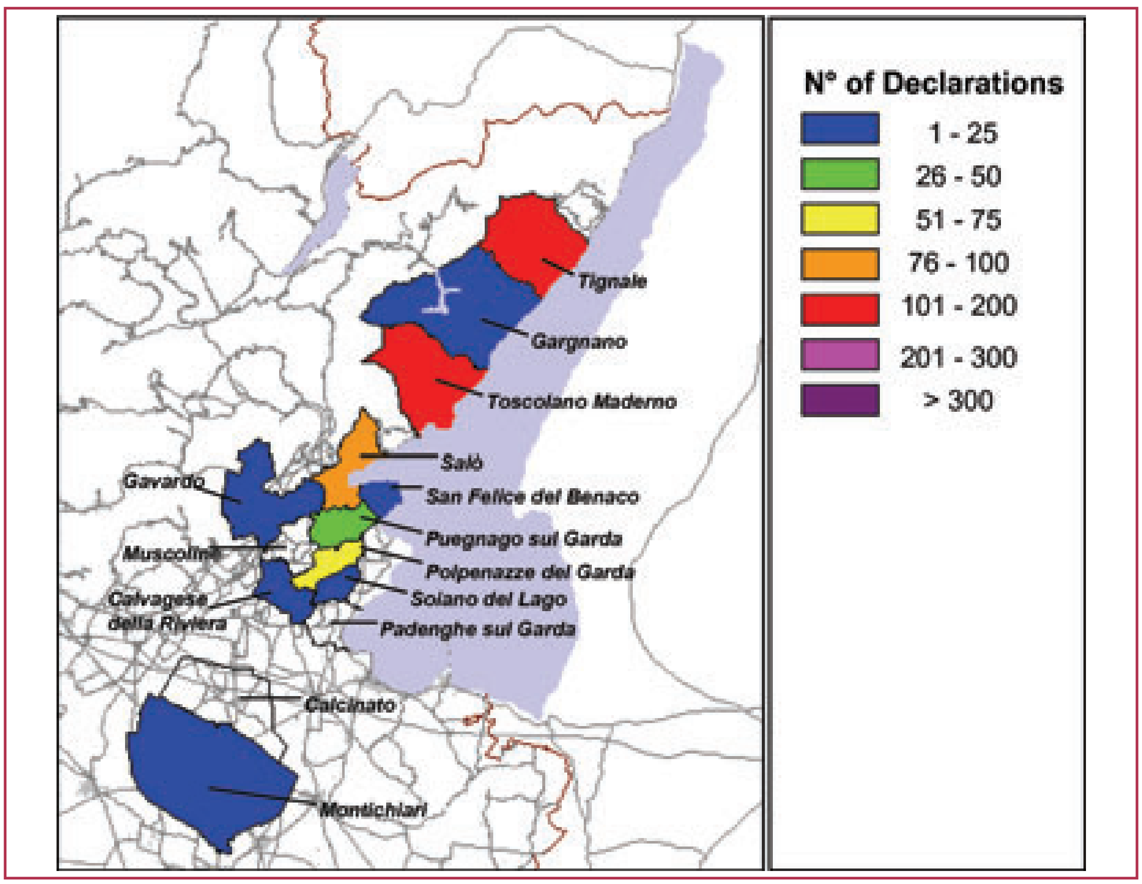



**Figure 3.** *Uptake of organic farming measure in selected communes in Lago di Garda test site in 1998 (source: RSDE)*

Control data are even more erratic than data from declarations and therefore even less reliable to use as a representative sample for generalisation purposes. Every year, a minimum of 5% of the applicants has to be controlled. The selection of those applicants is done in such a way that all schemes are represented. The data that result from the control activities follow the same spreading pattern as the entire population of farmers participating in the Rural Development Plan and therefore are not necessarily systematically distributed over the territory.

Many reasons for non-participation in the schemes are identified, going from the facts that the implementation rules are judged too complex or that the farmers do not consider the compensation worthwhile. But rather complex behaviour can also be linked to the fear for sanctions in case the farmer has not implemented the measure and the Usual Good Farming Practices (UGFP) correctly, to the difficulty to take a 5 year commitment for farmers renting a large part of their land, etc… What is important to bear in mind, is that there is no objective information on hand on the motives why certain farmers apply or don't apply for the AEM Schemes. And such information would be needed to correct the sample or the statistics from the RDP to arrive at statistically sound indicators.

In addition, whatever the reason for non-participation may be, there is no information available on the agricultural activities and agri-environmental behaviour of those farmers. Do they have environmentally valuable features on their fields, do they maintain them, do they use farming practices that are not harmful for the environment, etc. ?

The total uptake rate for a given AEM is definitely a good indicator for the administrative implementation of this AEM… But it doesn't provide an objective and independent assessment of the improvement of the environment in the area of interest. It may well be that without entering in the Rural Development subsidy system, many farmers cultivate their land in an environmentally friendly way, or oppositely that a minority of farmers strongly degrade it.





### 4.2.3 *Heterogeneity throughout Europe*

As indicated above, the databases on AEMs are specific and tailor made for the implementation of the Rural Development Policy. This leads to a high degree of heterogeneity in the databases, which is inherent to the way the Policy is implemented in the EU. Although EU guidelines are applicable on the contents of the national and regional RDPs, the concrete design and formulation of the plans and the measures they contain is decided by the Member States themselves. For the programming period 2000-2006 a total of 68 Rural Development Plans were put into place[7]. Because the RDP is targeted to solve the problems specific to every country or region, a part of the elements covered in the various RD Plans is specific for the country or region in question. As such, the concrete detailed actions that make up the commitments vary from one RD Plan to another and the objects included in the AEMs – and thus in the related databases – are not the same throughout the EU.

It is difficult to assess if common series of features with high environmental value are likely to be included in the RD Plans throughout larger regions of the EU. More in-depth analysis of the national and regional RD Plans would be needed to investigate this issue and to evaluate at what level this homogeneity would occur (maybe at bio-geographical region level) and whether it would be worthwhile to make efforts and possible to integrate data from the various Member States' RDP-related databases for deriving AEIs.

[7] Apart from the 68 RDPs, 20 Objective 2 programmes with RD measures and 69 Objective 1 programmes with RD measures were co-financed from EAGGF, as well as 73 Leader + programmes that also relate to rural development.

**Table 2.** *Hectares under AEM contracts in 2003*

| MS | ha under AEM | of which organic farming |
|---|---|---|
| AT | 5963274 | 295179 |
| BE | 53357 | 18873 |
| DE | 5161587 | 536822 |
| DK | 297901 | 110470 |
| ES | 34017 | 11571 |
| FI | 4124567 | 142510 |
| FR | 8407962 | 207793 |
| GR | 127192 | 18953 |
| IE | 1254746 | NA |
| IT | 1281811 | 249307 |
| LU | 137826 | 2260 |
| NL | 41827 | 10960 |
| PT | 410005 | 27904 |
| SE | NA | NA |
| UK | 214716 | 57760 |
| Total | 27510788 | 1690362 |





### 4.2.4 *Data quality*

The quality of any indicator depends on the quality of the data it is derived from.

In this respect one should bear in mind that the RD Administrative data come from declarations for subsidy applications and are not necessarily objective observations. A small overestimation bias could be therefore be expected as for the 1st Pillar. However, the vast majority of the farmers fills their subsidy application as accurately as possible and does not intentionally make false declarations. Moreover, the initial establishment of the contract by the administration and the complexity of the schemes and the control should reduce the rate of over-declaration.

If required, the results of the annual control activities (and especially the 25% random sample of OTS checks) – if accessible – could provide a good assessment of the correctness of the declaration data and/or a possible way to correct the statistical information.

### 4.2.5 *Data accessibility*

The management and control of the RD Plans and the related subsidy applications and their control are the responsibility of the Member States' Administrations and in many countries the implementation is done at regional level by the regional Administrations. As a result, not only do the contents of the databases differ as explained above, but also their structure and practical set-up varies according the national/regional databases. This implies moreover that physically, the data are stored in an important number of databases located in different places, (which can be estimated between 50 and 100 for EU 25). Even if provisions and procedures are made in each Member State to ensure some degree of compatibility and enabling cross checks between regions, the physical accessibility of those databases is therefore not an obvious issue.

A more pertinent point is, however, the confidential character of the administrative data because it concerns personal data about individual farmers, their holdings and their activities obtained from individual declaration and administrative controls. Such data are protected by specific acts and their use for purposes other than aid management is not always evident and would have to be negotiated on a case-by-case basis.

Some other issues are specific to the geographic information included in the GIS. On the one hand, the LPIS, according to its source, may be subject to copyrights or restrictions for use (especially when it concerns data from Cadastre or Ordonance Surveys). On the other hand, the very detailed geographic information (within parcel or property) could be considered as private or could encounter obstruction for its diffusion (possible use for taxation etc…)

In conclusion, any indicators on the evolution of the state of the environment will have to be based on an aggregation of the individual farmers' data with an appropriate geographic smoothing of the geographic information. The access to RD database will have to be negotiated on a case per case basis but it will become easier by a direct extraction of appropriate aggregated information.

## 4.3 Potential useful elements

### 4.3.1 *"Readily available" data*



Within the general limitations of the databases as presented in the preceding chapter, some of the indicators as listed by the Commission (cf Com. Communication COM(2001)144 final) could benefit from some "readily available" data, i.e. they could de derived directly from the databases that Member States' Administrations build in the framework of the implementation of the Rural Development Plan.

Both the database containing the information of the contracts that were established with the farmers (i.e. the intended implementation of the various measures) and the applications database containing the annual data of the declarations the farmers make could be used to this purpose.

#### Indicator 1: Area under agri-environment support

The total number of hectares under agri-environment schemes can be extracted from the said databases on a yearly basis. Subdivision of the area including the various measures concerned can easily be done, because farmers indicate both on the initial contract and on the yearly subsidy application which measure(s) they implement on each of their parcels. Several measures can be taken into account: (e) LFA and areas with environmental restrictions; (f) agri-environment and animal welfare; (h) afforestation of agricultural land; (i) other forestry measures; (t) protecting the environment in connection with agriculture, forestry and landscape management and improving animal welfare.

However, specific attention would have to be given to the fact that some of the measures can be cumulated on the same parcel, so that the sum of the total area of the individual measures, doesn't correspond to the total physical area under AEM.

#### Indicator 2: Regional levels of good farming practice

The number (or rate) of farms complying with regional standards of usual good farming practice could be a priori estimated by extrapolating the results of the annual On-The-Spot-control on the sample of 5% of the farmers who applied for support under the AEM schemes (as described above), taking into account that the good farming practice obligation refers to the entire holding, whereas the application for payment can relate to only a part of it.

However, this sample should be de-biased to take into account the risk analysis or reduced to the 1% sample (25% of 5%) which has to be random.

More generally, the use of such indicator and its interpretation should be done with great care, because the definition of UGFP and the consistency of their controls strongly varies between Member States/regions.

### Indicator 4: Area under nature protection

For part of the area considered under this indicator, a direct indication could be extracted from the databases for the subsidy claimed under measure (e) LFA and areas with environmental restrictions. It should be investigated further up to what extent additional information about other nature protection areas is provided at regional/national level in the respective databases of the various Member States. The RD regulation provides a frame for specific measures related to Natura 2000 sites (cfr. article 16 of Reg.1257/99), but the implementation of such measures strongly varies between Member States.

### Indicator 6: Technology and skills: holder's training level

The number of farmers applying for support for vocational training under the RDP support can be directly extracted from the applications database. More complete information, however, should be sought in the yearly monitoring data available from the Members States, where also information about the level of training of farmers who haven't applied for training support under the RDP is reported.

### Indicator 7: Area under organic farming

The number of hectares for which farmers apply for support for organic farming Schemes can be directly extracted from the databases mentioned above. However, the fact that some region or Member State may have not implemented such AEM schemes doesn't mean that there is no area cultivated in organic farming.

### Indicator 26: Area of high nature value, grassland, etc.

Since this indicator forms a subset of indicator 4, the same considerations apply here.

### Indicator 32: Landscape state

The number of existing landscape features included in the initial contracts with the farmers and the number of those to be established in the frame of contracts can contribute to establish the number and diversity of memorable elements visible. The data could be directly extracted from the RDP databases.

### Indicator 33: Impact on habitats and biodiversity

The data regarding the density of linear elements can be derived from the RDP databases by dividing the number of contracted linear elements by an appropriate area. This area could be the area of the parcels they relate to or the total area of the holding The density thus calculated will thus provide an indicator of the RD contracted areas (as biodiversity ilots).

Dividing the number of contracted linear elements by the total agricultural area of the region would give a more global figure but an unreliable picture of the investigated density, underestimating it because the non-contracted linear elements would not be included in such index.

The diversity of land cover at the level of the holding could be derived from the integration of data at parcel level from the RDP schemes and from the direct payment schemes. The calculation of Diversity indexes could be tested at this level, according methods studied in earlier publications at a much smaller scale[1].

Differences between 1968 and 1998 on black and white panchromatic composite - near Cantenay-Épinard (North of the study area):
– Black patches: no changes
– Red patches: evolution

Differences between 1968 and 1998 on infra-red coloured composite - near Briollay (North of the study area):
– Black patches: no changes
– Red patches: evolution (height of poplar groves and land covers)

**Example 6.** *Interpretation of land covers on aerial photographs*

### 4.3.2 *Data resulting from analyses/controls*

Apart from the actual contents extracted from the databases related to the implementation of the RDP/AEM, the methods developed in the frame of the control of the subsidy applications, as well as the availability of regularly updated orthophotos constitute potentially useful contributions towards the development of AEIs. They could be used to assess objectively the features of interest for AEIs all over the territory, or for the holdings and areas that are not included in the subsidy applications databases.

#### 4.3.2.1 *Detection of field level practices*

The pilot studies on the use of remote sensing for the control of AEMs showed that it is possible to detect by means of satellite imagery and/or orthophotography a certain number of the agricultural practices at field level that are part of the commitments under the AEM contracts in a (fairly) reliable way. Often medium of high resolution images suffice and so no need exists for acquiring the more expensive VHR images or for aerial photography, for which the production process is usually much more tedious and time-consuming. A high range of providers for this type of imagery exist, so in principle the required images should be easily obtainable – weather permitting of course.

Some of those practices are a “means to an end” in the agri-environmental context, e.g. autumn green cover for erosion control, specific harvest pattern for wildlife preservation, arable to grassland conversion for restoration of wild fauna, etc. Those elements can be detected on RS imagery, but are not an AEI as such. The development of the AEI requires additional processing of those observations. The question remains on what observations to aggregate, and how, to arrive at meaningful and useful AEIs.

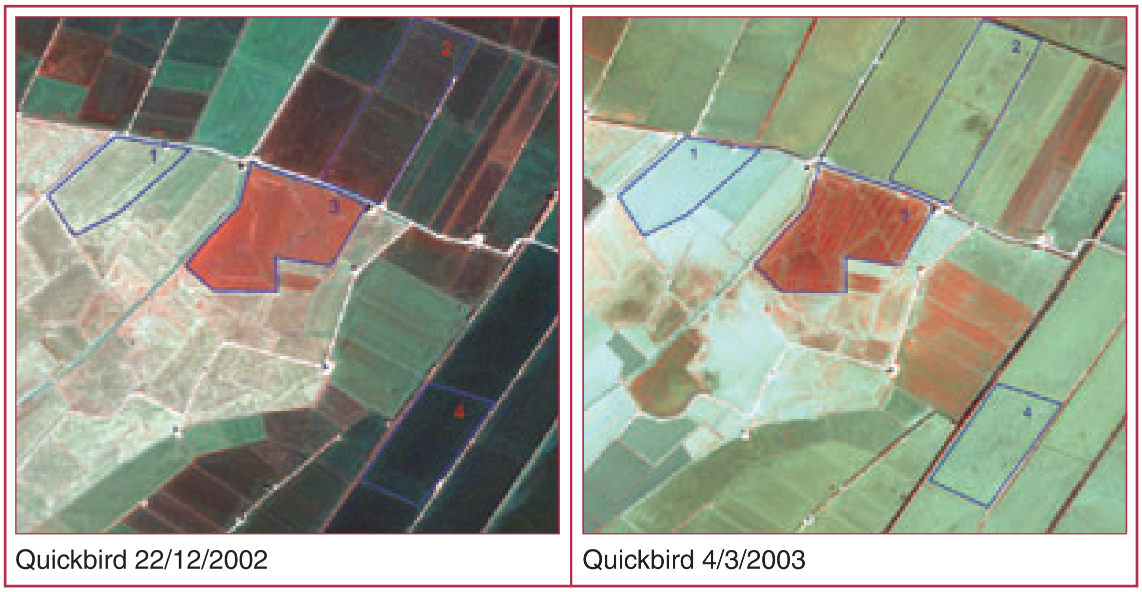



**Figure 4.** *Detection of extended flooding period on rice parcels, Valencia, Spain (source: SIRS/AURENSA)*

The methods for detection of the existence and maintenance of grassland and other environmentally valuable agricultural land use could, however, be used for indicators 4 and 26.

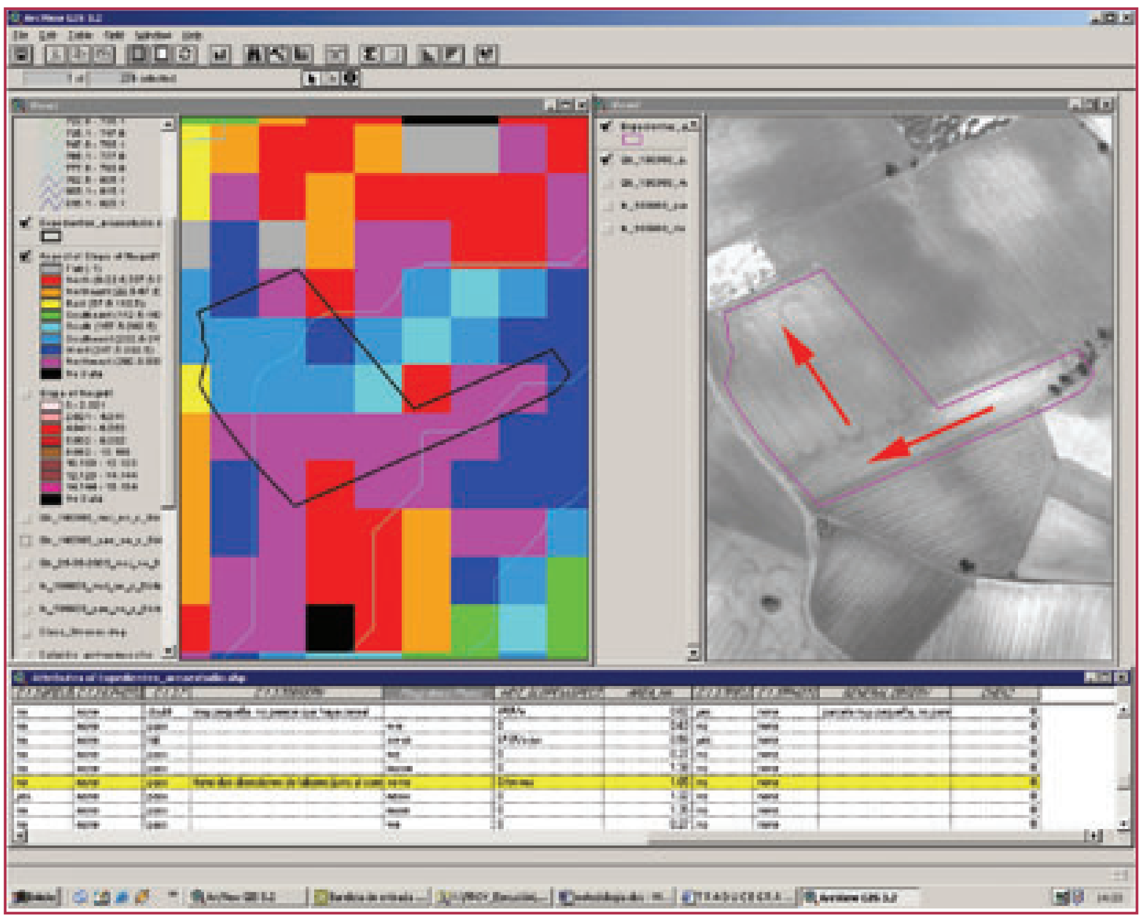


**Figure 5.** *Verification of ploughing direction in relation to slope, Cuenca, Spain (source: SIRS/AURENSA)*

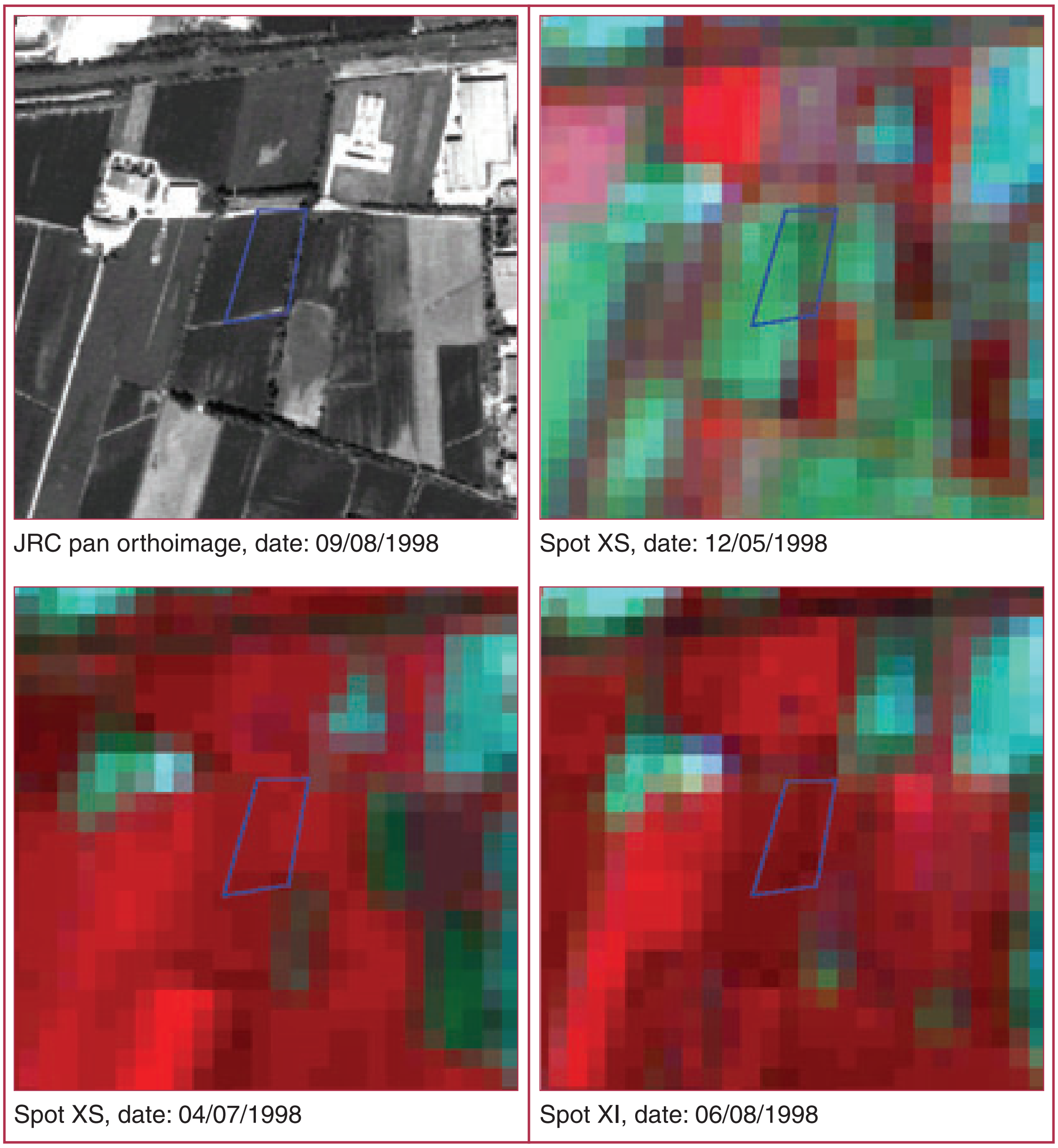



**Figure 6.** *Arable to grassland conversion control, Lombardia, Italy (source: RSDE)*

#### 4.3.2.2 Detection of landscape features using VHR and aerial photography

The features that are to be recorded/monitored for indicators 32 and 33 and that are not included in the contracts with the farmers can be detected using the methodology that has been investigated in the framework of the control of the subsidy applications.

The methods for feature detection that have been studied in the pilot projects mentioned above could prove useful for this purpose.

For Indicator 32 (Landscape state) it concerns the number and diversity of memorable elements visible and for Indicator 33 (Impact on habitats and biodiversity) it relates to the density of linear elements.

