ESPON

EU-LUPA
European Land Use Patterns

Applied Research 2013/1/8

VOLUME II
Land Use Functions and their linked to land use performance and efficiency

Methodology for assessment of regional land use performance and efficiency based on Land Use Functions

Part C Scientific report |

Version 30/November/2012

EUROPEAN UNION
Part-financed by the European Regional Development Fund
INVESTING IN YOUR FUTURE

This report presents the final results of an Applied Research Project conducted within the framework of the ESPON 2013 Programme, partly financed by the European Regional Development Fund.

The partnership behind the ESPON Programme consists of the EU Commission and the Member States of the EU27, plus Iceland, Liechtenstein, Norway and Switzerland. Each partner is represented in the ESPON Monitoring Committee.

This report does not necessarily reflect the opinion of the members of the Monitoring Committee.

Information on the ESPON Programme and projects can be found on www.espon.eu

The web site provides the possibility to download and examine the most recent documents produced by finalised and ongoing ESPON projects.

This basic report exists only in an electronic version.

List of authors

Alterra Wageningen UR, (The Netherlands)

Marta Pérez-Soba

Matthijs Danes

Sander Mücher

Michiel van Eupen

Gerard Hazeu

Table of contents

1. Why using Land Use Functions in LUPA?

The main objective of the EU LUPA project is to *provide a consistent methodology to analyse comparable information about European regions based on data from different sources and different levels […] integrating physical dimension (land cover) with social-economic (land use) and environmental, in order to understand and obtain a clear view on land use changes […] identifying main challenges […] and defining policy options to cope with those challenges.*

An **integrated assessment** of land use policies implies simultaneous consideration of all spatially relevant aspects of economic sectors and human activities that are linked to land (Helming et al. 2008). These include agriculture and forestry as the main traditional economic sectors, nature conservation and rural tourism as mainly land conserving activities, and settlement, transport and energy infrastructure as mainly urbanised land uses. All of these sectors and activities compete for land resources, so any policy change affecting one land use has the potential to induce changes in the others (Plummer 2009).

Sustainable land use implies a balanced consideration of the range of social, economic, and environmental goods and services provided by the land uses in a certain region/landscape (Wiggering et al., 2006; Pérez-Soba et al., 2008). It also implies a careful consideration of long term attributes of resilience and robustness that are to maintain underlying ecosystem processes. In an attempt to operationalize sustainable development for the case of land use, the concept of multi-functionality was introduced (Wiggering et al., 2006). The underlying rationale for **multi-functional land use** is to consider effects of any land use action interactively. Commodity production is analysed in the context of its negative and positive externalities in a spatial system.

The Land Use Functions (LUFs) conceptual framework is a functional analysis on how changes in land use (partly driven by policies) impact on the multiple functions attached to land use, which in turn affect sustainability and stock and quality of natural resources. The LUFs concept responds to the EU policy need for integrated impact assessment considering the three main dimensions of sustainability, i.e. economic, environmental and social. The LUFs concept enables the translation of a broad range of economic, environmental and social indicators into an integrated regional assessment.

The LUFs concept was developed in the FP6 SENSOR project (Pérez-Soba et al., 2008; Paracchini et al. 2011) and it has been implemented in other projects since then (König et al., 2010; Reidsma et al., 2011).

The main objectives of the LUFs framework in EU LUPA are:

- To assess quantitatively the degree of multi-functionality of regions by assessing the performance of the land use functions present;
- To assess the impacts of land use change in a comprehensive way and not based on the partial views provided by individual indicators;
- To estimate the impact of land use changes on the economic, social and environmental dimensions, addressing in this way the interface between socio-economic development and the environment, i.e. sustainable development.

This document describes the adaptation of the original LUFs methodology to the specific EU- LUPA objectives.

2. Definition of Land Use Functions

Land Use Functions (LUFs) express the goods and services that the use of the land provides to human society, which are of economical, ecological and socio-cultural value and are likely to be affected by policy changes.

In EU-LUPA six LUFs have been identified considering the following criteria:

- The main uses of the land in Europe are represented (agriculture and forestry as the main production sectors, nature conservation and rural tourism as land conserving activities, and settlement, transport and energy infrastructure as urbanised land uses);
- Ensure that relevant economic, environmental and societal key issues in land use have an equal representation;
- The functions are likely to be affected by European policies.

The six functions proposed by Alterra were reviewed by an expert panel during the ESPON seminar on 'Evidence on European Land Use' that was held on 24 May 2011 in Brussels. The panel found that the six LUFs provided a good compromise between the number of functions and the topics covered. Particularly it was concluded that the six LUFs considered key functions of land use, they could be assessed by the set of indicators currently available at a NUTS 2/3 level, and they were easy to communicate main messages to policy and decision makers. It was also concluded that many different classification of the functions could be made, if needed, since the approach is very flexible. The LUFs have been defined considering main links to the economic, environmental and social dimensions, and are listed in Table 1. It should be noted that the LUFs do not refer uniquely to a dimension of sustainability, but have a ''prevalent'' social, economic or environmental character, acknowledging that the pillars of sustainability are not isolated, but involve numerous cross-linkages. Consequently they are named as mainly economic, environmental and societal because the borders between the three dimensions are not sharp, e.g. provision of work is mainly societal but can be considered as well among the economic functions, provision of housing is considered economical (building areas are strongly linked with economic development), but it can be considered as well as social function.

Table 1 The six Land Use Functions in EU-LUPA

Sustainability dimension	LUF	Land Use Functions	Issues included
Mainly societal	LUF1	Provision of work	Employment provision for all in activities based on natural resources
	LUF2	Provision of Leisure	Recreational and cultural services, including cultural landscapes and green spaces in urban areas
Mainly economical	LUF3	Provision of land-based products	Land-dependent production of food, timber and biofuels
	LUF4	Provision of housing and infrastructure	Building of artificial surfaces: settlements (residential areas, offices, industries, etc.), transport infrastructure (roads, railways, airports and harbours)
Mainly environmental	LUF5	Provision of abiotic resources	Regulation of the supply and quality of air, water and minerals
	LUF6	Provision of biotic resources	Factors affecting the capacity of the land to support biodiversity (genetic diversity of organisms and habitats)

3. Methodology

The Land Use Functions (LUFs) methodology is described in this chapter. It consists of the following steps:

Step 1: Selection of indicators

In this step indicators are selected from an extensive survey of harmonised European datasets. Following this selection an indicator set is built that enables to measure quantitatively temporal changes in the performance of the six Land Use Functions defined in step 2.

Selection criteria

The selection of the indicators is based on the following criteria:

a) Data availability: the indicators should be available at least for two time steps, being considered the first time step as the reference; in EU-LUPA the changes in land use will be mainly based on changes observed in CORINE Land Cover, and therefore the time period selected is 2000 - 2006;
b) Data quality: the quality of the data should be checked avoiding datasets with large data gaps or poor quality;
c) Spatial resolution: in principle preference is given to indicators available at a detailed administrative level. In agreement in Volume 0 (Data Management) it was agreed to use the NUTS 2/3 level (a mixture of NUTS 2 and NUTS 3 to achieve a balanced size in the administrative regions; Renetzeder et al, 2008), as best option considering the data availability; it should be always possible to upscale the data to a lower resolution;
d) Proper balance between the three sustainability pillars: the indicators should be associated to the three main dimensions of sustainability, e.g. economic, environmental and societal and their number should be approximately the same for each dimension to keep a balanced approach;

e) <u>Ability for assessment of changes in LUFs in the area of study</u>: for example, the set of environmental indicators should reflect main trends regarding key environmental issues such as water, soil, air and biodiversity;

f) <u>Redundancy or correlation</u>: it should be avoided selecting indicators that are redundant in some way, i.e. describing trends in the same issue or statistically correlated. For example, habitat eutrophication is directly caused by deposition of NH_3 and therefore habitat eutrophication and NH_3 are redundant;

g) <u>Spatial coverage</u>: the indicators should be available for all EU-27 and if possible for the ESPON space countries.

Step 2: Definition of the links between indicators and the LUFs

The specific links between the selected indicators and the LUFs should be defined by a group of experts using *a generic table* similar to that shown in Table 2, which lists and quantifies the contribution of each indicator to each LUF, and justifies the scores.

Table 2 Indicators showing the change in performance in LUFs

Indicator code	Indicator name	Score	Justification for score

The relation between indicators and LUFs is measured as a score and is defined individually since the same indicator can have at the same time a positive relationship with one LUF while negative with other. For example, high cover of urban fabric, which is directly related to building, is given a positive score since it enhances the performance of LUF1 Provision of Work. On the contrary, high cover of urban fabric, which implies soil sealing, is given a negative score since it is associated with a decrease in the performance of LUF6 Provision of Biotic Resources. This is reflected in the direction the scale min-max is assigned to indicators in each LUF during the normalisation process. Therefore the maxima are attached to high urban fabric values in the first case and to low urban fabric values in the second.

The scores range from -1 to +1 as follows:

1 = the indicator shows a negative (-) or (+) performance of the land use function in a significant way. For example, the indicator ‘nights spent in touristic accommodations’ has a positive link with the LUF2 Provision of Leisure, because an increase in nights spent in touristic accommodations indicates a probable increase in leisure activities in the specific administrative region. On the other hand, the indicator ‘area harvested’ has a negative link with LUF5 Provision of abiotic resources, because an increase in area harvested means that the land used for agricultural activities is larger and therefore the provision of (abiotic) water and minerals resources is decreased.

0 = irrelevant, i.e. the relationship between the indicator and the LUF does not allow one to infer on the consequences that a change in the indicator value could have on the LUF , i.e. no direct link is known between the indicator and the LUF or maybe there are some impacts but they counterbalance each other. For example, the indicator ‘NH_3 emission’ is irrelevant for LUF1 Provision of work. This scoring principle has a second function in order to compensate for the number of indicators per LUF and is considered as weight 2, further explained at step 5 in this report.

Step 3: Assessment of the specific importance of each indicator for the economic, environmental and social dimensions of the region

The regional dimension of the assessment results from the recognition that not all indicators may be relevant in all regions, e.g. the indicator 'area harvested' is unlikely to be relevant in a region with small agricultural area. In effect, this step reflects the uncertainty and regional differences that need to be taken into account in the assessment.

This step provides the regional dimension to the framework by evaluating for each region considered in the analysis, the potential importance that each indicator may have on each of the economic, environmental and social dimensions. The regional dimension of sustainability assessment is at the heart of the of EU-LUPA. The approach reflects the considerable variety of situations that exist within the ESPON space and consists of a weighting of individual indicators within each of the regions considered. It combines information as to whether (i) the land use change actually does affect the region, (ii) if it does, are we likely to see impact in the land use functions of the region and finally (iii) if there is impact, does it affect the three dimensions of sustainability in the region.

It is well accepted that changes in indicators - that is measurements of something in the economy, environment or society – may be of different importance in relation to our efforts to assess the changes in phenomena (such as land use). In other words, it means that some 'things' are more important for the phenomena we are concerned than others. Therefore, weighting of different indicators is a normal procedure in Environmental Assessment and Strategic Environmental Assessment, and indeed finds its place in EU Impact Assessment. However, agreeing on the weighting is difficult. It can be imposed 'top-down' by policy makers/administrators and their advisory scientists, or generated 'bottom-up' by stakeholders. Ideally, one might have different weighting systems derived from different sources such as expert ('Delphi') panels, stakeholder valuation workshops, internet valuation, etc. and present them in final outcomes to assess the risk. We have chosen to limit ourselves to expert panels.

The description of the decision rules used by the experts is transparently done in individual fact-sheets, which include the 'importance' weighting showing how significant an issue (measured by the indicator) is in that region. It is an expert-based value judgment on what impact it would have on sustainability in the region if that indicator was to have an unacceptable value based on the current knowledge. The rule base determines the potential impact of change in an indicator for a particular region, and should be guided by supporting references describing the core bio-geographical (e.g. climate, altitude, relief, land use) and socio-economic (e.g. GDP, population, unemployment) characteristics of each region. For example, forest fire risk is deemed of low importance in a region with a small forest area, and a low population density, i.e. where the impact of a forest fire will be low. Conversely, Nitrogen and Phosphorus inputs are considered important in regions where agriculture dominates land use, and where the level of nutrients is already high. The detailed description should not be exhaustive and therefore for some indicators other sources explicitly concerning the impact of the indicator have been used. For example, some indicators, particularly the economic ones, are considered of equal importance in all regions. Care should be taken to minimize co-correlation of factors determining the rule base and those from which the indicator values themselves were derived.

The scores take values between 1 and 3 as follows: 1 (not important at all, or very low importance), 2 (of some importance), 3 (of great importance). Indicators may show multiple potential impacts across LUFs, therefore the rule-base needs to be accommodated to potential impacts on a number of different sectors. The rules are defined such that importance scores of 1 are only assigned where it is clear that there is no current importance AND that this is not likely to become important in the future, in order to preserve the validity of the assessment framework to future change. The rule base could be independently validated by a group of external experts in a workshop. The panel of experts can be selected according to criteria from recent practice of impact assessments. The regional importance scores should be summarized in a table as shown in Table 3 below, while full description of the rule bases and the scientific justification should be given separately (example shown in step 4).

Table 3 Example table to showing how the regional importance scores (1 to 3) are indicated for each selected indicator in the regions of analysis.

Region code	Region name	ENV 01	ENV 02	ENV 03	ECO 01	ECO 02	ECO 03	SOC 01	SOC 02

Step 4: Normalization and equalizing of indicators values

One of the requirements for processing multiple indicators within an aggregation framework is that all are transformed into the same scale with common units (Nardo et al., 2005). Thus all indicators must be normalised, preferably to a continuous numerical scale, in order to allow mathematical procedures such as linear-additive aggregation to be performed. Within this aggregation framework it is considered to normalize the values towards a nominal scale of 0 (low performance) to 10 (high performance).

The equation used for normalisation of indicators is then the following:

$$I_{NORM} = \frac{x - \min}{\max - \min} * 10$$

where *x* is the value of the indicator under a given situation (e.g. the specific region studied), and min and max are the ends of the normalization range, corresponding to minimum and maximum of the indicator itself.

Even though normalization is frequently applied within an aggregation framework to combine different indicators, it does not resolve the problem of data stretching. Figure 1 shows an example of the histogram distribution of the percentage of area covered by soil sealing. As only a few regions are covered with an extreme low or high percentage of soil sealing they pull the normalization result to one side of the histogram. The result is that the majority of the cases are classified only in one or two classes and all the existing differentiation disappears. The final consequence will be that, when aggregating several indicators (to show the performance of one LUF, as we do in this analysis), the lack of differentiation in one of these indicators will strongly push towards a homogeneous result.

One way to avoid such a homogeneous result is to stretch the individual indicators before aggregating. A commonly accepted method to do this is called *histogram equalization*. One example of histogram equalization can be found in Figure 1. In principle the objective of this method is to reclassify the indicator in such a way, that a linear trend arises in the cumulated frequency histogram.

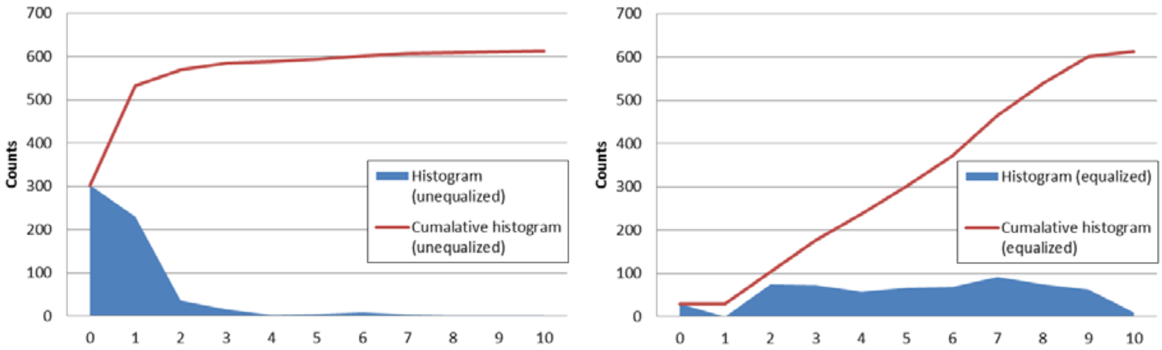


Figure 1 Example showing the effect of histogram equalization, for the normalized soil sealing information (percentage of CLC 111 + 112 + 121 +122 +123 + 124 + 125 within the NUTS 2/3-regions).

In case one works with multi-annual data, like we do in this project, one should be aware that the normalization and equalization are carried out on the multi-annual data set, instead of repeating this exercise for each year separately.

Step 5: Integrated assessment of the land use functionality

The final step is the integrated assessment in order to derive a final functionality score. The integrated weighing of all the indicators contributing to a LUF, provides a comprehensive description of changes observed in the indicators, which in turn shows the overall consequences (stimulating, hindering or none) for the LUFs performance. It is mainly based in the integrated weighing of all the indicator values and is described below in the aggregation scheme, as published in Paracchini et al. (2011).

(i) The aggregation scheme

Aggregation can be performed in compensatory or non-compensatory frames. In the first case the weights have the meaning of trade-offs (Jeffrey, 2004), therefore a decrease in a LUF value is considered comparable to an increase in one or more other LUF values. Due to the complexity and multiple dimensions of the impacts to be assessed in EU LUPA, it was decided to leave the analysis of trade-offs to the end user, since it would be impossible to assess *ex-ante* if conflicts between all possible targets exist. Therefore, a solution that holds some characters of non-compensation was sought. The basic aggregation framework is presented in Figure 2.

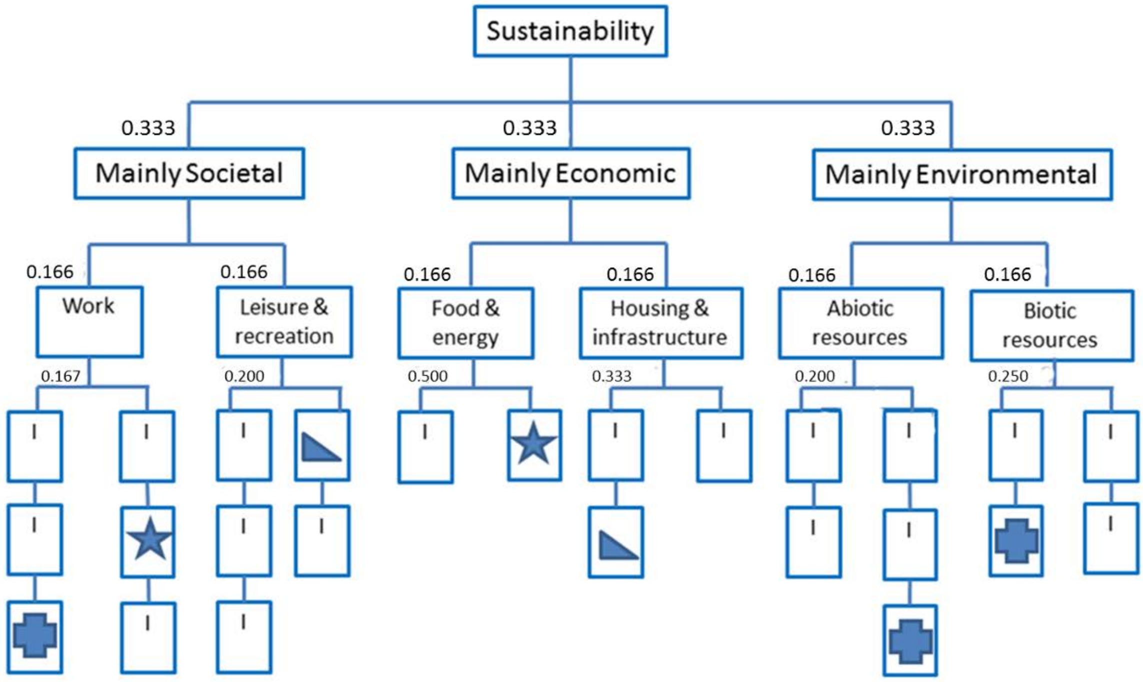


Figure 2 Basic aggregation scheme, after Paracchini *et al.* (2011). The symbols represent individual indicators contributing to more than one LUF.

In such a hierarchical scheme the six LUFs are grouped in pairs according to the three dimensions of sustainability, and indicators are individually assigned to one or several LUFs. In order to deal with the compensability problem in linear aggregation, and with the problem of assigning weights in a context of social choice, as suggested by Munda (2004) the value of the weighs attached to each LUF is decided *a-priori* and LUFs are considered to be equally weighted. The indicator weights are then derived by dividing the LUF weight by the number of indicators concurring to it. The method therefore remains compensatory within a LUF, but not among the LUFs. It is the end-user of the system, i.e. the policy maker at the EU level, who makes the decisions on the possibility of accepting trade-offs between LUFs.

In practice, the requirements of the system are complex. The LUFs do not refer uniquely to a dimension of sustainability, but have a *'prevalent'* social, economic or environmental character, acknowledging that the pillars of sustainability are not isolated, but involve numerous cross-linkages (mostly social, mostly economic and mostly environmental), as shown in Figure 2.

In this aggregation framework, three additional characteristics apply, as described in Paracchini et al (2011):

a. Each indicator can concur to more than one LUF (as shown in Figure 2);

b. The indicator link to a LUF can be positive or negative;

c. Each indicator may perform differently according to the geographical/economic, environmental, social context in which it is measured.

All these elements must be taken into account when building the aggregation frame, and concur in solving the questions:

- how is spatial variability of the European environmental/socio/economic context taken into account;
- how is multi-functionality and sustainability (represented by the economic, environmental and social dimensions) included in the aggregation framework.

(ii) The weighting

The system uses three weighting components to achieve this multi-dimensional, regional assessment, and is organised in a way that the aggregated values of indicators produce a final LUF score on the same 0 – 10 scale.

In case data are missing, the corresponding weights are excluded from the scheme. If this will not be done, then the sum of the weights will be smaller than 1, resulting in a lower score. The calculation method has been automatized for the EU LUPA project by Alterra and corrects the weighting whenever data are missing based on the principles that the sum of the weights must always be 1.

The three weights are used as follows:

w1 – Number and type of indicators contributing to each LUF

Figure 2 shows that aggregation of indicators to LUFs is performed on a compensatory basis, in which the contribution of each indicator is weighted according to the number of indicators concurring to a LUF, the indicator inherent importance (addressing issues of redundancy between indicators) and the balance of indicators across the three sustainability pillars. This is the first of two weighting factors: **w1**, and is calculated as follows:

w1 = intrinsic indicator weight x pillar balance weight x 1/ n_{LUF} (1)

where n_{LUF} is the number of indicators concurring to the LUF.

Intrinsic weights should be shown as in the example shown in Table 10 in chapter 5. The importance of some individual indicators may be down-weighted to account for issues of redundancy. For example, N and P surplus where both represent impact of the agricultural sector on water quality. However, the spatial pattern varies across Europe, so rather than selecting just one indicator and fail to adequately capture this impact, it can be decided to retain both, but to down-weight them equivalent to one indicator. The second component to weight 1 takes into account the differences in number of economic, social and environmental indicators to achieve balanced representation between the three pillars of sustainability. These two components are combined to a total weight of one. In the LUF framework, weight 1 is adjusted separately for each LUF to take into account the number of indicators contributing to that LUF (**n_{LUF}**)**,** ensuring LUF calculations are evenly balanced through the framework.

w2 – Strength and sign of indicator impact on LUF performance

Expert panels of internal and external experts can assign values to the link between each indicator and the LUFs. Such weights are attributed in close relation to the indicators’ ranges. Weight 2 describes the impact on sustainability, i.e. whether it has a positive or a negative impact on that LUF.

Since these indicator weights can show positive or negative relations, great attention must be paid to the meaning attached to minima and maxima per each indicator in the normalisation frame. As explained above the same indicator can have a positive relation to one LUF and a negative one to a different LUF, and this must be reflected in the direction the scale min-max is assigned to indicators in each LUF during the normalisation process (i.e. high GDP may be good for LUF provision of work and bad for LUF provision of biotic resources, therefore the maxima are attached to high GDP values in the first case, to low GDP values in the second).

This is the second of two weighting factors: **w2**, taking discrete values from -1 to +1.

w3 – Regional importance of the indicator

Weight 3 reflects the importance of each indicator at a regional level. Once more a panel of experts need to define a set of indicator-specific rules to determine the importance of an indicator in separate regions. For example, *area harvested* is deemed of low importance in a region with a small agricultural area. Some indicators, particularly the economic ones, are considered of equal importance in all regions. Care needs to be taken to minimise co-correlation of factors determining the rule base and those from which the indicator values themselves were derived. This is the third of three weighting factors: **w3**, taking discrete values from 0 (not relevant) to +3 (strong importance).