Landscape elements have often small dimensions and were not detectable on the medium and high resolution satellite images that were the only type of readily available and affordable imagery up till a couple of years ago. The arrival of VHR satellite imagery changed this and the availability of VHR data has improved considerably over the past few years. The pilot projects showed promising results for the detection of certain landscape elements on this type of imagery: ponds, creeks, isolated trees or exten-

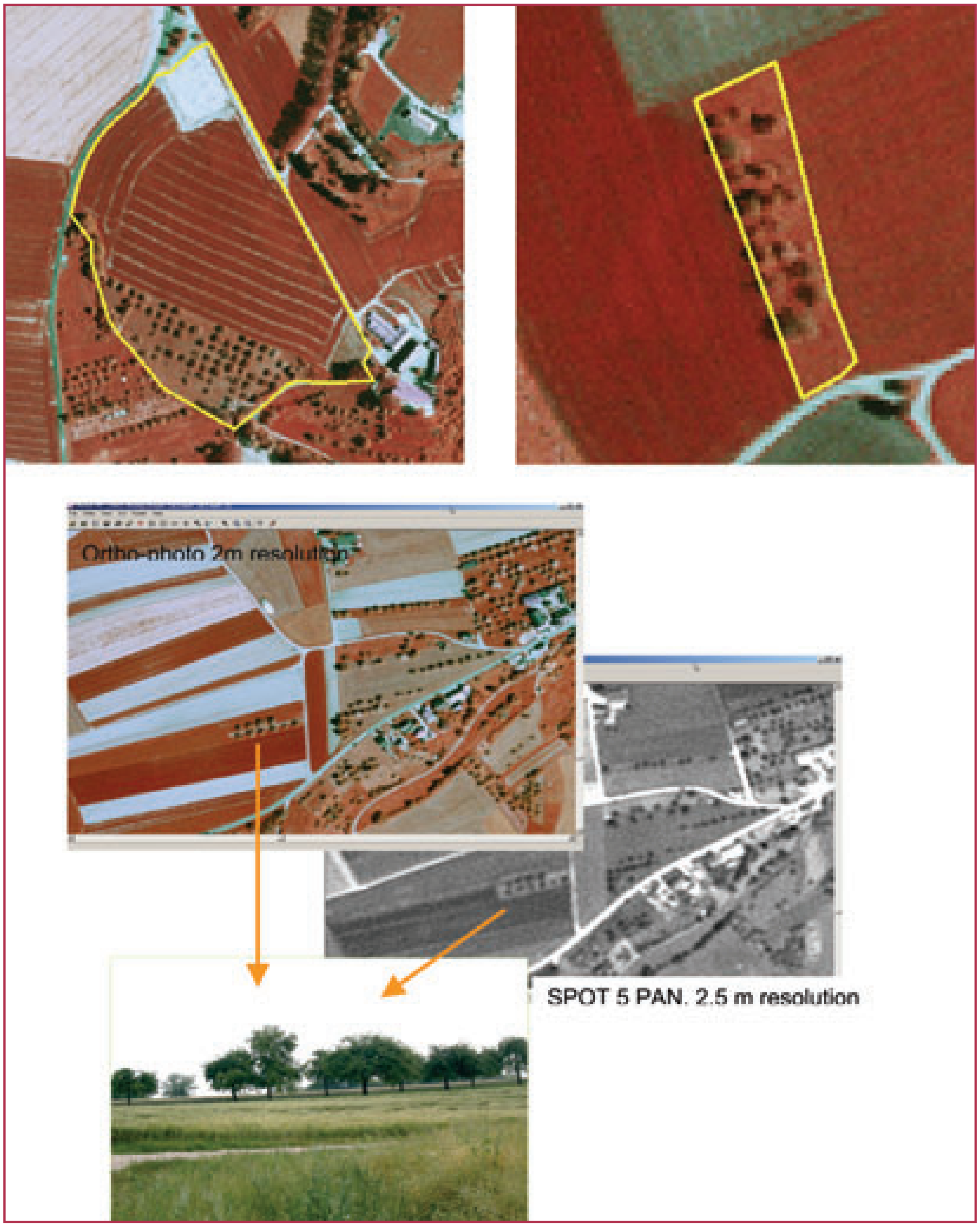
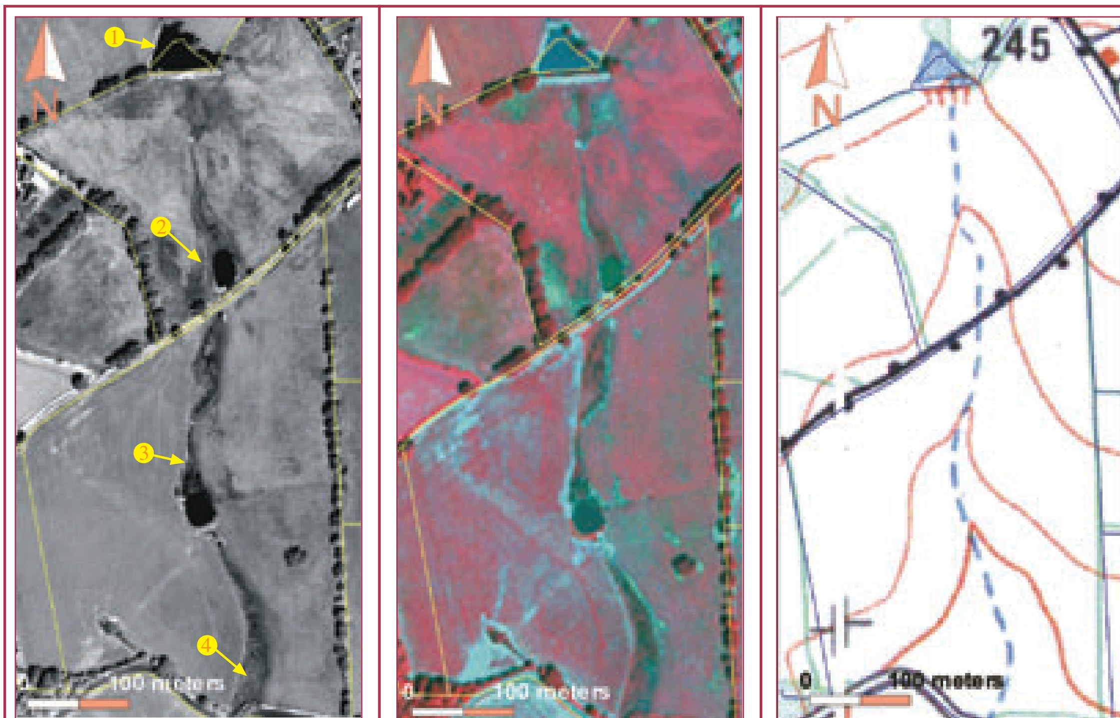



**Figure 7.** *Extensive orchard detection, Zwiefalten, Germany*

sive orchards, walls, hedges, field margins,… Also aerial photographs proved very useful, but it is more difficult to programme them at specific dates.

The VHR imagery can also be used to determine the size of many of the landscape elements investigated. The observation of their status and the fulfilment of the maintenance obligations were more difficult and often no conclusive interpretation of the image could be made.

Because of interference of surrounding objects, it is not always possible to identify the landscape elements of interest, or to observe their characteristics. For example trees and shrubs along the creek make it invisible on the image – although one could assume with a high certainty that the creek declared by the farmer in his subsidy appli-




61 centimeters - Pan QuickBird image (2003-06-20) | 2,44 meters - XS QuickBird image (2003-06-20) | SCAN 25 IGN3

**Figure 8.** *Identification of ponds and wetlands using VHR and ancillary data, Limousin, France (source: SIRS/AURENSA)*

**Figure 9.** *Lack of preservation of features constituting parcel boundaries, Cuenca, Spain (source: SIRS/AURENSA)*

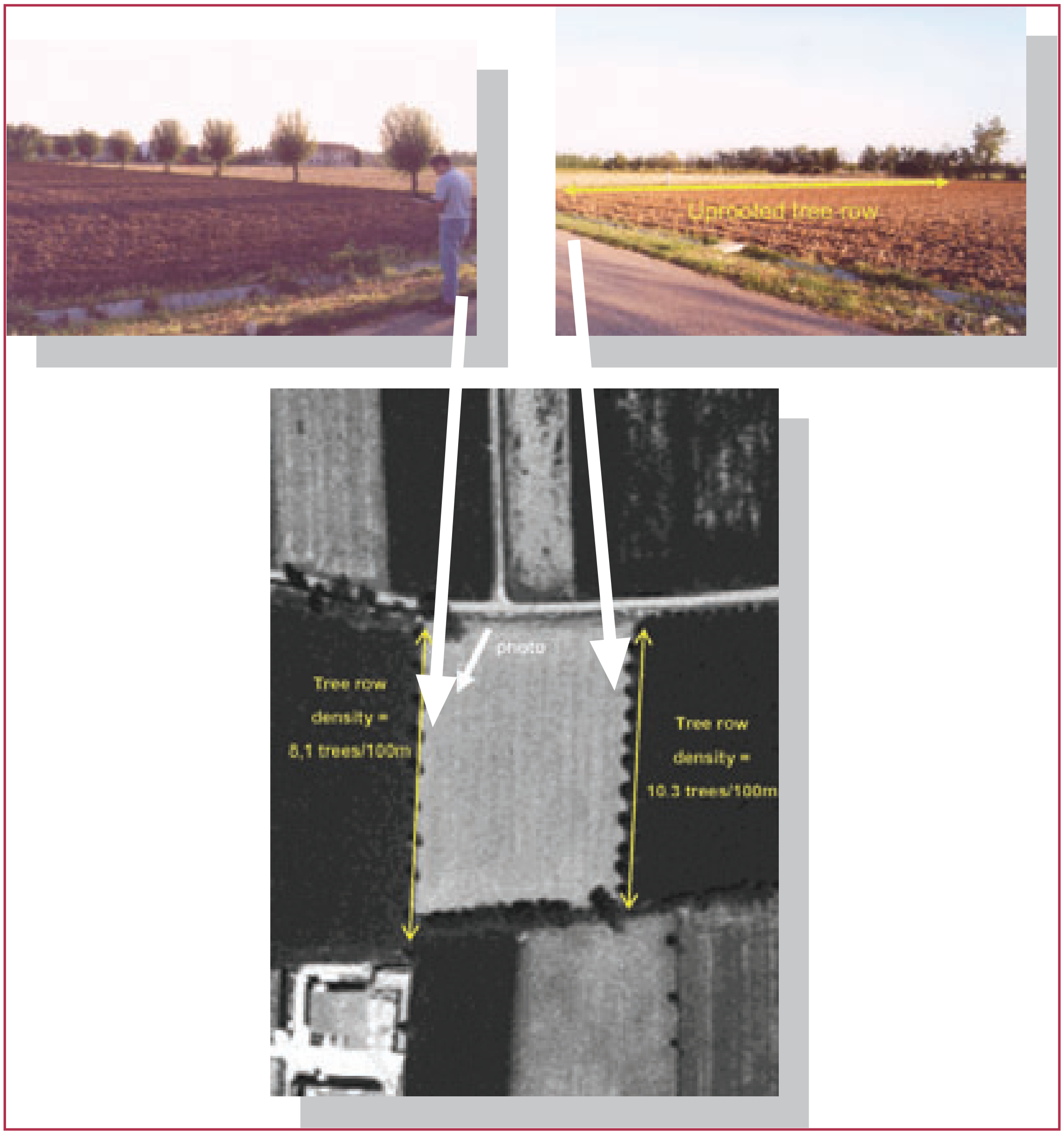



**Figure 10.** *Identification of tree rows, Lombardia, Italy (source: RSDE)*

cation is indeed located underneath the vegetation visible on the image, it is not possible to guarantee this, let alone make any statement about characteristics of the bands or maintenance. Additional information is therefore needed and this is discussed below.

### 4.3.2.3 Aggregating the results at an appropriate level

The data that could be derived using part of the methods described above need to be aggregated. The method of aggregation is not obvious, because it goes hand in hand with the question about the appropriate scale / level for impact assessment of an AEM.

Features and impact may be important at local scale, but may completely disappear when aggregating and generalising at a higher level. Deep knowledge about environmental importance of each of the observed features and trends is therefore essential when determining what elements to use and how to derive the AEIs.

The definition of landscape features and the objective collection of data about them will generally require very large scale data sets, such as 1m or 50 cm colour ortho-imagery. But according to the practical scale / level of use of the indicators, an exhaustive, detailed mapping will not always be efficient nor required. Area frame sampling techniques (as

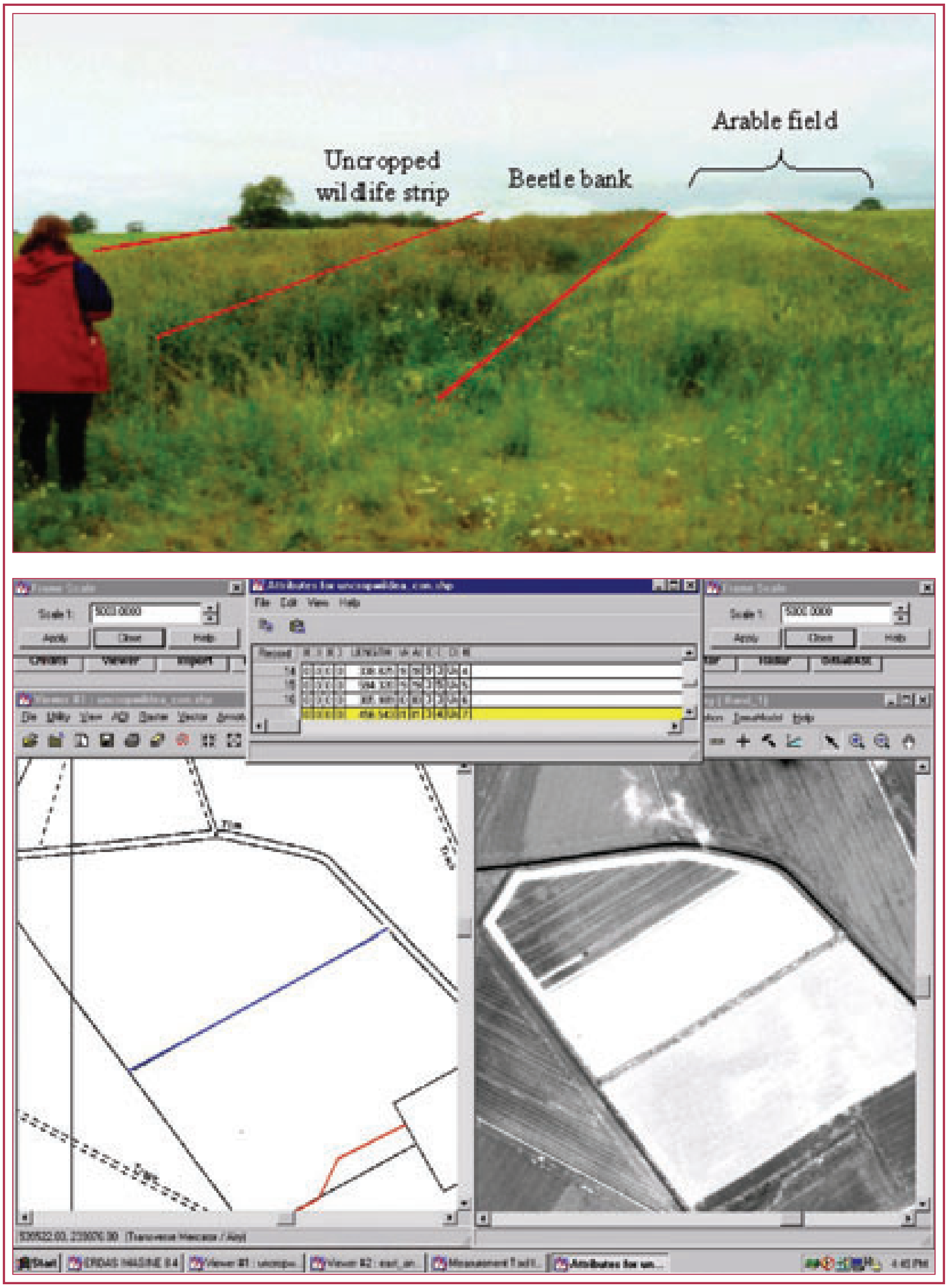



**Figure 11.** *Detection of uncropped wildlife strips using VHR, England, UK (source: ADAS/MAFF)*

applied in the LUCAS survey and the OLISTAT projects) could enable to derive objective indicators and to monitor landscape changes on a fixed sample of geographic sample.

The regular updating of the LPIS orthophotos (3-7 years) and their geometric accuracy (RMSE<2,5m) will allow to define sustainable systems to derive landscape indicators and monitor the changes.

However, one of the key points to address will be the design of the sampling plan in order to reach the target of accuracy required for the expected variations.

### 4.3.3 *Inventory of environmentally valuable objects*

As discussed above for each relevant AEI, the main point of interest regarding the contents of the databases used for RDP implementation, probably lies in the indication of the location of environmentally valuable objects under commitment. Having such GIS-database available over several years could constitute and instrument to detect spreading patterns and trends over time.

The location of the parcels contracted under AEM is accurately recorded, but as indicated above, it is usually the effect of the practices at field level on the wider environment that is important from environmental point of view. Having the inventory of the contracted parcels on itself is thus probably of less interest in the context of AEI development.

A more promising use of AEM databases for the development of AEIs lies in the potential inventory-function that GIS databases on AEM can have for landscape elements contained in the measures. It should be noted, however, that not all contracted landscape elements are identified and recorded in the Land Parcel Identification System or dedicated AEM GIS databases and that therefore, their geographical location is not always exactly known. The information that is available in many cases is only the location of the parcel to which the contracted object is linked. This often causes difficulties during the control (in the field or using remote sensing) when there is ambiguity about exactly where the contracted object is located. This is especially true in case only a part of a linear object is under contract, or if there are more than one object of the same type present on the parcel but only one under contract.

For this reason, a number of Member States have started implementing in LPIS or in an LPIS-compatible layer more info about the exact geographic location of the features contracted for RDP. It would entail a more elaborate data-capture phase at the time of establishment of the contract with the farmers and is directly linked to the creation of the reference status of the environment on the holding. It would also serve for checks of the eligibility at this stage. The establishment of a comprehensive GIS layer containing all the landscape elements under contract would not only facilitate the subsidy applications control activities, but could be of great value for its possible use for the development of AEIs. All the more because this inventory could also be linked to descriptive information about the objects contained in it, providing a qualitative picture.





## 5. Conclusions

The databases and the instruments implemented in the Member States for the administration and control of Rural Development Programme represent a tremendous source of information which should, in one way or another, be considered for the development of relevant AEIs over Europe.

On the 35 AEIs proposed by the Commission (Commission communications COM(2000) 20 of 26/1/2000 and COM(2001) 144 of 20/3/2001), we identify 8 indicators for which RD data sets could be an essential or a complementary source of information.

However, as for any other Administrative dataset, the use of these data will face problems of individual/privacy protection, of quality/objectivity of the declared information, of nomenclature of objects that will require further analysis, establishment of correspondences, specific process to aggregate and correct possible bias due to the nature of the data.

A number of Member States similarly succeeded in using part of their IACS databases (arable aids, 1st pillar of the CAP), to produce some geo-statistics on agriculture. But the operational use of RDP and AEM databases leads to three specific extra constraints, which will definitely make their use problematic or sometimes even questionable.

The RDPs are implemented in a coherent European frame, but the AEMs proposed to farmers, under similar headings, can be very heterogeneous in contents and procedures. The present patchwork of measures is somehow consistent with the environment and large eco-physiographic zones, but it translates also cultural aspects and historical situation (transfer in RDP of pre-existing national or regional schemes, which remain sometimes largely co-funded by national and regional budgets).

These measures are often defined at regional level and may be eligible for different overlapping area of interest, corresponding or not to the official Administrative boundaries.

As for IACS, farmers participates to the Rural Development Plan on a voluntary basis, but each farmer may select "a la carte" a different set of the measures proposed and the present rate of participation in the RDP can be very marginal (less than 10%) for some of the measures and only few measures reach an important population (> 65%).

More generally, the overall monitoring/evaluation cycle of the Rural Development Policy requires, in addition to the financial /administrative audits, independent and objective indicators enabling to assess if an AEM was properly defined and implemented, but also to evaluate its effective impact within its Area of Interest. An additional difficulty arises from the fact that the definition of the AEMs is sometimes not really focused on purely environmental objectives.

Unfortunately, too little Rural Development Plans include an objective picture of the state of the agro-environment before the start of the regulation; and the Administrative and control system focusing on the yearly management of control and payment of declarations will always remain not very appropriate for an objective and independent assessment.

In this general context, the establishment of complementary objective inventory and monitoring systems seems difficult to avoid. However, such system could take huge benefit from the existing IACS infrastructure and especially of the LPIS information, on which mapping exercises or the design of area frame sampling plan will be possible.

The two preceding approaches could be assessed according to the accuracy and the level of information at which the AEIs are required, but they could both make an essential use of the available and regularly updated digital LPIS orthoimagery.

## 6. References


[1] Council of the European Communities, 1992. Council Regulation 2078/92 on agricultural production methods compatible with the requirements of the protection of the environment and the maintenance of the countryside. Official Journal of the European Communities L215 30/7/1992 p. 85.

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# Use of the CORINE land cover to identify the rural character of communes and regions at EU level

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## 1. Introduction

### 1.1. Commission's Proposal for the Rural Development Policy Post 2006

Although in most rural areas the primary sector has become less important in terms of its economic weight and share in employment, agriculture and forestry are the main land users and play a key role in the management of the natural resources in rural areas and in determining the rural landscape and cultural heritage.

The EU's common agricultural policy (CAP) has been developing in recognition of this. It gives less emphasis to market mechanisms and places agriculture in its broader rural context through rural development measures. Those are more oriented towards satisfying the general public's growing demands regarding food safety, food quality, product differentiation, animal welfare, environmental quality and the conservation of nature and the countryside.

The EU Commission has issued a proposal for the Rural Development Policy for the next programming period 2007-2013 (EC, 2004).

In this context, some work has been carried out to give a picture of rural areas. Currently, no common definition exists at the EU level of what constitutes a rural area; in this article, some attempts have been made to use the CORINE Land cover inventory. This approach has been followed in order to take the increasing importance of territorial dimension in rural development policy into account.

As the "policy area" of rural development now covers agriculture, forestry and natural areas, these categories of land cover (or land use) are considered to represent a rural character. A special methodology has also been applied to the inland water bodies (lakes, etc) (see below).

This work has been performed in close and intensive collaboration of several units of Directorate General of Agriculture and with the help of the GISCO team of Eurostat.

As this work is innovative, results are compared with the OECD approach based on population density that has proven to be useful in making international comparisons of rural conditions and trends.

### 1.2. Classification and Analysis of Rural Areas

Territorial analysis can be made at different levels: local, regional, national, or even independent of administrative boundaries. The choice of the level depends, of course, in the first instance on the availability of data, but also on the accuracy required, on the variability of the information under investigation and on the subject.

In this scenario, to enable the linking of the territorial classification with the statistical sources, administrative units were used and a classical approach of a two level hierarchical classification was followed: local and regional.

The local level is LAU2[1]. This corresponds for instance to 'Comuni' in Italy or 'Gemeinde' in Germany. As in France, the size of a commune is very small compared to other EU Member States, the evaluation has been made at the 'canton' level (LAU1 - ex NUTS-4) instead of the 'commune' level.

The regional level is NUTS-3 which corresponds to 'Provincie' or 'Kreise' for the same countries.

## 2. Methodology

The following procedure has been applied:

1. Analysis of CORINE Land cover information in order to evaluate the percentage of different classes of areas at 'commune' level.
2. Classification of each "commune" as rural or non rural, based on the importance of different classes of area.
3. Classification of NUTS-3. Two methods have been tested:
   a. The first method depends only on the percentage of the areas of rural communes that constitute the NUTS-3,
   b. The second method combines the percentage of areas of rural communes and population density figures at NUTS-3 level.

### 2.1. CORINE Land Cover Analysis

In order to determine the land cover, the CORINE Land Cover database (CLC1990 - 100 × 100 m grid) for the 25 EU Member States has been used using 44 classes of the 3-level CORINE nomenclature. The CLC90 does not contain Sweden, Cyprus and the eastern part of Greece. In order to cover these territories, the PELCOM (Pan-European Land Cover Database)[2] was used (1 × 1 km grid) with its 10 major classes. As the PELCOM database is less detailed in terms of accuracy and of land cover categories, results for Sweden, Cyprus and eastern Greece are more rough than for other Member States.

The Land Cover data is represented in the form of raster or GRID data. Therefore, each raster is composed of pixels or GRID cells, comprising a value corresponding to the land cover class they represent. Each GRID cell is being appointed to a 'commune' on condition that its centroïd lies within a 'commune'. The value ('land cover class') of the GRID cell becomes than an attribute of that 'commune'. Only a few of the 108.000 communes do not contain any GRID cells as none of the centroïds of these GRID cells fall within the 'commune'.

The CORINE and PELCOM land cover classes were reclassified into 'forestry', 'agricultural area', 'natural area', 'inland water', 'sea' and 'artificial', as shown in *Table 1* and *Table 2* below. In CORINE reclassification it would have been more correct to define 3.2 'Scrub and/or herbaceous vegetation associations' as 'Natural' rather than as 'Forest'.

[1] LAU: Local Administrative Unit; LAU2 = formerly known as NUTS5

[2] The PELCOM project was a shared cost action under the Environment & Climate section of the European Union 4th Framework RTD Programme. PELCOM (EC contract ENV4-CT96-0315) is a shared-cost RTD project funded by the Environment & Climate Programme of the Fourth Framework Programme (1994-1998) under Area 3 entitled "Space techniques applied to environmental monitoring and research".

**Table 1.** *CORINE Reclassification*

| LEVEL 1 | LEVEL 2 | Reclassification |
|---|---|---|
| 1. ARTIFICIAL SURFACES | 1.1 Urban fabric | Artificial |
| | 1.2 Industrial, commercial and transport units | Artificial |
| | 1.3 Mine, dump and construction sites | Artificial |
| | 1.4 Artificial, non-agricultural vegetated areas | Artificial |
| 2. AGRICULTURAL AREAS | 2.1 Arable land | Agricultural |
| | 2.2 Permanent crops | Agricultural |
| | 2.3 Pastures | Agricultural |
| | 2.4 Heterogeneous agricultural areas | Agricultural |
| 3. FOREST AND SEMI-NATURAL AREAS | 3.1 Forests | Forest |
| | 3.2 Scrub and/or herbaceous vegetation associations | Forest |
| | 3.3 Open spaces with little or no vegetation | Natural |
| 4. WETLANDS | 4.1 Inland wetlands | Natural |
| | 4.2 Maritime wetlands | Sea |
| 5. WATER BODIES | 5.1 Inland waters | Inland Water |
| | 5.2 Marine waters | Sea |

**Table 2.** *PELCOM Reclassification*

| Class | | Reclassification |
|---|---|---|
| 11 | Coniferous forest | Forest |
| 12 | Deciduous forest | Forest |
| 13 | Mixed forest | Forest |
| 20 | Grassland | Agricultural |
| 31 | Rain fed arable land | Agricultural |
| 32 | Irrigated arable land | Agricultural |
| 40 | Permanent crops | Agricultural |
| 50 | Shrubland | Natural |
| 60 | Barren land | Natural |
| 70 | Permanent Ice & Snow | Natural |
| 80 | Wetlands | Natural |
| 91 | Inland waters | Inland Water |
| 92 | Sea | Sea |
| 100 | Urban areas | Artificial |

## 2.2. Rural Character of the Communes

The general rule is to classify a ‘commune’ as rural if at least 90% of its area is covered by agriculture, forestry or natural areas. As the character ‘rural/non-rural’ of inland water bodies is not obvious, different approaches have been tested to take this area into account for countries where lakes are important (i.e. Ireland, Sweden and Finland)[3]. The method finally adopted is

(1) To include 50% of the area of inland water bodies in the rural area and
(2) To deduce the other 50% from the reference area of the commune used to calculate the share of rural area.

> Example for a hypothetical commune:
>
> Agriculture 500 ha, Forest 150 ha, Natural 100 ha, Water 100 ha, Urban 200 ha = > Total = 1.050 ha
> 'Rural' area: 500 + 150 + 100 + 100/2 = 800 ha    Reference area: 1.050 – 100/2 = 1000 ha
> 800 / 1000 = 80% = > the commune is classified as 'non rural' as the share of 'rural' areas is lower than 90%.

In the establishment of CORINE Land Cover database 1990, there have been slight differences in methodology between Member States. For instance, in Belgium, the minimum polygon area is smaller than the minimum polygon area for the other countries, leading to more detailed data[4]. When mapping the results, it led to a too obvious borderline with The Netherlands. For this reason, a threshold of 80% has been empirically defined to replace the 90% threshold used for other Member States. This threshold of 80% proved to produce a more comparable 'rurality' as the 90% threshold for the Netherlands, even if some discrepancies remain.

## 2.3. Rural/Urban Character of NUTS-3

The communes are then aggregated to NUTS-3 level and each NUTS-3 is classified according to the following rule:

- Predominantly rural: the area of "rural" communes represents 85% or more of the total NUTS-3 area,
- Significantly rural: the area of "rural" communes represents between 50% and 85% of the total NUTS-3 area,
- Predominantly urban: the area of "rural" communes represents less than 50% of the total NUTS-3 area.

## 2.4. Rural/Urban Character using OECD Methodology

The OECD identifies local areas (communes) as rural, if the population density is below 150 inhabitants per square kilometre (OECD, 1994).

At regional level (NUTS 3) the OECD distinguishes:

- Predominantly rural: over 50% of the population lives in rural communes (with less than 150 inhabitants/ $km^2$)
- Significantly rural: 15 to 50% of the population lives in rural communes.
- Predominantly urban: less than 15% of the population lives in rural communes.

With the collaboration of the GISCO team of Eurostat, the most up-to-date figures – even if not 100% completed and checked – concerning 2000 population census at commune level have been used. Where this information was not available, the rural character has been defined directly at the regional level, on the basis of population surveys (average 1999-2001) using the following rules[5]:

[3] In the meantime, this method has been generalised to all member states for further analysis.

[4] Together with the new CLC 2000 update, Belgium will recalibrate the '90 inventory with a threshold of 25 hectares. In the today available '90 inventory, the minimum polygon size is 15 hectares.

[5] The levels have been defined following an analysis of the statistical distribution of density in predominantly rural, significantly rural and predominantly urban in regions where information was available at commune level.

- Predominantly rural: population density < 100 inhabitants/ km² 50% of the population lives in rural communes (with less than 150 inhabitants/ km²),
- Significantly rural: population density between 100 and 240 inhabitants/ km²,
- Predominantly urban: population density > 240 inhabitants/ km².

# 3. Main Results

## 3.1. Land Cover

Table 3 highlights the main importance of "rural" coverage of land in all EU Member states, because "rural land covers" represent more than 90% in most Member States (except 80% in Belgium and 87% in the Netherlands[6]).