As previously mentioned, this w3 was only calculated for the Netherlands(example of LUF implementation at national level), and it is described in chapter 4.

Together, the information in these weighting scores is used in the aggregation framework to address the issues a) to c) listed above, since they represent how much a LUF is sensitive to a change in a specific indicator and how much the relevance of a LUF changes across the European regions considered.

4. Application of the LUFs methodology considering the specificities of the region

In order to test the LUF methodology when considering regional specificities (i.e. including weight 3), the Netherlands was chosen as case study area considering the expertise of Alterra. Since this analysis was done before the Interim Report, NUTS 2 was used as the spatial unit for the assessment. Nevertheless, a relevant set of indicators (not available at pan European level) was selected to describe the specific characteristics of the 12 Dutch provinces, e.g. demographic indicators (see figures below in chapter 4.1). In the later European assessment, NUTS 2/3 regions were used to comply with the request from the CU in their Response on the Interim Report. The twelve NUTS 2 regions of the Netherlands are listed in Table 4.

Table 4 Region codes and names of the NUTS 2 regions considered in the test case for the Netherlands.

Region code NUTS 2	Region name
NL11	Groningen
NL12	Friesland (NL)
NL13	Drenthe
NL21	Overijssel
NL22	Gelderland
NL23	Flevoland
NL31	Utrecht
NL32	Noord-Holland

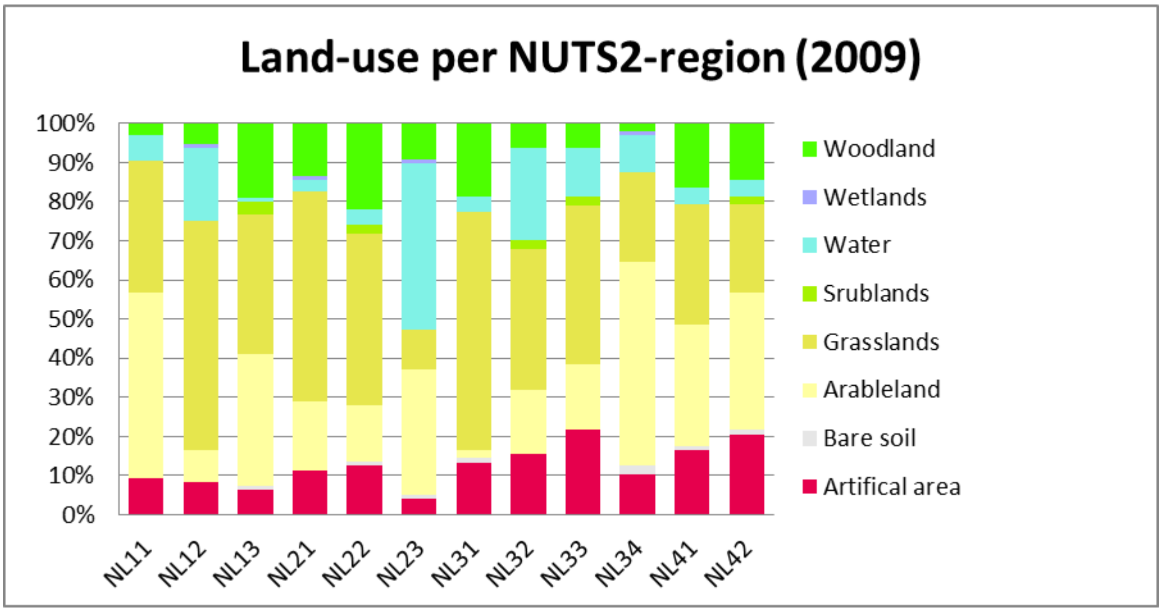
NL33	Zuid-Holland
NL34	Zeeland
NL41	Noord-Brabant
NL42	Limburg (NL)

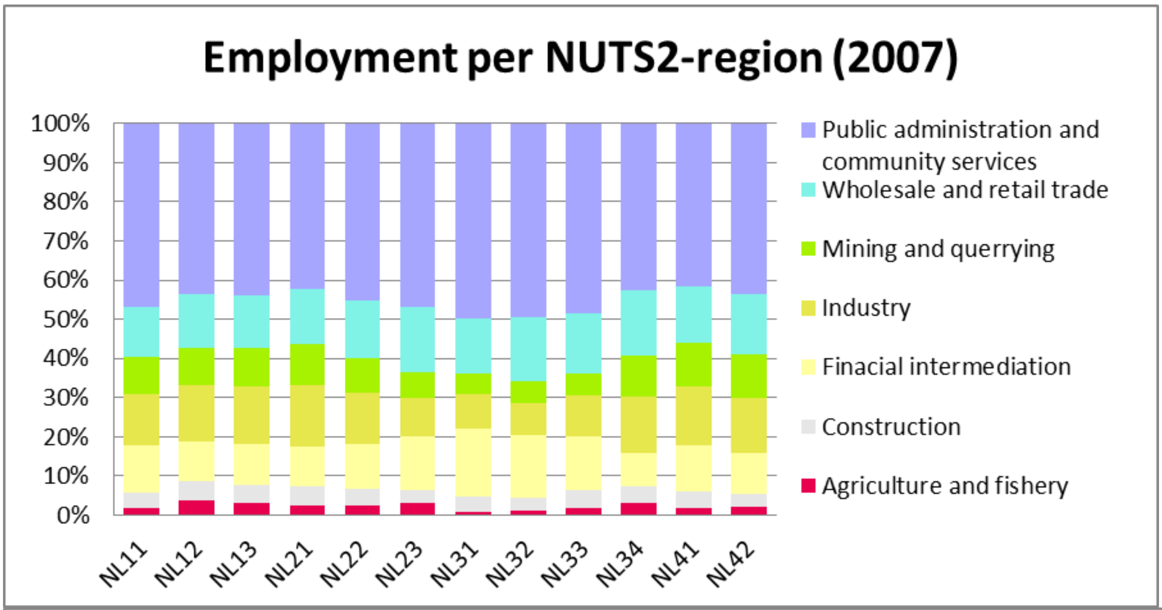
The objective of this exercise was:

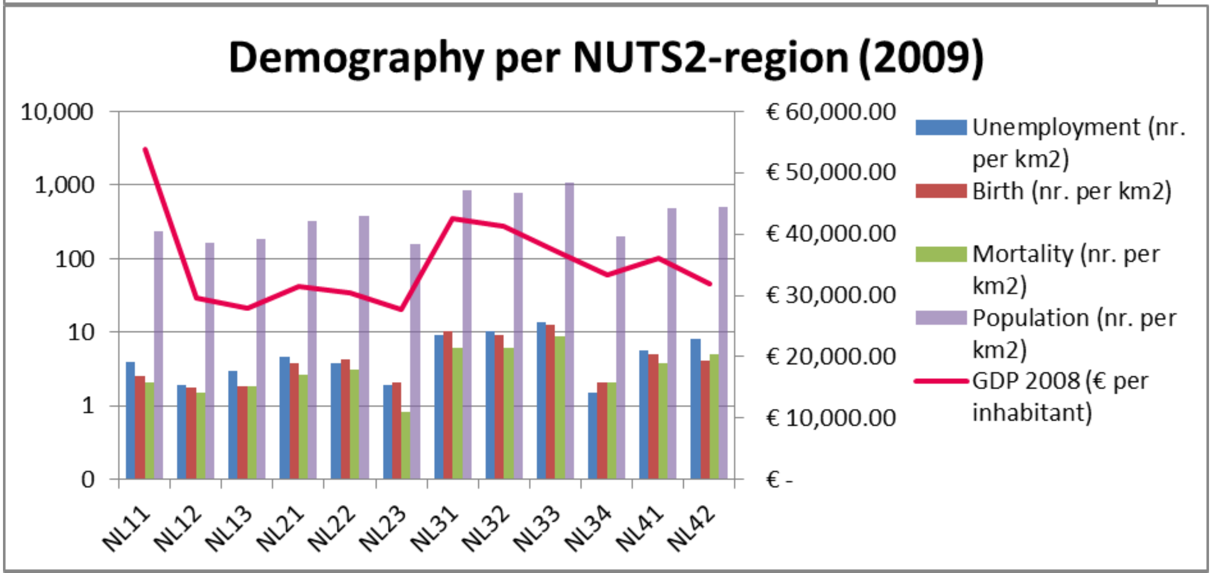
- To estimate the impact of land use changes between 2000 and 2006 on sustainability, measured as integration of the economic, social and environmental dimension, and not based on the partial views provided by individual indicators;
- To assess the suitability of the LUFs methodology in EU-LUPA for assessing the changes in main land functions considering regional specificities (i.e. including weight 3);
- To identify the number and quality of the land use functions present in the twelve Dutch provinces and therefore the degree of existing multi-functionality;

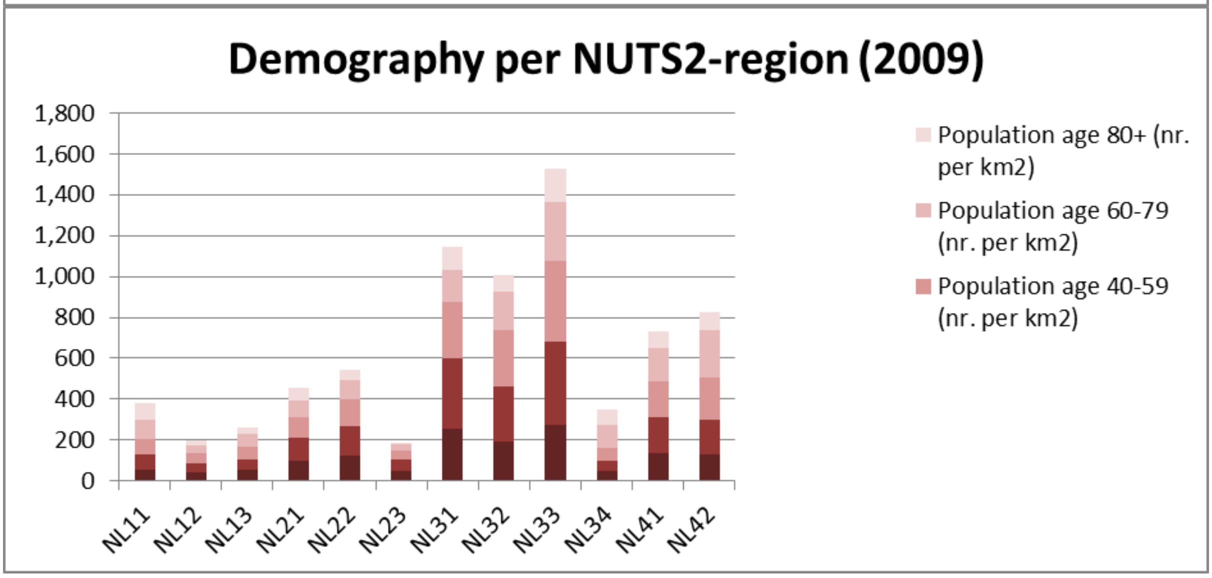
4.1 Detailed description of the 12 Dutch provinces (NUTS 2 regions)

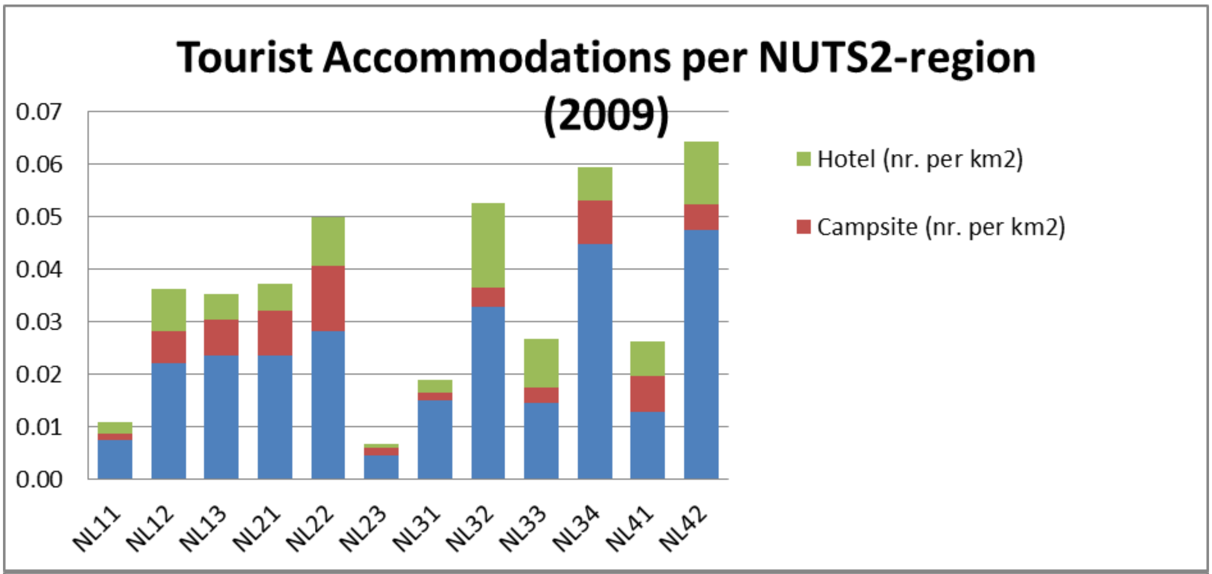
The objective was to describe in an easy to use and attractive way the key bio-physical and socio-economic variables describing the 12 Dutch provinces. The graphs provided below were used by the Alterra experts when filling in the regional tables (as those described in Table 3) linking indicators to Land Use Functions.



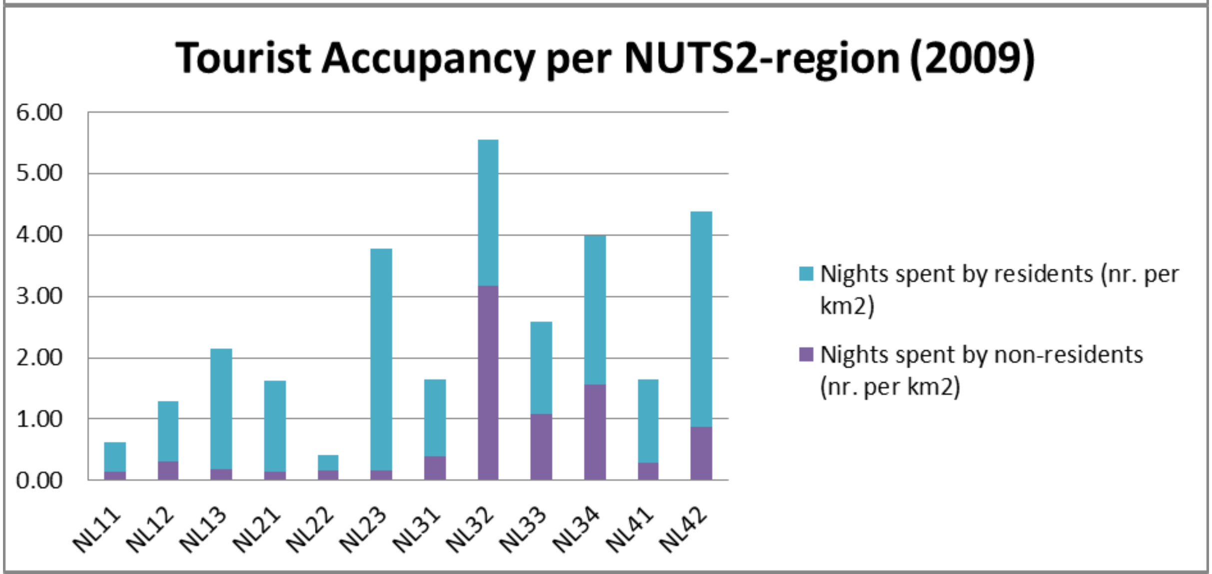

Employment per NUTS2-region (2007)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
NL11
NL12
NL13
NL21
NL22
NL23
NL31
NL32
NL33
NL34
NL41
NL42
Public administration and community services
Wholesale and retail trade
Mining and querrying
Industry
Finacial intermediation
Construction
Agriculture and fishery


Demography per NUTS2-region (2009)
10,000
1,000
100
10
1
0
€ 60,000.00
€ 50,000.00
€ 40,000.00
€ 30,000.00
€ 20,000.00
€ 10,000.00
€ -
NL11
NL12
NL13
NL21
NL22
NL23
NL31
NL32
NL33
NL34
NL41
NL42
Unemployment (nr. per km2)
Birth (nr. per km2)
Mortality (nr. per km2)
Population (nr. per km2)
GDP 2008 (€ per inhabitant)

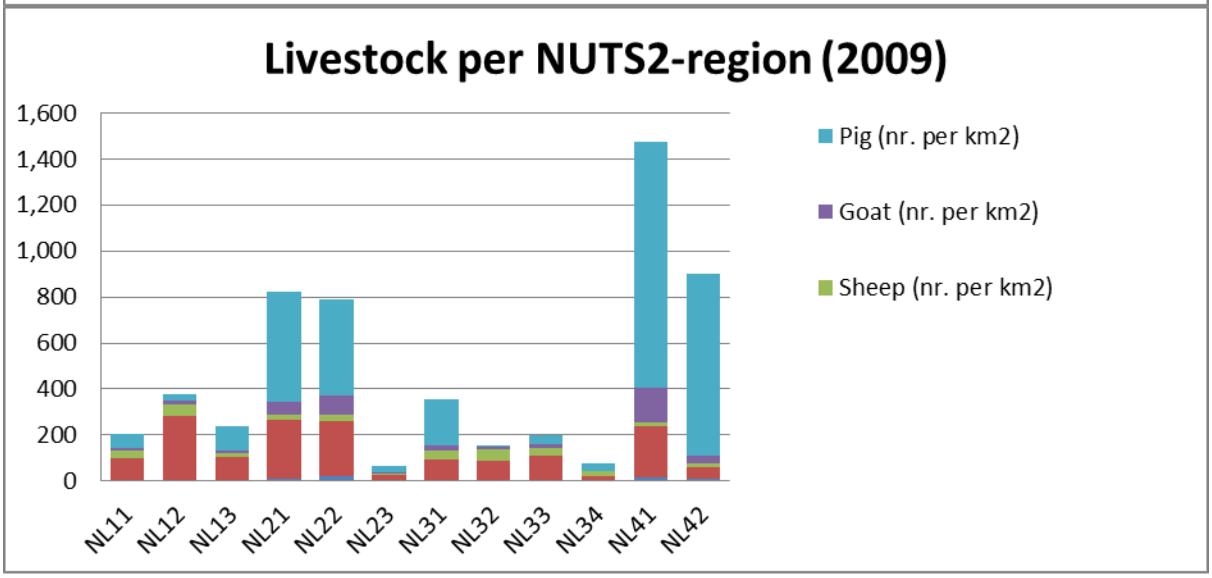

Demography per NUTS2-region (2009)
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
NL11
NL12
NL13
NL21
NL22
NL23
NL31
NL32
NL33
NL34
NL41
NL42
Population age 80+ (nr. per km2)
Population age 60-79 (nr. per km2)
Population age 40-59 (nr. per km2)



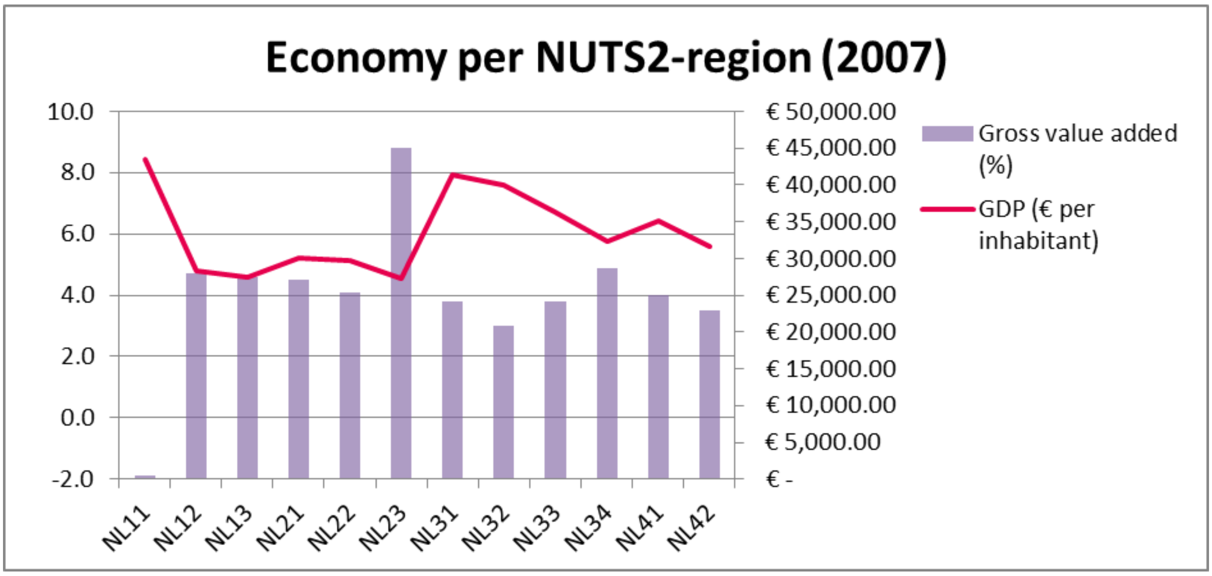
Tourist Accommodations per NUTS2-region (2009)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
NL11
NL12
NL13
NL21
NL22
NL23
NL31
NL32
NL33
NL34
NL41
NL42
Hotel (nr. per km2)
Campsite (nr. per km2)



Tourist Accupancy per NUTS2-region (2009)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
NL11
NL12
NL13
NL21
NL22
NL23
NL31
NL32
NL33
NL34
NL41
NL42
Nights spent by residents (nr. per km2)
Nights spent by non-residents (nr. per km2)



Livestock per NUTS2-region (2009)
1,600
1,400
1,200
1,000
800
600
400
200
0
NL11
NL12
NL13
NL21
NL22
NL23
NL31
NL32
NL33
NL34
NL41
NL42
Pig (nr. per km2)
Goat (nr. per km2)
Sheep (nr. per km2)



4.2 Implementation of LUF methodology

Step 1: Selection of indicators

The following sources were reviewed for the indicator selection: EUROSTAT database, EU-LUPA database (produced in Volume 0 - Data Management) and FP6 FARO-EU project database.

Justification for the selection of the indicators

The indicators were selected following the criteria described in step 1. In principle preference was given to indicators available at NUTS 3. However, only enough indicators were found at NUTS 2 level.

The final list of indicators considered in the test case is presented in Table 5. It consists of 17 indicators, namely 7 economic indicators, 5 environmental indicators and 5 social indicators. The slight imbalance between the number of indicators between the three dimensions is compensated using the *'weight 1'* which incorporates an intrinsic indicator weight (see step 5 in chapter 3).

Table 5 List of 17 indicators that were finally selected for the LUFs framework in the Netherlands. The spatial resolution is NUTS 2. The indicators are grouped according to the sustainability dimension to which they are most largely linked.

Indicator code	Indicator name
ECO_01	Value added per sector (total)
ECO_01a	Value added per agriculture
ECO_2	GDP PPP
ECO_3	Nights spent in tourist accommodations
ECO_4	Transport networks
ECO_5	Agricultural accounts
ECO_06	Area harvested
ENV_01	Soil sealing
ENV_02a	Agricultural area in protected area
ENV_02b	Green areas
ENV_02c	Green areas close to residential areas

	(Based on percentage of artificial area)
ENV_05	Livestock density (current livestock density and area of pastures)
SOC_1	Unemployment rate
SOC_2	Net migration
SOC_3	Services of general interest
SOC_05	Household with broadband
SOC_6	Population density

Step 2: Definition of the links of the indicators with the LUFs

The summary of contributions of indicators to the six LUFs is presented in Table 6. It shows a reasonable spread of indicators across the LUFs with most indicators contributing to more than one dimension of sustainability. Detailed tables (Annex 3) describe the conceptual contribution of each selected indicator to each of the six LUFs where clear links were identified. The generic tables present the scores associated to the contribution as well as the scientific justification and the confidence on the scoring.

Table 6 Summary of cross-linkages between the 15 selected indicators and the six LUFs. The full analysis is provided in Appendix 1 of the document.