**Table 3.** *Share of "Land Cover Classes" considered as "Rural". CORINE Land Cover 1990*

| | Land cover | | | | |
|---|---|---|---|---|---|
| | Agriculture | Forestry & semi-natural | Nature | Inland waterbodies | "Rural" (50% inland waterbodies) |
| AT | 36.2% | 53.2% | 8.1% | 0.0% | 97.5% |
| BE | 58.0% | 21.2% | 0.4% | 0.0% | 79.6% |
| CY | 29.6% | 16.4% | 53.8% | 0.0% | 99.8% |
| CZ | 59.1% | 34.6% | 0.1% | 0.0% | 93.8% |
| DE | 60.7% | 30.2% | 0.6% | 0.0% | 91.6% |
| DK | 78.9% | 12.6% | 1.2% | 0.0% | 92.7% |
| EE | 34.0% | 58.5% | 4.3% | 0.0% | 96.8% |
| ES | 50.7% | 43.8% | 2.9% | 0.0% | 97.4% |
| FI | 6.9% | 81.9% | 3.6% | 7.0% | 95.8% |
| FR | 62.3% | 31.3% | 1.9% | 0.0% | 95.5% |
| GR | 41.7% | 51.0% | 4.9% | 0.0% | 97.6% |
| HU | 72.0% | 20.5% | 0.8% | 0.0% | 93.2% |
| IE | 68.3% | 13.0% | 14.8% | 1.9% | 97.0% |
| IT | 53.9% | 36.6% | 4.4% | 0.0% | 94.9% |
| LT | 62.2% | 31.9% | 0.9% | 0.0% | 94.9% |
| LU | 55.5% | 37.3% | 0.0% | 0.0% | 92.8% |
| LV | 44.2% | 50.1% | 2.5% | 0.0% | 96.8% |
| MT | 96.1% | 0.4% | 3.3% | 0.0% | 99.7% |
| NL | 74.5% | 10.8% | 1.2% | 0.0% | 86.6% |
| PL | 65.3% | 29.7% | 0.5% | 0.0% | 95.5% |
| PT | 50.4% | 41.7% | 2.0% | 0.0% | 94.1% |
| SE | 26.4% | 53.2% | 11.4% | 4.6% | 93.3% |
| SI | 34.1% | 61.2% | 1.6% | 0.0% | 96.9% |
| SK | 50.5% | 43.1% | 0.4% | 0.0% | 94.0% |
| UK | 58.3% | 31.8% | 2.1% | 0.0% | 92.2% |
| **EU-25** | **49.5%** | **41.0%** | **3.7%** | 1.1% | 94.7% |
| **EU-15** | **51.8%** | **38.1%** | **4.2%** | 1.4% | 94.8% |

[6] A higher rural character in Belgium than in The Netherlands can be an artefact of the empirical adjustment of the method due to the different size of the polygon area, as explained previously.

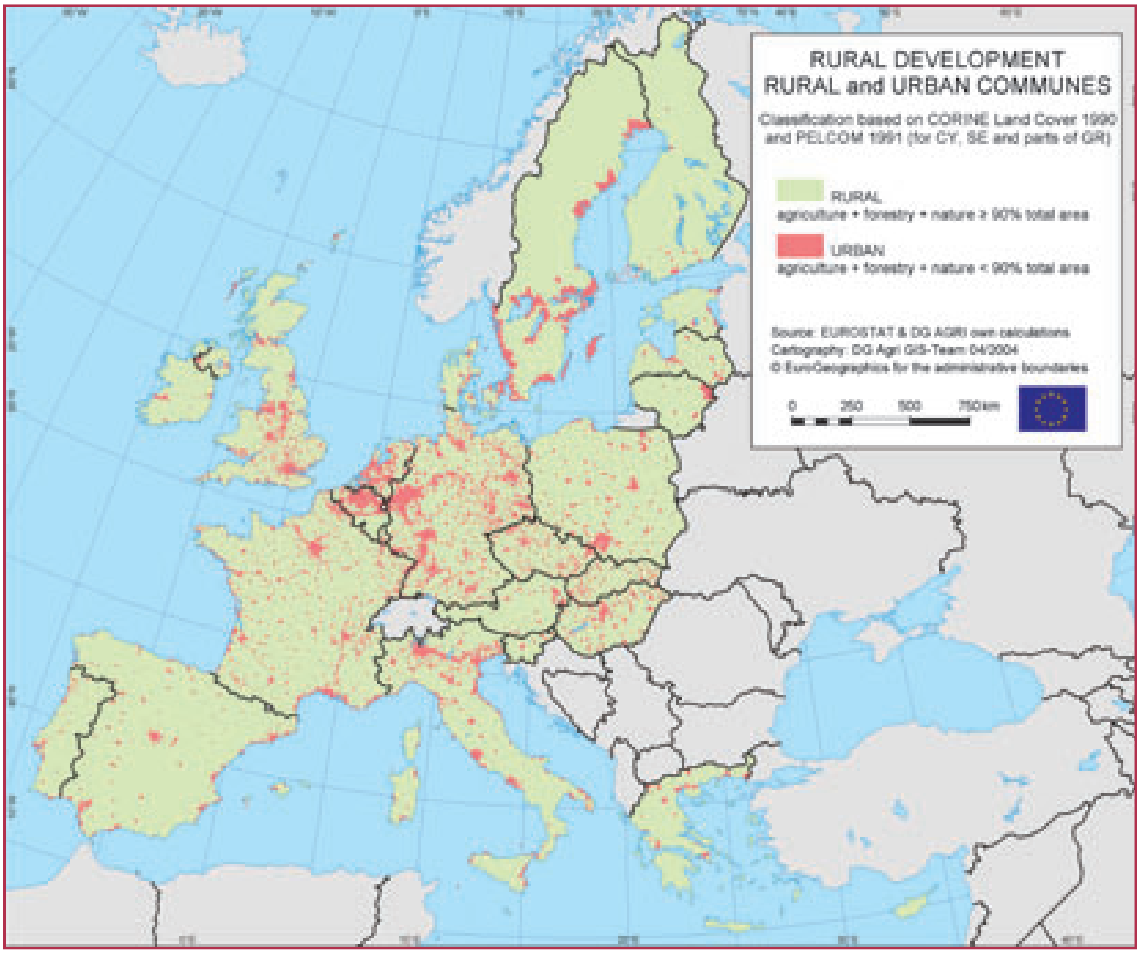
## 3.2. Rural Character at Commune Level

*Map 1* represents the classification of communes in rural/non rural, based on land cover approach, whereas *Map 2* is based on the population density method of OECD.

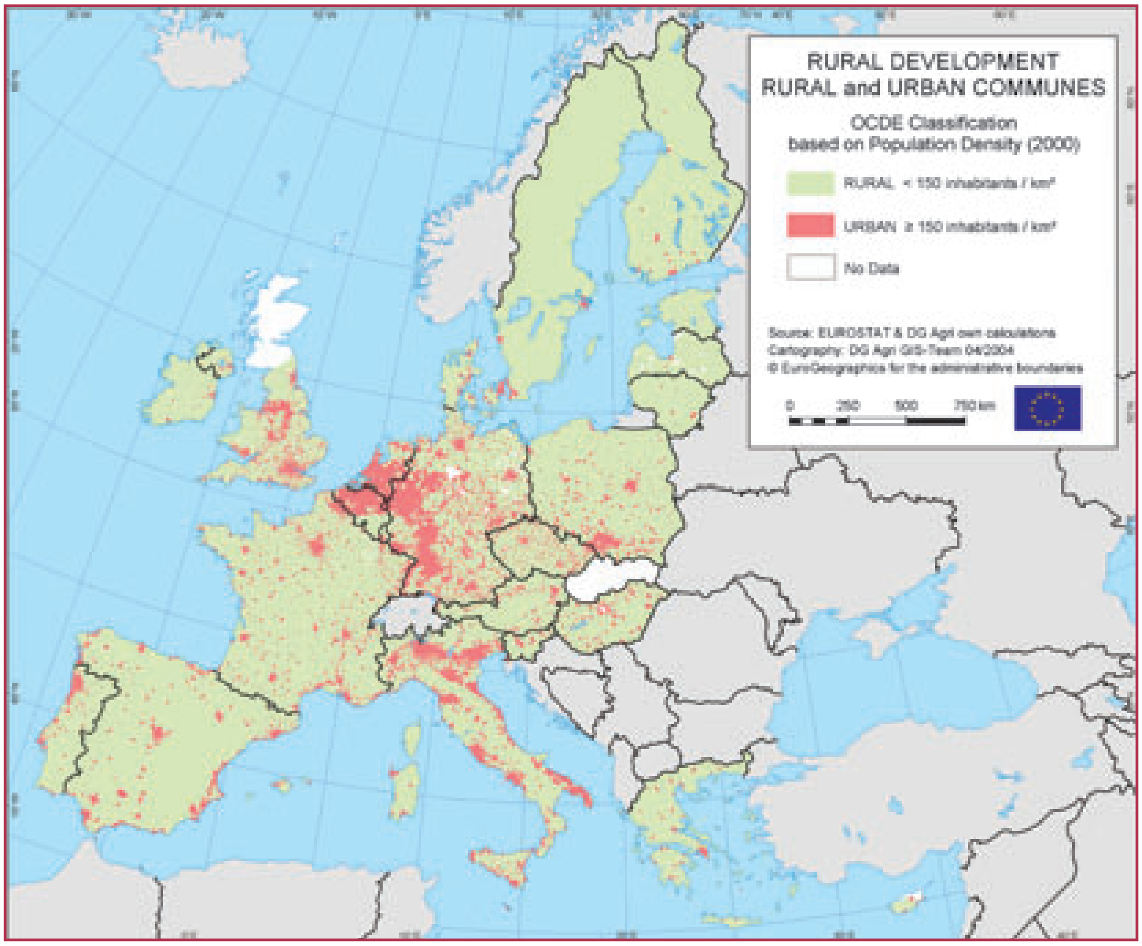
The green areas on the maps represent the "rural" area, while the red spots indicate the non-rural or urban municipalities. Global overview is quite similar, with the largest differences occurring in the most populated areas of Belgium, the Netherlands and Germany. In addition, the classification of communes is different in Italy, mainly in the Po Valley and in Puglia.

**Table 4.** *Share of area of "rural" communes with the Land Cover approach or the population density approach.*

| | Land Cover | Population Density |
|---|---|---|
| AT | 94.0% | 90.7% |
| BE | 59.1% | 40.4% |
| CY | 99.9% | 85.6% |
| CZ | 83.8% | 83.0% |
| DE | 76.6% | 64.3% |
| DK | 82.8% | 84.9% |
| EE | 94.1% | 98.5% |
| ES | 94.9% | 92.0% |
| FI | 98.6% | 98.6% |




**Map 1.** *Rural character of EU-25 communes based on land cover.*
Note: lack of accuracy in PELCOM explains the importance of 'urban' communes along the coasts in Sweden.

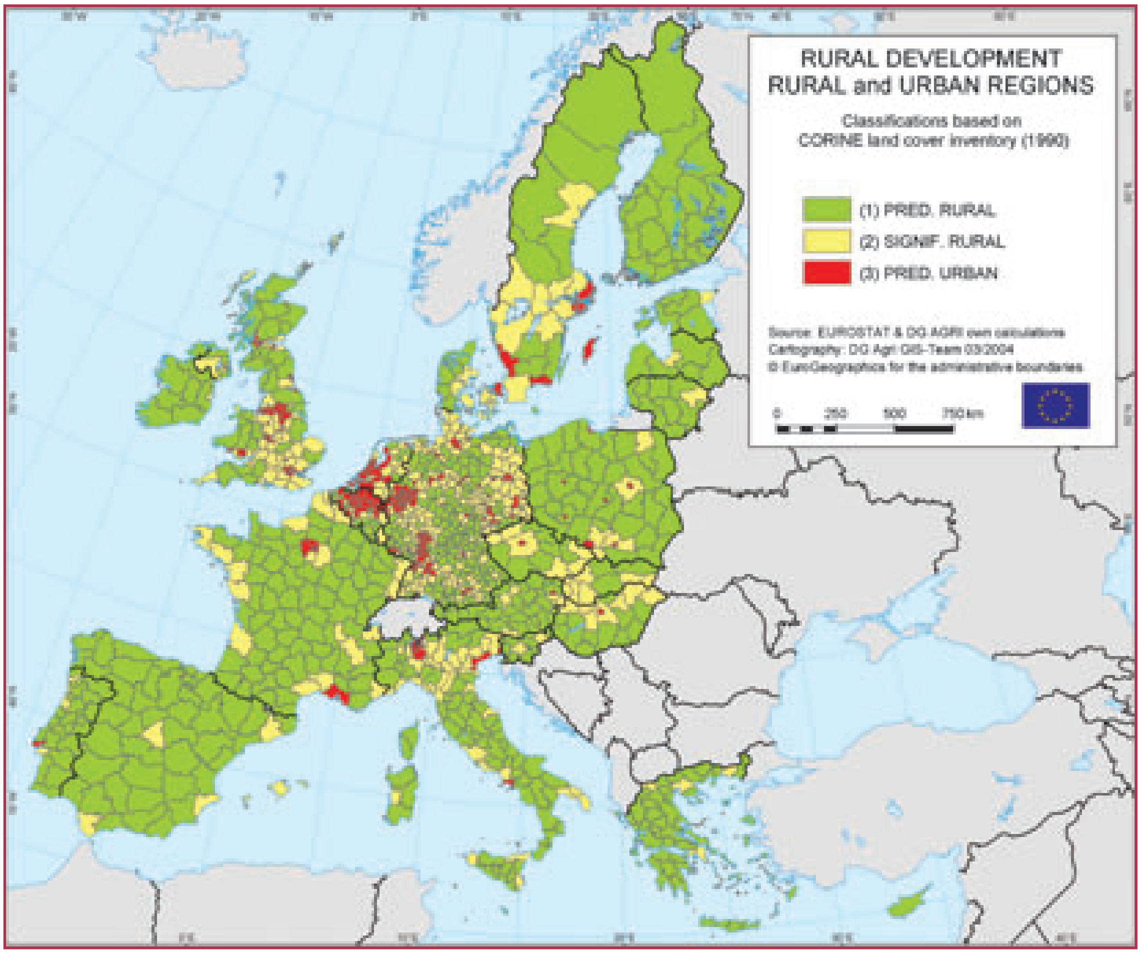



**Map 2.** *Rural character of EU-25 communes based on population density*

| | Land Cover | Population Density |
|---|---|---|
| FR | 90.9% | 89.4% |
| GR | 94.7% | 95.0% |
| HU | 85.1% | 88.1% |
| IE | 96.2% | 97.3% |
| IT | 86.5% | 70.9% |
| LT | 94.1% | |
| LU | 77.6% | 75.5% |
| LV | 93.2% | 98.3% |
| MT | 99.7% | 1.6% |
| NL | 56.8% | 31.5% |
| PL | 92.6% | 90.5% |
| PT | 93.5% | 89.1% |
| SE | 87.3% | 99.1% |
| SI | 93.9% | 87.9% |
| SK | 85.9% | |
| UK | 84.2% | 76.2% |
| **EU-25** | **89.2%** | **86.8%** |
| **EU-15** | **88.9%** | **86.1%** |

## 3.3 Rural Character at NUTS-3 Level

Differences between land cover and population density approaches become more important when the classifications are made at NUTS-3 level (maps 3 and 4). This is



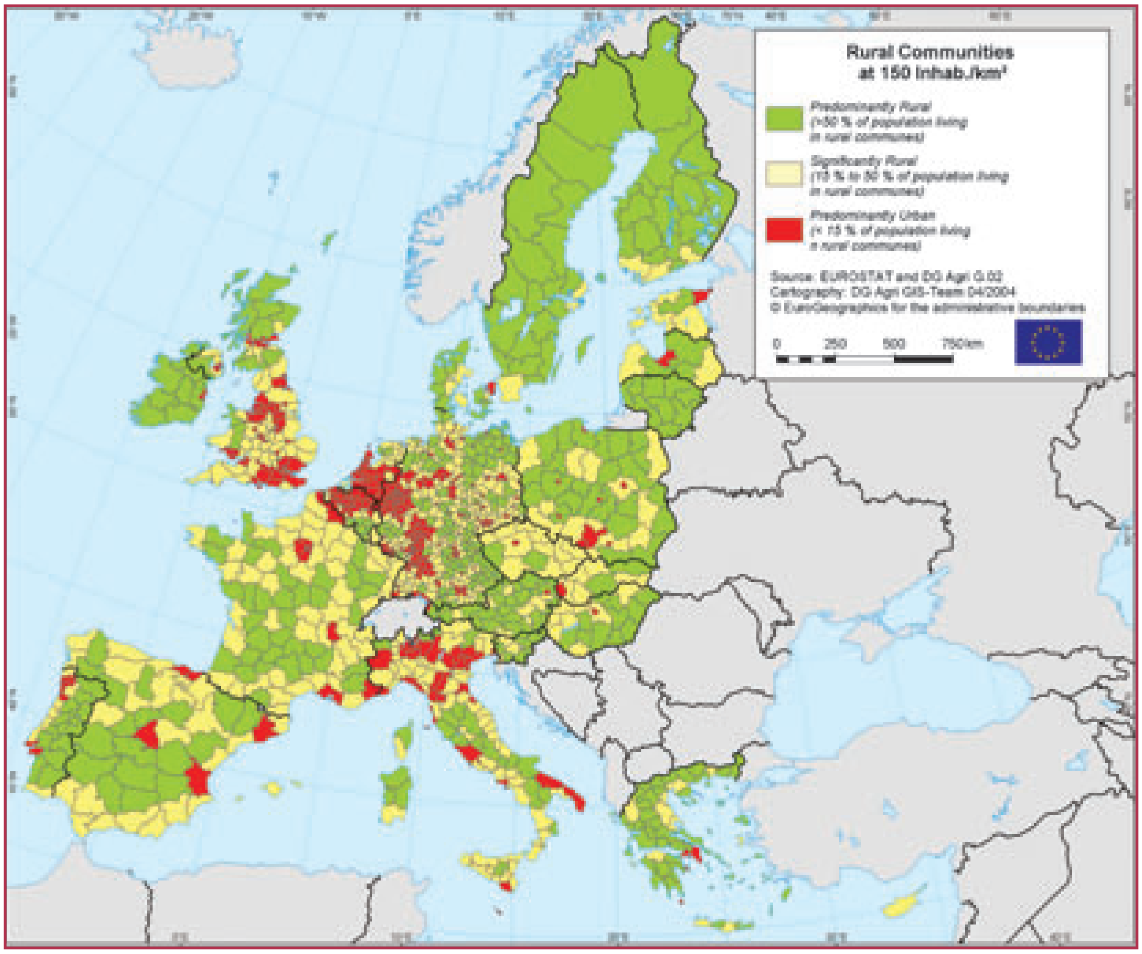



**Map 3.** *Rural character of EU-25 NUTS-3 based on land cover,*

mainly due to the fact that urban poles are often inserted in a large NUTS-3 area. Therefore, the population density is very high in some of the communes of these regions, resulting in "predominantly urban" classifications, with the population density method. However, the territorial expansion implicates a "significantly rural" classification, with the land cover approach. Such as, for instance, in the cases of Madrid, Barcelona, Roma, Athens, and parts of Paris' surroundings.

**Table 5.** *Distribution of area by type of rural character of regions with the Land Cover method and the Population Density method.*

| | Area by type of regions | | | | | |
|---|---|---|---|---|---|---|
| | Land Cover method | | | Population Density method | | |
| | Predominantly rural | Significantly rural | Predominantly urban | Predominantly rural | Significantly rural | Predominantly urban |
| AT | 87.3% | 12.2% | 0.5% | 78.5% | 20.2% | 1.3% |
| BE | 30.8% | 21.7% | 47.5% | 21.7% | 23.4% | 54.9% |
| CY | 100.0% | 0.0% | 0.0% | 0.0% | 100.0% | 0.0% |
| CZ | 53.4% | 45.9% | 0.6% | 18.4% | 81.0% | 0.6% |
| DE | 45.5% | 44.1% | 10.4% | 36.8% | 43.8% | 19.4% |
| DK | 52.9% | 42.5% | 4.5% | 67.7% | 27.8% | 4.5% |
| EE | 92.3% | 7.7% | 0.0% | 20.9% | 71.5% | 7.7% |
| ES | 91.8% | 6.7% | 1.5% | 47.4% | 46.5% | 6.1% |
| FI | 99.6% | 0.4% | 0.0% | 93.0% | 7.0% | 0.0% |




**Map 4.** *Rural character of EU-25 NUTS-3 based on population density*

| | Area by type of regions | | | | | |
|---|---|---|---|---|---|---|
| | Land Cover method | | | Population Density method | | |
| | Predominantly rural | Significantly rural | Predominantly urban | Predominantly rural | Significantly rural | Predominantly urban |
| FR | 79.1% | 19.1% | 1.7% | 40.8% | 54.7% | 4.5% |
| GR | 90.9% | 9.1% | 0.0% | 73.9% | 23.2% | 2.9% |
| HU | 62.7% | 36.7% | 0.6% | 60.7% | 38.7% | 0.6% |
| IE | 98.7% | 1.3% | 0.0% | 98.7% | 0.0% | 1.3% |
| IT | 69.1% | 28.1% | 2.9% | 27.4% | 50.2% | 22.4% |
| LT | 88.9% | 11.1% | 0.0% | 100.0% | 0.0% | 0.0% |
| LU | 0.0% | 100.0% | 0.0% | 0.0% | 100.0% | 0.0% |
| LV | 94.6% | 5.4% | 0.0% | 51.1% | 43.6% | 5.4% |
| MT | 100.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100.0% |
| NL | 16.5% | 44.7% | 38.8% | 5.2% | 37.5% | 57.3% |
| PL | 89.4% | 9.5% | 1.1% | 62.8% | 34.3% | 2.9% |
| PT | 89.5% | 5.9% | 4.6% | 69.7% | 22.0% | 8.3% |
| SE | 68.5% | 27.3% | 4.2% | 95.9% | 4.1% | 0.0% |
| SI | 76.7% | 23.3% | 0.0% | 70.4% | 29.6% | 0.0% |
| SK | 51.5% | 48.5% | 0.0% | 37.6% | 58.2% | 4.2% |
| UK | 59.4% | 34.7% | 5.9% | 33.7% | 45.7% | 20.6% |
| **EU-25** | **76.3%** | **20.3%** | **3.4%** | **56.4%** | **35.6%** | **7.9%** |
| **EU-15** | **75.4%** | **20.5%** | **4.0%** | **56.7%** | **34.2%** | **9.2%** |

To overcome this problem, a methodology is being developed to combine some population density rules with the land cover approach.

A first variant of the method of classification at NUTS-3 level is the following:

- Predominantly urban: population density > 500 / km? or area of "rural" communes represents less than 75% of its total area,

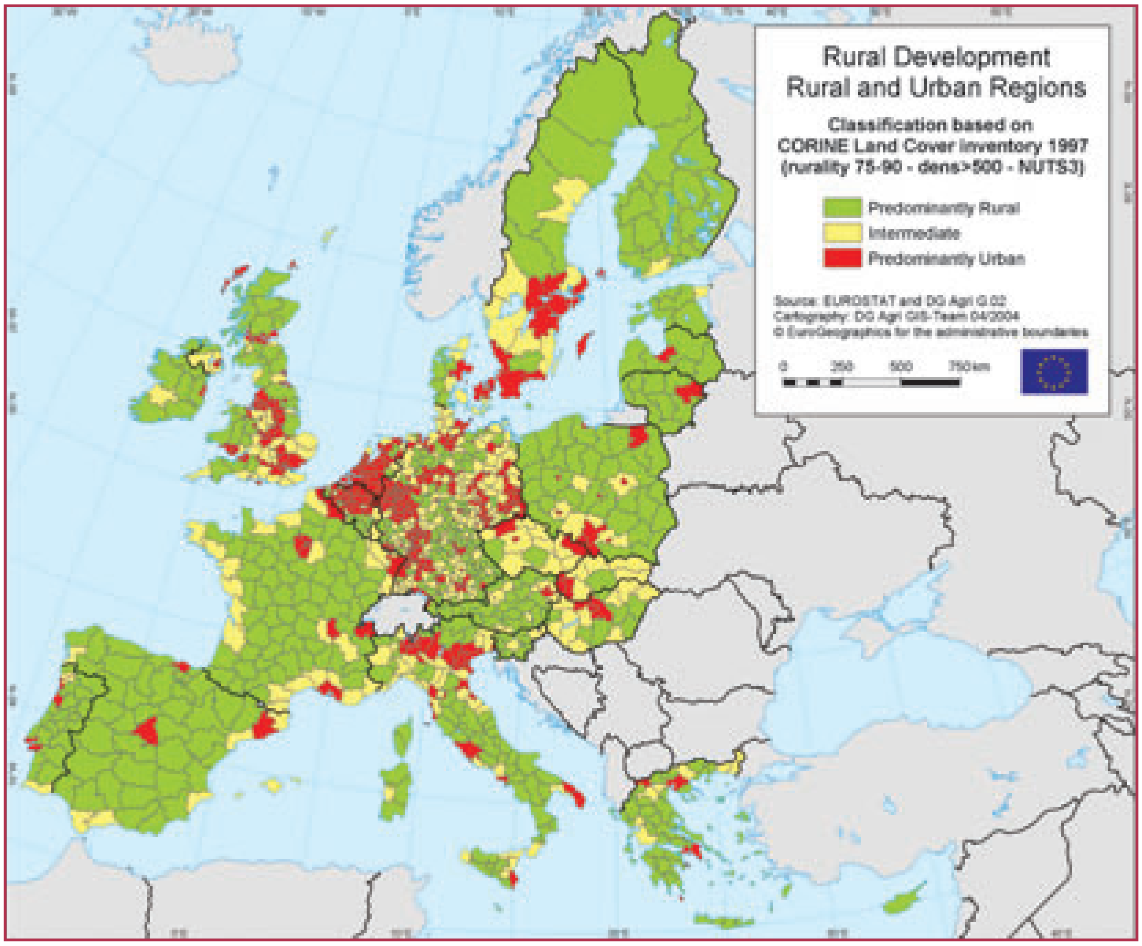
Else:

- Significantly rural: area of "rural" communes represents between 75% and 90% of its total area,
- Predominantly rural: area of "rural" communes represents 90% or more of its total area.

These results are more acceptable to common doctrine (see map 5 and table 6). However, other variants should be tested, such as applying the density rule at commune level.

**Table 6.** *Share of area and of population in predominantly rural areas, depending the classification method*

| | Share in predominantly rural areas | | | | | |
|---|---|---|---|---|---|---|
| | Area | | | Population | | |
| | Land Cover method | Population Density method | Land cover combined with Density rule method | Land Cover method | Population Density method | Land cover combined with Density rule method |
| AT | 87.3% | 78.5% | 79.0% | 59.0% | 46.2% | 45.1% |
| BE | 30.8% | 21.7% | 26.3% | 8.6% | 3.5% | 5.7% |
| CY | 100.0% | 0.0% | 100.0% | 100.0% | 0.0% | 100.0% |
| CZ | 53.4% | 18.4% | 18.4% | 37.3% | 10.4% | 10.4% |
| DE | 45.5% | 36.8% | 31.1% | 21.6% | 13.5% | 13.9% |
| DK | 52.9% | 67.7% | 38.6% | 28.6% | 39.0% | 19.3% |
| EE | 92.3% | 20.9% | 92.3% | 86.9% | 10.5% | 86.9% |
| ES | 91.8% | 47.4% | 86.6% | 62.6% | 15.6% | 51.5% |
| FI | 99.6% | 93.0% | 97.5% | 99.5% | 62.7% | 74.4% |
| FR | 79.1% | 40.8% | 70.2% | 48.4% | 17.0% | 38.5% |
| GR | 90.9% | 73.9% | 75.4% | 55.6% | 39.6% | 46.7% |
| HU | 62.7% | 60.7% | 38.3% | 44.1% | 44.0% | 26.0% |
| IE | 98.7% | 98.7% | 86.9% | 70.7% | 70.7% | 62.0% |
| IT | 69.1% | 27.4% | 58.9% | 45.2% | 9.6% | 34.5% |
| LT | 88.9% | 100.0% | 88.9% | 94.6% | 100.0% | 94.6% |
| LU | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| LV | 94.6% | 51.1% | 94.6% | 59.3% | 29.7% | 59.3% |
| MT | 100.0% | 0.0% | 100.0% | 100.0% | 0.0% | 0.0% |
| NL | 16.5% | 5.2% | 9.3% | 7.3% | 1.9% | 4.3% |
| PL | 89.4% | 62.8% | 82.3% | 66.5% | 42.7% | 61.4% |
| PT | 89.5% | 69.7% | 82.7% | 50.5% | 22.0% | 41.9% |
| SE | 68.5% | 95.9% | 63.3% | 21.9% | 66.9% | 15.6% |
| SI | 76.7% | 70.4% | 70.1% | 81.4% | 58.0% | 53.1% |
| SK | 51.5% | 37.6% | 19.3% | 39.7% | 26.9% | 12.3% |
| UK | 59.4% | 33.7% | 53.0% | 16.5% | 3.6% | 12.2% |
| **EU-25** | **76.3%** | **56.4%** | **67.6%** | **40.1%** | **18.6%** | **31.1%** |
| **EU-15** | **75.4%** | **56.7%** | **67.5%** | **36.2%** | **15.9%** | **27.8%** |




**Map 5.** *Rural character of EU-25 NUTS-3 based on a method combining land cover and population density*



## Conclusion

The use of the CORINE Land cover data enhanced with GIS tools has demonstrated to be a beneficial and flexible tool in the analysis of the rural character of EU localities. This method is based on a territorial approach and not on a population criterion like the OECD methodology. The most interesting features for this analysis have been:

The flexibility in aggregating classes of land cover,

The possibility to identify the commune boundaries,

The geographical precision in providing satisfactory accuracy at commune level.