Indicator main dimension	Indicator name	LUF 1	LUF 2	LUF 3	LUF 4	LUF 5	LUF 6
ECO	Value added per sector (total)	1	1		1		
ECO	Value added per agriculture			1			
ECO	GDP ppp	1	1		1	1	1
ECO	Nights spent (tourism)	1	1				
ECO	Transport networks (lot of artificial areas, minimum is 2)	1	1			-1	-1
ECO	Agricultural accounts			1			
ECO	Area harvested			1		-1	
ENV	Soil sealing	1		-1	1	-1	-1
ENV	Agricultural area in protected area	1					
ENV	Green areas		1				
ENV	Green areas close to residential areas (Based on percentage of artificial area)				1		
ENV	Livestock density (current livestock density and area of pastures)		-1	1			
SOC	Unemployment rate	-1		-1	-1		
SOC	Net migration	1			1		
SOC	Services of general interest	1			1		
SOC	Household with broadband				1		
SOC	Population density	1			1	-1	-1

Step 3: Assessment of the importance of each indicator for the sustainability of the region

The description of the decision rules used by the experts should be done in individual fact-sheets. The rule determines the relevance of an indicator for a particular region, and was based by the supporting descriptions of the 12 provinces presented at the start of this chapter 4. The 'regional importance' scores take values between 1 and 3 as explained in chapter 3, and are summarized in Table 7. A full description of the rule bases and the scientific justification should be given separately (example shown in Annex 4).

Table 7 The regional importance scores (1 to 3) are indicated for each selected indicator in the regions of analysis.

Indicator code	Indicator name	Twelve Dutch provinces (NUTS 2 regions)											
		NL11	NL12	NL13	NL21	NL22	NL23	NL31	NL32	NL33	NL34	NL41	NL42
		Groningen	Friesland	Drenthe	Overijssel	Gelderland	Flevoland	Utrecht	Noord-Holland	Zuid-Holland	Zeeland	Noord-Brabant	Limburg
ECO_01	Value added per sector (total)	2	2	2	2	2	2	2	2	2	2	2	2
ECO_01a	Value added per agriculture	3	3	2	2	2	3	2	3	2	3	3	2
ECO_2	GDP ppp	2	2	2	2	2	2	2	2	2	2	2	2
ECO_3	Nights spent (tourism)	1	2	2	2	3	1	2	3	2	3	2	3
ECO_4	Transport networks (there are many artificial areas, therefore the minimum score is 2)	2	2	2	2	2	2	3	3	3	2	2	3
ECO_5	Agricultural accounts	3	3	2	2	2	3	2	3	2	3	3	2
ECO_06	Area harvested	3	2	2	2	2	3	1	3	1	3	3	2
SOC_1	Unemployment rate	2	2	2	2	2	2	2	2	2	2	2	2
SOC_2	Net migration	3	2	2	2	2	2	2	2	2	3	2	3
SOC_3	Services of general interest	2	2	2	2	2	2	2	2	2	2	2	2
SOC_05	Household with broadband	2	2	2	2	2	2	2	2	2	2	2	2
SOC_6	Population density	1	1	1	2	2	1	3	3	3	1	2	2
ENV_01	Soil sealing	1	2	1	1	2	2	3	3	3	1	3	2
ENV_02a	Agricultural area in protected area	2	2	2	2	2	2	2	2	2	2	2	2
ENV_02b	Green areas	2	2	2	2	2	2	2	2	2	2	2	2
ENV_02c	Green areas close to residential areas (Based on percentage of artificial areaa)	1	1	1	2	2	1	2	2	3	1	2	3
ENV_05	Livestock density (current livestock density and area of pastures)	2	3	2	3	3	1	2	2	2	1	3	3

Step 4: Normalisation of the indicators

The equation used for normalisation of indicators is the following:

$$I_{NORM} = \frac{x - \min}{\max - \min} * 10$$

where x is the value of the indicator, and min and max are the minimum and maximum values of the whole range for the year 2000. These calculations are available in Excel sheets.

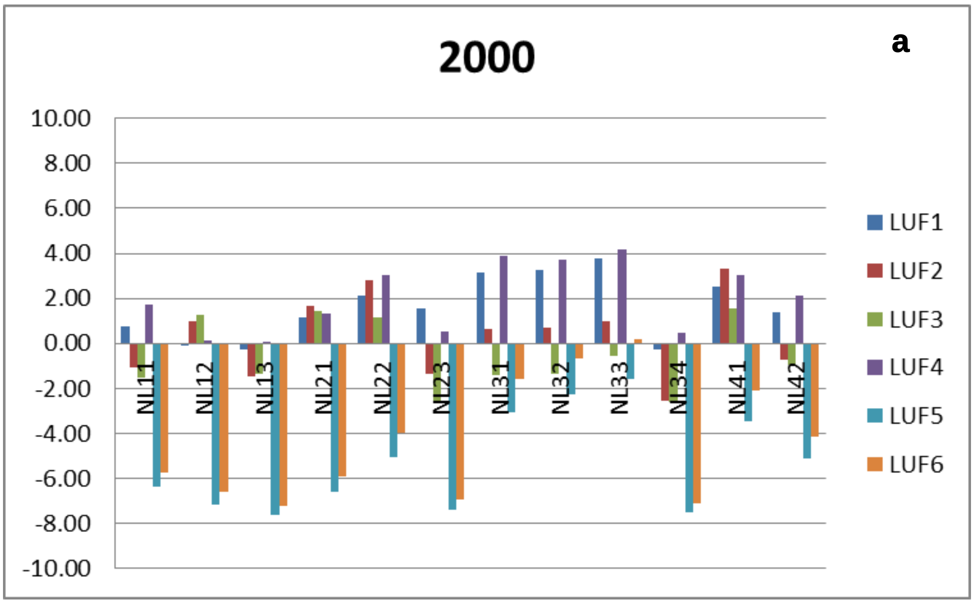
Step 5: Integrated assessment of changes in land use functionality: Land Use performance

The LUFs methodology has been successfully implemented, as it is shown in the following series of figures showing the variation in the impacts that the land use change that took place between 2000 and 2006 had on the six Land Use Functions in the 12 Dutch provinces.

The change in land use functionality was calculated using as reference the average values in 2000. This change is interpreted as change in the land use performance of the regions.

Figure 3a, 3b and 3c show the values of the six LUFs for each province, respectively, in 2000, 2006 and the difference between both years. Overall the economic functions (LUF1 and LUF2) are performing well, whereas the societal (LUF3 and LUF4) and especially the environmental (LUF5 and LUF6) have mainly negative values, which is in accordance to the predictions made by the experts based on their expert knowledge and characteristics of the region analysed in the section before.

Figure 3c shows as well how small are the differences between 2000 and 2006, which is in accordance to the small changes observed in CORINE Land Cover classes between the two years for the Netherlands. Still there are important differences between the regions, e.g. the three richest regions of the NL (NL31, NL32 and NL33) have higher values in the economic LUFs.



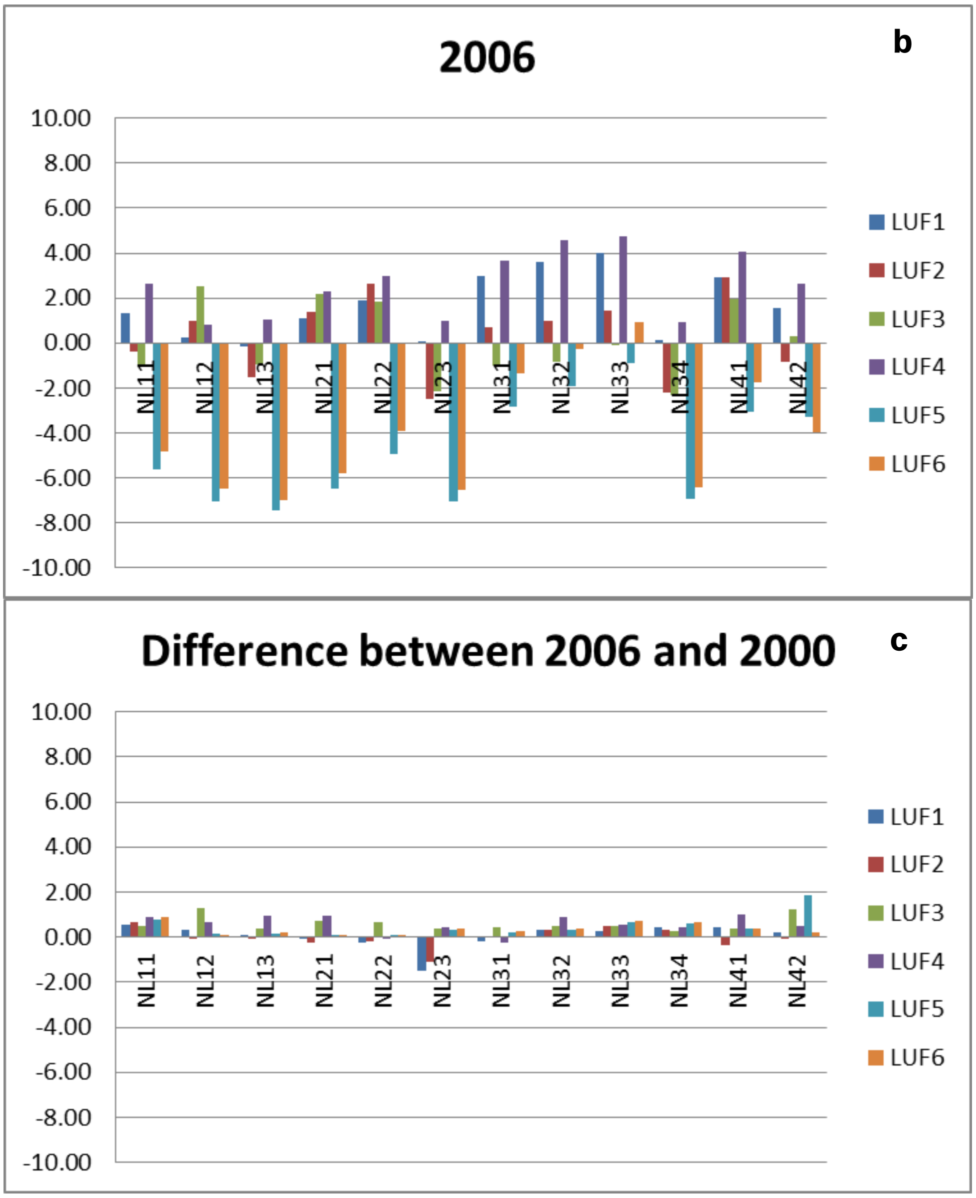


Figure 3 The values of the six LUFs for each Dutch province in (a) 2000, (b) in 2006, and (c) the difference between both years.

The second set of three figures (Figure 4a, b and c) show the aggregation of the six LUFs into the economic, environmental and social dimensions for each province in 2000 and 2006, and the difference between both years. In general terms, it shows how the economic and social functions are performing well, whereas the environmental dimension has negative values in all the provinces.

b

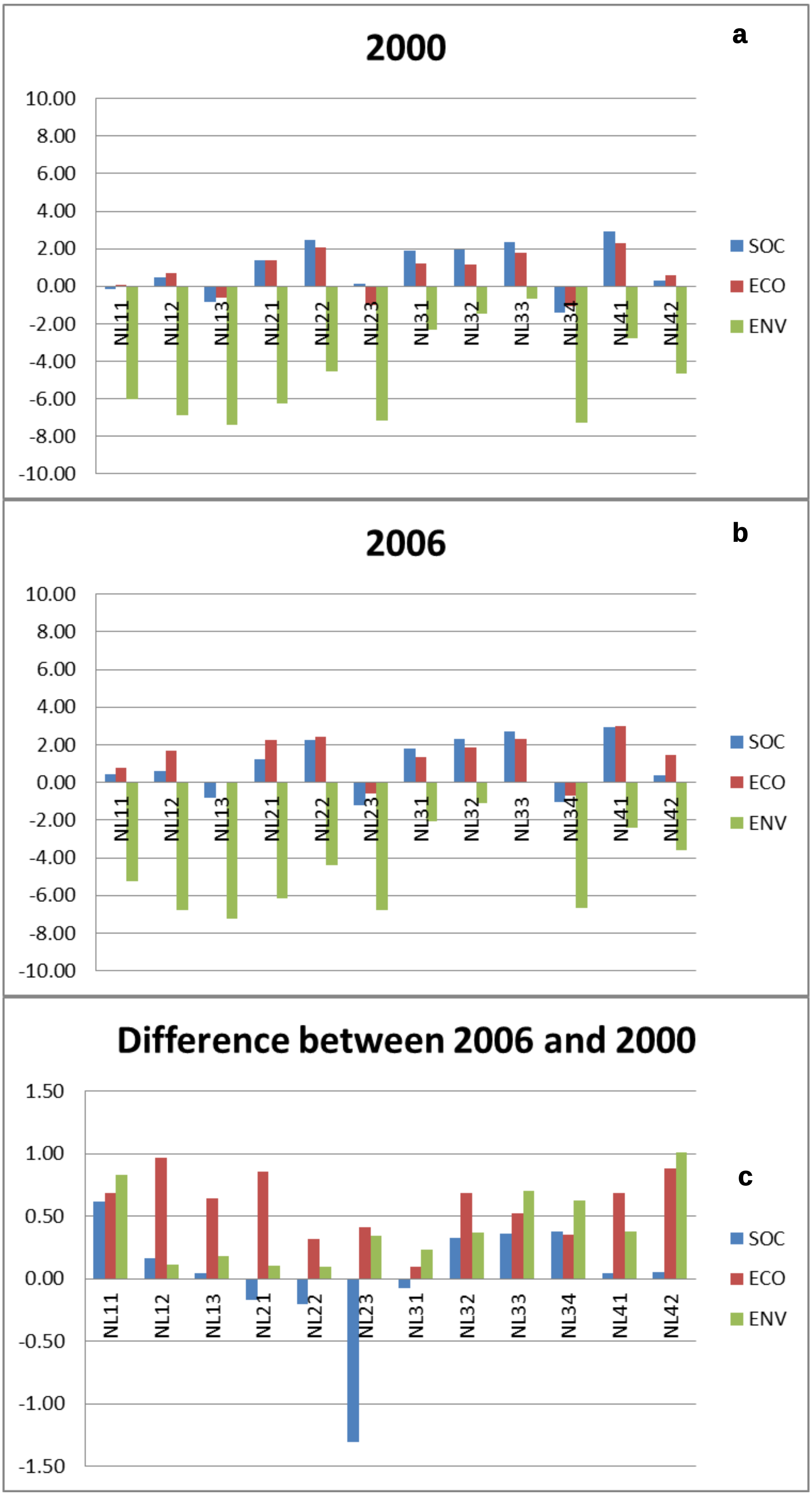

2000
a
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
-8.00
-10.00
NL11
NL12
NL13
NL21
NL22
NL23
NL31
NL32
NL33
NL34
NL41
NL42
SOC
ECO
ENV
2006
b
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
-8.00
-10.00
NL11
NL12
NL13
NL21
NL22
NL23
NL31
NL32
NL33
NL34
NL41
NL42
SOC
ECO
ENV
Difference between 2006 and 2000
c
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
NL11
NL12
NL13
NL21
NL22
NL23
NL31
NL32
NL33
NL34
NL41
NL42
SOC
ECO
ENV

Figure 4 The values of the aggregated LUFS into social, economic and environmental dimensions for each Dutch province in (a) 2000, (b) in 2006, and (c) the difference between both years.

Figure 5 shows the total performance of each Dutch province in 2000 and 2006, by aggregating the three sustainability dimensions. It shows how all the provinces have increased their performance in 2006 compared to 2000, and the regions of Utrecht, Noord-Holland, Zuid-Holland, and Noord-Brabant are performing in general above the average, whereas the other eight provinces have a total performance below the average.

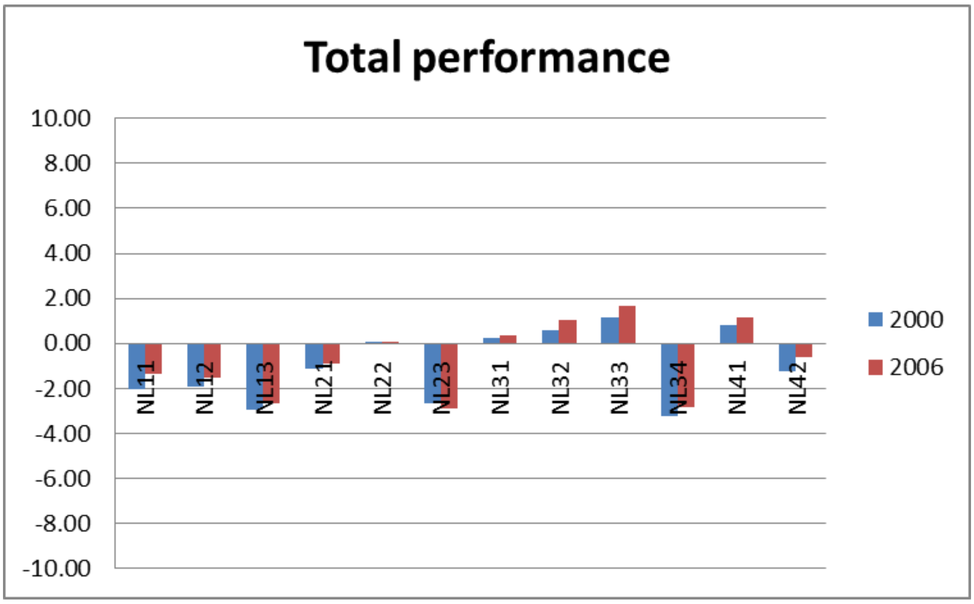


Figure 5 Total performance of each Dutch province in 2000 and 2006, by aggregating the three sustainability dimensions. The Land Use performance of each region is calculated using as reference the average of the 12 provinces for each year.

5. Application of the LUFs methodology at pan European level

The LUF methodology as described in chapter 3 was also applied at pan European level using NUTS 2/3 regions as spatial units. The specific regional weight 3 was not applied in this case due to the impossibility to determine regional weights for each NUTS 2/3 region within the framework of this project. The results are analysed at the end of this chapter.

Step 1: Selection of indicators

Preliminary indicator selection

The indicators were selected following the criteria specified in chapter 3. Based on the results of Volume 0 (Data Management) it is agreed to use the NUTS 2/3 level (a mixture of NUTS 2 and NUTS 3 to achieve a balanced size in the administrative regions; Renetzeder et al, 2008), as optimal spatial resolution considering the data availability. It should be always possible to upscale the data to a lower resolution. The selected indicators are presented in Table 8.

Table 8: List of 25 selected indicators, indicating their links to the three main dimensions of sustainability, e.g. economic, environmental and societal

Indicator Number	Dimension	Indicator
01	ECO	Multimodal potential accessibility normalised
07	ECO	Gross Domestic Product (Purchasing Power Standard per person)
08	ECO	Gross value added at basic prices - Agriculture and fishing (EURO per person)
09	ECO	Gross value added at basic prices - Total (EURO per person)
11	ECO	Industrial and commercial areas (Land cover)
16	ECO	Nights spent in tourist accommodations (nr/ha)
24	ECO	Urban fabric (Land cover)
02	ENV	Area harvested
03	ENV	Artificial non-agricultural vegetated areas (Land cover)
04	ENV	Status of bathing water (qualitative)
06	ENV	Forest and semi-natural areas (Land cover)
10	ENV	Green Urban Areas (Land cover)
12	ENV	Natural leisure (Land cover)
13	ENV	NH3 emission (kg N/ha)
14	ENV	Navigable rivers and canals (m/km2)
17	ENV	N-surplus (kg N/ha)
19	ENV	Natural protected areas - CDDA and Natura2000
20	ENV	P-surplus (kg P/ha)
21	ENV	Sport and leisure facilities (Land cover)
25	ENV	NO3 concentration of leaching water from agriculture (mg NO3/litre)
05	SOC	Pre-primary education – Total
15	SOC	Net migration - arrivals-departures (nr/km2)
18	SOC	Population density (nr/km)
22	SOC	Monuments and other tourist sights (index)
23	SOC	Unemployment (nr/km2)

The indicators and their sources are shortly described in Annex 1.

Final selection of indicators based on statistical correlation analysis and data quality

Once indicators have been selected, the next step is to analyse the statistical correlation between indicators at the NUTS 2/3-level. The correlations per LUFs are analysed using a "pairwise.complete.obs" method[1], which is based on multi-annual data. Those indicators that show a correlation above 0.8 were considered highly correlated and therefore only one was selected (see correlation matrixes per LUF in Appendix 2). For example, N surplus and P surplus were highly correlated and only the P surplus was considered. As a rule, indicators with the highest quality of the dataset had priority in the selection. In addition, a data quality check was done for all the indicators, which resulted in the dismissal of the indicator 'Natural protected areas - CDDA and Natura2000' because the database of 2000 was incomplete. As a result of the correlation analysis and data quality check, some indicators were rejected per LUF as shown in Table 9.

[1] r-manual (http://stat.ethz.ch/R-manual/R-patched/library/stats/html/cor.html)

Table 9: Indicators rejected per LUF as result of the correlation analysis and quality data check

LUF	Indicators rejected
LUF1	Pre-primary education – Total
	Population density (nr/km)
	Natural protected areas - CDDA and Natura2000
LUF2	Forest and semi-natural areas
	Natural protected areas - CDDA and Natura2000
LUF3	Land cover - Artificial non-agricultural vegetated areas
	Green Urban Areas
	Land cover - Industrial and commercial areas
	N-surplus (kg N/ha)
	Natural protected areas - CDDA and Natura2000
LUF4	Land cover - Industrial and commercial areas
	Nights spent in tourist accommodations (nr/ha)
	Population density (nr/km)
	Natural protected areas - CDDA and Natura2000
LUF5	NH3 emission (kg N/ha)
	N-surplus (kg N/ha)
	Natural protected areas - CDDA and Natura2000
LUF6	Green Urban Areas
	N-surplus (kg N/ha)
	Natural protected areas - CDDA and Natura2000

Step 2: Definition of the links between indicators and the LUFs

The specific links between the finally selected indicators and the LUFs were defined by a group of experts in Alterra and reviewed by Autonomous University of Barcelona. They are presented in Table 10.

Table 10 Summary of cross-linkages between the finally selected indicators and the six LUFs (for definition of LUFs, see chapter 2).

Indicator nr	Dimension	Indicator	LUF1	LUF2	LUF3	LUF4	LUF5	LUF6
0	ECO	Multimodal potential accessibility normalised	1	1		1		-1
1	ENV	Area harvested			1		-1	-1
3	ENV	Status of quality of bathing water		1			1	
4	SOC	Pre-primary education				1		
5	ENV	Forest and semi-natural areas (Land cover)			1		1	1
6	ECO	Gross Domestic Product (Purchasing Power Standard per person)				1		
7	ECO	Gross value added			1			

		at basic prices - Agriculture and fishing (EURO per person)						
8	ECO	Gross value added at basic prices - Total (EURO per person)	1	1				
9	ENV	Green Urban Areas (km^2) (Land cover)		1				
10	ECO	Industrial and commercial areas (km^2) (Land cover)	1					
11	ENV	Natural leisure (km^2) (Land cover)		1				1
13	ENV	Navigable rivers and canals (m/km2)		1			1	1
14	SOC	Net migration - arrivals-departures (nr/km2)	1			1		
15	ECO	Nights spent in tourist accommodations (nr/ha)	1	1				
17	SOC	Population density (nr/km)					-1	
19	ENV	P-surplus (kg P/ha)			1		-1	-1
20	ENV	Sport and leisure facilities (km^2) (Land cover)		1				
21	SOC	Monuments and other tourist sights (index)	1	1				
22	SOC	Unemployment (nr/km2)	-1					
23	ECO	Urban fabric (km^2) (Land cover)				1		-1

Step 3: Assessment of the importance of each indicator for the sustainability of the region

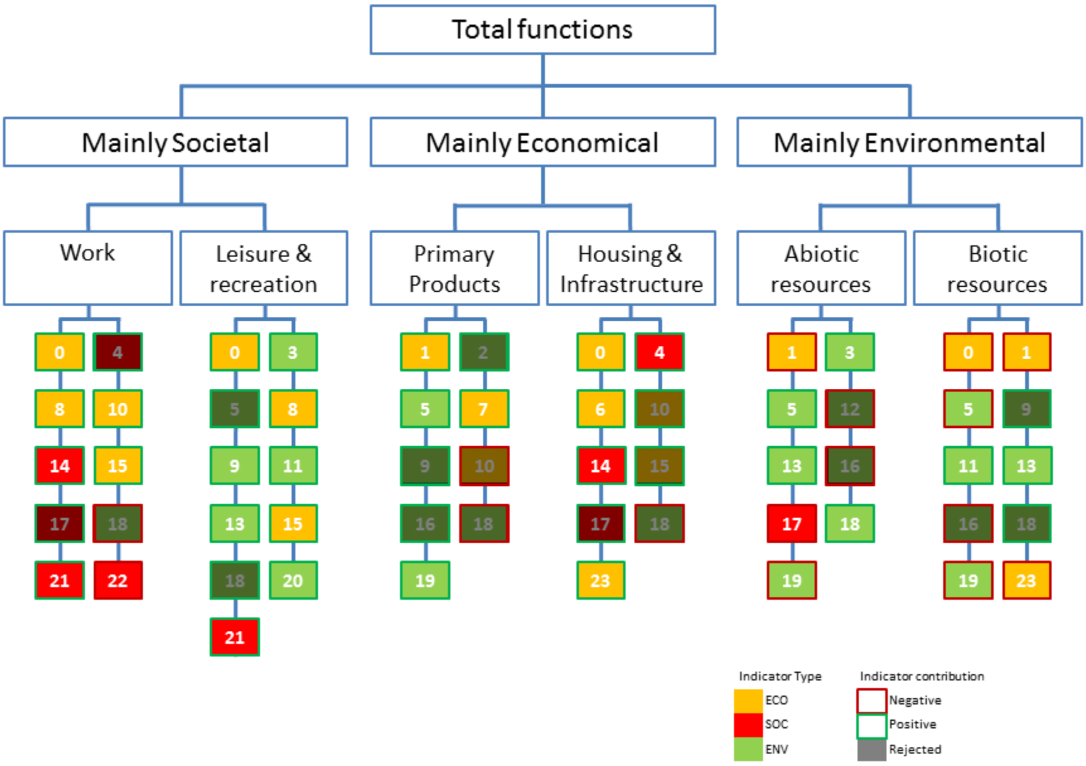
Due to the large number of NUTS 2/3 regions and the limitations of this study, the assessment of the regional importance was not done at pan European level. However it was done for one country (the Netherlands) to test the methodology. This regional analysis used other list of indicators that the ones used at pan European level and results were shown previously in chapter 4.