Limitations of the analysis have been:

the absence of recent data (some data is more than 10 years old) and the differences of accuracy between some countries in data sources.

the size of the commune can interfere with the calculation, for example an important urban nucleus surrounded by very huge agricultural fields can result in defining the commune as being rural. Of course, this might also be the case with the OECD method. However, with our analysis at polygon level, it would be possible to eliminate some clear outliers.

Moreover, even if different thresholds have been tested to determine the rural character of a commune, the used threshold (>90% of agriculture, forestry and natural areas) has been more or less empirically defined. Likewise, we can also make the same restriction with the thresholds chosen for regrouping the communes at regional level. Again, they were more or less empirically determined and more trials would have to be performed to analyse the sensitivity of the method. However, the same remarks can be made for the OECD approach; why is a level of 150 inhabitants/km? at commune level relevant for determining the rural character of a commune. And again, the thresholds used in the OECD approach to regroup the communes at regional level are questionable[7].

An updated analysis, with more recent and homogeneous information from the CORINE Land cover survey of 2000 is in progress. This new analysis will be carried out at a more standardised manner, at least a CLC inventory will be available for Sweden and the minimum polygon size of all countries will be the same.

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[7] Other thresholds were tested in “Rural Developments” a DG AGRI publication (see bibliography).

# Trend in atmospheric nitrogen deposition over the period 1990-2000

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## 1. Background

An excess of the nutrients nitrogen (N), phosphorus (P) and potassium (K) increases the risk of environmental pollution. Atmospheric deposition is one of the sources of these nutrients for agricultural lands, but usually the only source of these nutrients for protected natural areas. Since atmospheric deposition of phosphorus and potassium is negligible, the focus of this paper is on atmospheric nitrogen deposition.

National and regional atmospheric nitrogen deposition is the sum of respectively the national and regional deposition of reduced Nitrogen and oxidised Nitrogen. Agriculture is the main source of $NH_3$ emissions that are partly redeposited as reduced Nitrogen. Other reduced Nitrogen sources are transboundary deposits from neighbouring countries, consumers and industry. Traffic and transport are the main national and regional sources of $NO_x$ emissions that are partly returned as oxidised Nitrogen deposits. Again, transboundary deposits from neighbouring countries and regions are an important source of oxidised Nitrogen.



Atmospheric Nitrogen deposition on agricultural land is one of the calculation components on the input side of agricultural Nitrogen balances, alongside with the Nitrogen content of livestock manure, commercial fertilisers and seeds and Nitrogen fixation by leguminous plants and free living organisms. In order to be able to calculate regional agricultural N balances, an estimate of the regional atmospheric Nitrogen deposition on agricultural land is needed. For this purpose the EMEP[1] grid data on reduced Nitrogen and oxidised Nitrogen deposition were spatially disaggregated over NUTS 3[2] areas. The assumption was made that atmospheric Nitrogen deposition per ha for each EMEP grid and NUTS 3 area is equal on agricultural land and non-agricultural land. A comparison was made between the 1990 and 2000 situation.

## 2. The EMEP Programme

The Co-operative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe (EMEP[3]) is a scientifically based and policy driven programme under the Convention on Long-Range Transboundary Air Pollution (CLRTAP) for international co-operation to solve transboundary air pollution problems. The UNECE/EMEP emission database WebDab has been constructed to facilitate the access

[1] Co-operative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air pollutants in Europe.

[2] Regulation (EC) No 1059/2003 of the European Parliament and of the Council of 26 May 2003 on the establishment of a common classification of territorial units for statistics (NUTS) *Official Journal L 154, 21/06/2003 P. 0001 - 0041.*

[3] http://www.emep.int/

to the emission data reported to CLRTAP on Main Pollutants, Heavy Metals and Persistent Organic Pollutants. Modelled data of concentrations in air and depositions of Main Pollutants, Aerosols (PMs), Heavy Metals and Persistent Organic Pollutants calculated by EMEP models are available as yearly data as well as trend data for the whole EMEP grid.

The chemical transport models developed at the Meteorological Synthesizing Centre - West (MSC-W) model the regional atmospheric dispersion and deposition of acidifying and eutrophying compounds (S, N), ground level ozone ($O_3$) and particulate matter (PM2.5, PM10). Until 1998, the 2-D Lagrangian Acid Deposition model was routinely used at EMEP/MSC-W. In 1999, the 3-D Eulerian Acid Deposition Model was applied to calculate air concentration and deposition fields for major acidifying and eutrophying pollutants as well as their long-range transport and fluxes across national boundaries. Finally in 2002, the Unified EMEP model was introduced, being a modelling system that unified the acidifying and the oxidant versions of the Eulerian model.

The data used for this paper were based on the data from the EMEP grid (50 ¥ 50 km$^2$) calculated by the Unified EMEP model for the years 1990 and 2000 and were taken from the EMEP/MSC-W Status Report 1/2003 - Part II.





## 3. Geographic data processing

### 3.1 The EMEP grid

The atmospheric deposition of Nitrogen is estimated using a metric grid with a cell size of 50 km × 50 km. The grid consists of 110 rows and 130 columns, resulting in an extent of 6500 km by 5500 km. The extent of the EMEP grid was chosen to cover the European continent, from 32°W to 58°E.

The EMEP grid is based on the polar stereographic projection, which by definition is limited to one hemisphere. The earth surface is projected on a plane centred at the North Pole and viewed from the South Pole. The parameters of the projection were selected in a way that the latitude of 60°N has a true length, whereas the other latitudes are distorted. The rows of the grid are parallel to the meridian at 32°W.

The EMEP grid considers the earth as being a sphere with a radius of 6370 km. This can be accepted for small scale applications, i.e. with a scale smaller than 1: 10 Millions. For larger scale applications, the earth has to be modelled as an ellipsoid. For NUTS in the GISCO[4] database, the ellipsoid GRS80[5] is taken as reference ellipsoid.

The polar stereographic projection is conformal, i.e. local shapes are preserved. Other aspects, such as area, length and direction are distorted. Due to the distortion of area, the size of the grid cells varies from 1300 km$^2$ to 2860 km$^2$. According to the projection, the nominal size of the grid cells would be 2500 km$^2$.

In order to verify the generated grid, a map with the NUTS areas and the grid was produced. By comparing this map with the map on the Internet presentation of EMEP[6], a distortion between both grids could be observed. Further investigation showed that the distortion was created by the change of the size of the reference spheroid. The coordinates of the GISCO data are based on the spheroid GRS80. The axis dimensions of this spheroid differ from those of the EMEP sphere. The EMEP map obviously does not consider this change when overlaying both data sets. The ensuing geometric shift increases from the centre of the projection to a maximum value of about _ the grid size, with the risk that some areas of interest would be located outside the grid. Therefore, it was decided to neglect the change of ellipsoid for the estimation of the Nitrogen deposits within the presented work.

[4] Geographic reference database of the Commission.
[5] Geodetic Reference System of 1980.
[6] http://www.emep.int/grid/grid50.pdf

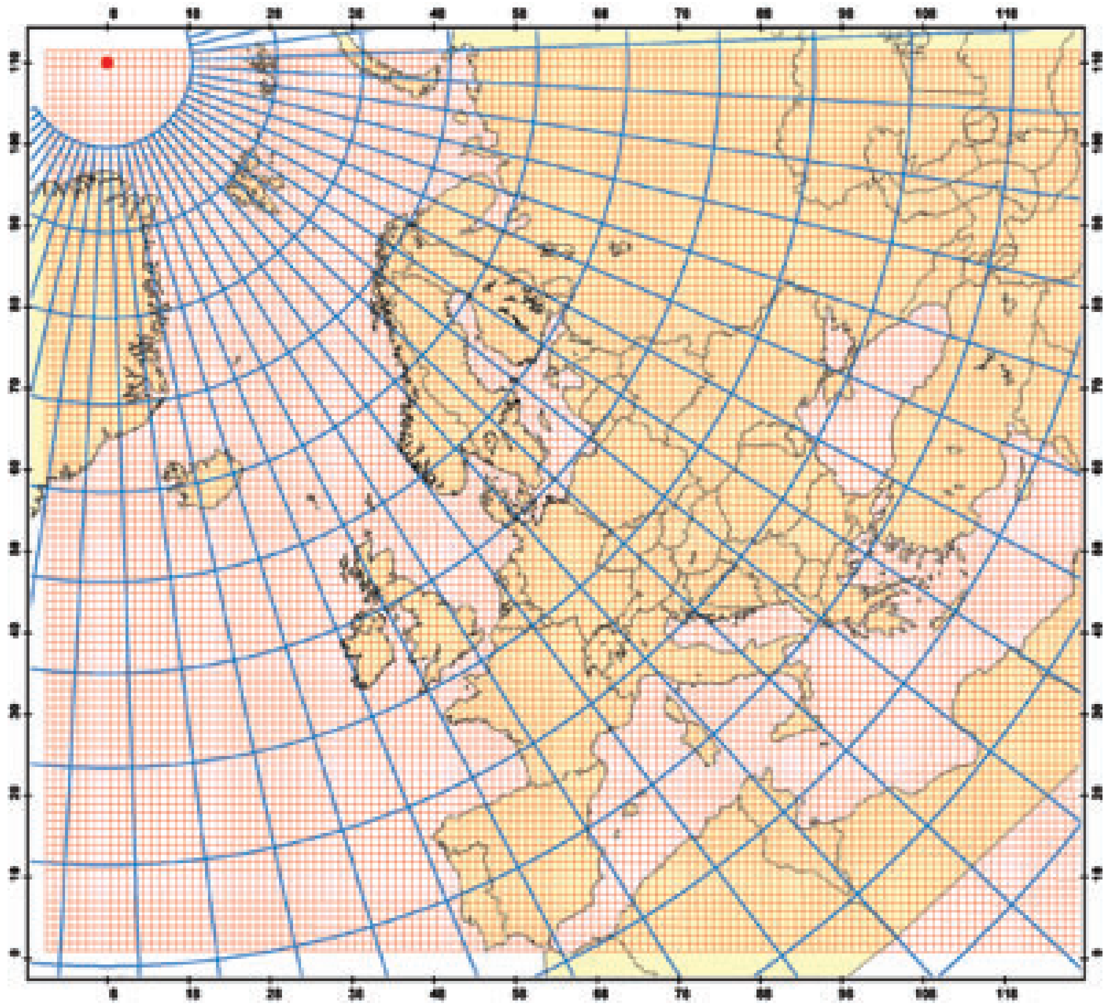

**Figure 1.** *The EMEP 50km grid*

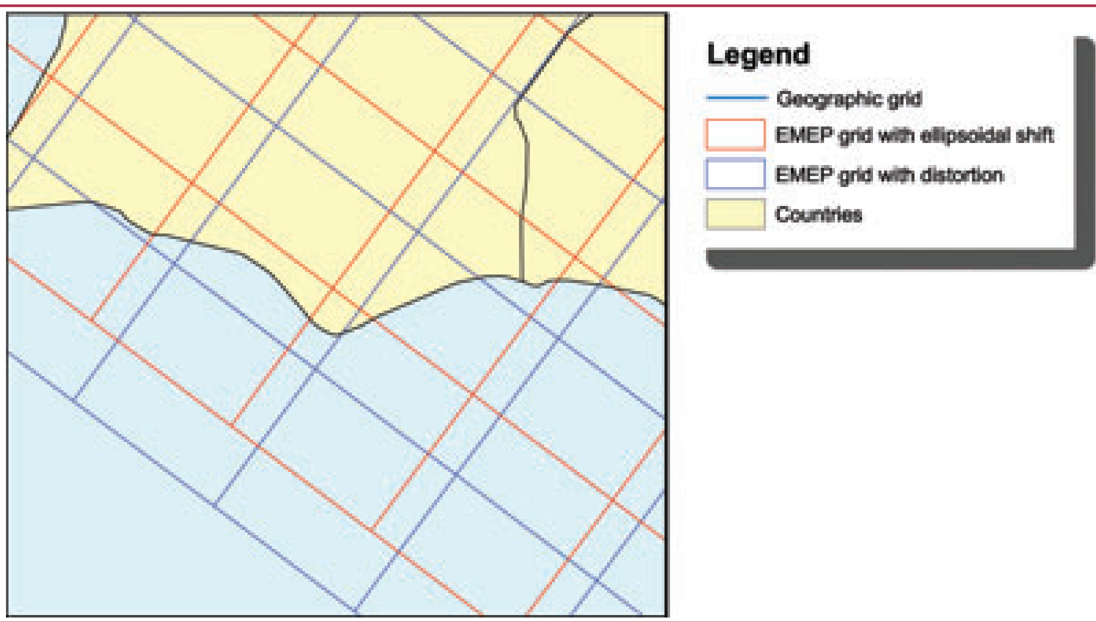


**Figure 2.** *Geometric shift of the grid due to change of ellipsoid*

## 3.2 Spatial Redistribution of grid data

The EMEP grid was projected to the Lambert's Azimuthal Equal Area projection to calculate correct area sizes of the grid cells. Then, the NUTS geographic data set was overlaid with the EMEP grid in order to calculate for each grid cell the share of area per NUTS region. The atmospheric nitrogen deposits were distributed proportionally to the share of area and then summed up to calculate the total deposits by NUTS region.

The NUTS regions are aggregated to Eurofarm districts and Eurofarm regions. According to the share of agricultural areas in each Eurofarm district, the total deposit of atmospheric nitrogen on agricultural area will be derived at a later stage. The aggregated deposits by Eurofarm regions can be used for subsequent modelling of the nitrogen cycle.

The spatial patterns that can be observed after the redistribution process are dependant on the relation in size between the grid cells and the NUTS or the Eurofarm regions. In case the regions are smaller than the grid cells, spatial patterns that can be observed in the grid, are preserved. For regions that are larger than a grid cell, regional spatial patterns might disappear.

According to the assumption of equal distribution, the calculation of the total depositions by region is correct. However, this procedure of averaging relative deposition values might have negative effects on the accuracy of the calculation of deposition on the agricultural areas.

The following example illustrates this issue. A region is covered by two grid cells. The deposition of nitrogen in one grid cell is significantly higher than in the other. The agricultural area is completely located in one of the grid cells. The total deposition is calculated by summing both deposition values. The spatial distribution of the agricultural area in the region cannot be derived from statistical information sources. The assumption of equal distribution of agricultural area between the two grid cells would lead to an average value of deposition. The actual value of deposition would deviate from the calculated value. In order to avoid those effects, spatial redistribution should always be performed at the highest applicable spatial resolution.

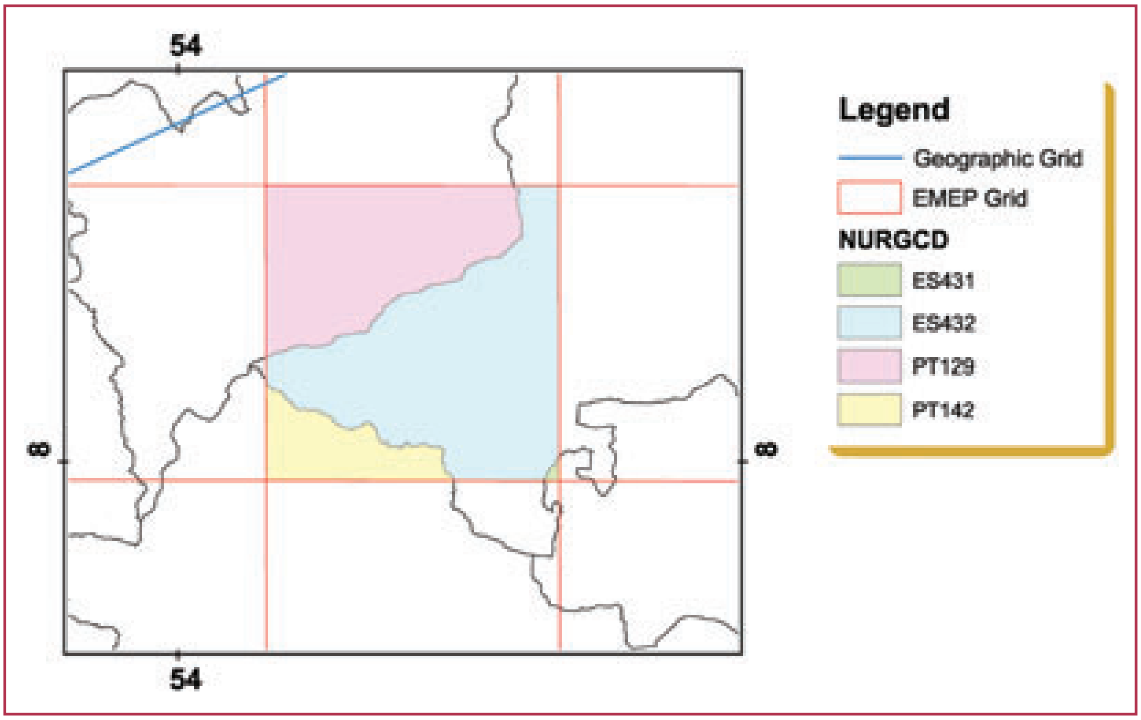


**Figure 3.** *Overlay of grid and NUTS regions*

Figure 4 shows the deposition of nitrogen by grid cell according to the definition of EMEP with the overlay of the NUTS 3 regions. It can be observed that the average size of the NUTS regions in the Netherlands, Belgium and Germany is smaller than an EMEP grid cell. On the contrary, the NUTS regions in France are larger than the grid cells as defined by EMEP. In consequence, spatial patterns generated by the grid cells can be preserved in the first case whereas this might not be the case for French NUTS regions. The relative value might be affected by the size and the shape of the regions. In any case, the sum of deposition by NUTS region is calculated correctly, according to the described assumption of equal distribution.

Figure 5 shows the relative deposition of Nitrogen by NUTS 3 region. Although the spatial patterns of the grid are recognizable, there are some differences due to the dissagregation algorithm and the shape of the NUTS regions. For example, the single grid cell with a value of > = 25 kg/ha in Northrine-Westphalia have disappeared.

Figure 6 shows the relative deposition of Nitrogen by Eurofarm region. The European patterns of nitrogen deposition are still visible, although regional variations are lost by calculating averages.

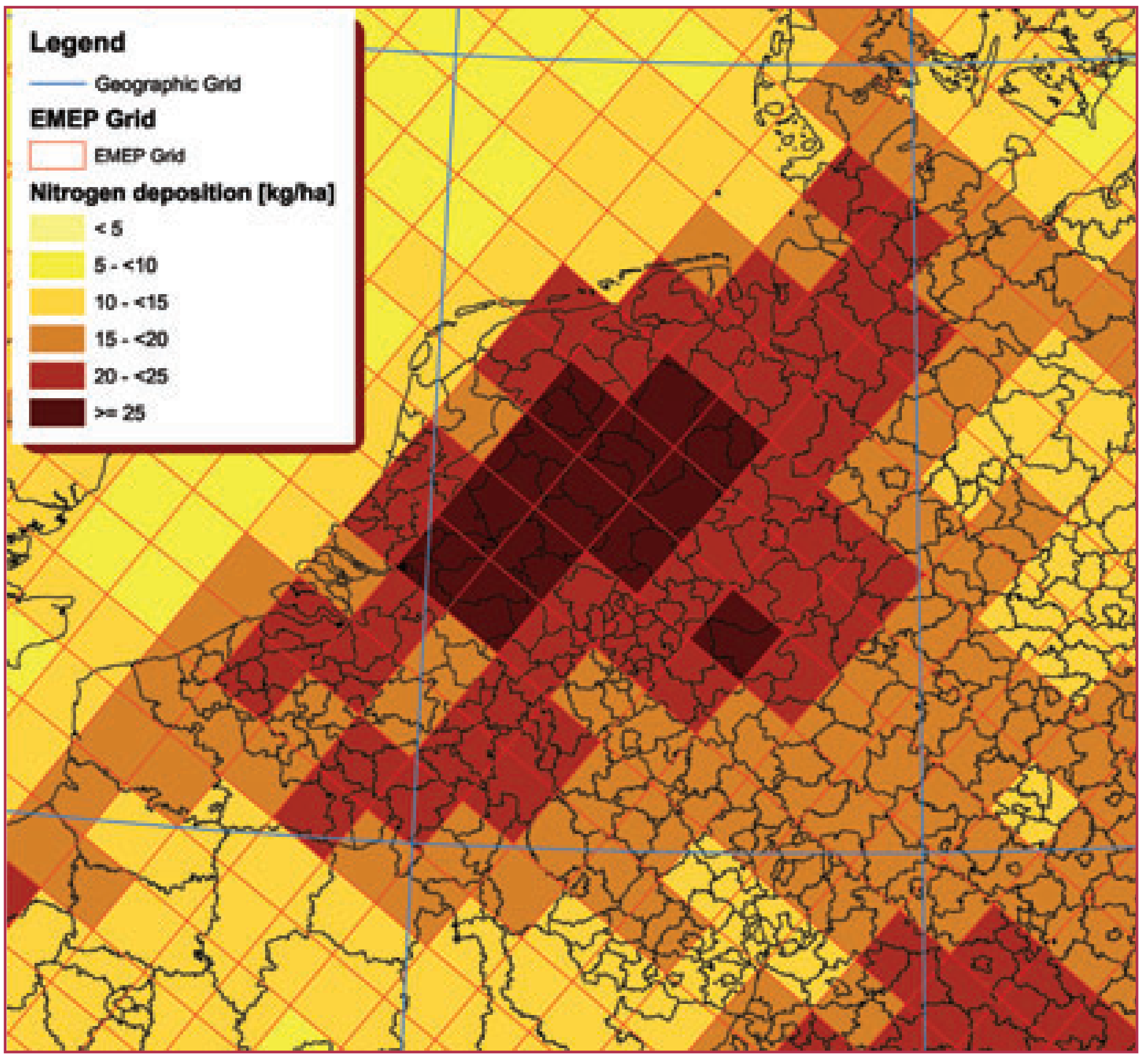


**Figure 4.** *Nitrogen deposit 2000 by grid cell*

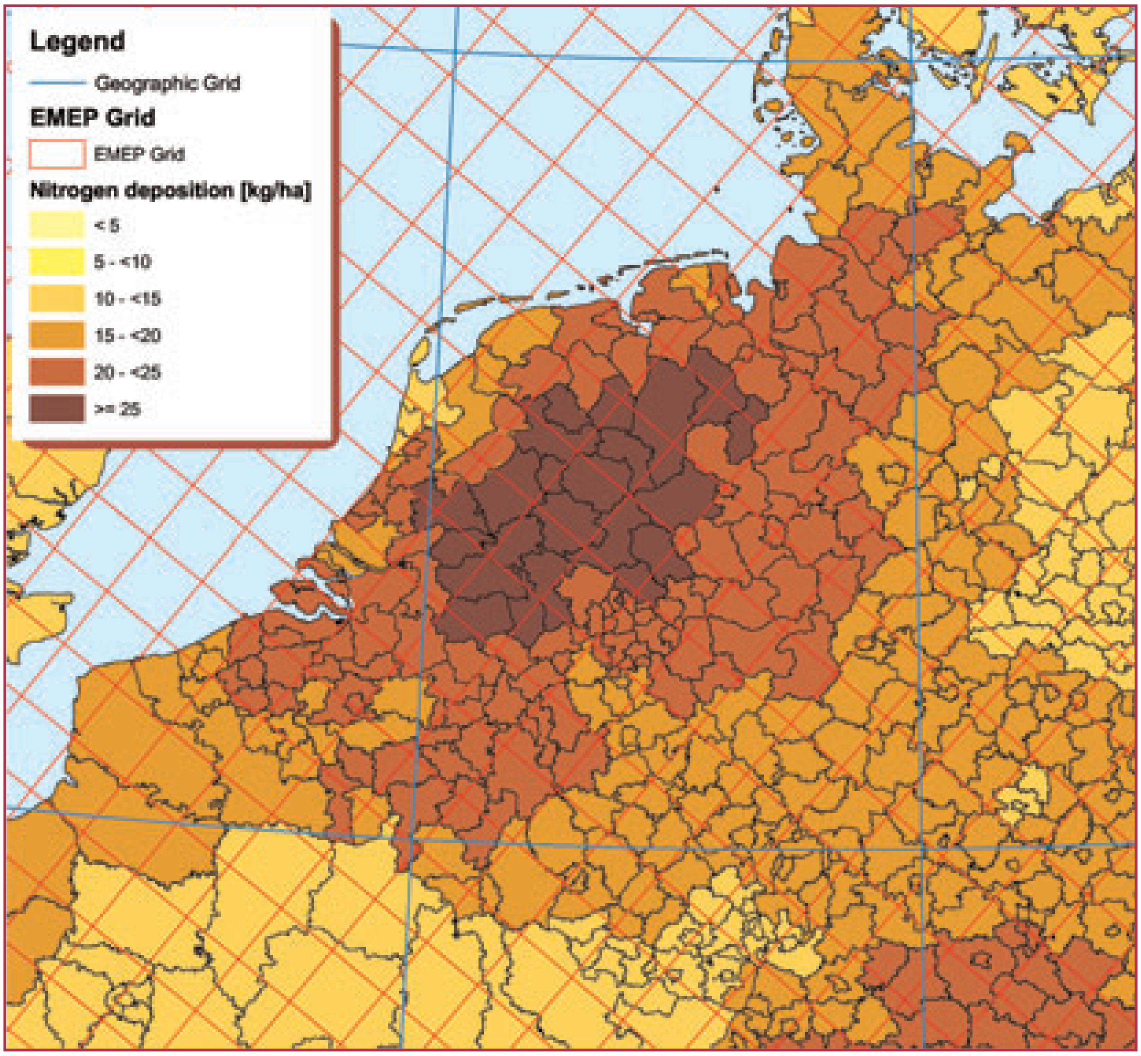


**Figure 5.** *Nitrogen deposit 2000 by NUTS 3 region*

## 4. Results

The total nitrogen deposition was derived for the years 1990 and 2000 by NUTS 3 regions and aggregated to Eurofarm regions and countries. Resulting spatial patterns can be observed and interpreted as well as the development of nitrogen deposition over time.

### 4.1 NUTS 3 regions

Figure 7 shows the atmospheric N deposition (in kg per ha) for the year 1990 for all NUTS 3 regions. The areas with the highest deposits are situated in the Netherlands, the west and south of Germany and the north of Italy. Other areas with high atmospheric Nitrogen deposits are Austria, Belgium, Czech Republic, Denmark, Lithuania, Poland, Slovakia, Switzerland and some parts of France. The peripheral areas of Europe show mostly low N deposition figures.

Figure 8 shows the situation for the year 2000 for all NUTS 3 regions. The areas with the highest deposits are still in the Netherlands, the west and south of Germany and the north of Italy, but also Belgium has to be added to this list. Other areas with high deposits are now the northwest of France and Switzerland. The peripheral areas still show low Nitrogen deposition rates.

On average for the whole of Europe, the deposition rates are lower than the situation

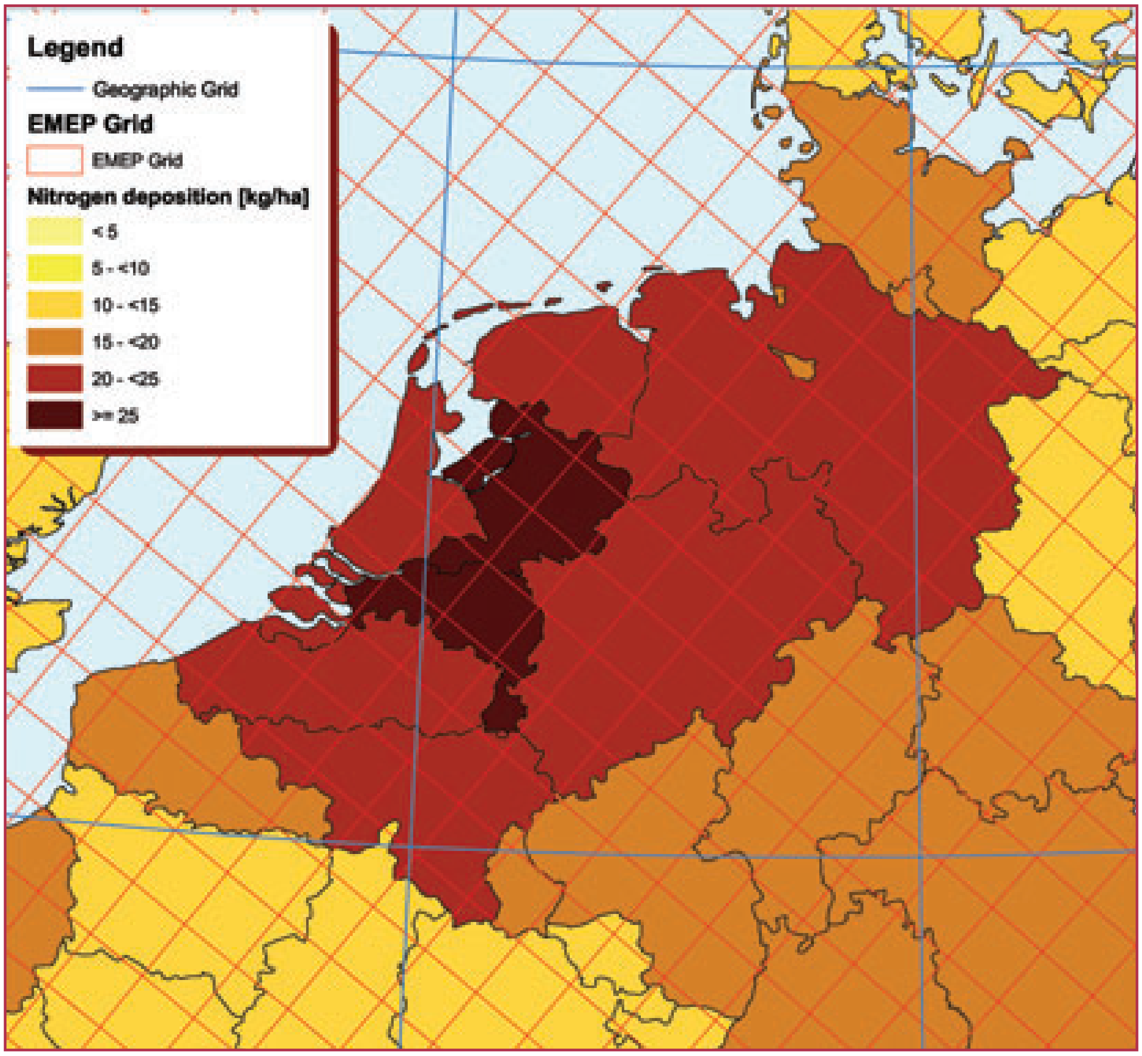


**Figure 6.** *Nitrogen deposit 2000 by Eurofarm region*

in 1990. Figure 9 shows the trend between 1990 and 2000 for all NUTS 3 regions. The areas with an increase in deposition rates (red) can be distinguished clearly and are situated mainly in Belgium, France, Greece, Ireland, Switzerland and the United Kingdom. The reduction in the N deposition rates has been high (> 20% - green) in the new EU Member States and the Candidate Countries, Iceland, Austria, east of Germany, southeast of France, mid-Italy, northeast of Greece and Spain.

The analysis of the reasons behind these increases, respectively reductions, goes beyond the scope of this paper.

## 4.2 EU-15 Eurofarm Regions

The Eurofarm regions include NUTS 1 and NUTS 2 regions depending on the country[7]. The aggregation to these larger areas has been carried out due to the fact that Eurostat calculates Nitrogen balances for the Eurofarm regions, in response to requests from policy makers for information on the regional distribution of Nitrogen balances. In order to arrive at reliable results for the regional Nitrogen balances, the aggregated Nitrogen deposition data for each Eurofarm region are used as default values in the calculation. Only when more accurate data on atmospheric Nitrogen deposition exist in Member States, the latter are used.

Figure 10 shows the Nitrogen deposition for each Eurofarm region for the year 1990. Like in Figure 7, it can be seen that the highest deposition rates are found in the

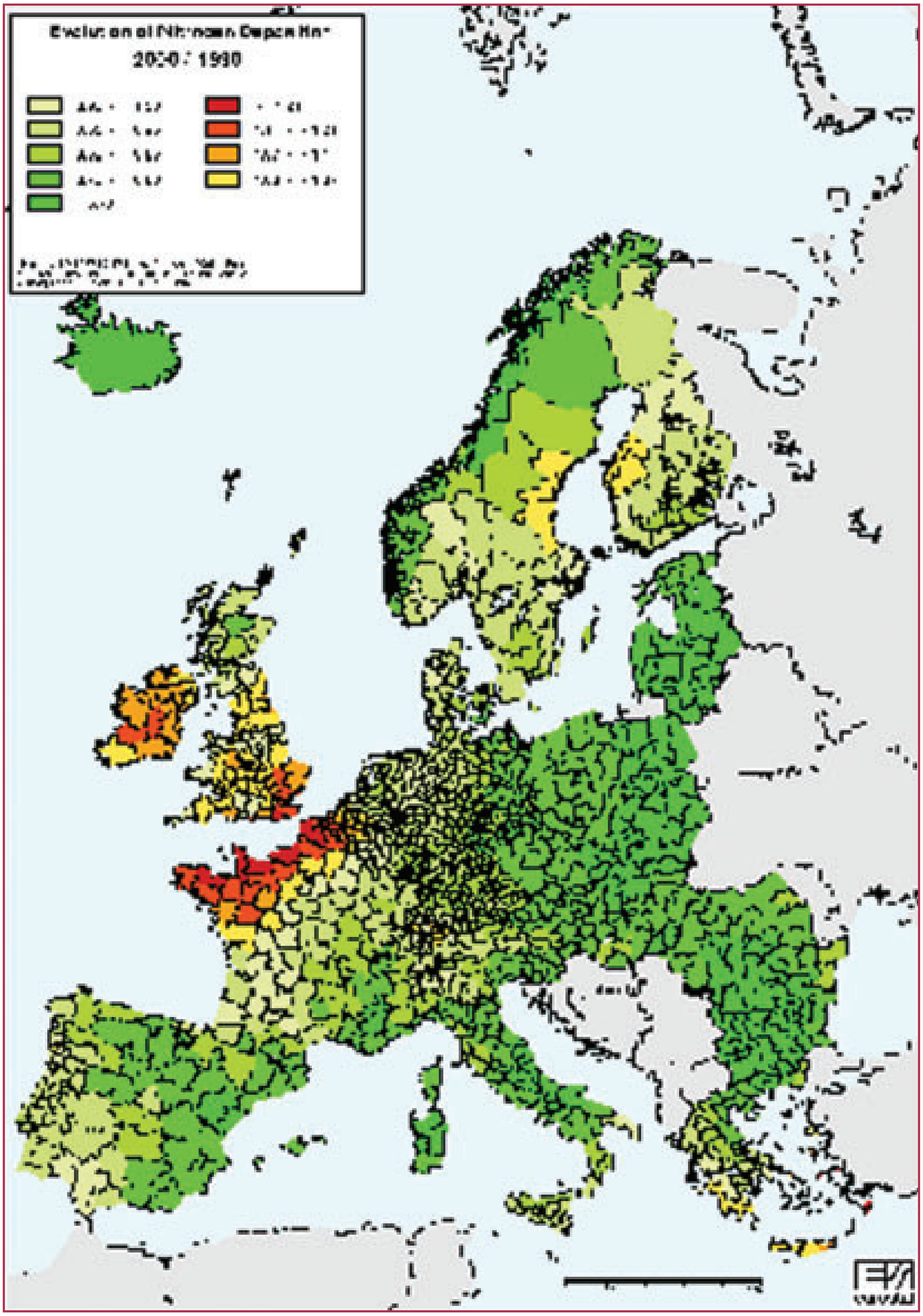

**Figure 7.** *Atmospheric Nitrogen deposition by NUTS 3 region in 1990*

Netherlands, Germany and northern Italy, while the peripheral areas show the lowest values.

Figure 11 shows the situation for the year 2000. Nitrogen deposition rates remain high in the Netherlands, western Germany and northern Italy, but are now also high in Belgium and north-western France. The peripheral areas still show the lowest values.

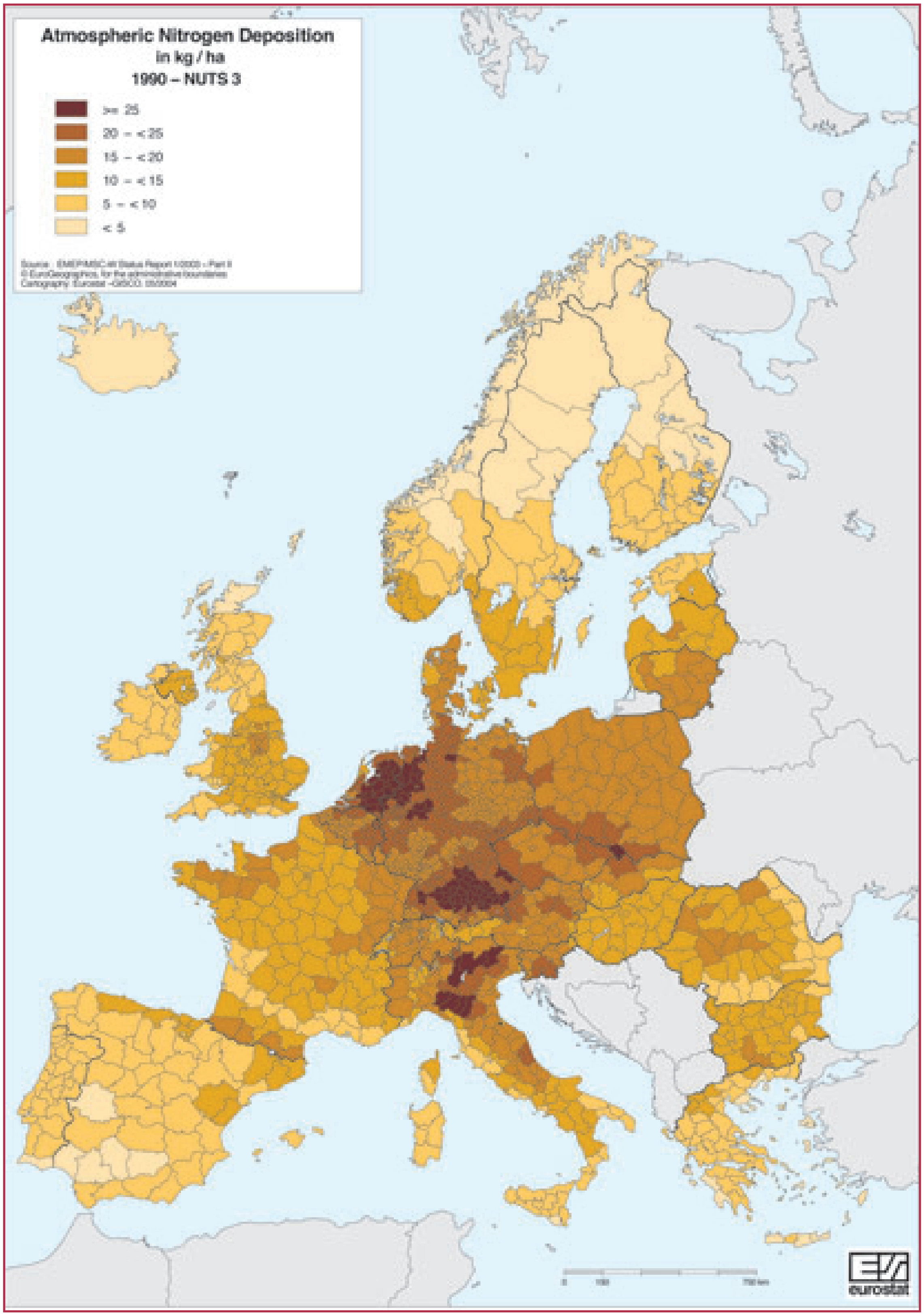


**Figure 8.** *Atmospheric Nitrogen deposition by NUTS 3 region in 2000*

The trend in atmospheric Nitrogen deposition over the period 1990-2000 shows a decrease for most of the Eurofarm regions, except for some regions in France and Belgium.

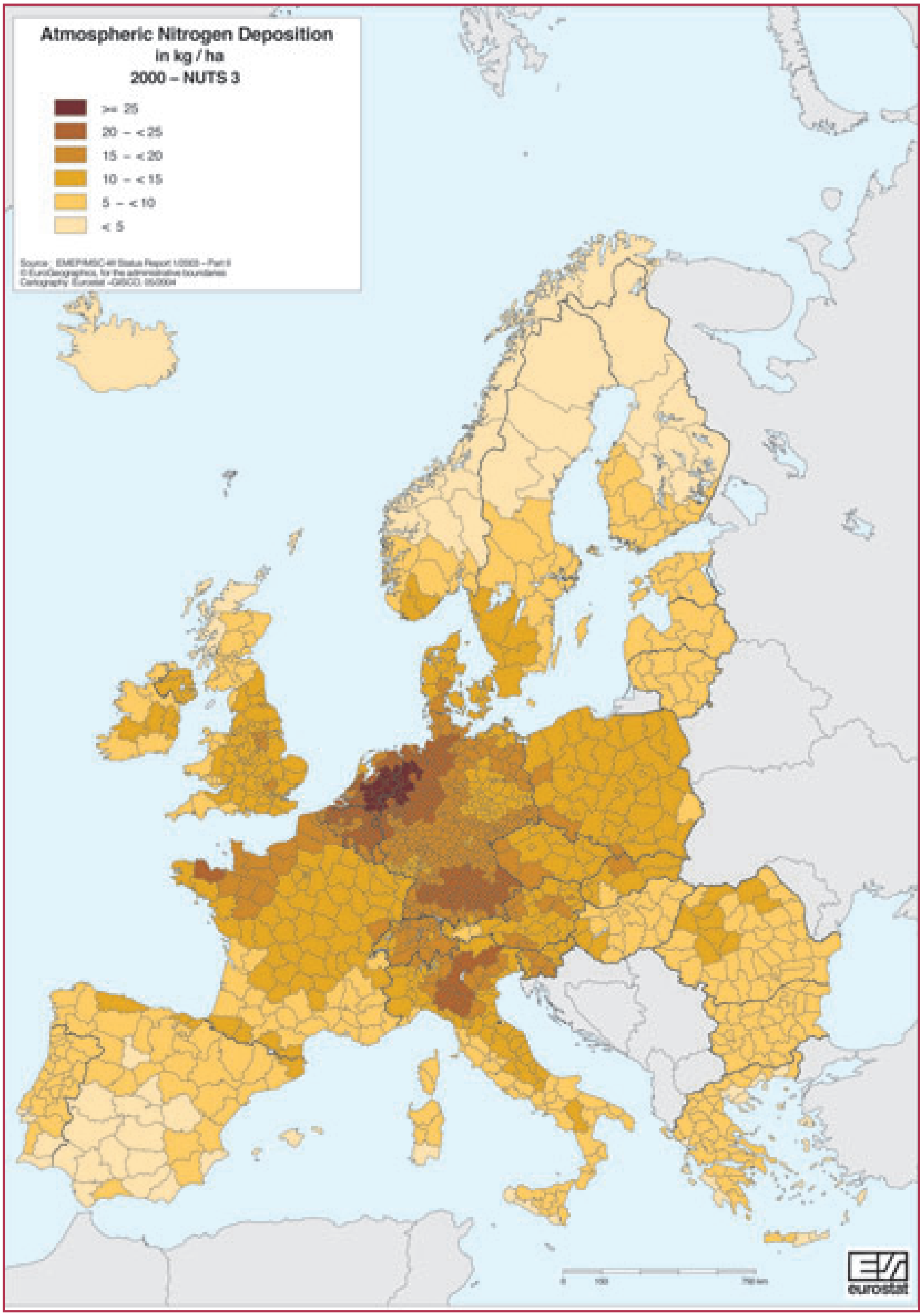


**Figure 9.** *Evolution in atmospheric Nitrogen deposition by NUTS 3 region 1990-2000*

## 4.3 European countries (EU-25, EFTA8 and EU Candidate Countries)

Table 1 shows the results of the aggregation of the NUTS 3 data to the national level. The highest reductions (> 0%) over the timespan 1990-2000 have taken place in Lithuania, Latvia, Iceland, Bulgaria, Slovak Republic and Poland. An increase can be

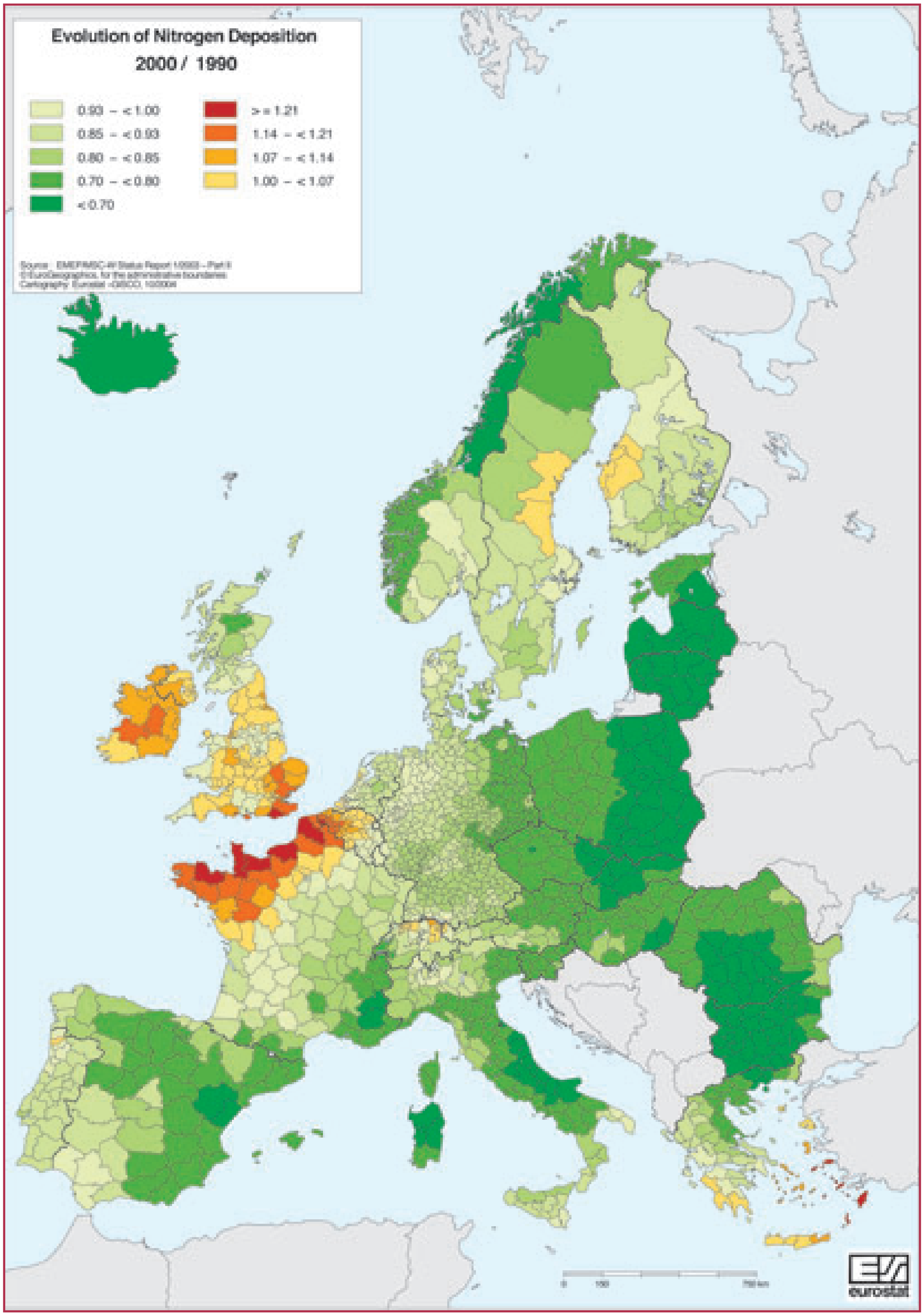


**Figure 10.** *Atmospheric Nitrogen deposition by Eurofarm region in 1990*

noticed over the same period in Ireland, Liechtenstein, Belgium and the United Kingdom, due to a considerable increase in reduced N deposits that reverted the oxidised Nitrogen reduction.

For the whole of Europe (31 countries) the Nitrogen deposition reduced by almost 20%.

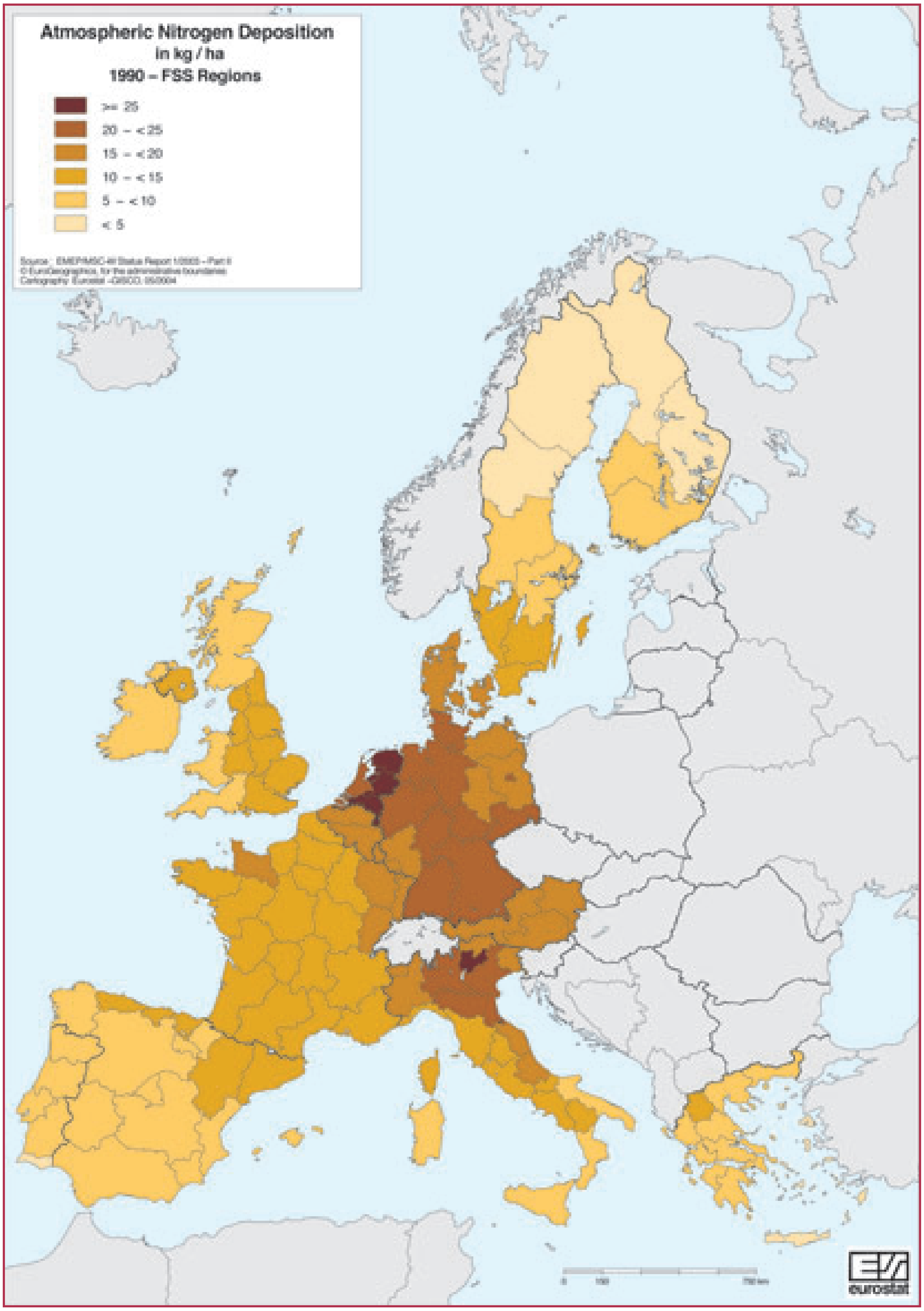


**Figure 11.** *Atmospheric Nitrogen deposition by Eurofarm region in 2000*

## 5. Conclusions

The analysis proved the feasibility of the approach for spatial redistribution of the EMEP grid data on atmospheric nitrogen deposition to statistical regions (NUTS). The derived figures can be used for statistical analysis together with economic data.

**Table 1.** *Evolution in Atmospheric Nitrogen deposition by country over the period 1990-2000*

| | Total dep 1990 kg/ha | Total dep 2000 kg/ha | Trend oxN | Trend redN | Trend dep |
|---|---|---|---|---|---|
| AT | 17.32 | 13.88 | –25% | –15% | –20% |
| BE | 19.62 | 20.42 | –6% | 13% | 4% |
| BG | 12.19 | 7.66 | –35% | –39% | –37% |
| CH | 16.82 | 15.50 | –23% | 5% | –8% |
| CY | 3.42 | 3.33 | 7% | –22% | –3% |
| CZ | 19.67 | 14.20 | –29% | –27% | –28% |
| DE | 21.56 | 18.37 | –24% | –7% | –15% |
| DK | 15.41 | 13.65 | –16% | –8% | –11% |
| EE | 9.52 | 6.79 | –26% | –32% | –29% |
| EL | 6.88 | 5.98 | –16% | –9% | –13% |
| ES | 7.65 | 5.99 | –24% | –20% | –22% |
| FI | 4.28 | 3.92 | –13% | 1% | –9% |
| FR | 12.77 | 12.01 | –21% | 7% | –6% |
| HU | 11.72 | 8.81 | –24% | –26% | –25% |
| IE | 7.70 | 8.57 | –18% | 27% | 11% |
| IS | 1.19 | 0.73 | –36% | –47% | –39% |
| IT | 14.44 | 11.30 | –29% | –13% | –22% |
| LI | 13.67 | 14.43 | –16% | 26% | 6% |
| LT | 15.71 | 8.37 | –44% | –49% | –47% |
| LU | 17.42 | 16.82 | –20% | 13% | –3% |
| LV | 12.59 | 7.00 | –41% | –48% | –44% |
| MT | 3.55 | 2.99 | –17% | –12% | –16% |
| NL | 26.91 | 24.27 | –9% | –10% | –10% |
| NO | 4.58 | 3.82 | –21% | –9% | –17% |
| PL | 18.01 | 12.49 | –31% | –30% | –31% |
| PT | 6.45 | 5.76 | –13% | –9% | –11% |
| RO | 12.31 | 8.71 | –36% | –24% | –29% |
| SE | 6.07 | 5.35 | –18% | –1% | –12% |
| SI | 18.48 | 14.16 | –27% | –19% | –23% |
| SK | 17.49 | 11.92 | –30% | –34% | –32% |
| UK | 9.92 | 10.02 | –14% | 17% | 1% |
| Europe | 11.22 | 9.18 | –24% | –12% | –18% |

However, aggregation of figures to larger statistical areas results in a loss of spatial resolution. Regional spatial patterns of nitrogen distribution disappear during the aggregation process. In general, the type of analysis determines the choice of data types. Geographic Information Systems provide tools for generating those different types of data in a flexible way.