Step 4: Normalization and equalizing of indicators values

The normalization was done following the method described in chapter 3. The calculations were automatized and excel sheets are available.

Step 5: Integrated assessment of the land use functionality

The resulting aggregation scheme showing the links between the selected indicators and the LUFs is shown in Table 6.



Basic aggregation scheme, after Paracchini *et al.* (2011).

Figure 6 Basic aggregation scheme, after Paracchini et al. (2011). The colours indicate the economic, social and environmental dimensions. The number indicate the code of the indicators. The outlines define the type of link between the indicator and the functions (weight 2), i.e. red is a negative link and green is a positive link. The grey shadow shows the indicators that were finally rejected due to statistical correlation or data quality problems.

Weight 1 was calculated as described in chapter 3 and the results are shown in Table 11.

Table 11: Example showing how components combine to form Weight 1. The first component is the intrinsic indicator weight (to account for issues of redundancy), The second component considers differences in number of economic, social and environmental indicators to achieve balanced representation between the three dimensions. These two components are combined to a total weight of one.

Indicator code	Indicator	Intrinsic indicator weight (A)	LUF balanced weight (B)	Product (A) x (B)	Balanced Weight 1
0	Multimodal potential accessibility normalised	1	0.14	0.14	0.14
6	Gross Domestic Product (Purchasing Power Standard per person)	1	0.14	0.14	0.14
7	Gross value added at basic prices - Agriculture and fishing (EURO per person)	1	0.14	0.14	0.14
8	Gross value added at basic prices - Total (EURO per person)	1	0.14	0.14	0.14

Indicator code	Indicator	Intrinsic indicator weight (A)	LUF balanced weight (B)	Product (A) x (B)	Balanced Weight 1
10	Industrial and commercial areas (km^2) (Land cover)	1	0.14	0.14	0.14
15	Nights spent in tourist accommodations (nr/ha)	1	0.14	0.14	0.14
23	Urban fabric (km^2 (Land cover)	1	0.14	0.14	0.14
	No. ECO indicators	**7**			**1**
1	Area harvested	1	0.14	0.14	0.14
3	Status of quality of bathing water	1	0.14	0.14	0.14
5	Forest and semi-natural areas (Land cover)	1	0.14	0.14	0.14
9	Green Urban Areas (km^2) (Land cover)	1	0.14	0.14	0.14
11	Natural leisure (km^2) (Land cover)	1	0.14	0.14	0.14
13	Navigable rivers and canals (m/km2)	1	0.14	0.14	0.14
19	P-surplus (kg P/ha)	1	0.14	0.14	0.14
	No. ENV indicators	**7**			**1**
4	Pre-primary education	1	0.17	0.17	0.17
14	Net migration - arrivals-departures (nr/km2)	1	0.17	0.17	0.17
17	Population density (nr/km)	1	0.17	0.17	0.17
20	Sport and leisure facilities (km^2) (Land cover)	1	0.17	0.17	0.17
21	Monuments and other tourist sights (index)	1	0.17	0.17	0.17
22	Unemployment (nr/km2)	1	0.17	0.17	0.17
	No. SOC indicators	**6**			**1**

Results

When mapping the results of the analysis, it was considered that:

- The sum of all normalized indicators (with a nominal scale from 0 to 10) weights must add to one. The final LUF result will also be a nominal scale ranging from 0 to 10. However, as a nominal scale to describe performance of the functions can be unclear, the end result was converted into the following three classes; 1 = little functional performance (score 0 to 3); 2 moderate functional performance (score 3 to 6); 3 high functional performance (score 6 to 10).

- The results of the two different time steps are combined in a two digit number, in which the first digit expresses the functional performance in the year 2000, and the second digit the functional performance in the year 2006. Combining these two digits results in nine different classes, with three classes showing a functional performance increase, three classes show a decrease and three classes indicate that changes did not occur (Figure 7).

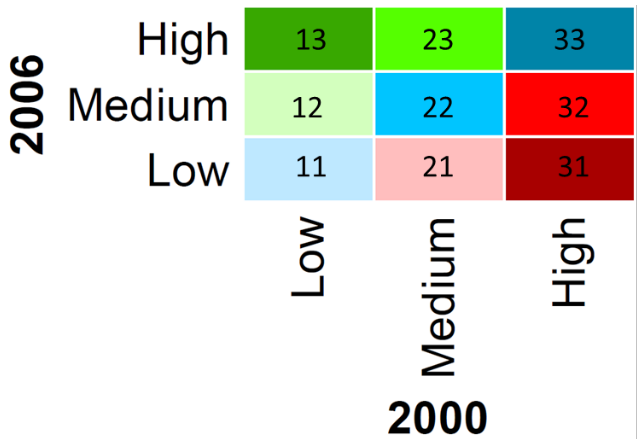


Figure 7: Description of legend used in the mapping of LUF performance changes between 2000 and 2006. Blue indicates no change, red indicates decrease and green indicates increase. The intensity of the colours shows the level of the LUF performance, from light colour (low performance) to deep colour (high performance).

As a result of the implementation maps were developed for:

- the economic, environmental and social dimensions (aggregated results of the contributing LUFs) presented in Figure 8 to Figure 10;
- the six LUFs (aggregation of the selected indicators following the LUF methodology) ; shown in Figure 11 to Figure 14;
- each indicator contributing to the LUFs (see Annex 3).

The spatial assessment of the changes in land use functionality between 2000 and 2006 starts with a general overview of the performance of economic, environmental and social dimensions. As it can be seen in Figure 8 to Figure 10 the performance of the three dimensions remained quite stable (i.e. dominance of the blue colours). Few changes are observed, mainly in the economic and environmental aspects, and these changes are moderated – never from high to low or low to high. They do not follow apparently any geographical specific pattern. The social performance is high in the *Blue Banana* corridor. Interestingly, the regions where changes in economic performance are found do not coincide with those regions showing changes in environmental or social performance. This indicates that the three dimensions are not following the same development patterns. The economic aspects show a decrease in performance in Southern Finland, Northern Denmark, North France, Cataluña (North-eastern Spain) and central Italy, and increases in southern Norway and Levante (eastern Spain).

The assessment of the changes in the six LUFs provides a more detailed insight at functional level (Figure 11 to Figure 14). The analysis of the LUFs maps show that:

- Extreme changes do not occur and the overall pattern shows relative stability during the six years studied. Overall Scandinavia shows the highest stability, being central and southern Europe more unstable with mixed patterns.
- The two mainly economic LUFs (*LUF1 Provision of work, and LUF2 Leisure*) show a high and stable performance in the *Blue Banana* corridor, as it could be expected, although some negative changes in LUF1 are observed in the fringes, e.g. in the Netherlands and East Germany, Eastern France and Barcelona. Positive changes are scattered except in Scandinavia and the Baltic countries. Other countries showing positive development are eastern Turkey, western Spain and central Europe.

- *LUF2 Leisure* shows a more general trend to increase the performance than to decrease. In general, coastal areas and the Canarias islands improve. Romania and Bulgaria increase from low to medium, showing developments in the tourist sector in the previous years to their entrance in the EU (2007).
- In contrast with the economic LUFS, *LUF3 Provision of food, timber and biofuels* shows negative developments in several regions, especially in the Mediterranean countries, which could be associated to land abandonment and decrease in area harvested (mainly due to conversion of rural areas into urban). In contrast, there are positive changes in Scotland and central Europe. It is interesting to see the different geographical patterns in Sweden, with a high and stable performance in the North (associated to forestry production), and a negative performance in the south (linked to agricultural production).
- *LUF4 Housing and infrastructure* shows a high stable performance in the Blue Banana, similarly to the economic LUFs, indicating significant urban and infrastructure developments in the European Megalopolis. Coastal areas in the Mediterranean show as well a high and stable performance and even an increase in some regions. Increases are also observed in southern Spain, southern Italy and eastern Germany, as well in main cities in central Europe (Budapest, Bratislava and surroundings). Decrease is found in few rural areas of Romania, Poland, South Sweden and Lleida (Spain).
- *LUF5 abiotic resources* shows scattered changes as it describes broad environmental issues linked to air, water and soil quality. Therefore variations are difficult to explain without assessing the changes in the specific indicators affecting the LUF.
- *LUF6 biotic resources* shows significant improvement in central Spain and north-western France. There are more negative developments than in the other environmental LUF. For example, in some regions of the Dutch ‘randstad’ (industrial and metropolitan conurbation occupying west-central Netherlands) where significant infrastructure and urban development has taken place. This trend appears as well in the southern Alps including the densely populated Po valley.

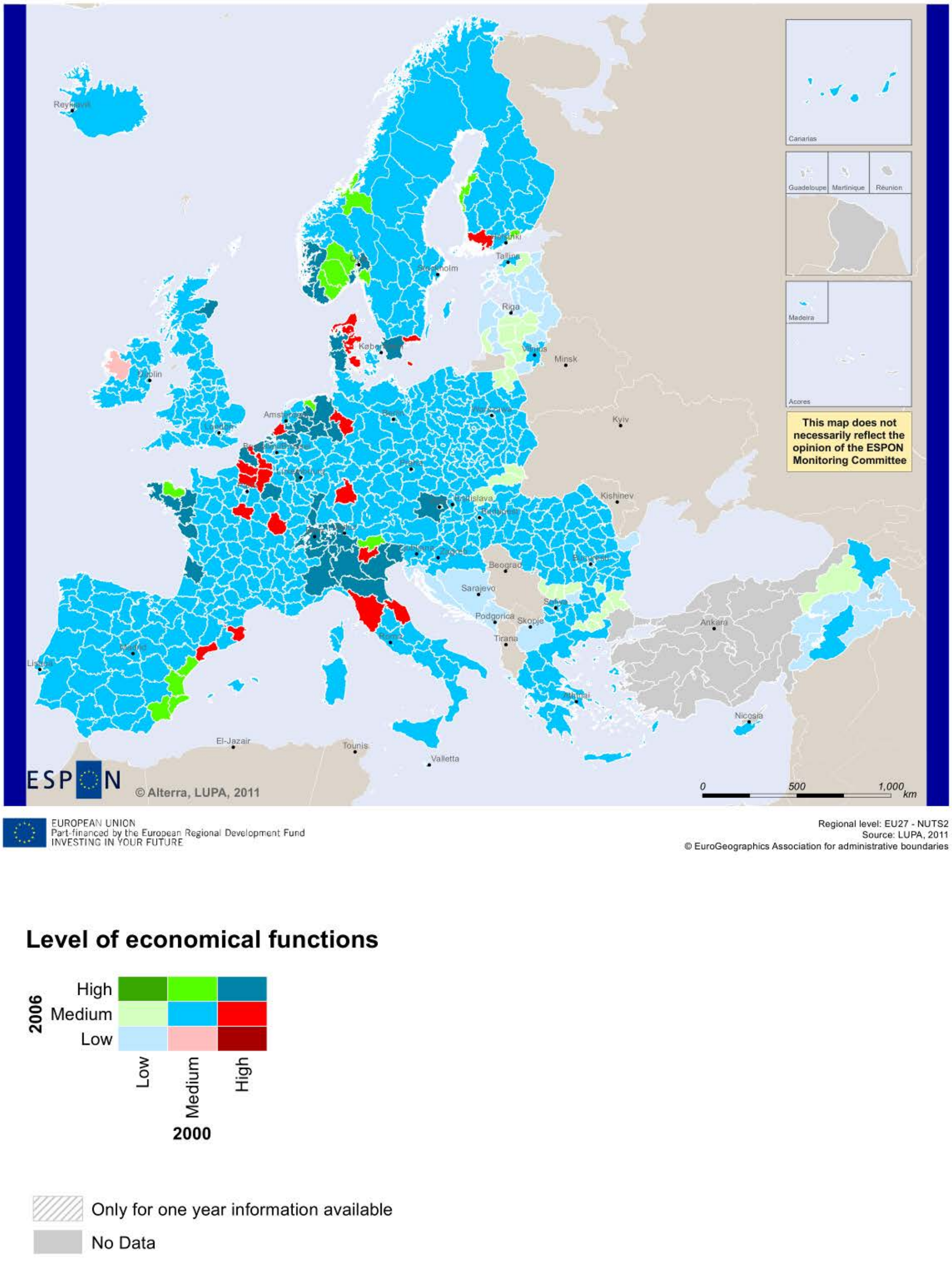


Figure 8 Changes in the economic dimensions in the period 2000-2006, based on aggregated changes observed in Land Use Functions.

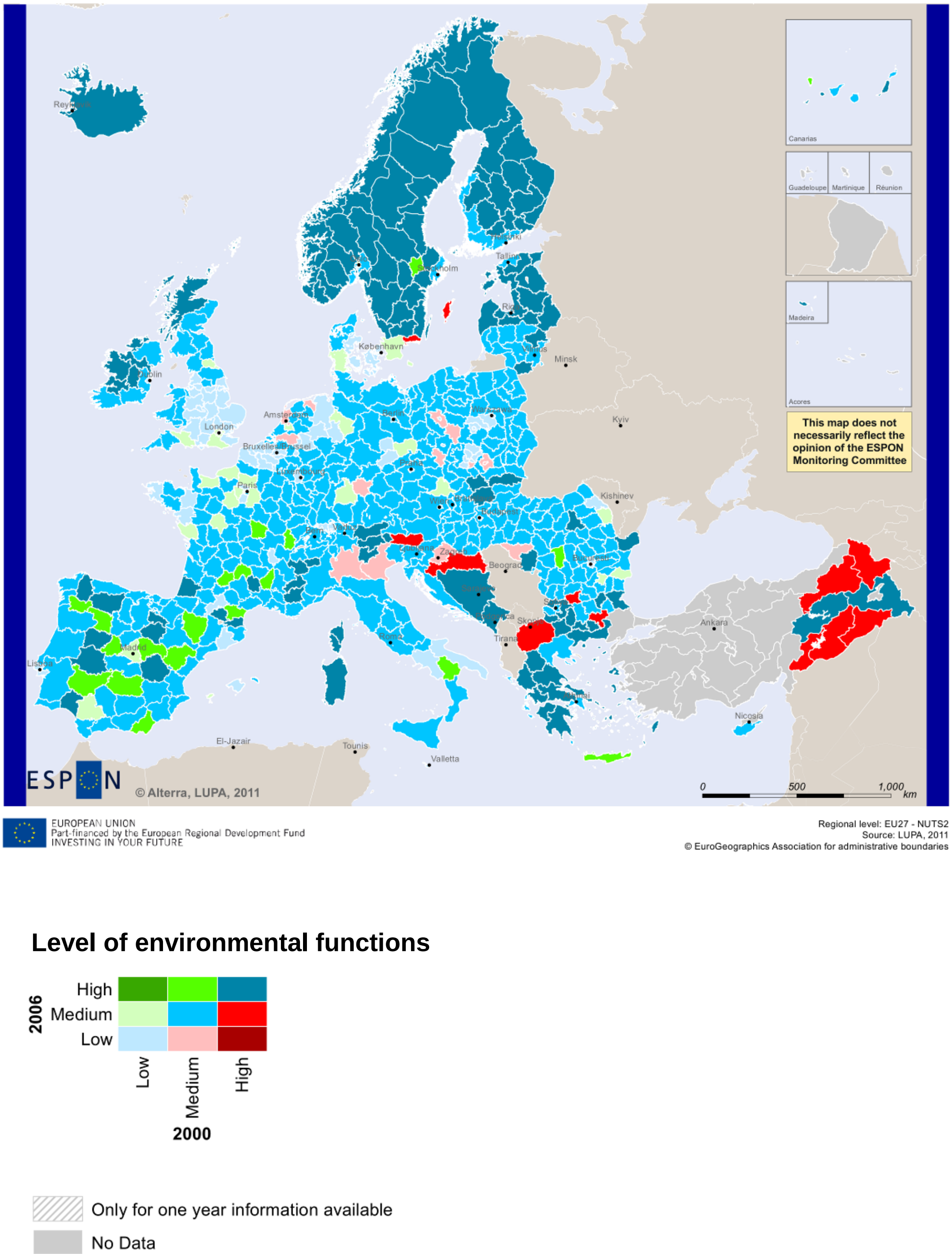


Figure 9 Changes in the environmental dimensions in the period 2000-2006, based on aggregated changes observed in Land Use Functions.

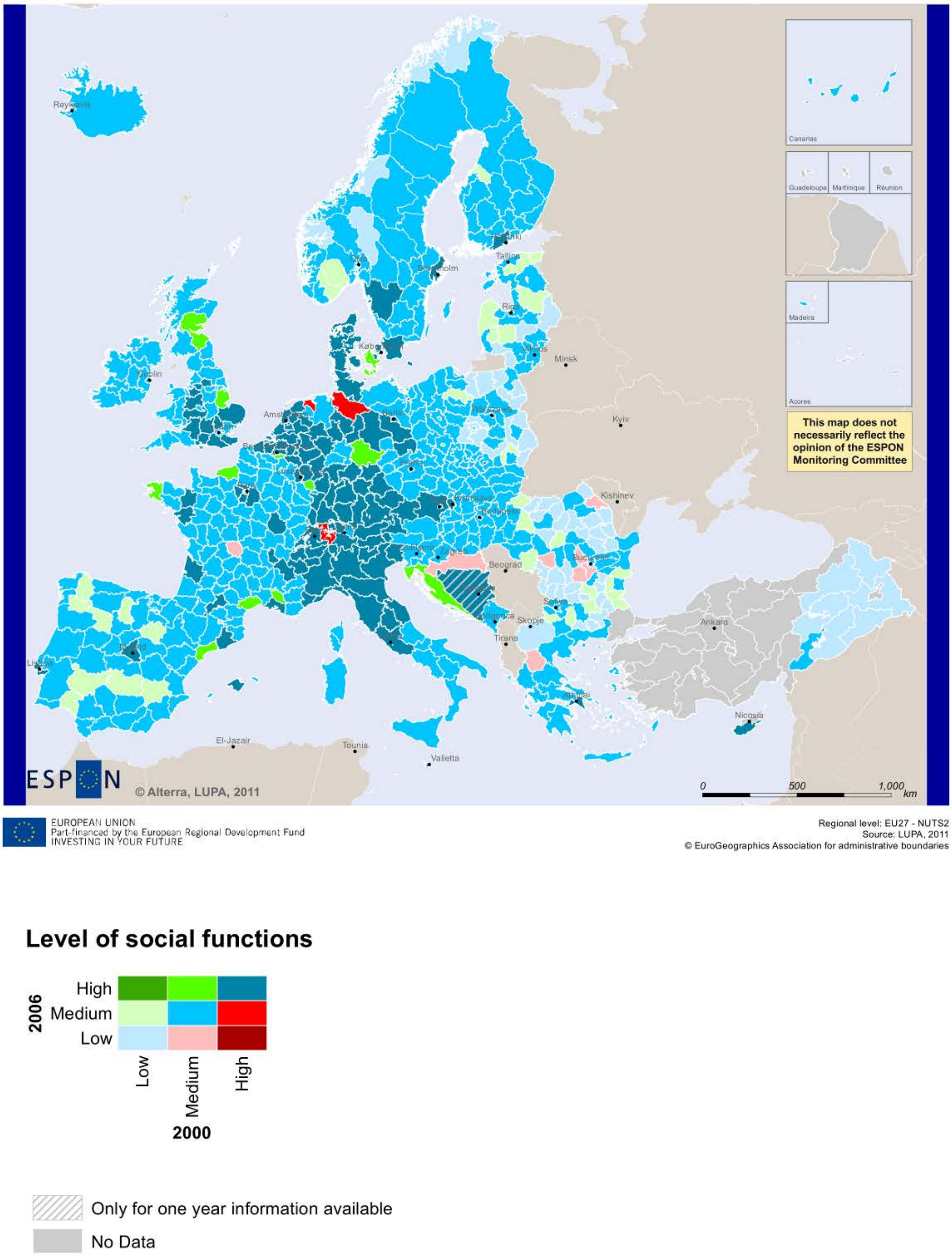


Figure 10 Changes in the social dimensions in the period 2000-2006, based on aggregated changes observed in Land Use Functions.

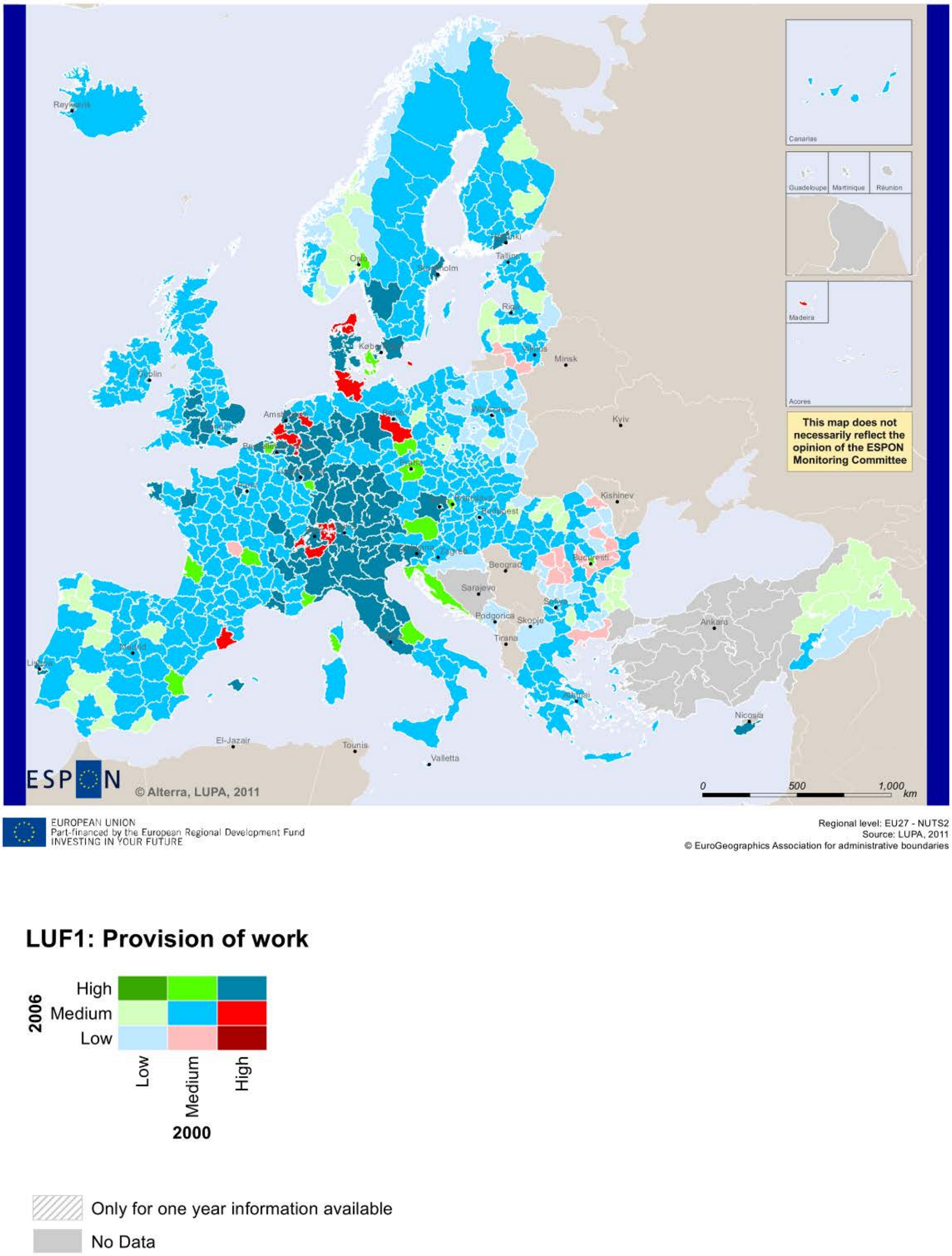


Figure 11: Changes in the performance of LUF1 Provision of work for the period 2000-2006.