The derived figures on atmospheric nitrogen deposition showed a reduction for the majority of the European regions and countries. However, a limited number of regions, especially in Western Europe saw a growth from 1990 to 2000.

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# Linear landscape features in the European Union. Developing indicators related to linear landscape features based on LUCAS transect data

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## 1. Introduction: Significance of linear landscape features

Linear landscape features, such as hedges, row of trees, grass margins (beetle banks) and traditional stonewalls are important characteristics in European agricultural landscapes for a number of reasons (Knauer 1993, Solagro 2002, CS2000, p. 52):

- they contribute significantly to the **maintenance** of a high level of **biodiversity** due to their valuable function as habitats for plants and animals;
- trees and hedges in open landscapes in particular, where the agricultural land use dominates, provide a concentrated network of corridors, **connecting** different **habitats** and allowing the **movement and dispersal** for many **wildlife** species, and
- hedges and stone walls are part of the **rural heritage** of many regions and are perceived as important visual features, which contribute to **cultural identity** and the overall landscape scenery.

Given these important roles, it is clear why the conservation, maintenance and restoration of linear landscape features in European agricultural landscapes have become the central theme in many agri-environmental programmes.

Despite their significance, however, information about the state and change of hedges and trees is rare (OECD 2001, p. 377). Only a few of the EU Member States maintain related monitoring systems or conduct studies that enable adequate reporting of these characteristics (CS 2000; Swedish Environmental Agency (2003), Piorr et al. 2003). Moreover, what little information is available from the Member States is barely comparable because definitions and observation methods differ.

This information deficit could be overcome, however, using the Land Use / Cover Area Frame Statistical Survey (LUCAS) that collects information about the presence of linear features and is collected in a harmonised and comparable way all over Europe[1].

This paper describes briefly how this LUCAS information is collected and how the data could be used to provide a coherent picture about linear landscape features throughout EU 15.

## 2. LUCAS Transect observation and estimation

The LUCAS is based on the observation of land cover and land use within Primary Sampling Units (PSU). The territory of the EU15 is divided into grids of a size of 18 km × 18 km, and the PSU's are located at the grid (cross) points. Within each PSU, there are ten Secondary Sampling Units (SSU's), at which the corresponding land cover and land use is recorded (see Fig. 1).

[1] For more information about LUCAS, particularly the sample design and observation methods, see Eurostat (2003) and Eurostat (2004).


**Figure 1.** *Location of LUCAS Secondary Sampling Units (SSU's) and the transect within a Primary Sampling Unit (PSU)*

Systematically distributed across the whole of the EU 15, there are a total of 10,000 Primary Sampling Units and 100,000 Secondary Sampling Units in the LUCAS.

The observation of linear features takes place along each transect-line of a PSU. These lines always start at the so-called SSU 11 and end at SSU 15. In their field work, the surveyors have to observe all the intersections of different linear features with the transect along its full length of about 1200 m. Tab. 1 provides a list of the linear features which are to be recorded.

In addition to the intersecting linear features that must be recorded along the length of the transect, all land cover transitions must also be recorded. The nomenclature encompasses the eight aggregated land cover types that are presented in Table 2.





**Table 1.** *Type of linear features observed along the transects (Source: Eurostat 2003: LUCAS Technical Document N° 4)*

| Linear Feature | Width | Code | Definition/Observation |
|---|---|---|---|
| Grass margin | >1 - < 3 m<br>> 3 m | 01<br>02 | Strip of mainly uncultivated (not used for agriculture) vegetation, dominated by grasses, grass-like plants, forbs or herbs. Often located at the edge of fields, between cropped areas (beetle banks) or bordering roads and tracks (roadside verges) as well as associated with water courses. |
| Shrub or wood margin including line of trees | >1 - < 3 m<br>> 3 m | 11<br>12 | Shrubby or woody vegetation in a continuous linear shape, often managed (hedge) but also without evidence of recent management. This category also includes lines of trees. Shrub or wood margins are found as field boundaries within agricultural land or alongside roads or water courses. |
| Cultural, man made features | >1 - < 3 m<br>> 3 m | 21<br>22 | Various man made built structures e.g. walls, dams or ter races etc. of different materials, such as dry stones or bricks but also mortared walls. All walls are to be recorded, independently from their width. |
| Ditches, channels | >1 - < 3 m<br>> 3 m | 31<br>32 | "Artificial" drainage or irrigation line, usually straight, temporary or permanently wet, often as standing water. Ditches are frequently found in agricultural land to lower the water table or as drainage. They are often associated with roadside verges used to drain the runoff from the associated road. Ditches are to be recorded independently from their width. Edges or banks along a small water body are to be recorded separately as grass, shrub or wood margin. |

| Linear Feature | Width | Code | Definition/Observation |
|---|---|---|---|
| Rivers and streams | >1 - < 3 m<br>> 3 m | 41<br>42 | A linear body of water, often flowing in its naturally shaped bed through the land into a body of water such another stream, a lake or the ocean. Banks or edges (riverside vegetation) have to be recorded separately as grass, shrub or wood margin. |
| Electric lines | | 50 | Power supply line mounted on pylons used to transport electricity, including telephone lines. |
| Tracks | >1 - < 3 m<br>> 3 m | 61<br>62 | Usually rough tracks, mainly used to access agricultural land or forests, in most cases unpaved. They are not part of the public road network and are usually closed to public transport. This category includes all types of paths and cycle tracks. Roadside vegetation has to be recorded separately. |
| Roads | >1 - < 3 m<br>> 3 m | 71<br>72 | Mainly part of the official traffic road network composed of roads of different levels (urban streets to highways). Roadside vegetation has to be recorded separately. |
| Railways | | 80 | A set of rails on which trains run. Green linear features bordering the railway track are to be recorded separately. |
| Other | | 90 | Anything not specified in other classes. Description is to be given in the "Remarks". |

**Tab. 2.** *Nomenclature used to capture the transition of land cover along the transects (Source: Eurostat 2003: LUCAS Technical Document N° 4)*

| Land Cover Transitions | Code |
|---|---|
| Artificial | A |
| Arable Land | Ba |
| Permanent crops | Bp |
| Woodland | C |

| Land Cover Transitions | Code |
|---|---|
| Shrubland | D |
| Permanent grass | E |
| Bareland | F |
| Water and wetland | G |

The observation of a single transect results in a "character string" (e.g. Ba-C-E-02-Ba-12-e), in which the land cover transitions as well as the intersecting linear features are recorded in their successive sequence, across from SSU 11 to SSU 15. The "character string" provides the basis for the estimation of the length of the different linear features as well as for further analysis.

The estimation of the length of linear elements is based on the Buffon's Needle theory (DeVries 1979, Eurostat 1993). Buffon's Needle theory deals with a well-known problem in probability theory, where the question is "with what probability will a needle of a known length intersect a line, if the needle is randomly thrown onto an infinite plane on which equidistant lines at mutually known distances are drawn?" This theoretical concept can be applied and adapted to estimate the length of linear features. In LUCAS, the transects are considered as the "needles" that are "thrown" (systematically) over an area (with a known surface). As the intersects of linear features are known, the probability can be calculated. This allows the length of the network of linear features to be estimated.

In this paper, the data from the LUCAS 2003 field campaign are analysed, based on information from about 9500 transects.

## 3. Linear landscape features: concept behind indicator proposals

The starting point for the analysis of transect data and the definition of meaningful indicators on linear landscape features is the estimated length.

Tab 3 presents the estimates of the length of grass margins, shrub margins and cultural linear features, which are considered as relevant in a biodiversity or landscape context.

**Table 3.** *Estimated length of selected linear features (Source: LUCAS 2003 data)*

| Type of linear feature | Width | Estimated length (2003) in km for EU15 | in % |
|---|---|---|---|
| Grass margin | 1-3m | 4 108 043 | 34.4 |
| | > 3m | 1 137 335 | 9.5 |
| Shrub margin, row of tress | 1-3m | 2 706 268 | 22.7 |
| | > 3m | 2 276 182 | 19.1 |
| Cultural features (e.g. stone walls) | 1-3m | 1 612 533 | 13.5 |
| | > 3m | 104 921 | 0.9 |
| Total | | 11 945 282 | |

Tab. 3 shows that small grass margins were the most common linear feature in 2003, followed by shrub margins (e.g. hedges). The length of the so-called "cultural features" (mainly stonewalls) was also significant.

This estimated length of grass margins, hedges or cultural linear features serves as a first quantitative baseline indicator, against which changes can be measured. For the first time, comparable data for the entire territory of the EU 15 are available, based on a harmonised data-collection system[2].

In an agri-environmental context, however, further details are required for more precise indicators. For example, the category of "grass margins" subsumes all types of grass margins, regardless whether they are roadside verges or located elsewhere. It is a similar situation for the estimated length of shrub margins, which may be included as features within agricultural land, but also those within wetlands or public parks. The direct link to agriculture or the agri-environment is not necessarily given.

Using the LUCAS transect data, however, different types of linear landscape features which are of key interest in an agri-environmental context can be extracted. Three indicators are defined:

– Length of different types of field divides;
– Length of different types of boundary features, and
– Density of linear landscape features.

These indicators aim to narrow down the figures for the higher-level of classification to different and more specific types of linear features, by considering the surrounding "environment", i.e. the agricultural use.

The length of field divides refers to different types of linear features within agricultural land, those surrounded by cropland, permanent crops or grassland. This type of linear feature divides the agricultural countryside into a diverse mosaic of agricultural parcels and a close network of corridors.

[2] Due to the current LUCAS sample size, which is adapted to provide information at EU 15 level, a territorial breakdown at national level is limited. Reliable and accurate data with an acceptable statistical precision can only be obtained for large countries.

**Figure 2.** *Examples of field divides (cultural features and green linear features) (Source: LUCAS landscape photo archive)*

**Figure 3.** *Examples for boundary features (Source: LUCAS landscape photo archive)*



Boundary features are defined as all those linear features that border agricultural land on one side and non-agricultural land on the other one.

Both indicators give a first indication of the abundance of linear features within agricultural land.

An alternative way of presenting the presence of linear features within agricultural landscapes is to calculate their density within the countryside as a commonly used measurement.

## 4. Transect data processing

The calculation of the length of field divides and boundary features is based on the analysis of the sequence of transect codes ("character string") and thus requires some advanced data processing, which is outlined briefly below.

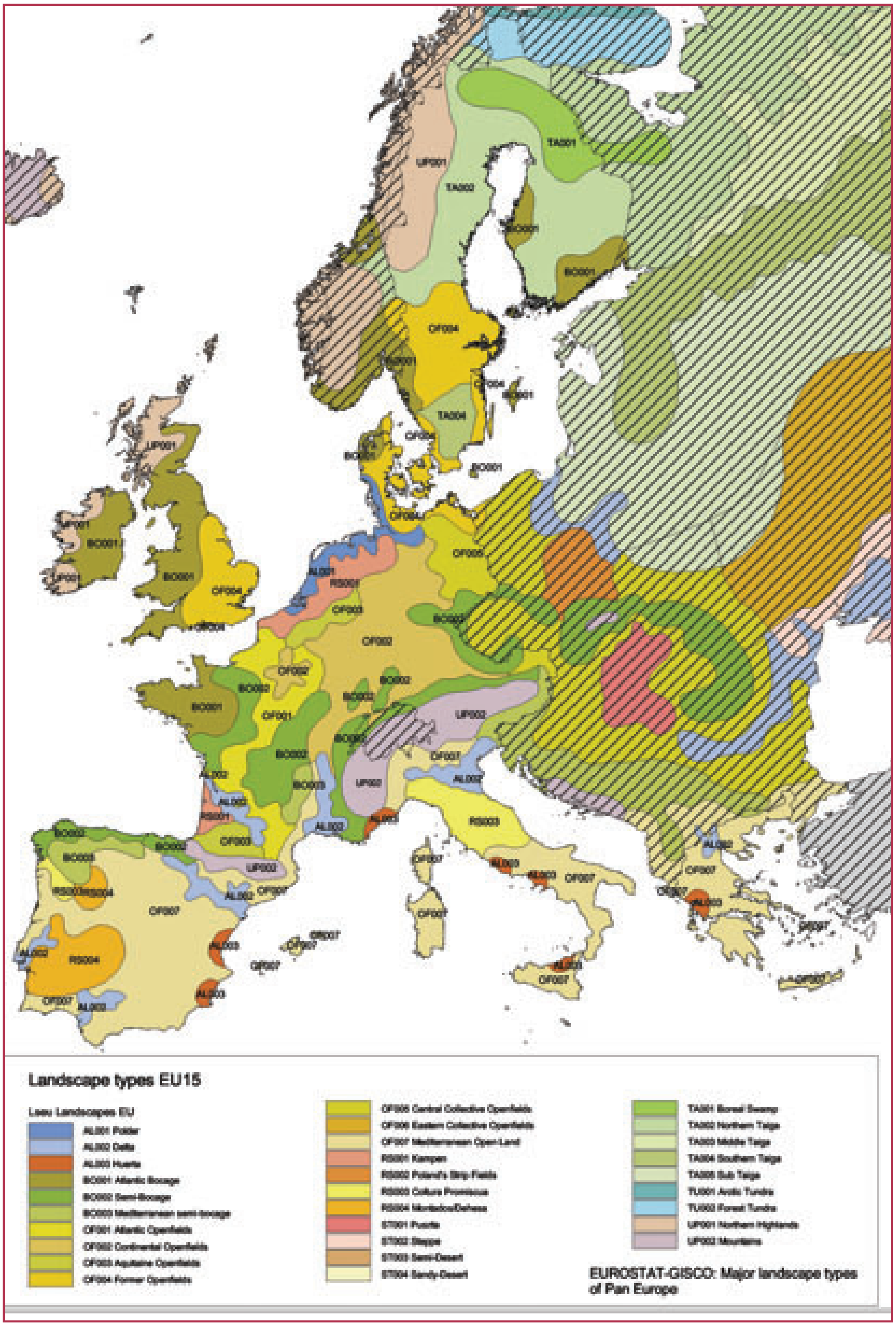
In order to obtain coherent results only complete transect observations (i.e. those transects where the entire section from SSU 11 to SSU 15 was observed) were included in the analysis.

In order to extract the different types of linear features from the LUCAS transect database, a specific Visual Basic Programme (VBA) was developed.

The principle of the algorithm can be described as follows: within the "transect character string" all green linear features (LUCAS codes 01, 02, 11, 12) as well as all cultural elements (coded as 21 and 22) are identified. They are then re-coded in a manner that links them with adjacent agricultural land cover codes for cropland (Ba) and/or permanent crops (Bp) and/or grassland (E), in order to extract only those which are either field divides or boundary features. The following rules are defined to characterise the linear features based on their spatial context:

- If a linear feature (or a combination of different linear features) is surrounded on both sides by an agricultural land cover class, then the linear features are recoded in the database as a "field divide".
- If a linear feature is bordered on one side by an agricultural cover class and by a non-agricultural cover on the other, then the linear feature is recoded as a "boundary feature".

Once the specific types of linear features are identified within each transect, their overall length is estimated. The estimation is based on the use of an expansion factor (the number of elements/total length of elements).




**Map 1.** *European Landscape Units as defined by Meeus, 1995 (hatched areas not in LUCAS) (Source: GISCO reference database)*

The calculation of the density of linear features initially requires the definition of a reference zone. Since the derivation of a single value for the EU 15 is not so meaningful, an attempt was made to relate the linear feature density to landscape units, as they are defined by Meeus (1995, see Map 1).

In a first data processing step, the landscape units were intersected with the transect location map, in order to assign each transect to a landscape unit. In a further step, the number of field divides/boundary features, as well as the number of SSU's under agricultural use, was retrieved for each of the 22 landscape units. By means of the expansion factors, the used agricultural area and the length of both types of linear feature were calculated.

**Table 4.** *Expansion factors for different types of linear features*

| Type of linear feature | Width | Code | Length in km | N° of elements | Expansion factor (av. km length per element) |
|---|---|---|---|---|---|
| Grass margins | 1-3m | 1 | 4 108 043 | 9 012 | 455.8 |
| | > 3 | 2 | 1 137 335 | 2 490 | 456.8 |
| Shrub-wood margins | 1-3m | 11 | 2 706 268 | 6 040 | 448.1 |
| | > 3 | 12 | 2 276 182 | 5 102 | 446.1 |
| Cultural features | 1-3m | 21 | 1 612 533 | 3 384 | 476.5 |
| | > 3 | 22 | 104 921 | 2 532 | 41.4 |

In a final step, both input variables were used to calculate the density of linear features, defined as the ratio of linear features to the utilised agricultural area (m/ha).

## 5. Results

The results of the compilation of these indicators are presented in the tables that follow below. Some analysis of the figures is given without alluding to them in an environmental context.

### 5.1. Length of field divides

In the European Union as a whole (EU-15), it is estimated that field divides run for an estimated 3 Mio km. Their presence within agricultural land and their upkeep depends, either directly or indirectly, on farmers.

**Table 5.** *Length of field divides (Source: LUCAS 2003 transect data)*

| Field divides | | | |
|---|---|---|---|
| Type | Width | Estimated length in km (2003) | % |
| Grass | < 3m | 449 419 | 15 |
| | > 3m | 109 058 | 4 |
| Shrubs/hedge | < 3m | 946 490 | 31 |
| | > 3m | 672 881 | 23 |
| Cultural elements | | 694 737 | 22 |
| Combined features | | 156 288 | 5 |
| Total | | 3 028 873 | |

A little over half of all the divides recorded in 2003 related to shrubs (such as traditional hedges); about 31% of all field divides were classified as shrubs of between 1 and 3m in width and a further 23% as shrubs of a width greater than 3m. Another significant share of field divides was accounted for by cultural linear elements (22% of the total). A crosscheck with the corresponding landscape images indicated that a substantial proportion of these cultural elements were stone walls. Grass margins accounted for just under a fifth (19%) of all field divides, with the vast majority of these being of a width between 1 and 3m. The figures suggest that it is unusual to see combined linear features (i.e. features composed of two to four linear elements and accounting for only an estimated 5% of all field divides).

## 5.2. Length of boundary features

The estimated length of boundary features (i.e. linear elements between agricultural and non agricultural land) in the EU 15 is calculated to have been about 5.1 Mio km in 2003. In contrast to the field divides, grass margins (particularly narrow ones) were the single most common form of boundary divide. Shrub margins also accounted, however, for a sizeable share (39%) of all boundary features. Combined linear features were observed as one in ten of boundary features.





**Table 6.** *Length of boundary features (Source: LUCAS 2003 transect data)*

| Boundary features | | | |
|---|---|---|---|
| **Type** | **Width** | **Estimated length in km** | **%** |
| Grass | < 3m | 1 835 507 | 36 |
| | > 3m | 382 342 | 7 |
| Shrubs/hedge | < 3m | 1 063 789 | 21 |
| | > 3m | 887 293 | 18 |
| Cultural elements | | 454 581 | 8 |
| Combined features | | 524 424 | 10 |
| Total | | 5 147 935 | |

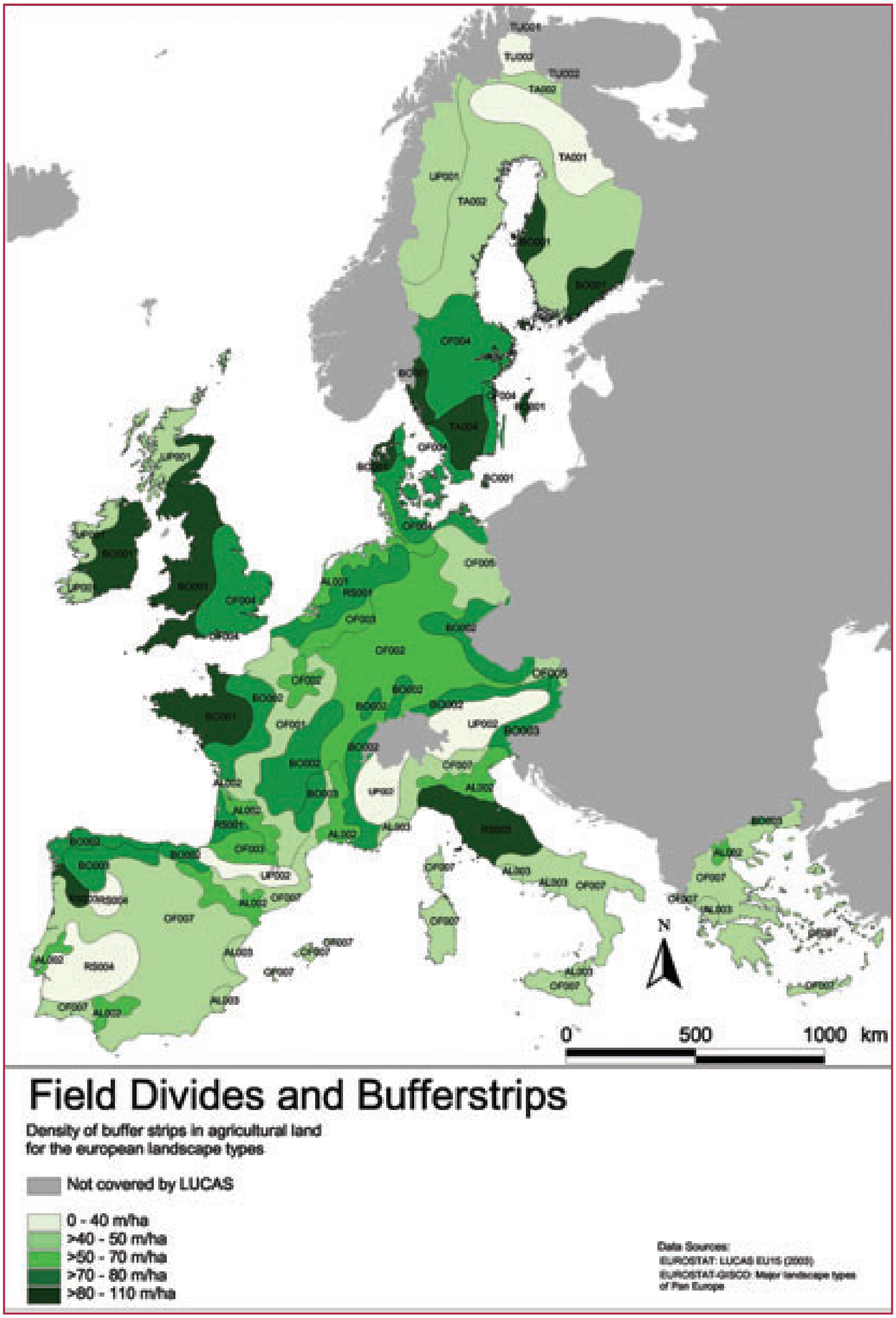
## 5.3. Density of linear features

A complementary approach to capturing the abundance of field margins and buffer strips in agricultural land is to calculate the linear feature density, commonly called “hedge density”. Linear feature density (m/ha) refers to the ratio between the length of field divides and boundary features (in metres) and total agricultural land (in hectares).

As part of the project, an attempt was made to relate this hedge density to the landscape units, as it was thought that the use of landscape units as a spatial breakdown might reveal significant differences between the landscape units and could improve the interpretation of the data. Nevertheless, there was concern that the number of transects per landscape unit using the LUCAS sample might be insufficient to derive reliable estimates for small landscape units. The landscape typology used is the one defined by Meeus (1995)[3]. Despite the fact that others are in development (oral rep. Wascher 2004), the Meeus landscape units are the only pan European landscape typology currently available.

[3] A digital version of the Meeus landscape units is available in the Eurostat GISCO reference database.

Table 7 provides an overview of the input variables used for the calculation of the density of linear features, as well as the final results for the 22 landscape units. Map 2 shows the corresponding map.




**Map 2.** *Density of linear landscape features in major landscape unit (Meeus landscape units) (Source: LUCAS 2003 data)*

**Table 7.** *Hedge density in the European landscape units*

| Landscape type | Code | N° of SSUs | Total landscape area (1000 km²) | Area under agricultural use ('000 km²) | Share of landscape agricultural use (%) | N° of Transects | N° of Buffers and Divides | Length of Buffers and Divides (in 1000 km) | Hedge Density (m/ha) |
|---|---|---|---|---|---|---|---|---|---|
| Polder | AL001 | 1 307 | 43.8 | 27.4 | 62.6 | 128 | 417 | 188.3 | 68.7 |
| Delta | AL002 | 3 533 | 118.4 | 67.0 | 56.6 | 345 | 756 | 341.3 | 50.9 |
| Huerta | AL003 | 956 | 32.0 | 11.0 | 34.4 | 95 | 98 | 44.2 | 40.1 |
| Atlantic bocage | BO001 | 9 370 | 314.1 | 187.7 | 59.8 | 902 | 3 466 | 1 564.9 | 83.4 |
| Semi bocage | BO002 | 7 425 | 248.9 | 124.0 | 49.8 | 733 | 2 021 | 912.5 | 73.6 |
| Mediterranean Semi bocage | BO003 | 2 020 | 67.7 | 24.3 | 35.9 | 199 | 426 | 192.3 | 79.2 |
| Atlantic open fields | OF001 | 3 390 | 113.6 | 69.2 | 60.9 | 335 | 736 | 332.3 | 48.0 |
| Continental open fields | OF002 | 7 852 | 263.2 | 134.0 | 50.9 | 757 | 1 909 | 861.9 | 64.3 |
| Aquitaine open fields | OF003 | 1 515 | 50.8 | 27.0 | 53.1 | 147 | 331 | 149.5 | 55.4 |
| Former open fields | OF004 | 8 238 | 276.1 | 107.4 | 38.9 | 764 | 1 766 | 797.4 | 74.2 |
| Central collective open fields | OF005 | 2 087 | 70.0 | 34.5 | 49.3 | 204 | 366 | 165.3 | 48.0 |
| Mediterranean open fields | OF007 | 17 874 | 599.1 | 308.1 | 51.4 | 1 766 | 3 114 | 1 406.0 | 45.6 |
| Kampen | RS001 | 1 996 | 66.9 | 33.3 | 49.8 | 189 | 531 | 239.8 | 71.9 |
| Coltura promiscua | RS003 | 2 488 | 83.4 | 36.0 | 43.2 | 243 | 834 | 376.6 | 104.5 |
| Dehesas/ montados | RS004 | 2 551 | 85.5 | 52.6 | 61.5 | 253 | 296 | 133.6 | 25.4 |
| Boreal swamps | TA001 | 2 893 | 97.0 | 0.9 | 0.9 | 286 | 4 | 1.8 | 20.0 |
| Northern taiga | TA002 | 9 908 | 332.1 | 15.2 | 4.6 | 967 | 148 | 66.8 | 44.0 |
| Southern taiga | TA004 | 1 171 | 39.2 | 4.5 | 11.4 | 116 | 89 | 40.2 | 90.1 |
| Artic tundra | TU001 | 10 | 0.3 | 0.0 | 0.0 | 1 | 0 | 0.0 | 0.0 |
| Forest tundra | TU002 | 612 | 20.5 | 0.0 | 0.0 | 60 | 0 | 0.0 | 0.0 |
| Northern highlands | UP001 | 5 544 | 185.8 | 41.9 | 22.6 | 527 | 455 | 205.4 | 49.0 |
| Mountains | UP002 | 3 657 | 122.6 | 23.9 | 19.5 | 359 | 177 | 79.9 | 33.4 |
| Total | | 96 645 | 3 239.3 | 1 331.0 | 41.1 | 9 376 | 17 940 | 8 100.1 | 60.9 |

The densities of linear features range from 20m/ha in the boreal swamps to 104m/ha in the Coltura Promiscua region.

When these hedge densities are displayed on a map, they seem to coincide quite well with known landscape appearances: a high hedge density in the "Atlantic Bocage" (Brittany/France, the Western parts of the UK and in Tuscany/Italy), low values in the

Dehesas/Montado landscapes in Spain and Portugal as well as in the mountain areas of the Alps and Pyrenees.

From a methodological point of view, it is important to mention that the significance of the results is determined by the sampling rate; the higher the sampling rate, the more accurate the estimates. For some landscape units, the number of transects is quite small, meaning that the hedge density in these regions is only a rough estimate (e.g. Huerta or Taiga Landscapes). In contrast, there are other units where the number of transects is substantially higher and for which estimates are considered, therefore, accurate.

There is little in the way of data and information available with which to validate the LUCAS-based estimates, nor to estimate the coefficient of variation which would provide information about the statistical precision of the hedge density calculations.

Attention must also be drawn to the fact that certain landscape units are not necessarily spatially coherent units (as seen in Map 1). For example, the "Atlantic Bocage" (BO001) can be found in Brittany (France), the UK as well as in Sweden and Finland. Differences in the hedge density (which might exist) between each individual unit are hidden, since the average is calculated over all sub-units.

Despite these reservations, it is considered that the approach adopted has much promise. For the first time, consistent and comparable information about green linear features in agricultural landscapes can be presented. Moreover, the link between linear features and landscape units seems to provide a framework better suited for interpretation and assessment.

## 6. Conclusions

The results presented demonstrate that the transect data that is collected by the LUCAS serve as a valuable data source with which to retrieve quantitative information about linear landscape features throughout the EU 15.

Given the lack of national data in many EU Member States, as well as the incompatibility of existing data sources, for the first time, consistent and comparable information about green linear features in agricultural landscapes can be provided through the LUCAS. Data about the length of field divides, boundary features and the density of linear features may serve as baseline indicators against which changes can be observed.

Moreover, the link between linear features and landscape units seems to provide a framework better suited for interpretation and assessment.

Although the sampling size for the current LUCAS pilot phase only enable statements at the level of the EU 15 as a whole and some "larger" landscape units, the potential for retrieving agri-environmentally relevant data is clear. Recurring surveys combined with an appropriate sample size could further enhance the applicability of LUCAS transect data and provide sensitive and policy relevant indicators for linear landscape features, which are of utmost importance in European agricultural landscapes.

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# Trends in "Landscape State" based on farm structural characteristics and landscape heterogeneity

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## Introduction

The Cardiff Integration Process is the process launched by European heads of state and government at the meeting in Cardiff, in June 1998 requiring the different European Councils to integrate environmental considerations into their respective activities. At subsequent meetings in Vienna (December 1998) and Helsinki (December 1999), the European Council required the Commission to report on the integration of environmental concerns into Community sectoral policies. Agri-environmental indicators (AEI) have been adopted as a tool to contribute to meeting reporting requirements to monitor environmental integration into agricultural policy. A set of AEIs was identified in the Communication from the Commission to the Council and European Parliament, COM (2000) 20, and this set, and the statistics and other information needed to realise the indicators, was the subject of a further Commission Communication COM (2001) 144.



COM (2001) 144 identifies "Landscape State" as a State indicator within the Driving Force - Pressure - State-Impact - Response environmental indicator framework, viewing it as an analytical indicator that describes the diversity and composition of agricultural landscapes at different levels across Europe. Landscape State, as an agri-environmental indicator, focuses on the role of agriculture in maintaining landscapes and describes landscape characteristics and diversity. Landscape state is the result of a variety of actions and interactions involving human activities and the environment. At the European scale, landscape state accounts for the wide range of biophysical and socio-economic conditions, both past and present.

One way of integrating different factors to understand change is to use a landscape typology as a starting point and identify measurable agricultural landscape parameters, which can be used to both typify and monitor changes. Measurable agricultural landscape parameters that can distinguish agricultural landscapes are: farm parcel sizes, linear features (such as walls, hedgerows, ditches and canals) and farm structural characteristics. This article addresses indicators based on farm structural characteristics landscape heterogeneity, that can be used to assess trends in landscape state.

## Methodology

### European Landscapes

The Dobris Report (EEA, 1995) uses the typology of Meeus *et al* (1990) as the basis for an environmental appraisal of European landscapes. The typology aims to describe the ecological, economical and cultural aspects of different types of European landscapes, with a special focus on anthropogenic influences. The interaction of human activities and natural systems that result in recognisable scenery is fundamental to the

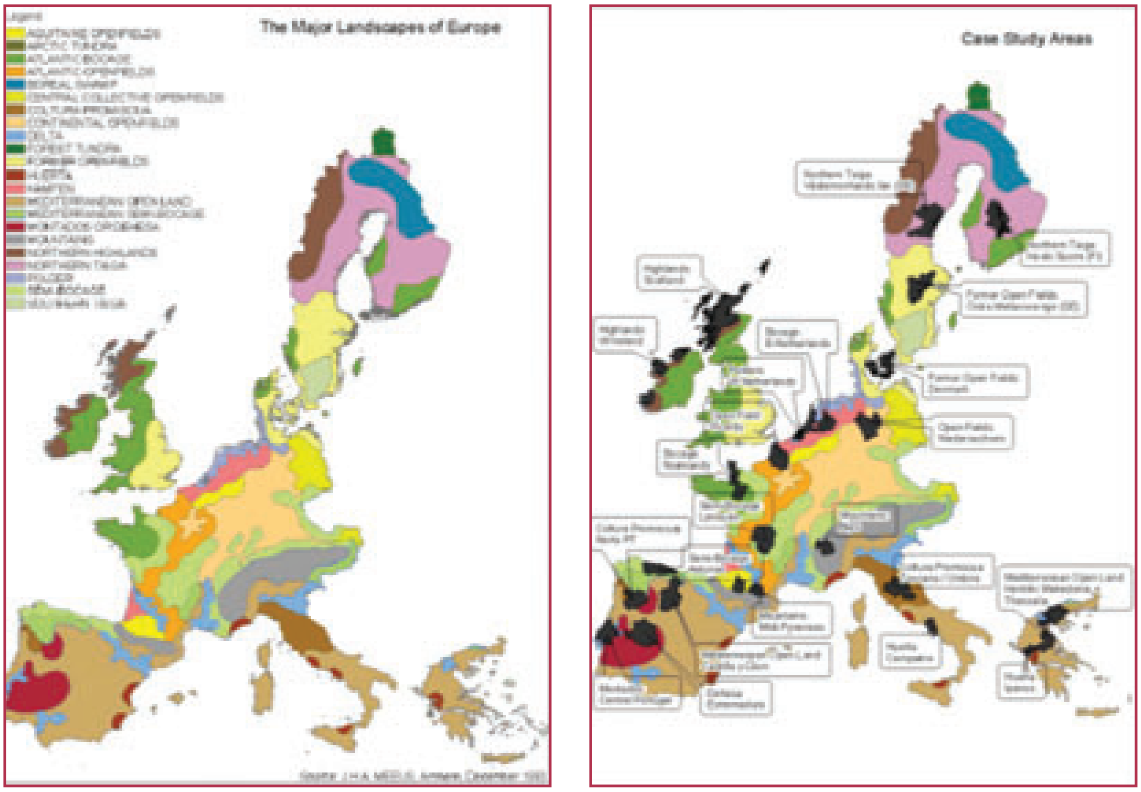


**Figure 1.** *(Left) The major landscapes of Europe (Meeus, 1990). (Right) Selected case study administrative areas representative of different landscapes*

approach. The major landscapes have a minimum area of 100 by 100 km, although several distinct but smaller landscapes are included. The emphasis is therefore on a pragmatic, qualitative, and expert judgement approach rather than an explicitly quantitative approach. The advantage of the Meeus approach is that the selected landscape classes are recognizable (and memorable) and the number of classes is small and manageable. The disadvantage is that the delineation of areas is imprecise and based on qualitative criteria.

There is a more quantitative approach being developed by Mucher *et al* (2003) to produce a European Landscape Classification (LANMAP). The core parameters for LANMAP are parent material, topography and land use. The eCognition object-oriented image classification software is used to distinguish landscape classes. Presently 202 landscapes are distinguished - a process of validation and consultation with Member States is on-going.

The Meeus typology of landscapes is currently the only landscape baseline description at European level. There are seven broad landscape categories identified by Meeus on the basis of climatology, geomorphology, soils, ecology and occupational history (left): Tundra, Taiga, Uplands, Bocage, Open Fields, Regional Landscapes, Artificial landscapes. A description of each landscape is provided in Annex 1.

A case study approach is adopted to investigate the importance of agriculture in maintaining landscapes. An overlay analysis of administrative regions and the map of major landscapes is carried out to select administrative regions that are representative of particular landscapes (Figure 1 (right) and Annex 1).

## Landscape parameters

The Farm Structure Survey (FSS) is used to assess the importance and characteristics of agriculture in the selected case study areas. The FSS is an agricultural census survey designed to report on the structure of agricultural holdings across the European

Union. Information is collected on land use, livestock, farm holder characteristics, and the labour force. The survey is carried out by the statistical services of each Member State. A full census survey is done every 10 years (e.g. 1990 and 2000), and sample survey is done in the third, fifth, and seventh year of a decade (e.g. 1993, 1995 and 1997). Data is transferred to EUROSTAT for compilation and validation in the EUROFARM database system.

The Land Use/Cover Area Frame Statistical Survey (LUCAS) is a survey carried out by EUROSTAT, which collects data on land use/cover, agricultural practices and environmental features, at approximately 100 000 observation points across EU 15. The survey was carried out for the first time in 2000, and will be repeated every year. One of the particularities of the LUCAS survey is the fact that this survey is the only one containing observations of land cover and linear features along *transects*. The surveyors observe land cover transitions and linear features along transect-lines of about 1200 m.

Three landscape parameters are developed on the basis of FSS data: Agricultural importance index, Land use importance, Agricultural intensity index (Table 1). Two indicators can be derived from the LUCAS transect dataset: the Land Cover Transition Index and the Fragmentation Index (Table 1).

**Table 1.** *Landscape parameters developed on the basis of Farm Structure Survey data and the LUCAS transect data.*

| Landscape parameter | Description | Data Source | Calculation |
|---|---|---|---|
| Agricultural importance index (AgrII) | Percentage area of agricultural land | FSS | AgrII = Total agricultural area /area of administrative region |
| Agricultural land use importance index (AgrLUII) | Distribution of broad agricultural land use classes | FSS | AgrLUII = Percentage distribution of Arable, Permanent grasslands, Permanent crops, and Other land |
| Agricultural intensity index (AgrIntI) | Ratio between the mean farm economic size in ESU and the mean farm size area in ha | FSS | AgrIntI = mean farm economic size/mean farm size area |
| Land Cover Transition Index (LCTI) | Number of land cover transitions per kilometer | LUCAS | LCTI = number of transitions / km |
| Fragmentation Index (FI) | Number of land cover transitions and linear elements per kilometer | LUCAS | FI = Number of land cover transitions (with or without linear element in between) + number of linear elements (between identical land covers) per km |

The *Agricultural importance index* (AgrII) indicates the role that agriculture has in a particular region. High index values show that agriculture is important in maintaining and managing landscape, whereas low values indicate that agriculture is less important. In areas where low values occur, forestry, semi-natural, water, or urban land uses are more important.

The *Agricultural land use importance index* (AgrLUII) provides an indication of the type of crops prevalent in a case study area. The land uses are grouped according to arable, permanent grasslands, permanent crops, and other land. Other land includes the following categories: kitchen gardens, unutilised agricultural land and wooded areas.

The *Agricultural intensity index* (AgrIntI) for a region is calculated by dividing the mean economic size of farms (i.e. the standard gross margin[1] for the area divided by the number of holdings) by the mean area of farms (i.e. the agricultural area divided by the number of holdings). High values of AgrIntI indicate that production is more intensive, because there is predominance of large, productive farms in the region, whereas low values of AgrIntI indicate that production is less intensive, because there is predominance of small, less productive farms in the region.

The *Land Cover Transition Index (LCTI)* for a region is the average number of land cover transitions along a transect line of 1 km. The index value is high in areas with a many small plots with different land covers. Regions with a homogeneous land cover and large (agricultural) plots have a low Land Cover Transition Index.

The *Fragmentation Index* indicates how much of the landscape is broken up by changes in land use and the occurrence of linear features. The fragmentation index of a region is always higher than the LCTI, because linear elements between identical land cover types are taken into account in the Fragmentation Index, and not in the Land Cover Transition Index.

The Land Cover Transition Index as well as the Fragmentation Index are indicators representing the degree of landscape heterogeneity: small-scale, heterogeneous, “closed” landscapes have a high LCTI/FI, while large-scale, homogeneous, “open” landscapes have a low LCTI/FI.

For the indicators derived from the LUCAS transect data (LCTI and FI), no time series are available yet at the time of research (summer 2003), but they will become available in the future.



# Results



## Agricultural importance index

Landscapes where agriculture plays an important role (i.e. AgrII>0.5) are the bocage (semi-), dehesas/montados, open field, Mediterranean open field, polder and coltura promiscua. Agriculture plays a minor role (i.e. AgrII<0.5) in taiga, mountain and northern highlands landscapes (Figure 2). There are no major changes in the AgrII between 1990 and 2000. In 13 case study areas the AgrII has declined slightly, whereas in 6 case study areas the AgrII has increased slightly. The largest increases have occurred in Mediterranean Open Land: Castilla y León (ES) (0.72 to 0.83) and Semi-Bocage: Principado de Asturias (ES) (0.58 to 0.64). Increases indicate that more land has been taken into production. In EU-15 this is an unlikely occurrence, unless land under fallow was not registered in 1990. The largest decreases have occurred in Coltura promiscua: Toscana / Umbria (IT) (0.81 to 0.74) and Bocage: Normandy (F) (0.84 to0.79). Decreases imply agricultural land being taken out of production - being converted to wooded or conservation areas.

## Agricultural land use importance index

The land use importance index shows that arable crops are predominant (i.e. $LUII_{arable}$ > 50%) in the following landscapes: polder, open fields, Mediterranean open land, and former open field landscapes. Permanent grasslands are predominant (i.e. $LUII_{grasslands}$ > 50%) in bocage, dehesas/Montados, mountains and northern highlands landscapes. Permanent crops play an important role (i.e. $LUII_{permanent\ crops}$>10%) in Coltura promiscua and Huerta landscapes. There are no significant changes in the dis-

[1] The standard Gross Margin (SGM) of a crop or livestock item is defined as the value of output from one hectare or from one animal less the cost of variable inputs required to produce that output

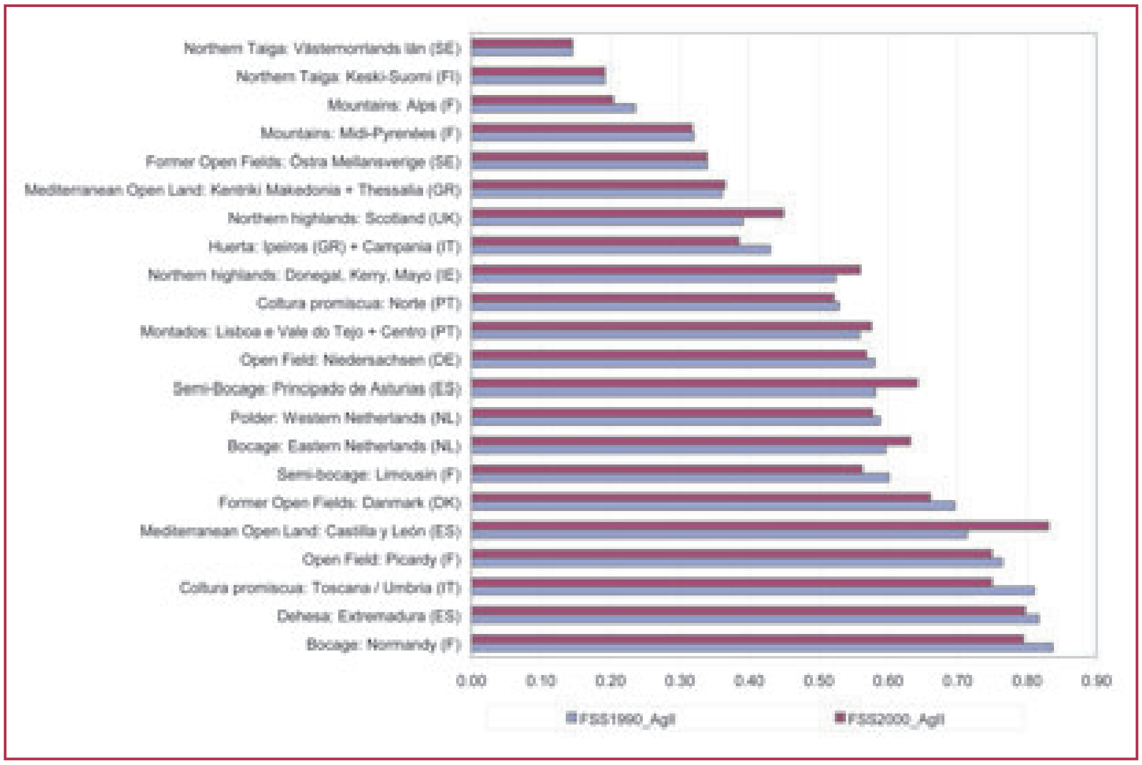


**Figure 2.** *Change in the agricultural importance index between 1990 and 2000 for selected case study administrative areas*[2]

tribution of general agricultural land use classes between 1990 and 2000 in the selected case study administrative areas (Figure 3 and Figure 4).

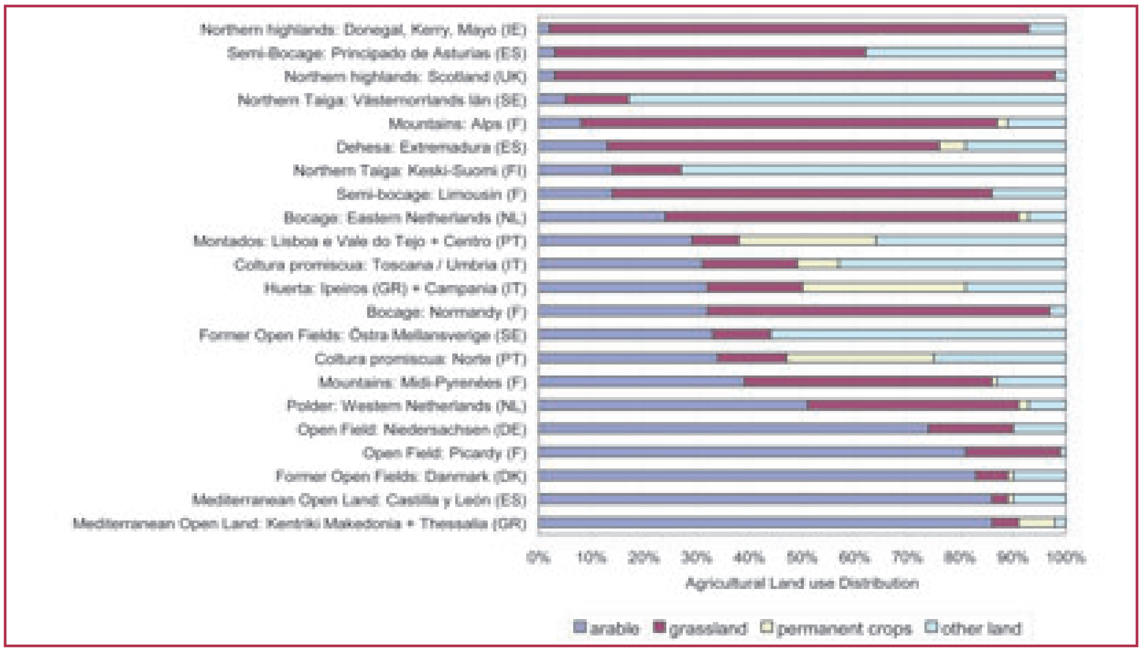


**Figure 3.** *Distribution of general agricultural land use classes (arable, grassland, permanent crop, other land) for selected case study administrative areas in 1990*[1]

[2] 2000 data is used instead of "no data" Västernorrlands län (SE), Östra Mellansverige (SE) and Keski-Suomi (FI) in 1990 data.

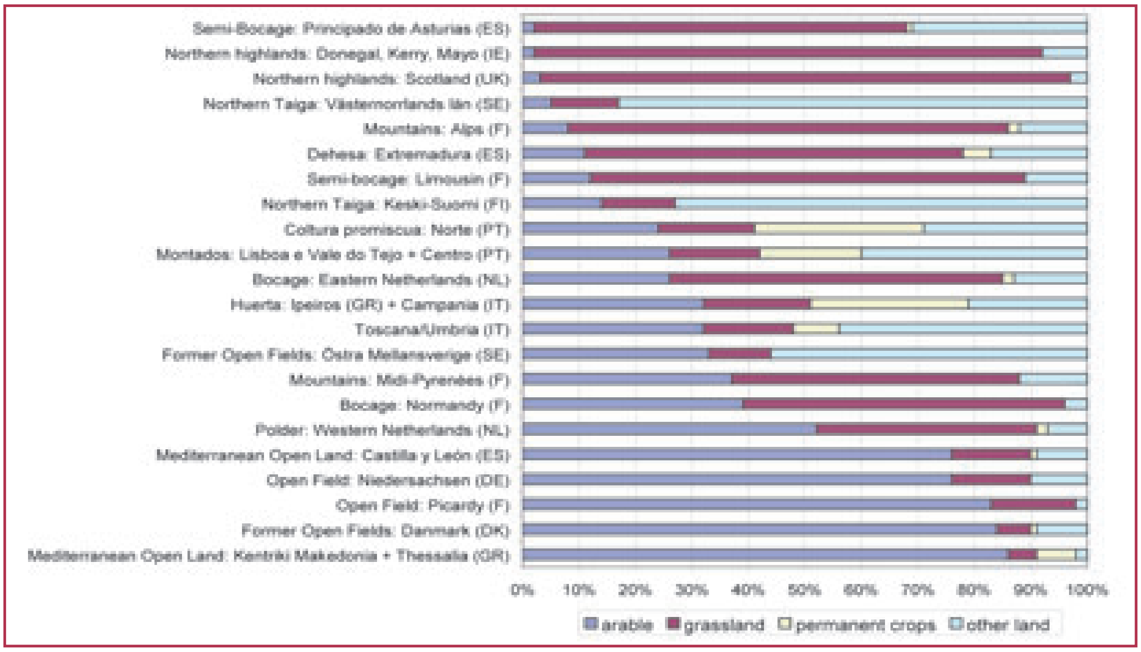


**Figure 4.** *Distribution of general agricultural land use classes (arable, grassland, permanent crop, other land) for selected case study administrative areas in 2000*

## Agricultural intensity index

The agricultural intensity index shows increases of intensity in the polder, bocage and herta landscapes (Figure 5). On the other hand the agricultural intensity index shows decreases of intensity in the coltura promiscua, Mediterranean open lands, and open fields. There is a surprisingly large decrease in intensity for the mountain landscapes - this is most likely due to an erroneous submission of SGM data for these regions in 1990.

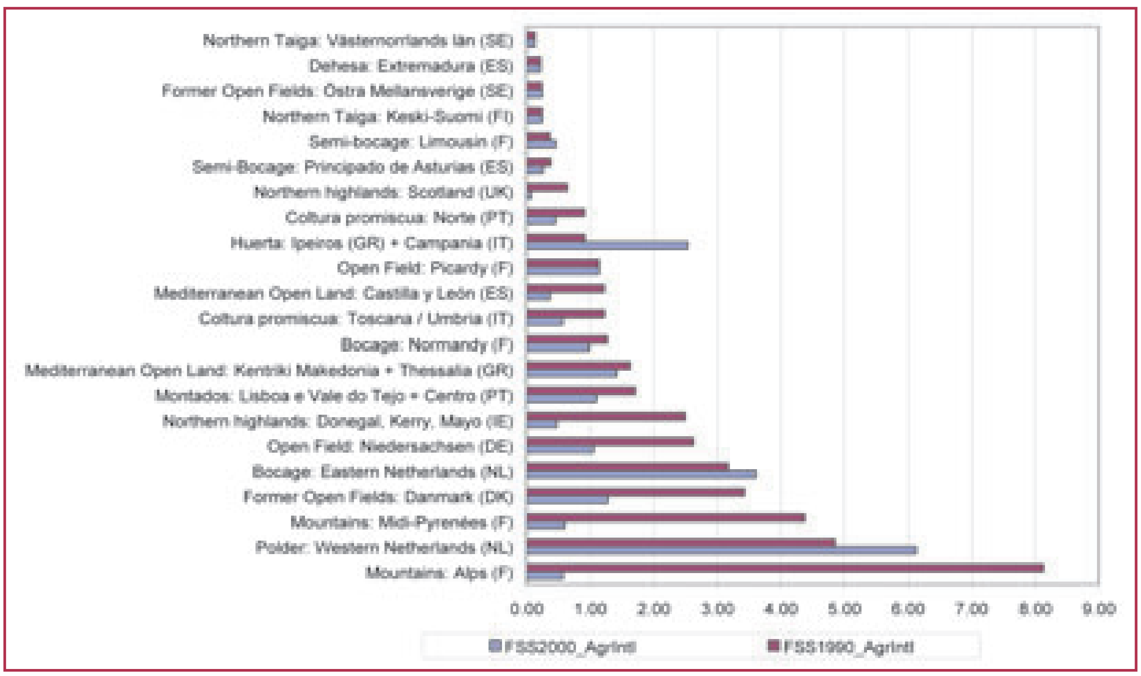


**Figure 5.** *Change in the agricultural intensity index between 1990 and 2000 for selected case study administrative areas*

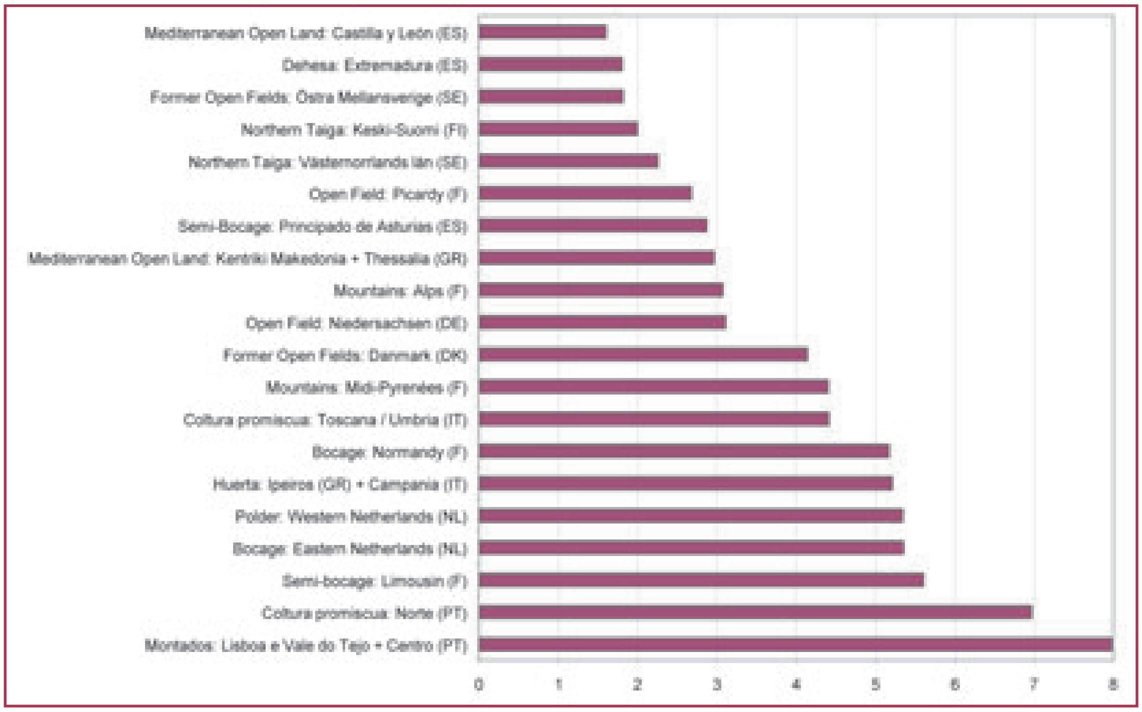


**Figure 6.** *Land Cover Transition Index for selected case study administrative areas in 2000*

## Land Cover Transition index

The Land cover transition Index has an average value across Europe of 3.69 land cover transitions per kilometer. The range for the case study areas is from 1.6 (Mediterranean Open Land) to 7.98 (Central Portugal). The highest number of Land Cover Transitions occur in the small scale farming lands of the Montados, Coltura Promiscua, Mountain areas, (semi-) Bocage, Polder and Huerta landscapes (Figure 6).