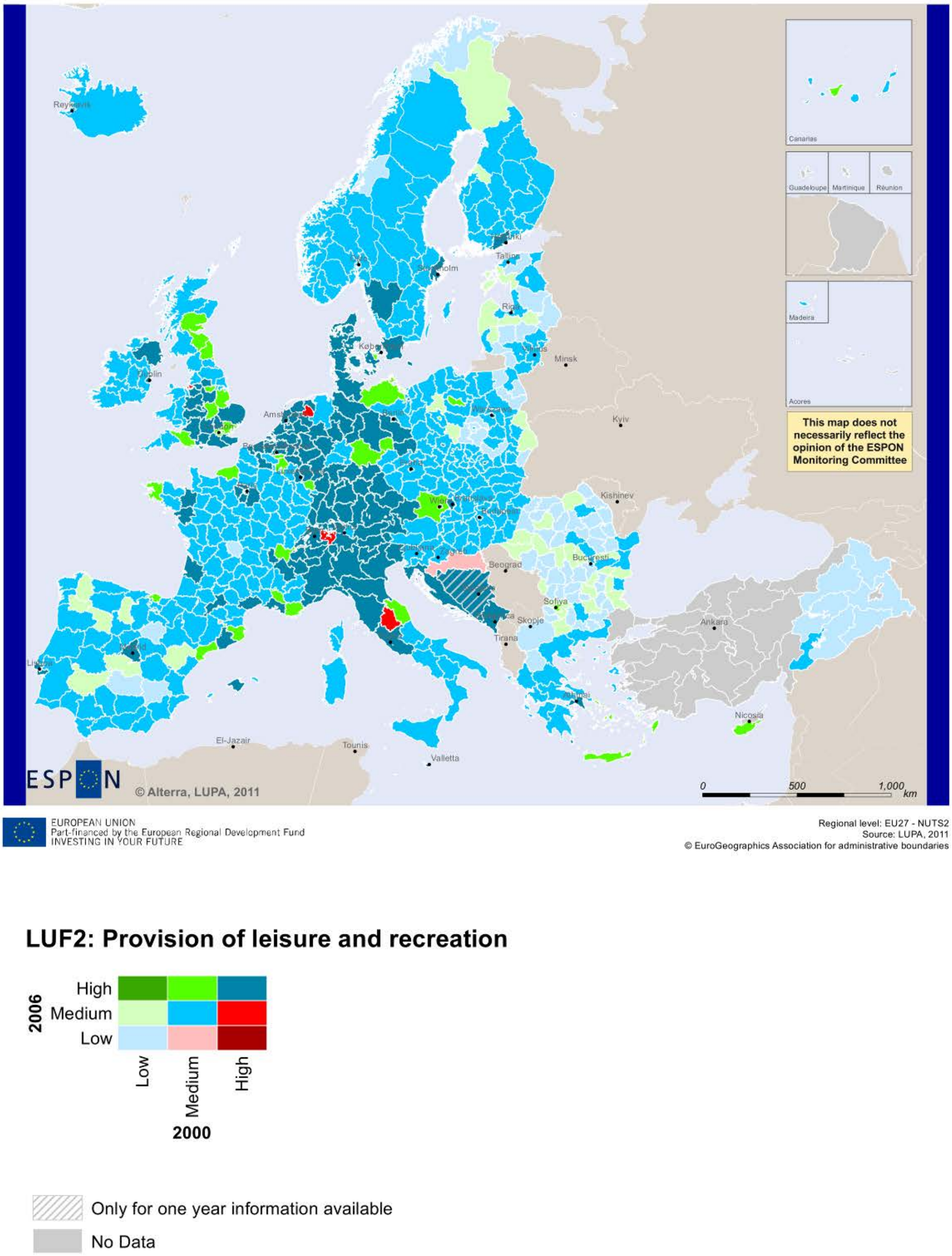


Figure 12: Changes in the performance of LUF2 Provision of leisure and recreation for the period 2000-2006.

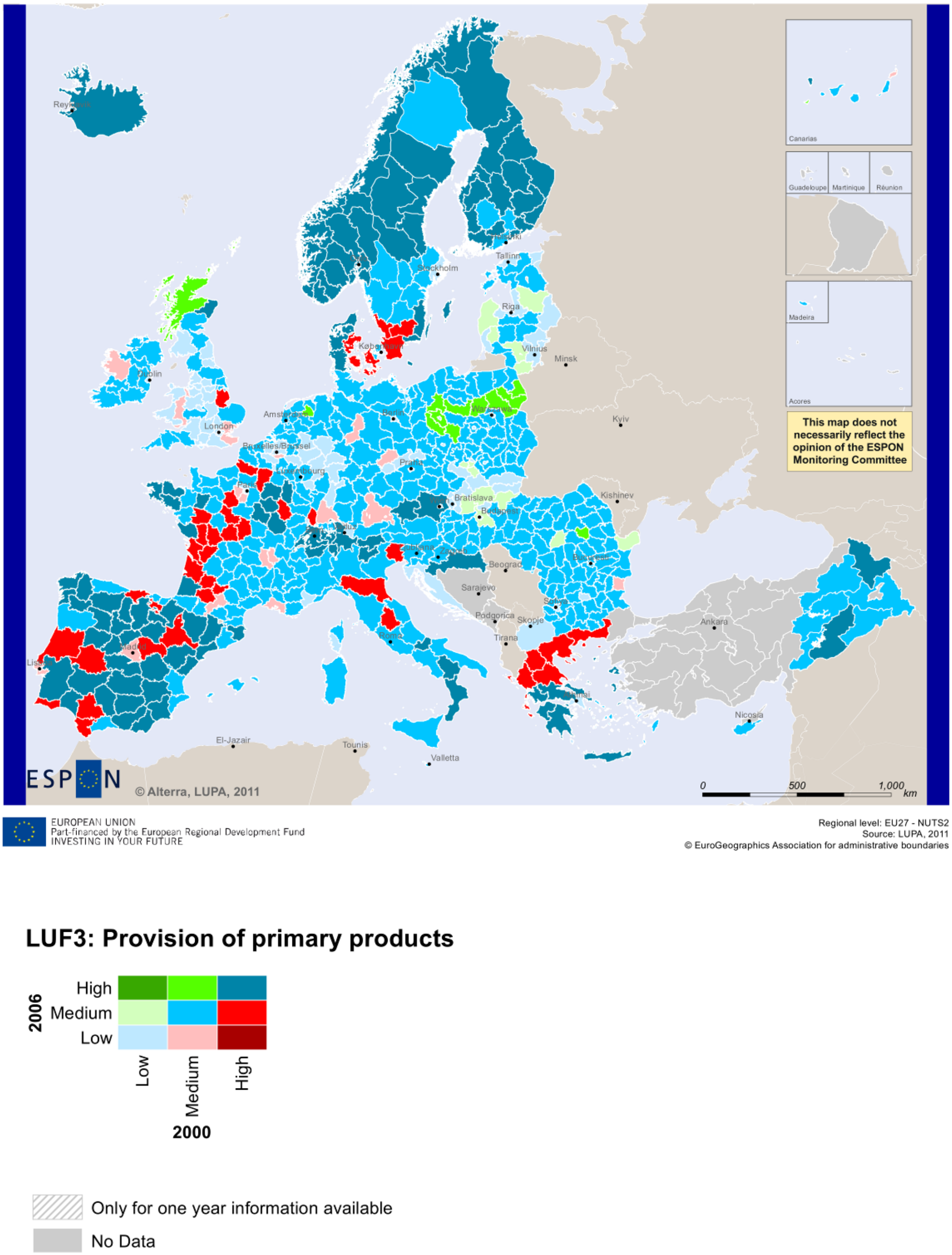


Figure 13: Changes in the performance of LUF3 Provision of primary products for the period 2000-2006.

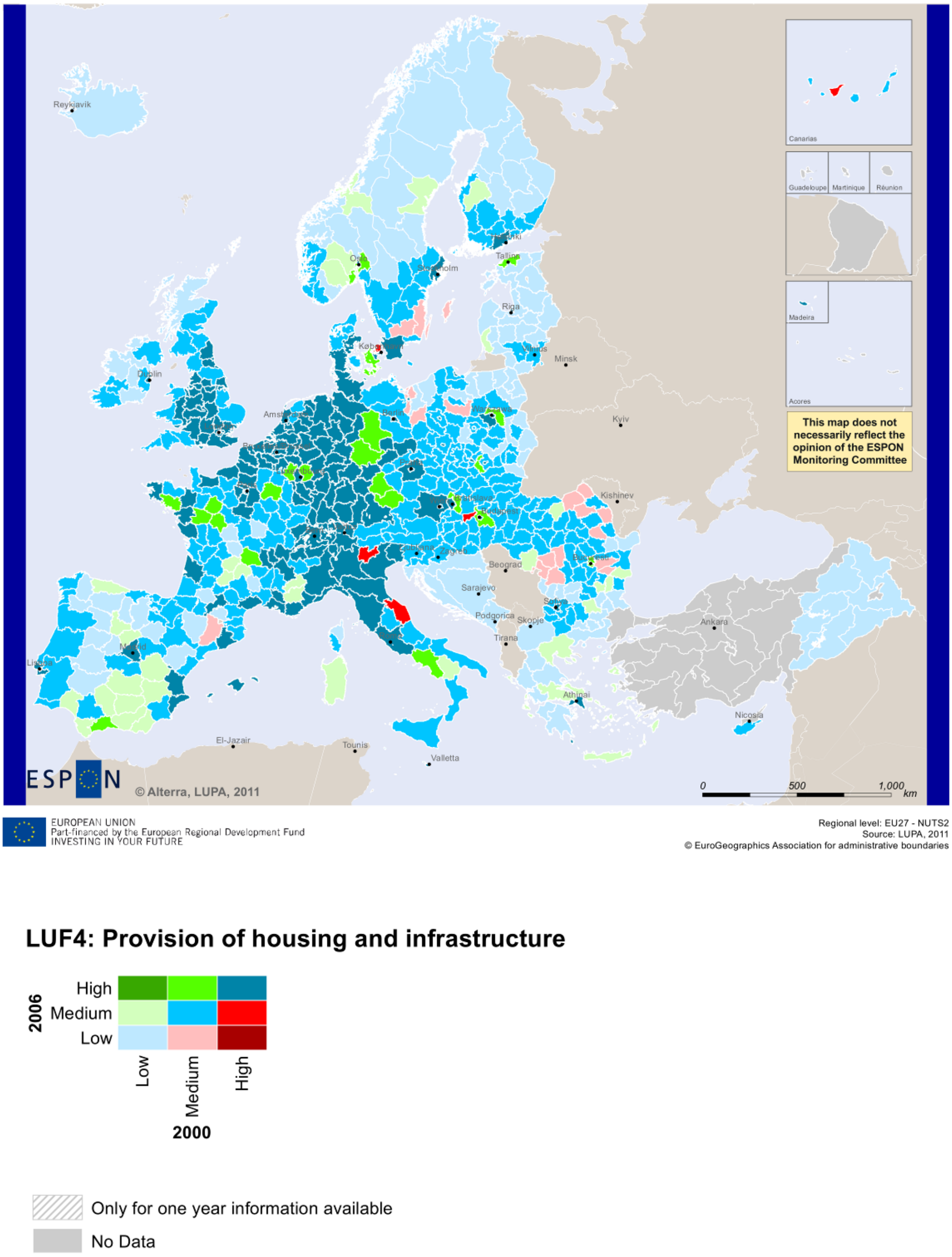


Figure 14: Changes in the performance of LUF4 Provision of housing and infrastructure for the period 2000-2006.

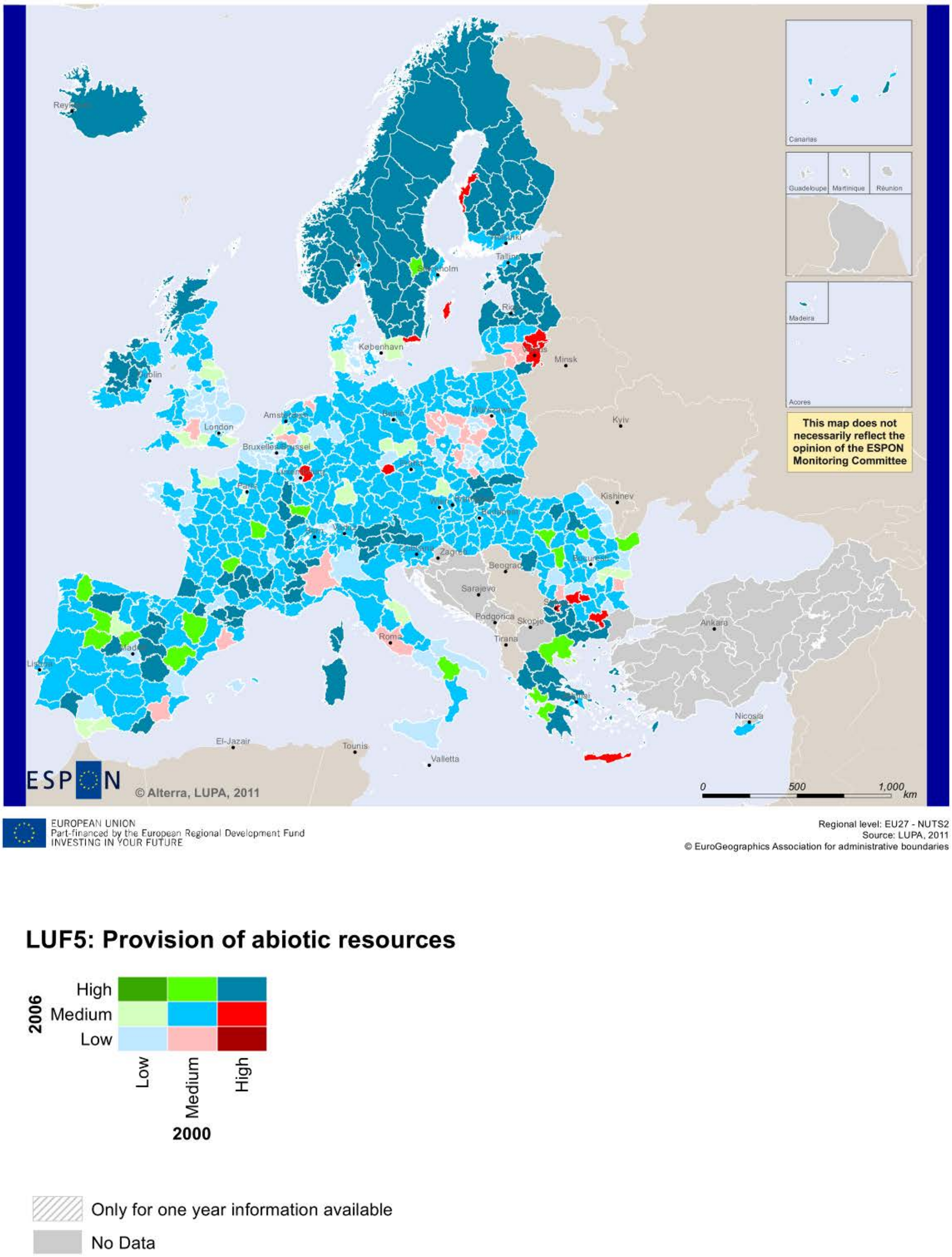


Figure 15: Changes in the performance of LUF5 Provision of abiotic resources for the period 2000-2006.

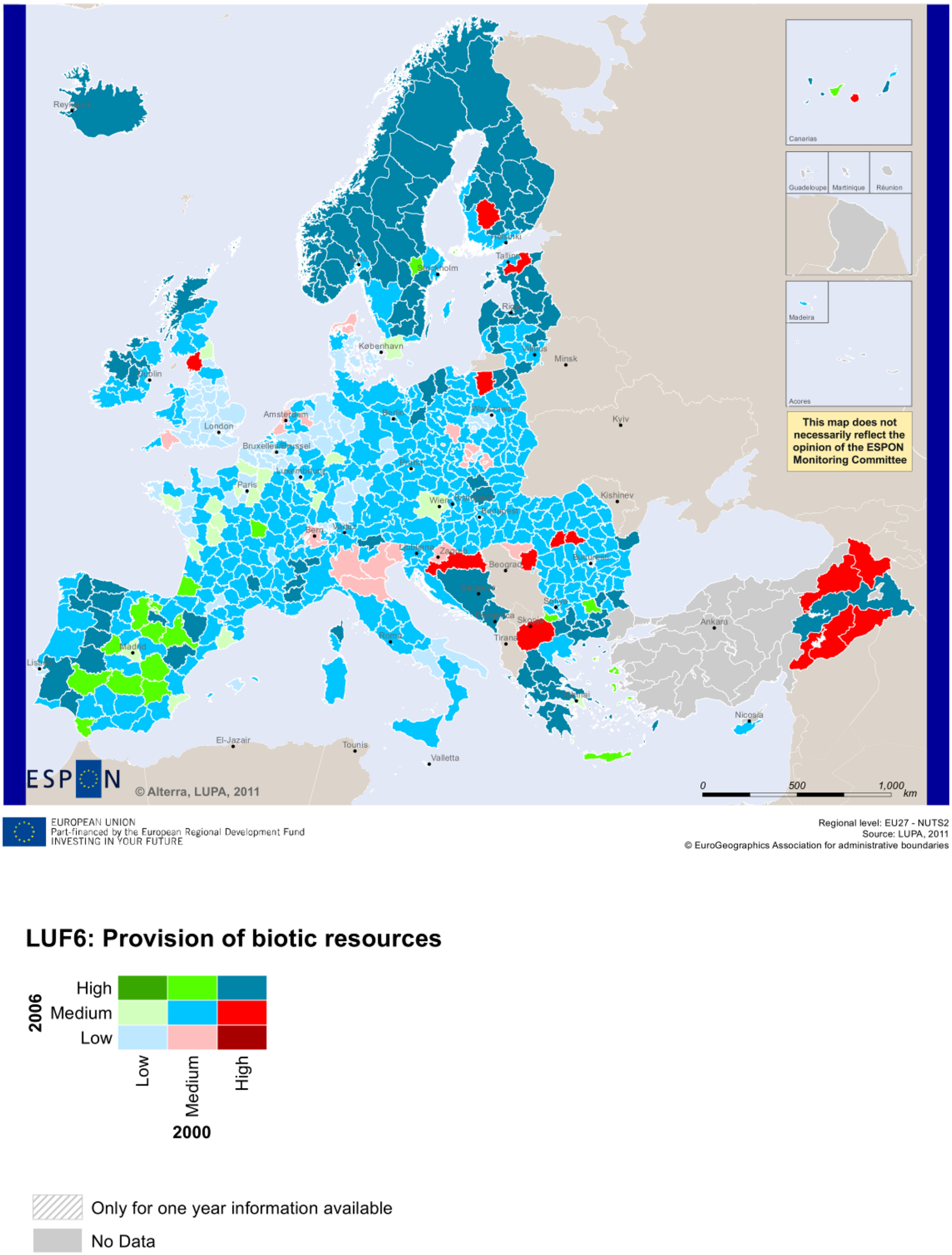


Figure 16: Changes in the performance of LUF6 Provision of biotic resources for the period 2000-2006.

6. Land Use Performance and Land Use Efficiency

In this chapter the concept of Land Use Functions is further applied to define Land Use Performance and Land Use Efficiency. By assessing the individual performance and efficiency of the six LUFs, a deeper insight is reached in the depiction of the multi-functionality of a region.

6.1 Land Use Performance

Land Use performance is defined in EU-LUPA as the degree in which the land that is used for a specific function complies with a related policy target. The policy goals should be clearly defined and could be simple (e.g. job provision, air quality, soil quality) or combined (e.g. job-to-housing ratio). In addition they should allow linkages to quantifiable measures/indicators belonging to the list of indicators selected to define the Land Use Functions. The policy goals should be ideally available at national or regional level In EU LUPA these goals were identified in the policy analysis presented in chapter 4. Alterra and Autonomous University of Barcelona analysed these policy goals and concluded that it was not feasible to use them as reference to calculate the LU performance (see Annex 6). The reasons were that only few policy targets were found that were quantifiable and could be therefore linked to the values of the LUFs indicators. Considering that policy goals were not be directly available, it was decided to use the EU or national averages or other statistical measures as reference for the analysis.

Example of Land Use Performance calculation when a policy target is available: Nitrate Directive

In order to show how the calculations could be done if quantifiable policy targets and corresponding indicators were available at NUTS 2/3 level, the LU performance was calculated as regards the Nitrate Directive. The Nitrate Directive requires MS to monitor surface waters and groundwater for nitrate pollution against a maximum limit of **50 mg nitrate/l** (Directive 91/676/EEC on pollution caused by nitrates from agricultural sources). '...*The Directive seeks to reduce or prevent the pollution of water caused by the application and storage of inorganic fertiliser and manure on farmland. It is designed both to safeguard drinking water supplies and to prevent wider ecological damage in the form of the eutrophication of freshwater and marine waters generally*...'. This policy target clearly refers to the two environmental LUFs (LUF5 Provision of abiotic resources and LUF6 Provision of biotic resources). One of the indicators considered underpinning these functions is the Nitrogen surplus, for which values are available at NUTS 3 level. The Nitrogen surplus values were calculated as nitrate concentration of leaching water from agriculture for the years 2000, as calculated by the model MITERRA Europe (Velthof et al., 2009).

Two options were considered:

<u>Option 1</u>: Showing the level of compliance above and below the policy target: f nitrate concentration in the NUTS 3 region is > 50 mg Nitrate / litre (policy target) (which is considered as 100%), then the LUF5 and LUF6 performances are negative and it is expressed as a proportion below the 100%; If nitrate concentration is < 50 mg Nitrate/l , then the LUF5 and LUF6 performances are positive as it is expressed as a proportion above the 100%.
<u>Option 2:</u> Showing only the level of compliance when the values are above the policy target and considering all values below the threshold as 100% compliance.

The results are shown in Figure 10 and Figure 11, respectively for Options 1 and 2. The results in Figure 10 and Figure 11show that regions in eastern and central Spain, Bretagne in France, south of the Netherlands, Belgium, some regions in the western part of Germany, Finland and some regions in Poland do not comply with the nitrate directive and therefore their LUF5 and LUF6 environmental land use performance regarding the agricultural land use is negative.