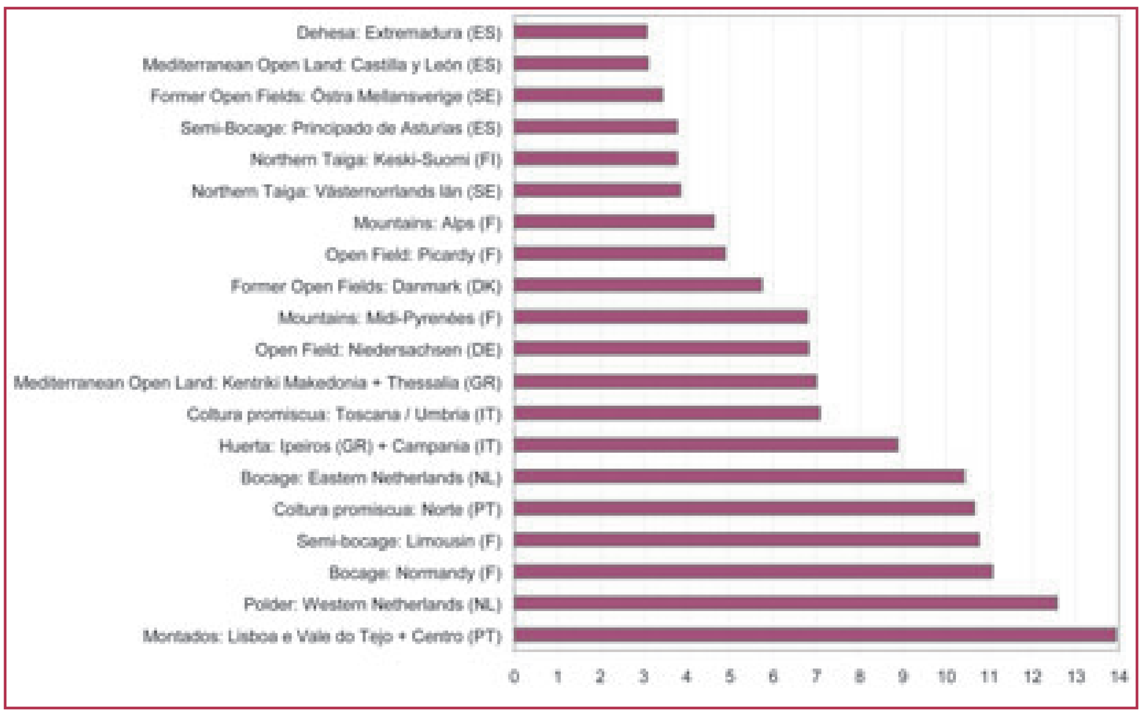


**Figure 7.** *Fragmentation Index for selected case study administrative areas in 2000*

## Fragmentation Index

The Fragmentation index indicates how much of the landscape is broken up by changes in land use and the occurrence of linear features. The fragmentation index for Europe is 6.45. The range for the case study areas is 3.07 (Dehesa: Extremadura) to 13.93 (Montados of Central Portugal). In general the fragmentation is very high for the (semi)Bocage, the Montados of Central Portugal and the Polder landscape of the Netherlands (index = 10 to 14). In Extremadura the fragmentation is surprisingly low (3.07). This can be explained by the fact that many small walls or hedges are not registered in the LUCAS dataset, although these linear elements occur very frequently.

# Discussion and Conclusion



The five landscape parameters based on data from the Farm Structure Survey provide useful insights into the importance of agriculture and its characteristics for landscapes across Europe. Where agriculture plays an important role, it is interesting to investigate whether there have been significant changes in the structural characteristics of agriculture.

The AgrII shows agriculture is important for bocage (semi-), dehesas/montados, open field, Mediterranean open field, polder and coltura promiscua landscapes. It is therefore possible on this basis to distinguish between agricultural and non-agricultural landscapes.

The AgrLUII shows that there are no major changes in the distribution of land use types in the agricultural landscapes, but the AgrIntI shows some changes in the intensity of farming. There is an increase of farming intensity in Bocage and Polder landscapes, whereas there is a decrease in farming intensity indicated for open field landscapes. The Bocage and Polder landscapes are typified by small to medium scale farms - so the increasing intensity implies larger farms. On the other hand the Open Field landscapes generally feature large, arable farms so the decrease in intensity implies a decrease in productivity, rather than a change in farm size.

The indicators above show that the FSS dataset is a useful and reliable dataset to distinguish between the characteristics of European landscapes. Results show that there have been no siginificant changes in the case stusy landscape between 1990 and 2000. What is perhaps more important to note is that differences in index values between landscapes shows the wide diversity of agricultrual landscapes across Europe. This obvious heterogeneity is supported by the two indices derived from the LUCAS survey. Although LUCAS is designed to provide information representative for EU-15 - there are large variations in the index values for change in lancover types and the occurrence of linear features. The index values correspond to known landscape features recognised in the respective landscapes, with the possible exception of landscapes in the Extremadura region.

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**Annex 1.** *Major European landscape types and selected case study areas* (continue)

| Landscape | Landscape characteristics | Representative Regions | Selected case study areas |
|---|---|---|---|
| A. Tundra's | **Naturally treeless, sparsely vegetated, inaccessible lowlands and valleys above the Arctic circle** | | |
| A.1 Forest tundra | Boreal forests, thin and open. No dense forests, only bare rocks. | Northern Finland | — |
| B. Taiga's | **Coniferous forests of the boreal zone in Scandinavia** | | |
| B.1 Boreal Swamp | Wet, sparsely forested areas with an open scenery. Peat lands, with bogs and fens. | Northern Finland and Sweden | — |
| B.2 Northern taiga | Semi-open coniferous forest in the hills and plains of the Nordic and the northern Russian region. | Large parts of central Sweden and Finland | Västernorrlands län (SE071), Keski-Suomi (FI141) |
| B.4 Southern taiga | Semi-open forest landscape, expanding in an easterly direction from the Gulf of Finland to the Ural mountains. | Southern Sweden | — |
| C. Uplands | **Occurrence of high mountains with a strongly dissected topography and alpine climate or highlands on middle mountains in temperate zone. Both are rocky, desolate and wild** | | |
| C.1 Northern highlands | Open landscapes, on a hilly and mountainous terrain. | West Ireland, Scotland and Norway | Scotland (UKM44/UKA3), Donegal, Kerry, Mayo (IE00102, IE00703, IE00803) |
| C.2 Mountains | Alpine landscape with glaciers, bare rocks and steep slopes on the one hand, and forests, pastures and valleys on the other. | Alps and Pyrenees | Alps (FR717), Midi-Pyrenees (FR621, FR626) |
| D. Bocages Enclosed landscapes | **Enclosed landscapes where the mosaic of small plots, surrounded by hedges, trees, forests or walls betrays the influence of a long history of in- and extensive cultivation** | | |
| D.1 Atlantic bocage | A mosaic of plots, each surrounded by a wall or hedge. | W-France, E-Ireland, W-England, E-Denmark, SE-Norway and SW-Sweden | Normandy (FR252, FR513), Eastern Netherlands (NL21, NL22) |
| D.2 Semi-bocage | Bocage landscape with fewer hedges, more walls, more fallow land and larger forests. | Massif Central (F), Galicia (ES), northern foothills of the Alps, Atlantic coast of Spain | Limousin (FR631, FR632, FR633), Principado de Asturias (ES12) |
| D.3 Mediterranean semi-bocage | Dry and extensively cultivated semi-bocage landscapes in a hilly and mountainous terrain. The landscape is a mixture of open and enclosed areas. | N-Portugal, NW-Spain, SE-Austria, N-Greece (Drama) | — |

**Annex 1.** *Major European landscape types and selected case study areas* (continue)

| Landscape | Landscape characteristics | Representative Regions | Selected case study areas |
|---|---|---|---|
| E Open Fields | Extremely open landscape of wide undulating plains with regular plots of arable land on fertile soil | | |
| E.1 Atlantic open fields | High level of openness, fertile loamy and clayey soils, temperate marine climate. | Central France (from N to S): Picardy - Loiret - Indre - Charente - Tarn - Aude | Picardy (FR302, FR223) |
| E.2 Continental open fields | Contain more forests and pastures and less large-scale arable land. | NW Europe from the Paris Basin to middle Germany | Niedersachsen (DE91, DE92) |
| E.3 Aquitaine open fields | A mosaic of plots in an open scenery and a great variety of crops. | South western France, Loess region of Nord (FR) - Flanders (BE) and Köln-Düsseldorf (DE) | — |
| E.4 Former open fields | Hybrid semi-open landscapes on hilly terrain. | South west England, east Denmark and south Sweden | Östra Mellansverige (SE024, SE025), Denmark (DK003, DK004, DK005, Dk006, DK008) |
| E.5 Central collective open fields | Large-scale, almost treeless, open landscape on undulating plains, intensively used for arable crops, with a large-scale network of rural roads and collective farms. | Eastern Germany and Austria | — |
| E.6 Mediterranean open land | High level of openness, fertile loamy and clayey soils, temperate marine climate. | Spanish highlands, mountain regions of north and south Italy, Greece | Castilla y León (ES414, ES418), Kentriki Makedonia + Thessalia (GR121, GR122, GR123, GR126, GR141, GR142) |
| F. Regional landscapes | **Answer of cultivation and management to specific local and regional conditions of land form, soil, climate or habitation** | | |
| F.1 Kampen | Enclosed landscapes, with a patchwork lay-out of woods, heath, swamps, mixed crops, scattered farmsteads and roads. | Vlaanderen (B), south and east Netherlands and Nordrein Westfalen (D) | — |
| F.2 Coltura promiscua | Enclosed landscape, characterised by intensive traditional mixed farming. | Middle Italy | Toscana / Umbria (IT518, IT519, IT521), Norte (PT117, PT118) |
| F.3 Montados / dehesa | Savannah or grazed thin forest landscape. | South Portugal and south west Spain | Lisboa e Vale do Tejo + Centro (PT123, PT131, PT134, PT135), Extremadura (ES432) |

**Annex 1.** *Major European landscape types and selected case study areas*

| Landscape | Landscape characteristics | Representative Regions | Selected case study areas |
|---|---|---|---|
| G. Artificial landscapes | **Man has taken over the landscape forming process almost completely during a long period of time** | | |
| G.1 Polder | Flat open landscapes in the lowlands of North Western Europe. | West Netherlands and Niedersachsen | Western Netherlands (NL32-33-34) |
| G.2 Delta | Open, flat landscapes near rivers and outwash plains of mountainous areas. | Taag (P), Guadalquiver and Ebro (ES), Po (I), Thessaloniki Plain (G), Rhone and Gironde (F) | — |
| G.3 Huerta | Compact, intensively cultivated agricultural areas. | Along the coast of the Mediterranean Sea | Compania (IT801, IT803, GR214) + Ipeiros (GR211) |

# Acronyms

| | |
|---|---|
| AEI | Agri-Environmental Indicator |
| AEM | Agri-Environmental Measure |
| AgrII | Agricultural Imortance Index |
| AgrLUII | Agricultural land use importance index |
| AgrIntI | Agricultural intensity index |
| BIOPRESS | Linking pan-European land cover change to pressures on biodiversity |
| CAP | Common Agricultural Policy |
| CLC | CORINE Land Cover |
| CLC90 | CORINE Land Cover 1990 |
| CLRTAP | Convention on Long-Range Transboundary Air Pollution |
| DG | Directorate General |
| EAGGF | European Agricultural Guidance and Guarantee Fund |
| EC | European Commission |
| ED | Edge Density |
| EMEP | Programme for Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe |
| ETC | European Topic Centre |
| ETC-NPB | European Topic Centre on Nature Protection and Biodiversity |
| ETC-TE | European Topic Centre on Terrestrial Environment |
| EU | European Union |
| Eurofarm | Project for standardisation of methods for obtaining agricultural statistics |
| FI | Fragementation Index |
| FSS | Farm Structure Survey |
| GIS | Geographical Information System |
| GISCO | Geographic reference database of the Commission |
| GMES | Global Monitoring for Environment and Security |
| GPS | Global Positioning System |
| GRS80 | Geodetic Reference System of 1980 |
| IACS | Integrated Administration and control system |
| ID | IDentification number |
| IRENA | Indicator reporting on the integration of environmental concerns into agricultural policy |
| JRC | Joint Research Centre of the EC |

| | |
|---|---|
| LADAMER | Land Degradation Assessment in Mediterranean Europe |
| LANMAP | European Landscape Classification |
| LCC | Land Cover Change |
| LCF | Land Cover Flow |
| LCTI | Land Cover Transition Index |
| LEAC | Land Ecosystems ACcounts |
| LFA | Less Favored Areas |
| LPIS | Land Parcel Identification System |
| LUCAS | Land Use / Cover Area statistical Survey |
| LUCAS | Land use/cover area frame statistical survey. |
| MARS | Monitoring Agriculture with Remote Sensing |
| MSC-W | Meteorological Synthesizing Centre - West |
| Natura2000 | a coherent ecological network of special areas of conservation across the European Union |
| NFI | National Forest Inventory |
| NUTS | Nomenclature of Territorial Units for Statistics |
| OECD | Organisation for Economic Co-operation and Development |
| OTS | On-The-Spot (checks) |
| OTSC | On-The-Spot Checks |
| PAR | Perimeter Area Ratio |
| PELCOM | Pan-European Land Use and Land Cover Monitoring |
| RD | Rural Development |
| RDP | Rural Development Policy |
| RMSE | Root Mean Square Error |
| RS | Remote Sensing |
| SAC | Special Areas of Conservation |
| SPA | Special Protection Area to conserve the 187 bird species and sub-species listed in Annex I of the Birds Directive as well as migratory birds |
| SCI | Sites of Community Importance to conserve the 253 habitat types, 200 animal and 434 plant species listed under the Habitats Directive |
| SDI | Shannon Diversity Index |
| TERUTI | Utilisation du Territoire, French statistical survey of land cover and land use. |
| UAA | Utilised Agricultural Area |
| UGFP | Usual Good Farming Practices |
| UNECE | United Nations Economic Commission for Europe |
| VHR | Very High Resolution |

# Glossary

**Agri-environmental indicators.** Parameters to help to monitor and assess agri-environmental policies and programmes and to provide contextual information for rural development in general; to identify environmenatl issues related to agriculture, to help target programmes that address agri-environmental issues, to understand the linkages between agricultureal practices and the environment. They should be responsive, analytically sound, measurable, easy to interpret and cost effective.

**Area Frame Survey.** Survey carried out on an area sampling frame.

**Area Sampling Frame.** Sampling frame defined by a subset of a two-dimensional space. Most often it is a geographic space in a given topographic projection. The elementary units can be points or area units, often named segments.

**Bias.** There are two types of errors in an estimation method: sampling errors are generally balanced: they can be positive or negative and their average is approximately zero. Other types of error are often systematic and their average is generally not zero. The average (the expectation in more rigorous terms) of such errors is termed "bias".



**Bio-geographic region.** These are regions with similar climate conditions and similar natural vegetation.

**Breeding Bird Survey.** Large-scale long-term monitoring of breeding bird populations, usually organized at a national scale with a sampling design and standardized sampling method. Breeding birds are counted each spring on fix sites by same observers at similar dates in similar meteorological conditions.

**Cokriging.** A statistical interpolation method that uses data from multiple data types (multiple attributes) to predict values of the primary data type. Cokriging also provides standard errors of the predictions.

**Compactness index.** The compactness index corresponds to the ratio of the surface and the perimeter and it is calculated for each category of land cover.

$$K = \frac{4 \prod S}{P^2}$$

This index qualifies the shape of the patches. For the same area, when the index decreases, the perimeter increases and the coverage edges are more pronounced.

**Confusion matrix.** Correspondence table for two classification criteria for the same population with the same nomenclature and the same reference time. Usually one of the criteria is more reliable than the other.

**Contingency table.** See correspondence table.

**CORINE Land Cover (CLC).** CLC is one of a number of inventories undertaken in the framework of the EC CORINE Programme between 1985 and 1998. Its aim is to provide the European Commission and Member States with reliable quantitative information on land cover, which is consistent and comparable across Europe. The CLC database can generate simple cartographic representations or statistical overviews and also provides one of the inputs for the production of more complex information on other environmental themes. Updating of the CLC database for the year 2000 in Europe is going on and expected to finish in 2004.

**Correspondence table (Contingency table).** A contingency table describes the behaviour of two categorical variables on a population or set of observations. Each cell (i,j) of the table gives the number of observations in category i of the first variable and category j of the second variable. When the two categorical variables have the same nomenclature, the contingency table is often named confusion matrix.

**Declustering.** Method used to weigh the elements of a purposive or preferential sampling (unbalanced) inversely to the density of the sample in each area (cluster) of a certain partition. This method may give problems on the edges of the region under analysis.

**Detrending.** Decomposition of a process into a smooth trend and a random stationary (possibly autocorrelated) process.





**Disaggregation (Spatial).** Spatial transfer of data from units to embedded sub-units. A common transfer is based on the principal of areal weighting.

**EFTA.** European Free Trade Association. Iceland, Liechtenstein, Norway and Switzerland are members of EFTA. The EFTA Convention established a free trade area among its Member States in 1960.

**EMEP.** The Convention on Long Range Transboundary Air Pollution (LRTAP) was signed in 1979. It establishes a broad framework for cooperative action on reducing the impact of air pollution and sets up a process for negotiating concrete measures to control emissions of air pollutants through legally binding protocols. In this process, the main objective of the EMEP programme (Co-operative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air pollutants in Europe) is to regularly provide Governments and subsidiary bodies under the LRTAP Convention with qualified scientific information to support the development and further evaluation of the international protocols on emission reductions negotiated within the Convention.

**EU-15.** The European Union with 15 member states, between 1 January 1995 - 30 April 2004.

**EU-25.** The European Union with 25 member states since 1 May 2005.

**Eurofarm.** Eurofarm is a database containing data in the form of standard tables from the Farm Structure Survey.

**Eurostat.** Statistical office of the European Communities. Eurostat, which is based in Luxembourg, is one of the directorates general of the European Commisison. Its mission is to provide the European Union with a high-quality statistical information service. Eurostat uses uniform rules for collecting statistical data from the national statistical services, in particular from the member states of the European Union.

**Farm Structure Survey.** Farm Structure Survey is a European Survey on Agricultural holdings It consists of a census organised every 10 years to which are added intermediate surveys by sample survey every two or three years. The first survey, carried out 1966/67, arose from the need to have harmonised information at the Community level. Since then, regulatory texts have defined the methodological frameworks and the contents of the survey's questionnaires.

**Fuzzy.** The concept of fuzziness was introduced in the 60's into set theory and logics to cope with situations in which a sentence is not fully true or false, but something in between. A value between 0 and 1 is used to describe the degree or truth or the degree of belonging to a subset.

**GISCO.** Geographic Information System of the Commission. GISCO is based in Eurostat.

**Grid.** An abstraction of the real world where spatial data is expressed as a matrix of array of equally sized square cells or pixels arranged in rows and columns, with spatial position implicit in the ordering of the pixels.

**GRS80.** The geodetic reference system of 1980 is a geodetic reference system consisting of a global reference ellipsoid and a gravity field model. The GRS80 is defined by its semi major axis (the equatorial radius) and flattening, that expresses the flattening of the earth at the poles.



**IACS: Integrated Administration and Control System.** The system to be set up by EU Member States for the management and control of agricultural subsidies. It includes a GIS that contains the reference for the identification of agricultural parcels.

**Infrared.** An electromagnetic radiation of a wavelength longer than visible light but shorter than microwave radiation. Infrared radiation is composed of three orders of magnitude, near, middle and far, according to wavelengths, between 700 nm and 1 mm.

**Kriging.** A statistical interpolation method that uses data from a single data type (single attribute) to predict (interpolate) values of that same data type at unsampled locations. Kriging also provides standard errors of the predictions.

**Lambert's Azimuthal Equal Area projection.** A projection, which maps a sphere (or spheroid) onto a plane. Azimuthal projections are projections that are radially symmetric in all directions from the centre point of the map. Cartographic features are mapped according to their true area. It was first presented by Johann Heinrich Lambert in 1772.

**Land cover flow.** Given a nomenclature in $K$ classes, the land cover flow is described by a $K$ x $K$ matrix giving the area that has changed from land cover $c$ to land cover $c'$.

**Land cover profile of a part of the territory.** For a given portion of territory, we call here land cover profile the proportions of different land cover classes with a given land cover nomenclature at a given scale.

**Land use/land cover.** Although the meaning of both expressions is rather obvious, they are sometimes used in a careless way mixing with each other. In the LUCAS nomenclature the difference between both concepts is essential: e.g. permanent grassland is a class of land cover and not of land use. It may correspond to several land use classes: agricultural, residential, sport, etc.

**Land use flow.** Similar to “land cover flow”

**Landscape metrics.** Numerical indicators that describe specific aspects of the landscape structure.

**Landscape structure.** In this volume this expression only refers to aspects of the landscape that can be quantified from land cover or land use information.

**Least squares criterion.** Technique to fit a model in such a way that the sum of squares between the real values and the estimated or foreseen values is minimised.

**Linear regression model.** Describes the linear relationship between two quantitative variables on the basis of the least squares criterion.

**LUCAS: Land Use/Cover Area statistical Survey.** European wide survey on land use and land cover, launched in 2000 by Eurostat, in collaboration with the Directorate-General for Agriculture of the European Commission (DG AGRI) and the Joint Research Centre (DG JRC) in response to Decision 1445/2000/EC of the European Parliament and the Council on the application of area surveys and remote-sensing techniques to agricultural statistics for 1999 to 2003 (prolonged until 2007 by decision 2066/2003/EC).
In 2001, the LUCAS survey was carried out for the first time in the EU15, followed by a second pilot survey in 2003. Currently the LUCAS 2006 pilot survey at EU25 level is in preparation.

**LUCAS Transect.** Straight line of 1200m length between SSU 11 and SSU 15.

**Minimum mapping unit.** The surface area of the smallest unit considered for mapping in a project. The smaller the minimum mapping unit is, the larger the cost and time is to map a given area. Its value is limited by the used mapping technology. It is 25 hectare in the CORINE Land Cover inventory.

**NATURA 2000 activity.** Human activities in or close to a site affecting in one or another way the NATURA 2000 sites.

**NATURA 2000 network.** A network of sites covering between 12 and 15% of the EU where the preservation of biodiversity is top priority. It is the main instrument through which the EU nature conservation policy is implemented.

**Natural habitat.** The place or type of site where an organism or population naturally occurs or in which an organism, population, or species lives.

**Number of classes.** This diversity indicator is the number of classes found. This criterion is really simple to calculate but hard to analyse.
As a matter of fact, the image obtained by the indicator can be false because the population can be represented by a lot of categories of land covers but, for most of them, with a low surface area.

**Number of LUCAS land cover transitions.** In this volume number of land cover changes detected along a LUCAS 1200 m transect with a reduced nomenclature of 7 classes.

**NUTS.** Nomenclature of Territorial Units for Statistics. The NUTS were established by Eurostat, providing a single uniform breakdown of territorial units for the production of regional statistics for the European Union.

**Object-oriented classification.** This type of classification comprises two parts. The first one prepares image data by creating segments from them and the second one allows their classification.

**Persistent Organic Pollutants.** An organic compound that remains in the environment for a long time is regarded as a persistent organic pollutant (POP).

**Photo-interpretation.** The act of a human expert in examining images for the purpose of identifying and classifying objects. The CORINE Land Cover inventory is produced by photointerpretation

**Picture standardisation.** Pre-processing of 2 images for an automatic comparison of radiometries. This operation aims at removing all the effects which depend, in particular, on different conditions of observation.

**Planimetric precision of digitising.** The planimetric precision can be qualified by the average quadratic error (ΔD). Control points have to be found on Orthophotos and on the ground. The ground coordinates ($x_{gps}$ and $y_{gps}$) are compared to the orthophotos coordinates ($x_{ortho}$ and $y_{ortho}$) by calculation of the following index:

$$\Delta D = \sqrt{\left(x_{gps} - x_{ortho}\right)^2 + \left(y_{gps} - y_{ortho}\right)^2}$$

The same process can be used with the coverage created by photo digitisation technique.
The resulting product is summarised by the sample and multiplied by –1.

**Point Frame Survey.** Area frame survey in which the elementary units are points.

**Primary Sampling Unit (PSU).** A two-stage sampling frame divides the population into clusters of units, named primary sampling units (PSU). In the first stage a sample of PSUs is selected. In each of the selected PSUs a sample of elementary units or secondary sampling units is selected.

**Raster format.** A raster representation of a spatial variable is based on a square grid covering the territory. Each square is often called a pixel, and its size the resolution of the map. A raster format is a simple list of the alphanumeric codes of the values attributed to each pixel. Processing GIS layers in raster format with a moderate resolution is generally faster than in vector format, but there may be a loss of spatial accuracy.

**REGIO.** Eurostat's harmonised regional statistical database. It covers the main aspects of economic and social life in the European Union, classified to the first three levels of the Nomenclature of Statistical Territorial Units (NUTS). http://epp.eurostat.cec.eu.int/.

**SABE.** The Seamless Administrative Boundaries of Europe dataset has been compiled from source data provided by 34 National Mapping and Cadastral Agencies (NMCAs), members of EuroGeographics. It contains all administrative units from the country level down to commune level. The term “seamless” means that there are no gaps or overlaps between polygons initially derived from different sources.

**Sampling Frame.** Representation of the population or universe to be sampled. It can be a list, or the equivalent of a list. If the list cannot be built (for example if the population is infinite), the frame is a definition of a set, as close as possible to the population, on which the sampling procedure can be applied.

**Secondary Sampling Unit (SSU).** Elementary units of a two-stage sampling frame (see PSU).

**Segment.** In many area frame surveys, the word segment is a piece of territory used as sampling unit. In LUCAS or similar point frame surveys, it may refer to PSUs.

**Shannon index.** The Shannon diversity $I_1$ index is commonly used to characterise species diversity in a community.

$$I_1 = -\sum_{i=1}^{n} p_i Logp_i$$

$p_i$ represents the relative proportion of individuals in group i.
The proportion of species i relative to the total number of species ($p_i$) is calculated, and then multiplied by the logarithm of this proportion ($Logp_i$). The resulting product is summarised by the sample and multiplied by –1.





**Simpson index.** The Simpson index $I_2$ increases the correction done by the Shannon index. As a matter of fact, this index uses the sum of the relative frequencies of the couple i-j.

$$I_2 = \sum_{i=1}^{n} \sum_{j \neq i}^{n} p_i p_j$$

n represents the total number of patches in the categories of land cover we are considering, and ni represents the number of patches in group i. $p_i$ therefore represents the relative proportion of individuals in group i.
The Index ranges from 0 to 1. More the index is closer to 1 the less diverse is the community.

**Sites of Community Importance (SCI).** Areas for the conservation of natural habitats and wild fauna and flora, defined by the Habitats directive. They are proposed by Member States and must be approved by the Commission after a scientific evaluation in the respective Bio-geographical Committees.

**Special Protection Areas (SPA).** NATURA 2000 sites for the protection of wild birds as defined in the Birds directive. They are designated by Member States.

**Transect = transept.** Line of a given length used as sampling unit in some area frame surveys, mainly for environmental purpose.

**Unused land.** Land for which no current economic use is apparent, possibly because it (building, agricultural land) has been abandoned. For some land cover types, such as shrub, some scarcely productive activities can be difficult to identify.

**EUROPEAN COMMISSION**
DG JOINT RESEARCH CENTRE
DG AGRICULTURE AND RURAL DEVELOPMENT
DG ENVIRONMENT
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It presents the progress of the work carried out by the teams on the development of some agri-environmental indicators and their evolution, based on existing databases such as land cover maps, agricultural surveys and other spatial databases related to agriculture and forestry.

# TRENDS

## of some **agri-environmental indicators** in the European Union

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