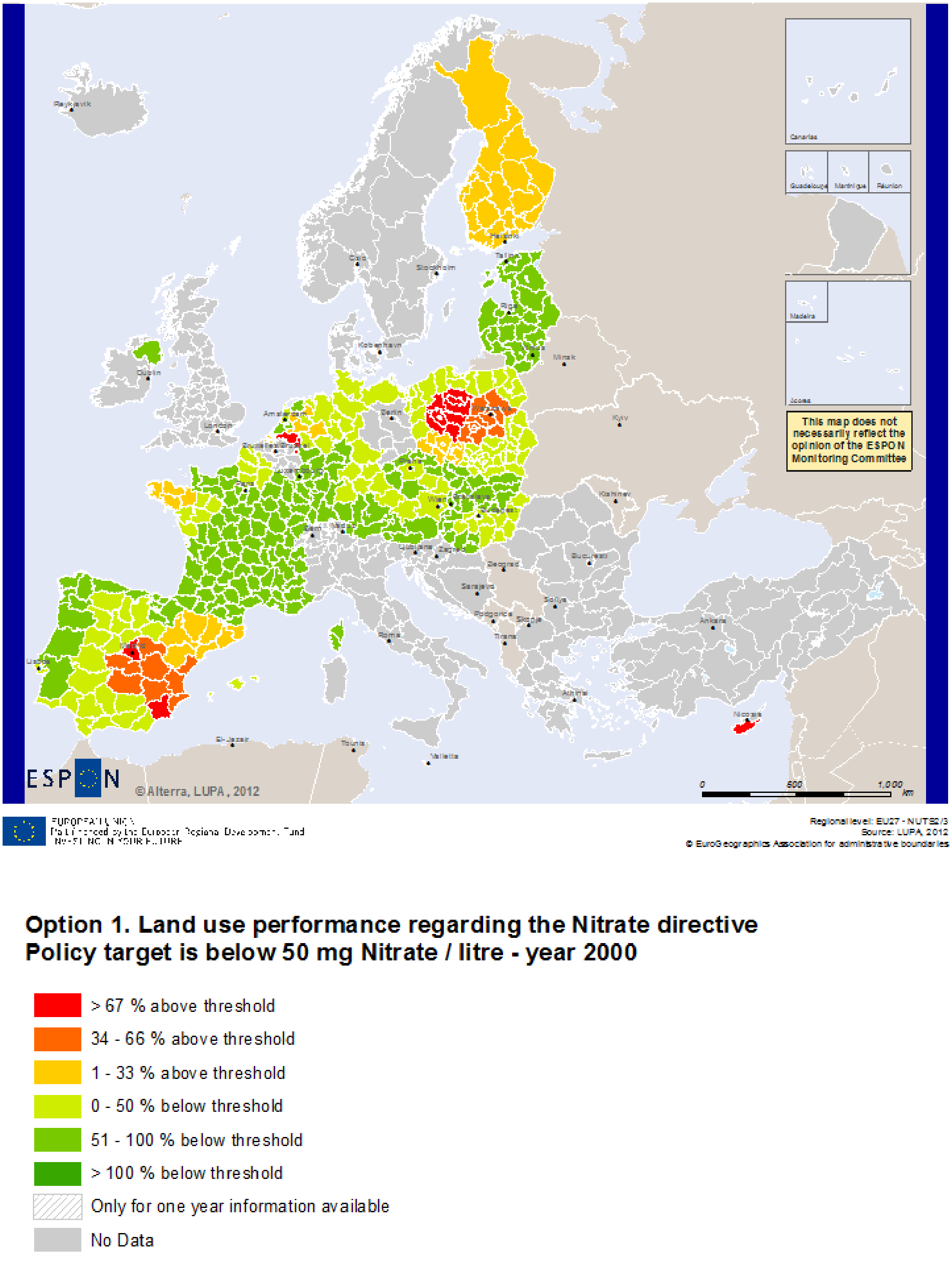
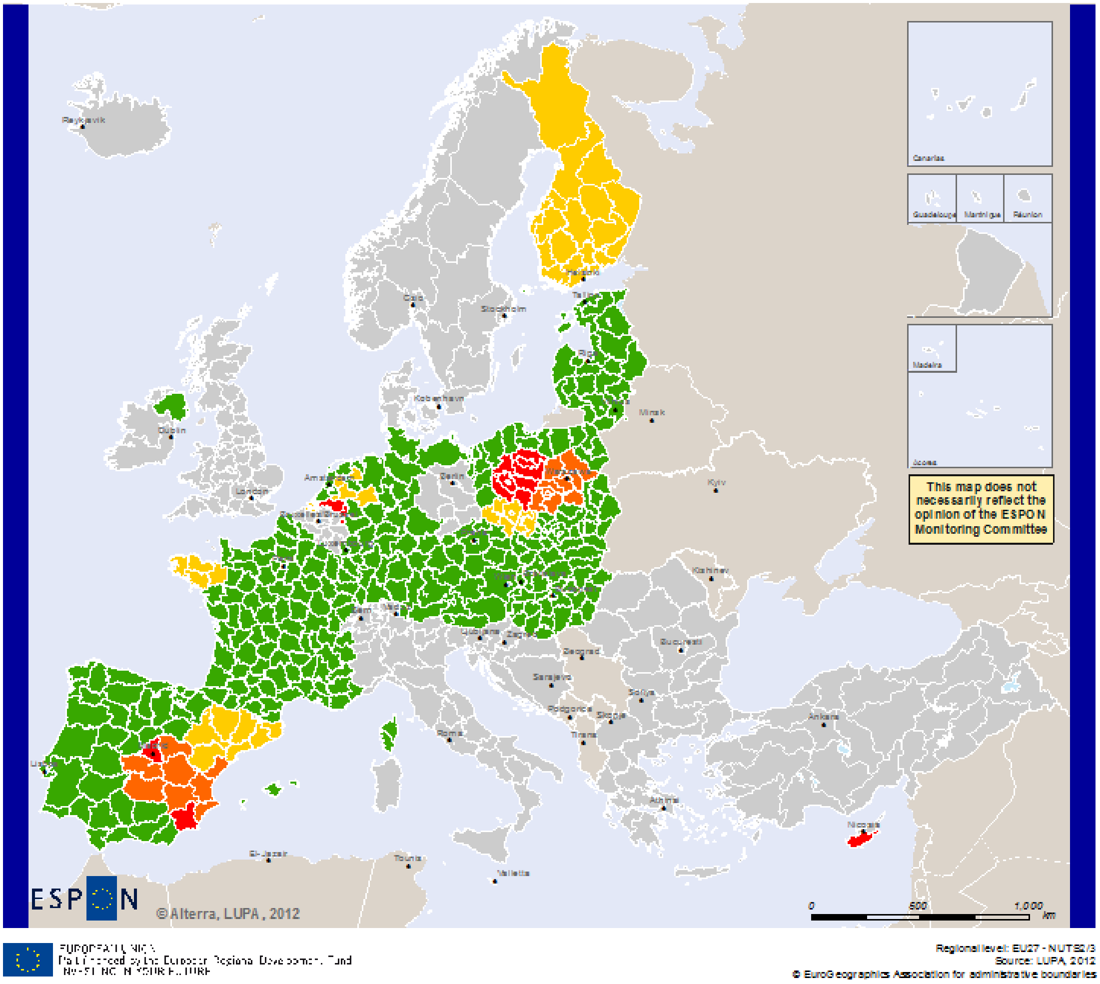


Figure 17 Land Use Performance of the agricultural land use regarding Nitrate Directive showing the level of compliance above and below the policy target



Option 2. Land use performance regarding the Nitrate directive
Policy target is below 50 mg Nitrate / litre - year 2000

- > 67 % above threshold
- 34 - 66 % above threshold
- 1 - 33 % above threshold
- Complying policy target
- Only for one year information available
- No Data

Figure 18 Land Use Performance of the agricultural land use regarding Nitrate Directive showing the level of compliance only above the policy target

Example of Land Use Performance calculation when policy targets are not available or suitable for the calculation

The limited number of policy targets related to land use made necessary to develop other approach for the calculation of the LU performance. This approach calculated the LU performance by considering the individual performance of each indicator having as reference the European average, as it is often used, and the performance of the indicators was aggregated per LUF to calculate the LUFs performance in the same way as described in chapter 3.

As example of the calculation of the LU performance using as reference the EU average, we used again as indicator the Nitrogen surplus. The same assessment was made but considering the distance of the regional nitrate values to the European average, in the case that no policy target would be available. In the same way as before, Figure 12 shows the distances above and below the European average, and Figure 13 only the distances above the European average.

The results in Figure 12 and Figure 13 show that in case no policy target would be available for the nitrogen surplus and then the distance to the European average will be considered as estimation of the Land use performance, the results would be quite different since the European average is below the threshold of 50 mg nitrate/ l. Consequently, more regions would show a low environmental land use performance concerning agricultural land use, with values above the European nitrate concentration average.

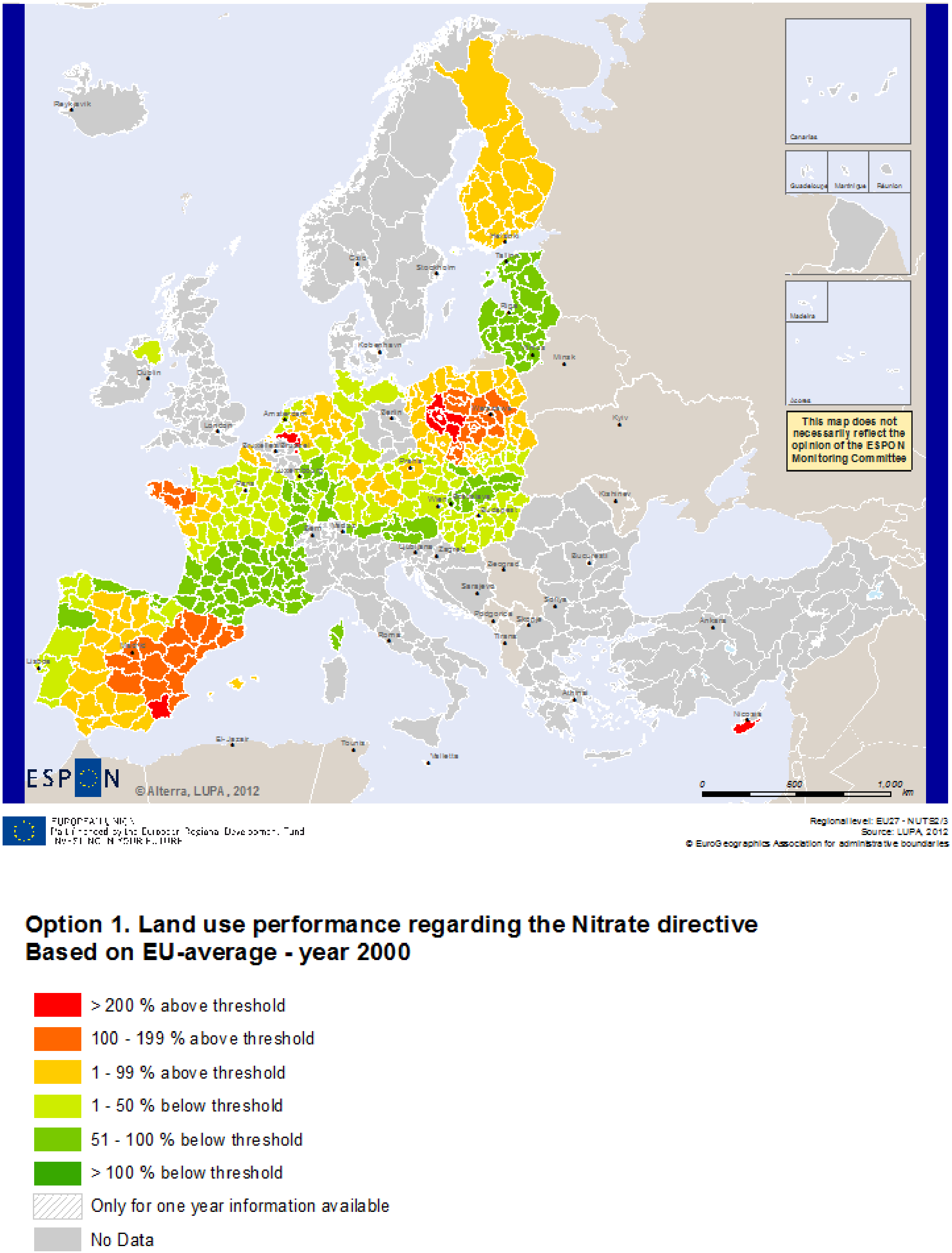


Figure 19 Land Use Performance of the agricultural land use regarding the European average showing the distances above and below the average

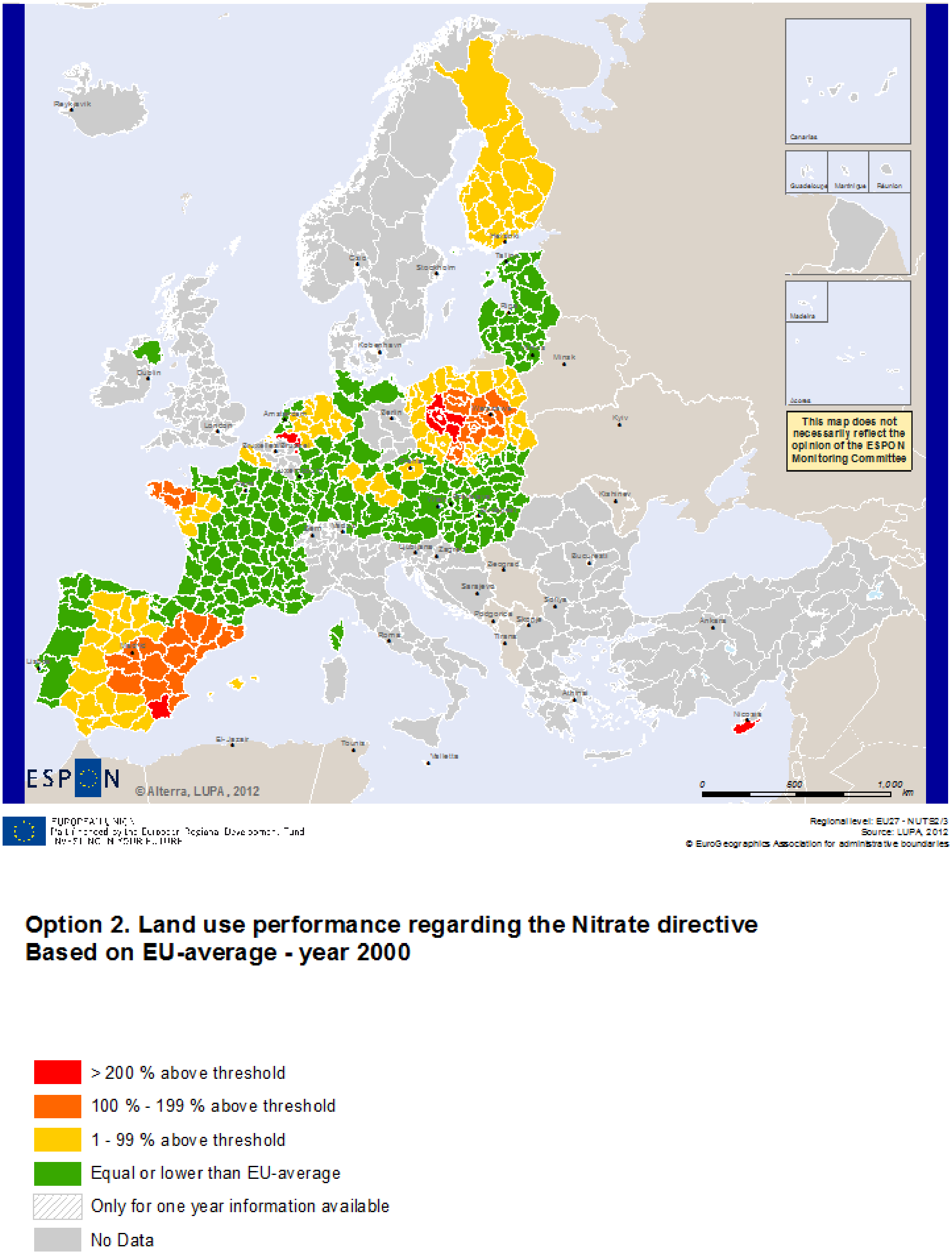


Figure 20 Land Use Performance of the agricultural land use regarding the European average showing the distances above the average

In addition to the maps, the Land Use Performance results were visualised as well using spider diagrams, which show the normalised scores for the indicators or the Land Use Functions, compared to the normalised value of the European average. The normalisation by range is given a nominal scale of 0 to 10.

Spider diagrams were produced for all NUTS 2/3 regions. As example we produced spider diagrams for regions in Finland, the Netherlands and Spain (showed below) and for Poland (shown in the next chapter as part of the testing of the LUF methodology for a case study region).

As the figures below show, the spider diagrams seem to be an useful tool to visualise at once all the indicators or the LUFs for a single region, displaying their distance to the EU average. Being able to analyse simultaneously the spider diagrams of the indicators and the LUFs, also helps to understand the role that the indicators play in underpinning the values of the LUFs. The spider diagrams show as well the large differences between the Nuts 2/3 regions and highlight their main functional specificities, as shown in Figure 14-Figure 18.

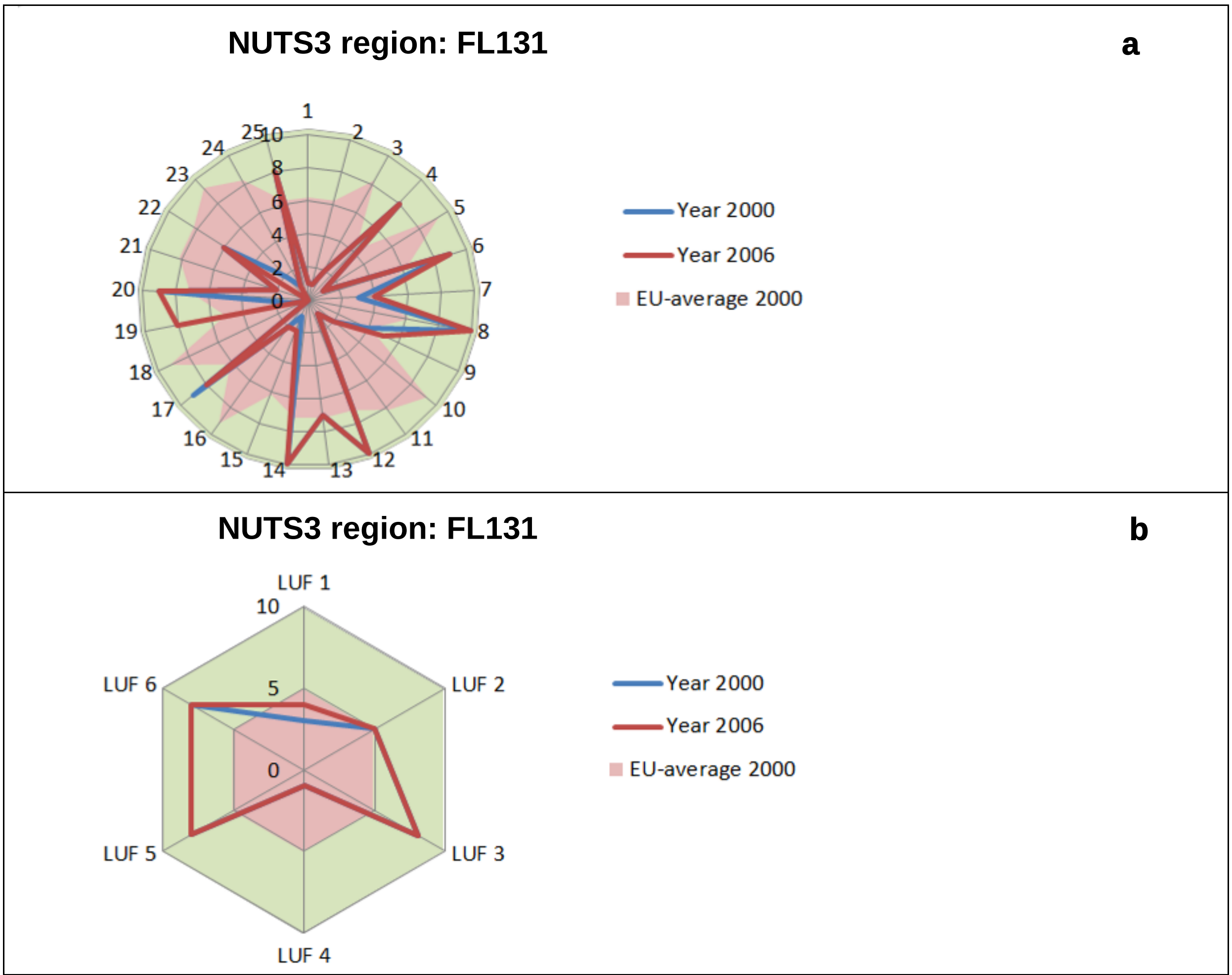


Figure 21: Spider diagrams showing the results of (a) the 25 individual indicators and (b) LUFs for NUTS 3 region FL131 - Etelä-Savo. The names of the 25 indicators are provided in Table 8.

Ëtela-Savo (Southern Savonia) is a region in the south-east of Finland. It is located in the heart of the Finnish lake district. It has only two major towns in the region, the rest being mainly rural or remote areas (shown by the low values of LUF4 and high values of LUF5 and LUF6). Its key economic sectors are services (67%) and manufacturing (24%), with a minor role of the primary sector (9,2%). Because of the climate, agricultural development is limited to maintaining self-sufficiency in basic products. Forestry, an important export earner, provides a secondary occupation for the rural population (shown by high values above EU average of LUF3). It has a high unemployment rate (12%) (shown by low values of LUF1).

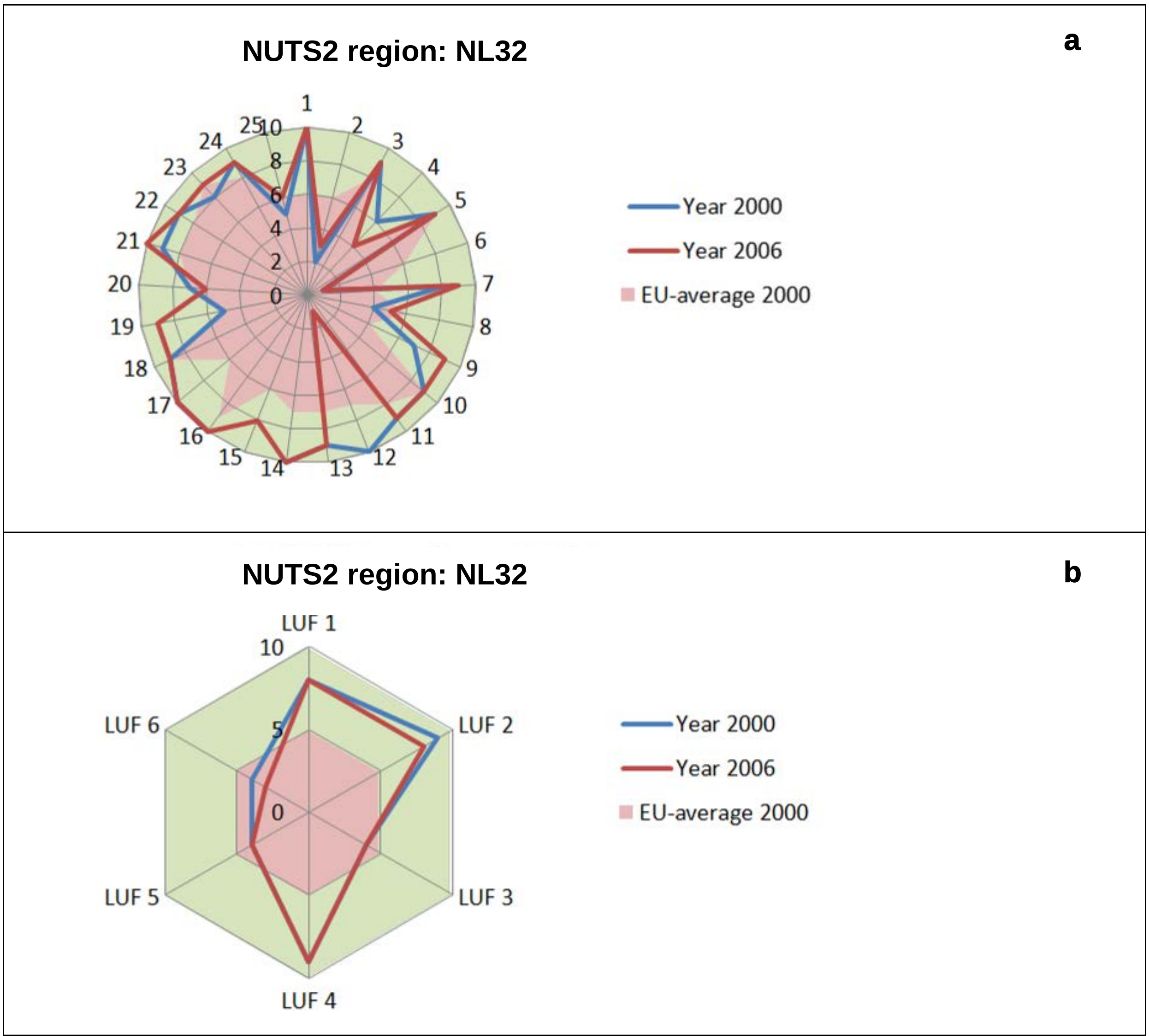
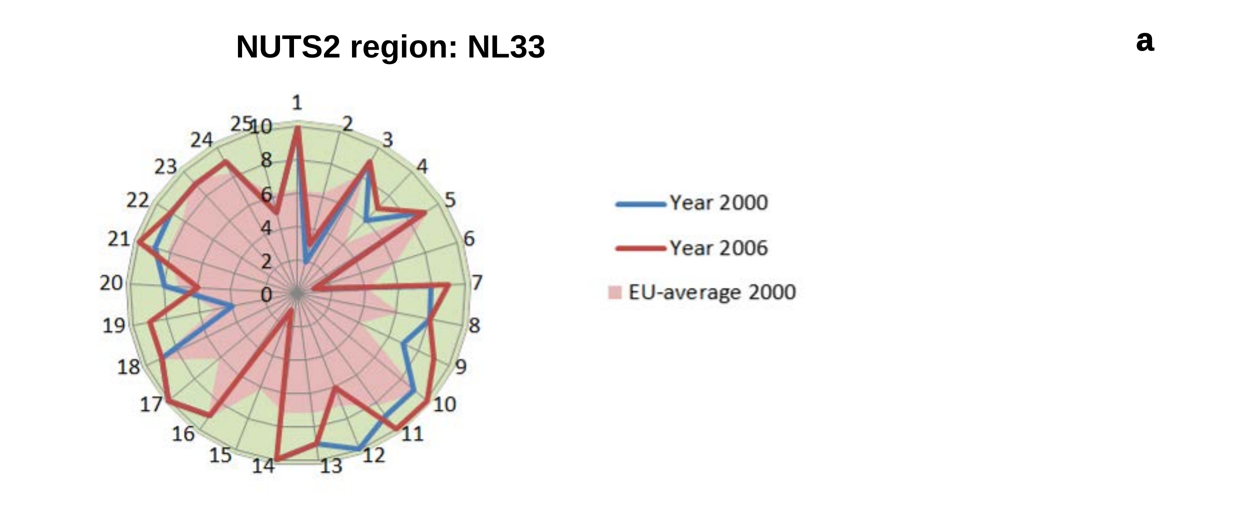


Figure 22: Spider diagrams showing the results of (a) the 25 individual indicators and (b) LUFs for NUTS 2 region NL32 Noord-Holland. The names of the 25 indicators are provided in Table 8.

Noord-Holland is a province situated on the North Sea in the northwest part of the Netherlands. Noord-Holland is the country's second most densely populated province, with high level of urbanisation (as shown by the very high values of LUF4 compared to the EU average). It is as well one of the most attractive touristic areas as it is shown by the also very high values of LUF2.



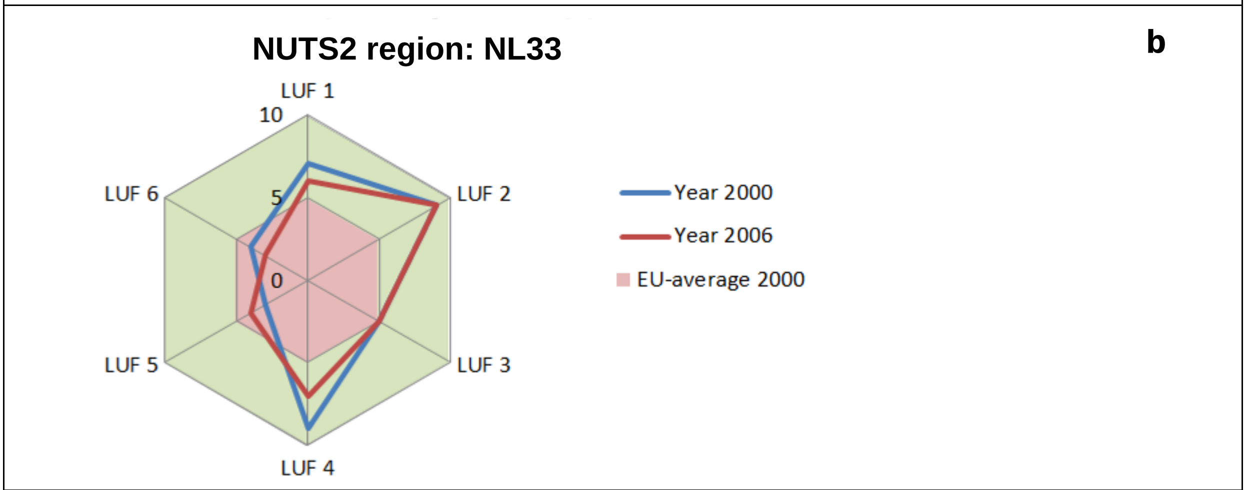


Figure 23: Spider diagrams showing the results of (a) the 25 individual indicators and (b) LUFs for NUTS 2 region NL33 Zuid-Holland. The names of the 25 indicators are provided in Table 8.

Zuid-Holland is a province situated on the North Sea in the western part of the Netherlands. Zuid-Holland is one of the most densely populated and industrialised areas in the world (as it is shown by LUF4), and is the province with the highest population density in the Netherlands. Zuid-Holland is the country's most important province in terms of economy, agriculture and the provision of services (as it is indicated by the very high scores of LUF1 and LUF4). It is a hive of activity, criss-crossed by a busy network of roads, railways and waterways. Rotterdam with its mainport is Zuid-Holland's largest city. The provincial capital is The Hague, which is the seat of national government and the Queen's official place of residence. Outside its urban heart, Zuid-Holland offers spacious tranquillity, sprawling countryside, rivers, polders, lakes, dunes and endless sandy beaches (high level of LUF2). Despite being neighbour provinces in the same country, it is interesting to see the differences between the two Dutch provinces regarding agricultural production (LUF3) –higher in Zuid-Holland, and the two environmental LUFs.

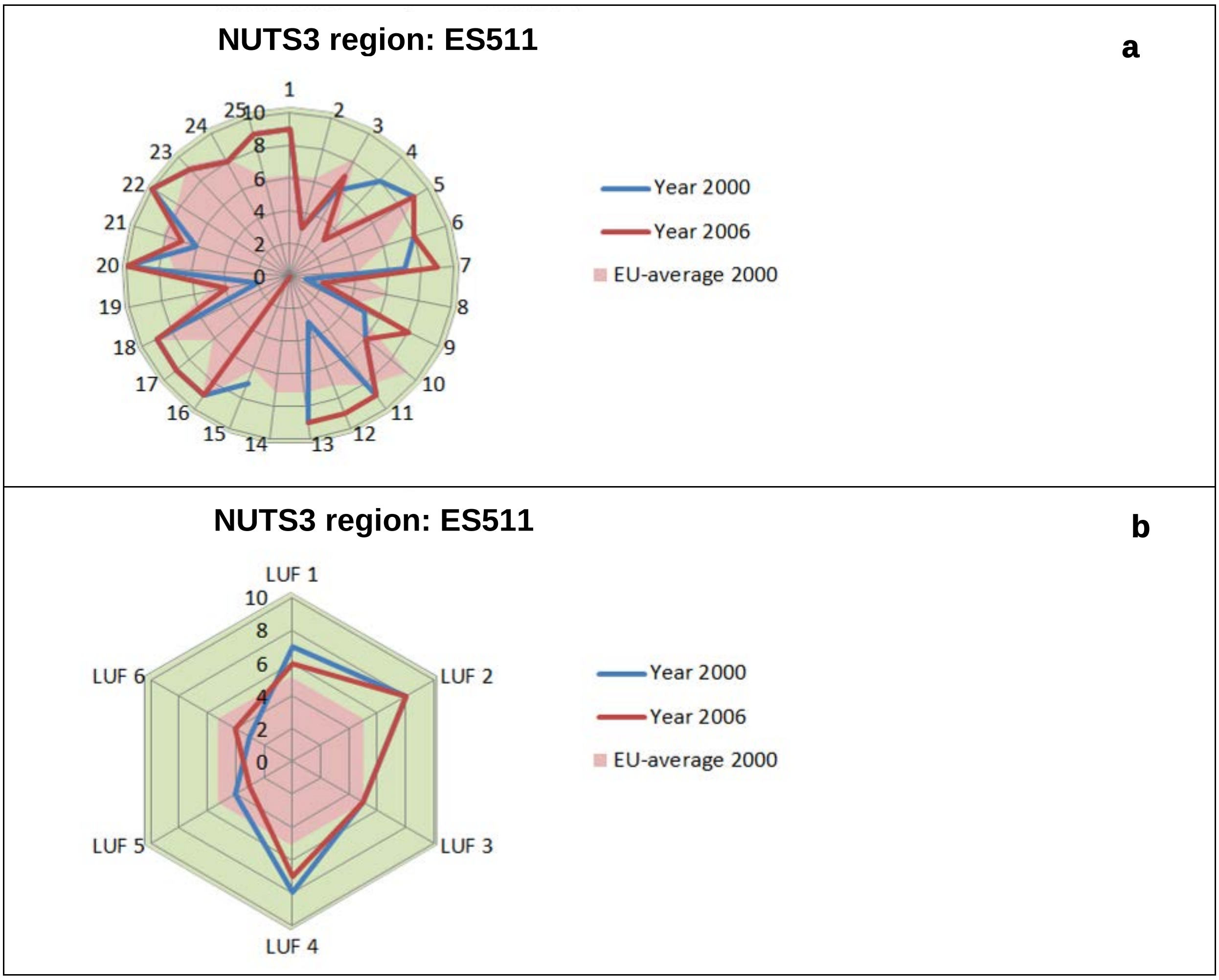


Figure 24: Spider diagrams showing the results of (a) the 25 individual indicators and (b) LUFs for NUTS 3 ES511 Barcelona. The names of the 25 indicators are provided in Table 8.

The province Barcelona is located in eastern Spain on the Mediterranean coast. It is one of the most touristic provinces in Spain with its capital Barcelona one of the most visited cities in the world (high LUF2). The whole province is highly populated and very urbanised (high values of LUF4) which has significant impacts on the environmental resources (low values of LUF5 and LUF6).

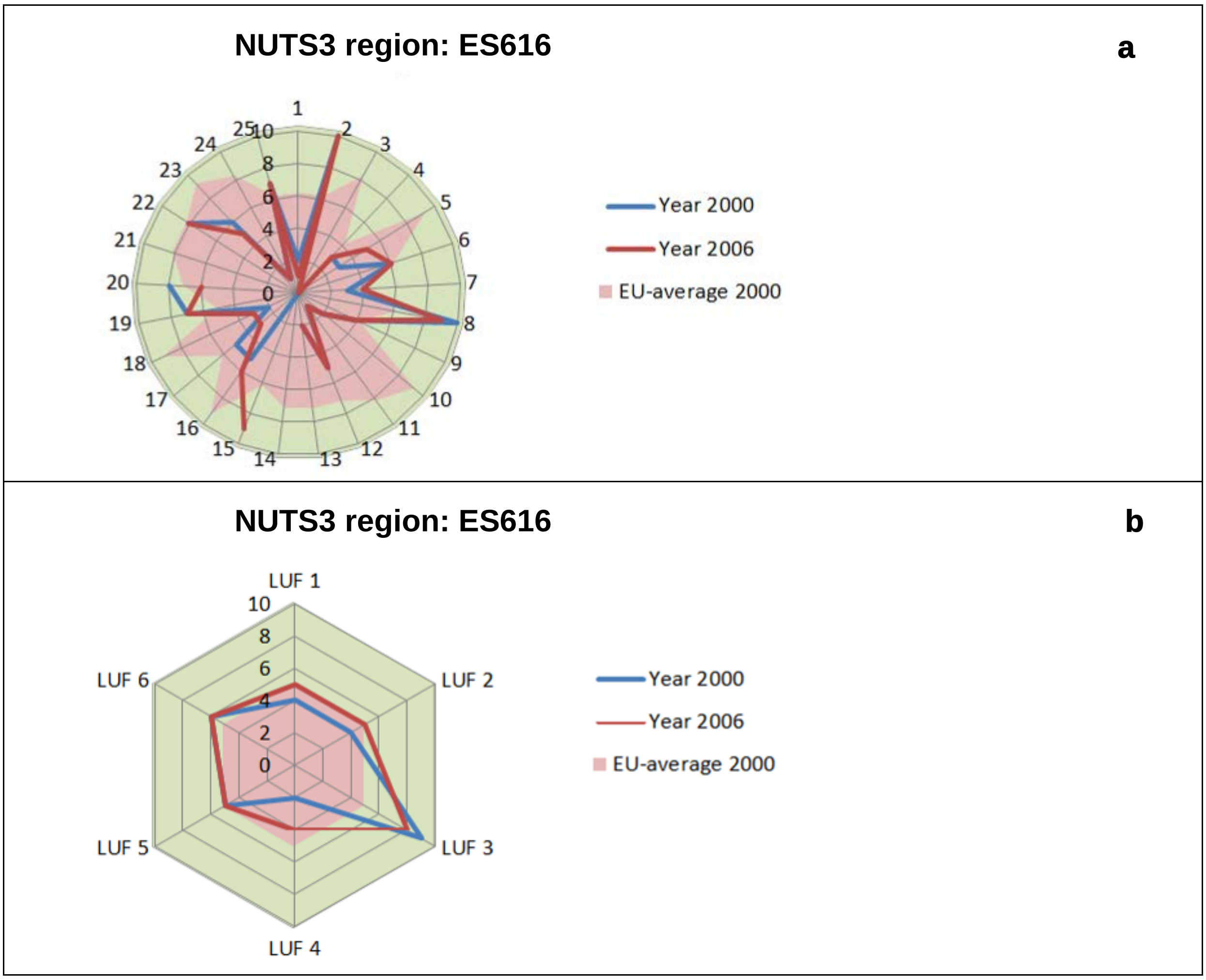


Figure 25: Spider diagrams showing the results of (a) the 25 individual indicators and (b) LUFs for NUTS 3 ES616 Jaén. The names of the 25 indicators are provided in Table 8.

Jaén is a province of southern Spain, in the eastern part of the autonomous community of Andalusia. Jaén consists of mainly rural and remote areas with few cities. It is one of the larger producer of olive oil in the world. The results show indeed the main relevance of the LUF3 for land-based production, which is far above the EU average, and the slight increase in this LUF between 2000 and 2006, which could be explained by the influence of the CAP. At present, olive oil production is heavily subsidised by the CAP. This policy has led to intensification and increased output. On the other hand, it has helped to reduce the land abandonments in marginal regions.

6.2 Land Use Efficiency

The definition of Land Use efficiency in EU-LUPA is a complex issue. This complexity not only relies on the need to relate to key concepts used and developed in the project (i.e. multi-functionality through the LUFs approach and LU performance), but also on the viability to measure it in a quantitative way based on the current data availability at pan European level.

Efficiency has a wide variation in meaning for different disciplines. In general terms, efficiency describes the extent to which time or effort is well used for the intended task or purpose. In the case of land use science, this definition could be translated as the extent to which land is well used for the intended function considered.

The term "efficient" is very much confused and misused with the term "effective". In general, efficiency is a measurable concept, quantitatively determined by the ratio of output to input. "Effectiveness", is a non-quantitative concept, mainly concerned with achieving objectives. In EU-LUPA effectiveness is clearly related with the Land use performance definition, i.e. achieving policy objectives.

How to measure land use efficiency quantitatively? Efficiency can be expressed as a result by way of a percentage of what ideally could be expected, hence with 100% as ideal case. This does not always apply, not even in all cases where efficiency can be assigned a numerical value, as it is the case in EU-LUPA. In this case, it is suggested to use a slightly broader model of efficiency, i.e. efficiency corresponds to the ratio;

Land Use efficiency=Output/Input

of the amount *Output* of some valuable resource/revenue produced by the use of the land, per amount *Input* of land used.

In the context of the EU LUPA project, LU efficiency is defined considering the central concept of multi-functionality, i.e. Land Use Functions. Therefore the LU efficiency ratio is calculated for each of the six Land Use Functions. For example, in LUF1 Provision of Work, the main *output* is the nr of jobs, and the LU efficiency will be defined as the nr of jobs per sector related to the use of the land for that specific sector. The definition of efficiency is therefore linked to the specific functionality of the land used and does not always correspond to a percentage when the resource/revenue produced and the areal (amount of land) used are not compatible units, or if they are transformed into products. For example, in the analysis of the efficiency for the LUF3 Provision of food, the *Output* may be the revenues obtained by the production of food, timber and bioenergy, while the *Input* is the amount of land used as input.

The definition of the Output and Input to calculate Land use Efficiency ratio for each Land Use Function are described in Table 12.

Table 12 Definition of the Land Use Efficiency Output and Input for each Land Use Function. CLC nr refers to the second level of CORINE Land Cover classes. CLC 11 = urban fabric; CLC 14 = Artificial non-agricultural vegetated areas; CLC 21 = Arable land; CLC 22 = Permanent crops and CLC 24 = Heterogeneous agricultural areas.

LUF	Output	Input	Definition
Provision of work	Nr of jobs per sector	Area used by each sector	Based on NACE data on jobs per sector; considering two categories: (i) the agricultural sector and (ii) all the other sectors: (i) Nr of agri-jobs / km2 agriculture (CLC 21 + 22 + 24) (ii) Nr of jobs outside agriculture / km2 built-up area (CLC 11)
Provision of leisure	Nr of tourists (proxi: Nights spent in tourist accommodations)	Urban areas	Nr of nights spend in tourist accommodations / km2 urban areas (CLC 11 + 14)
Provision of food and bioenergy (only for agricultural production)	Area harvested	Agricultural area	Area harvested (km2) / agricultural area (CLC 21 + 22 + 24)
Provision of housing and transport and transport infrastructure	Population nr	Built-up area or roads longitude	(i) For housing: Population nr / km2 built-up area CLC 11) (ii) For transport infrastructure: Population nr / km roads

Provision of abiotic resources	All the soil that is not sealed is consider as potential source of abiotic resources	Area of the region	Un-sealed area (km2) / Total area region (km2)
Provision of biotic resources	Area covered by N2000 and CDDA in 2006	Area of the region	Protected area (km2) / Total area (km2)

The maps in the eight following figures visualise the LU efficiency for the six LUFs, as defined above.

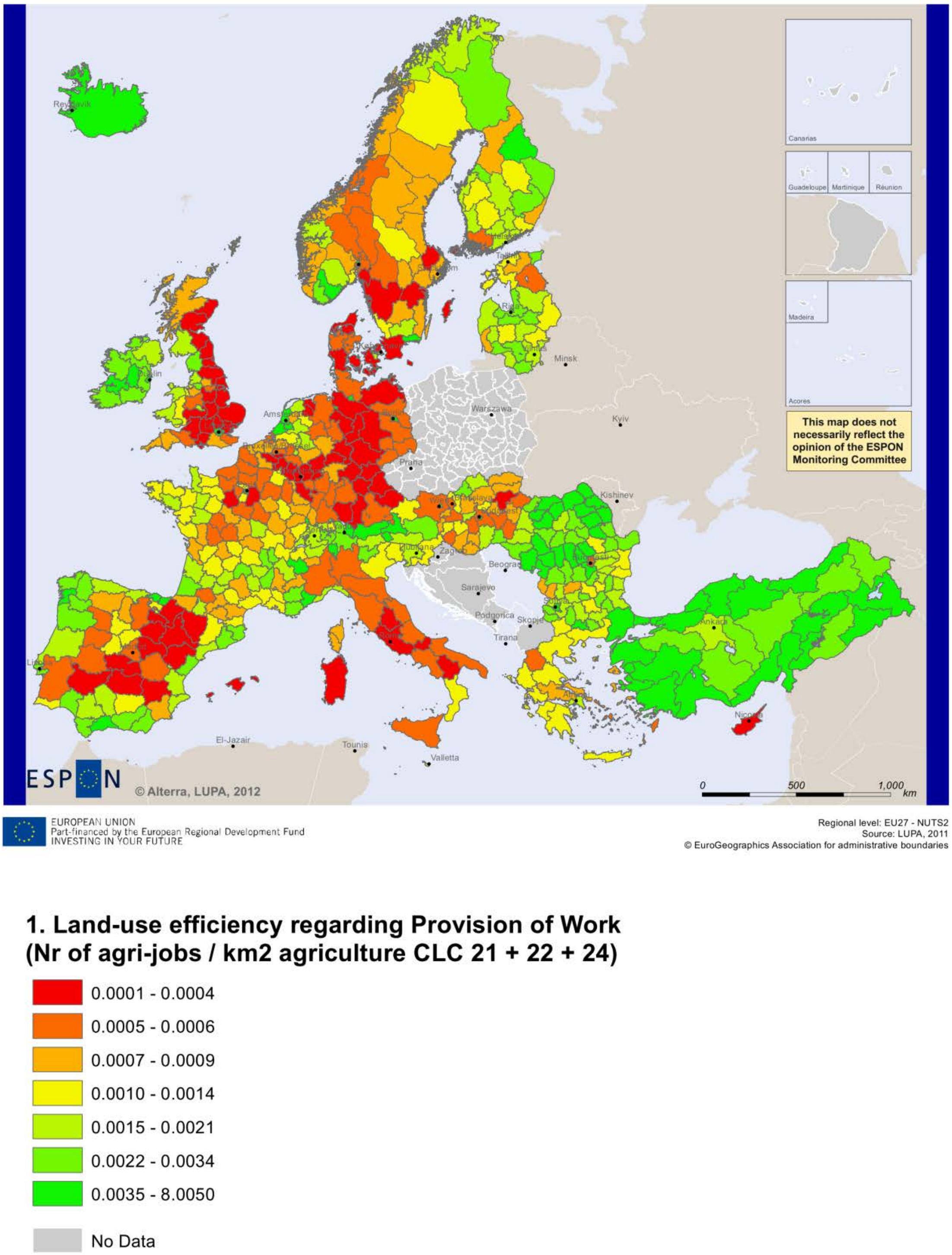


Figure 26: Land Use Efficiency regarding to (1) Provision of work based on agricultural land use.

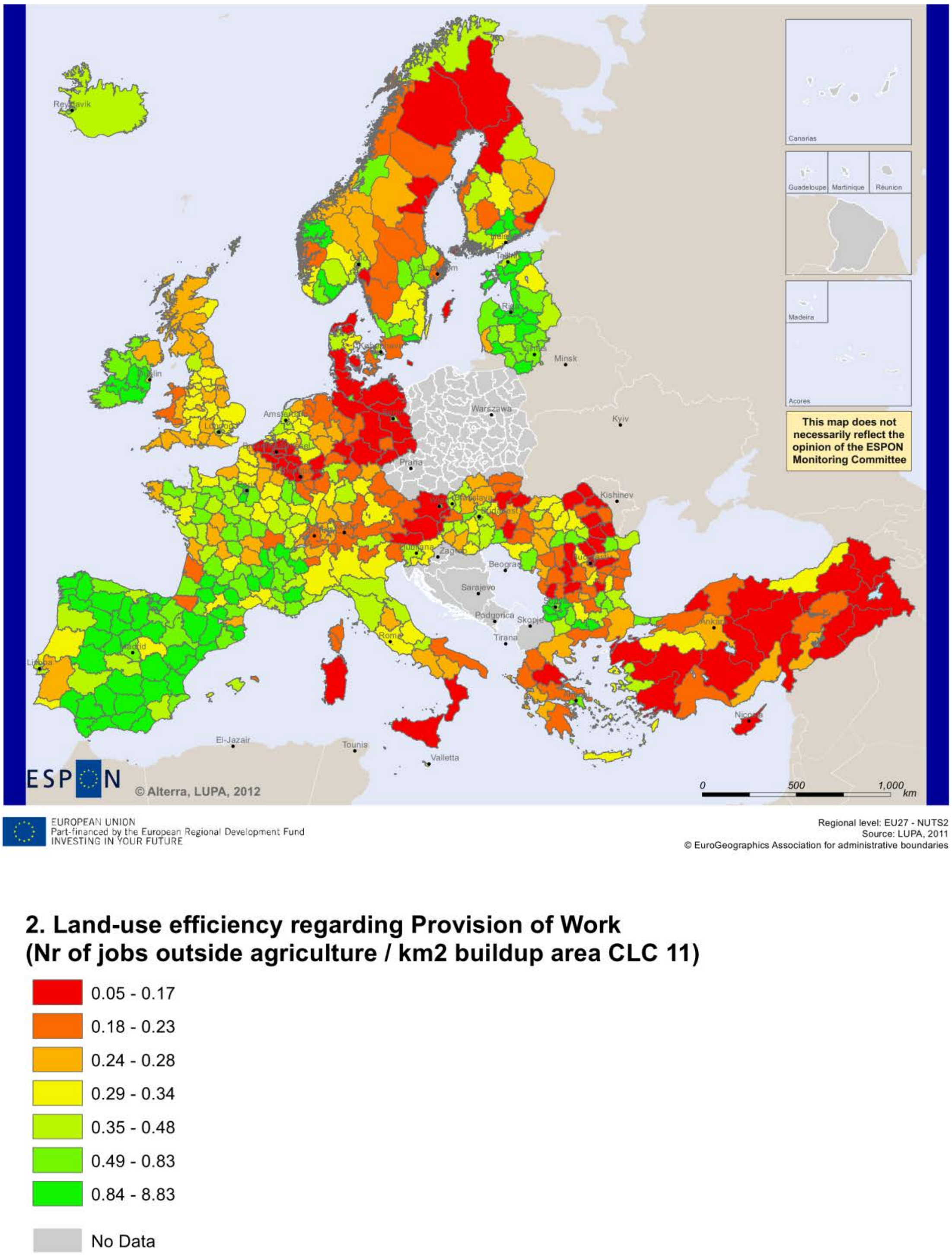


Figure 27: Land Use Efficiency regarding to (2) Provision of work based on other activities than agriculture.

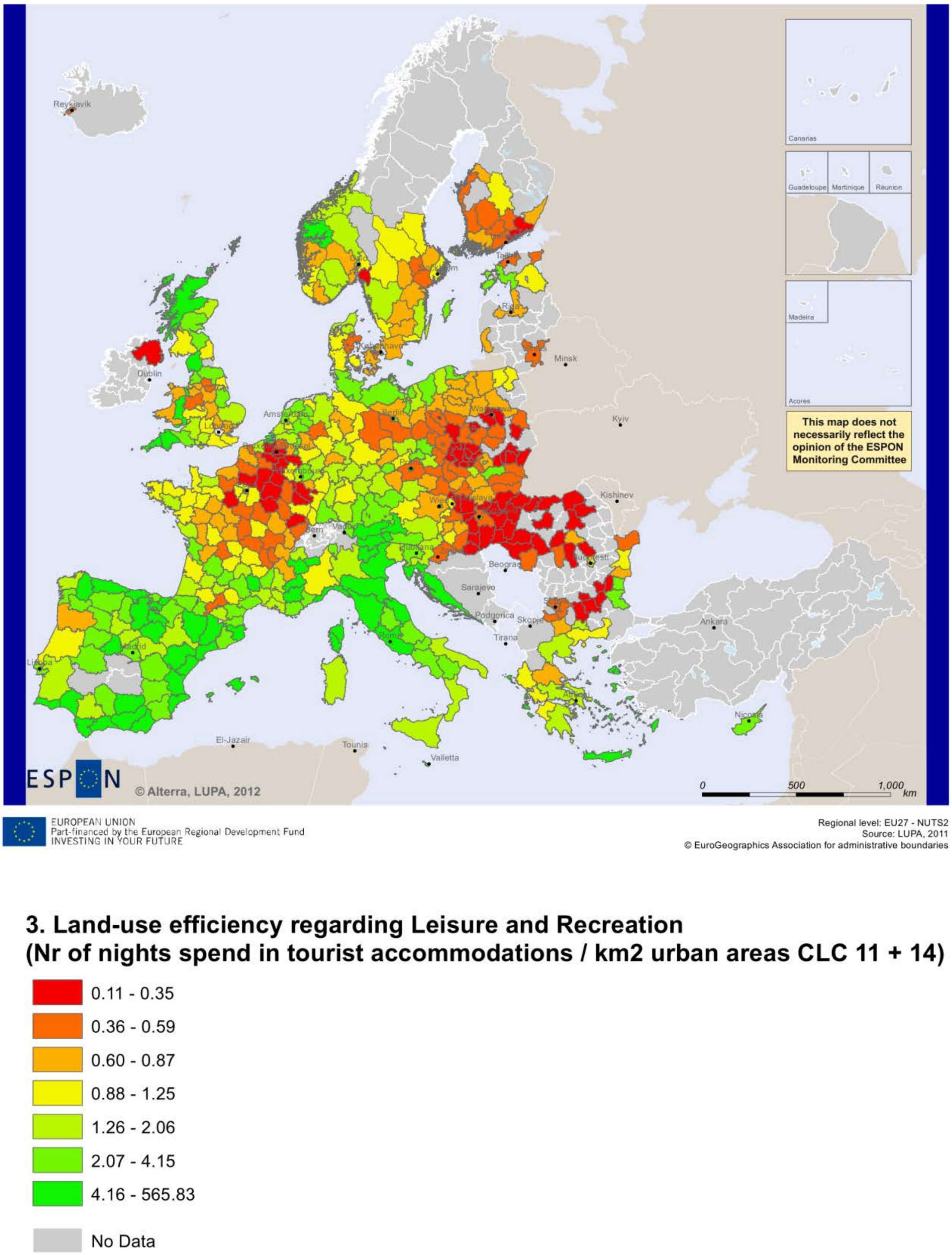


Figure 28: Land Use Efficiency regarding to (3) Provision of leisure.

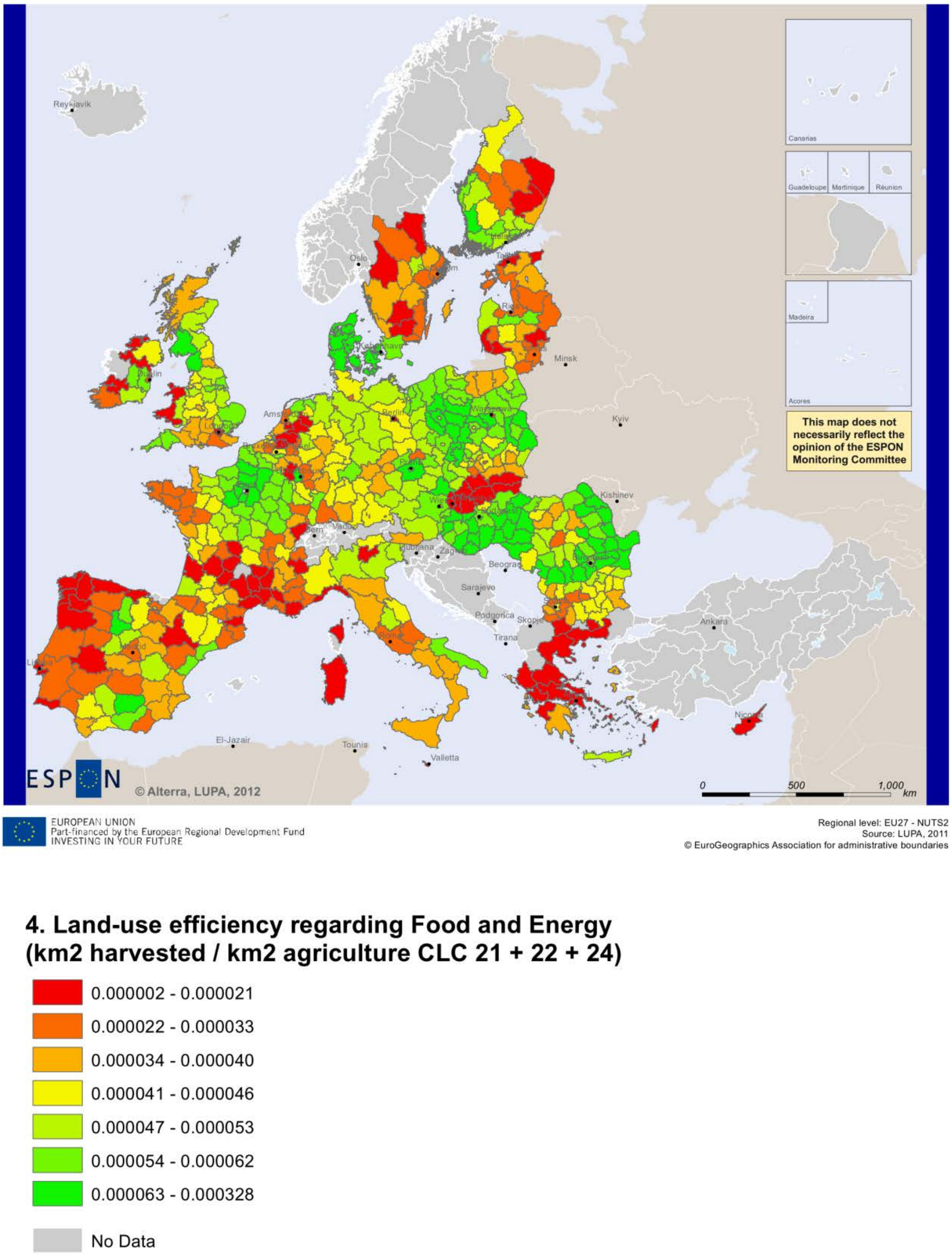


Figure 29: Land Use Efficiency regarding to (4) Provision of food and bioenergy.

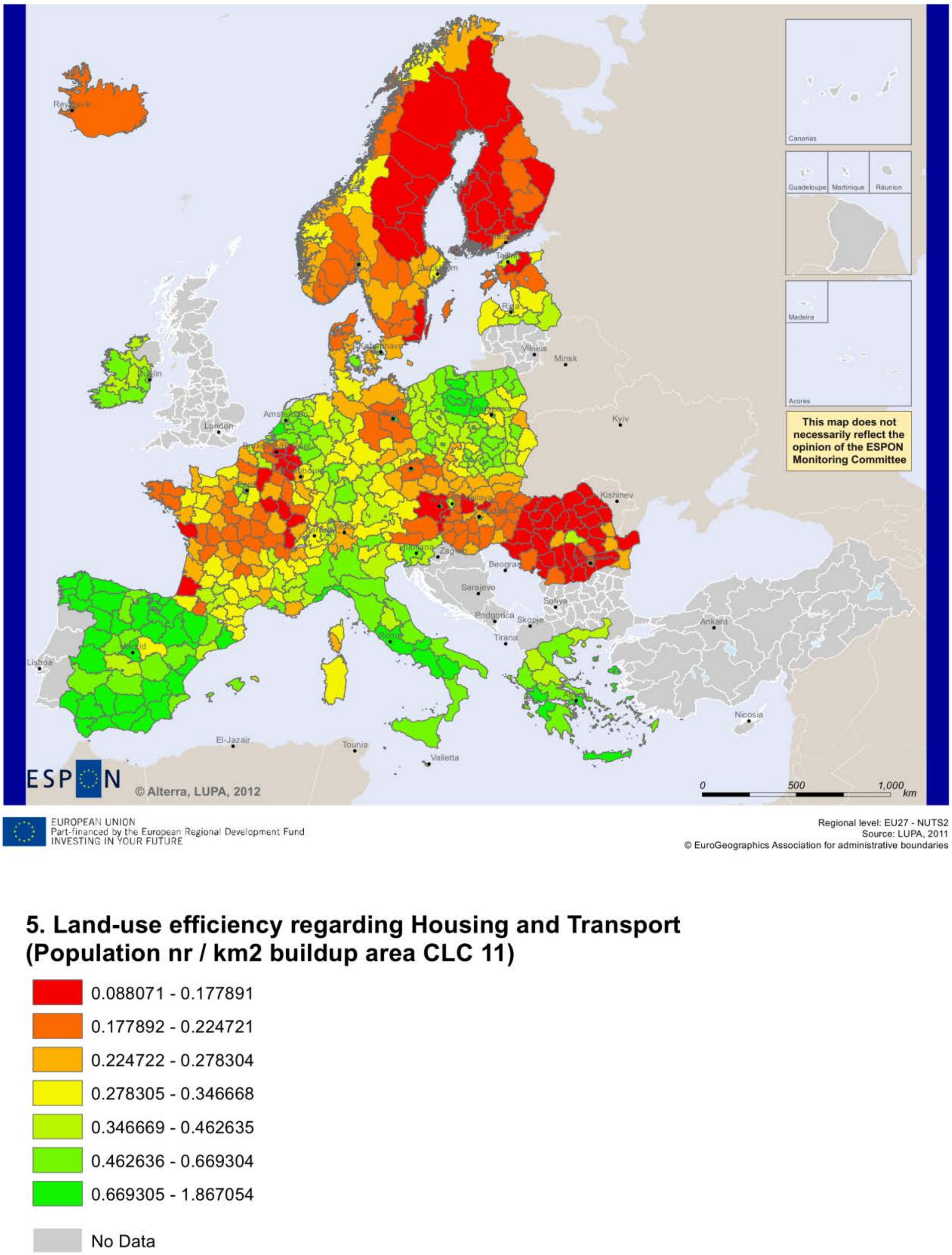


Figure 30: Land Use Efficiency regarding to (5) Provision of housing.

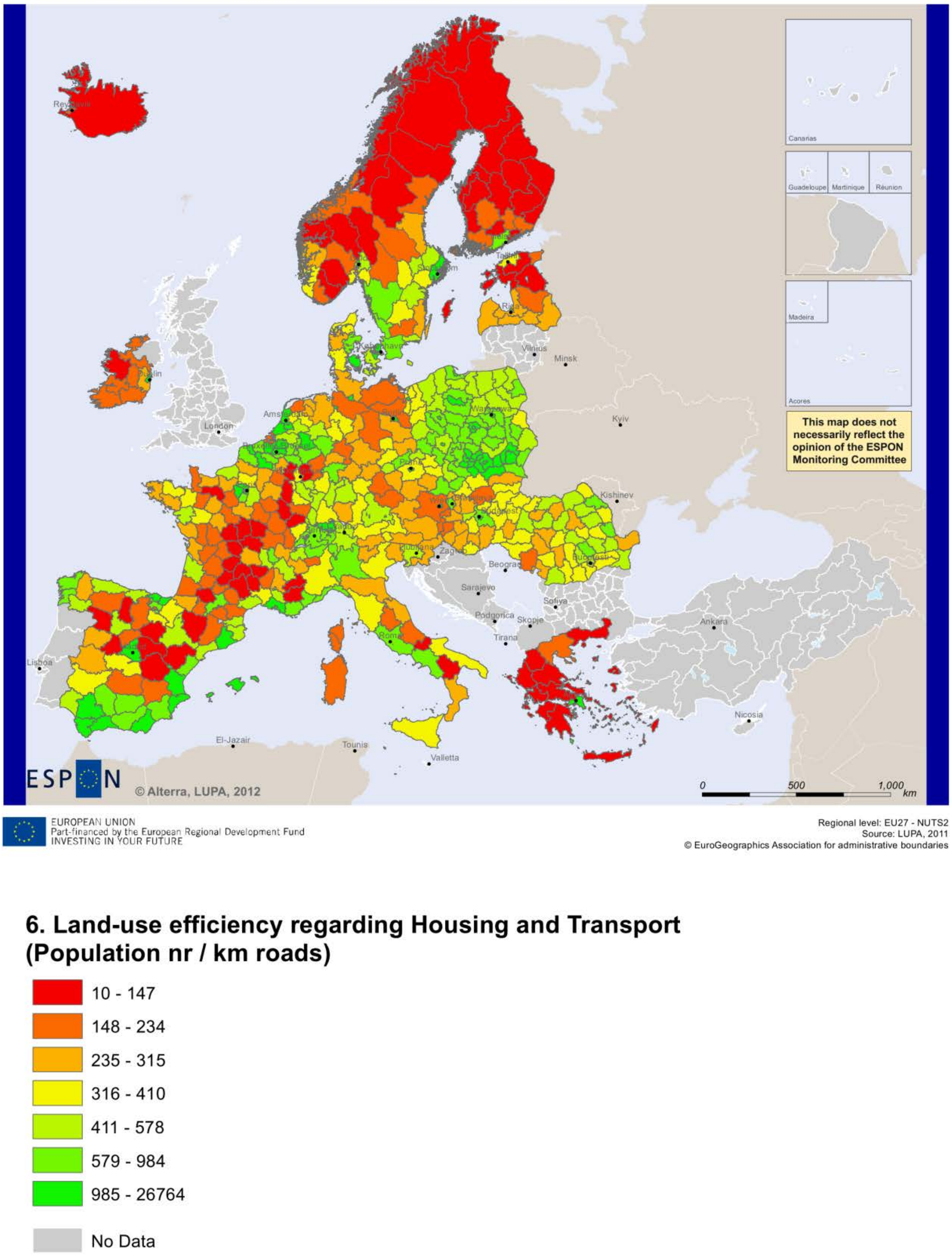


Figure 31: Land Use Efficiency regarding to (6) Provision of transport infrastructure.

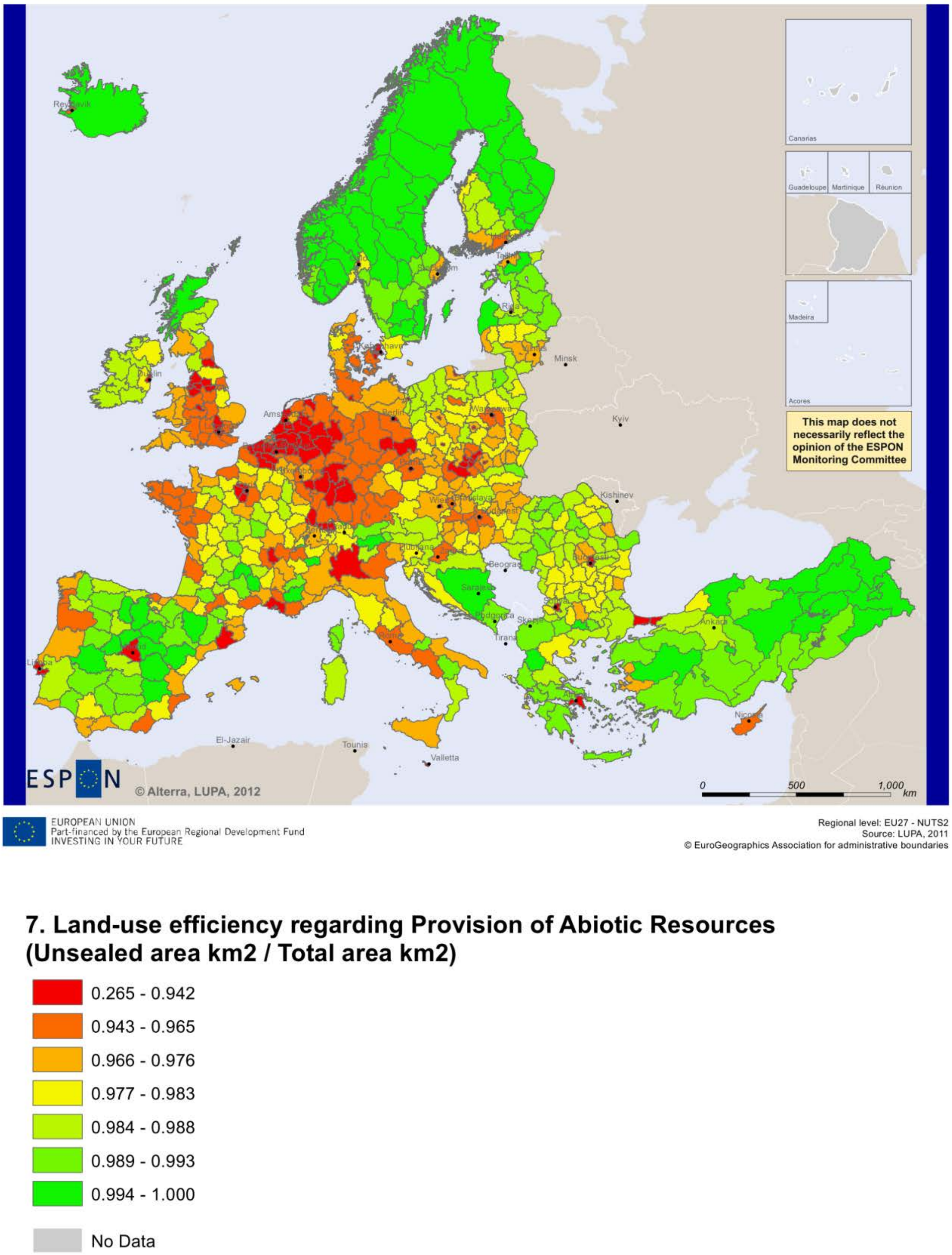


Figure 32: Land Use Efficiency regarding to (7) Potential Provision of abiotic resources.

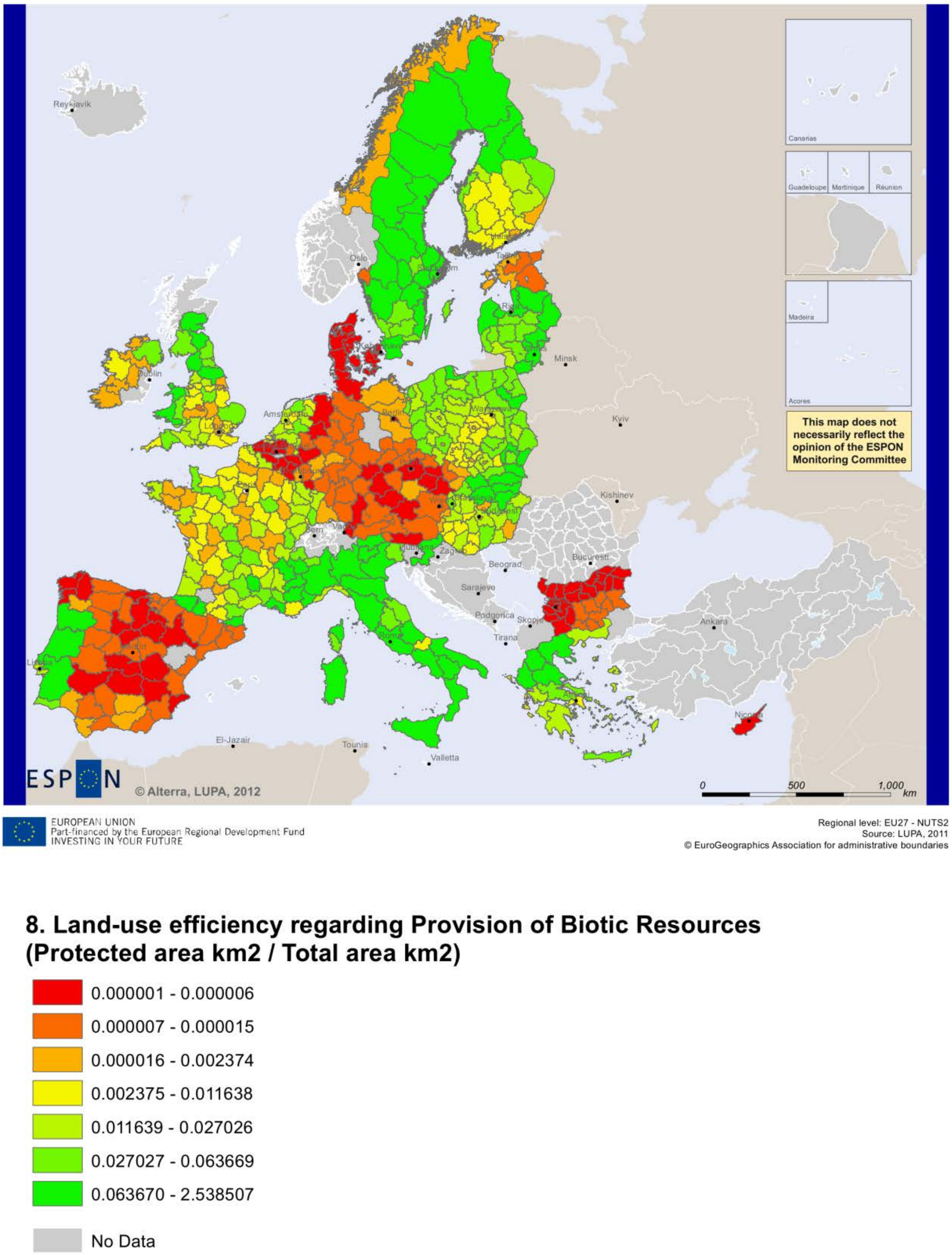


Figure 33: Land Use Efficiency regarding to (8) Provision of biotic resources.

The approach to assess LU efficiency is in principle quite coarse. However it helps to show how relatively efficient works out multi-functionality in every region. For example, the land of a region can be used very efficiently to provide food, while at the same time being inefficient in providing housing and abiotic resources (e.g. some North provinces of the Netherlands). The LU efficiency approach also helps to find out the degree of current use regarding the maximum (e.g. provision of food and bioenergy) or the potential use (e.g. in provision of abiotic resources).

7. Testing the pan European LUF results for a case study in Poland

In order to test the results obtained when applying the LUF methodology at pan European level, it was decided to compare the results with those obtained for one of the case studies in Poland. The case study NUTS 3 region PL515 Jeleniogorski was selected for the test.

7.1 Results based on LUF analysis

Firstly we analysed the indicators and LUFs spider diagrams of the NUTS 3 region to get an impression of the performance of this region compared to the European average (Figure 20).

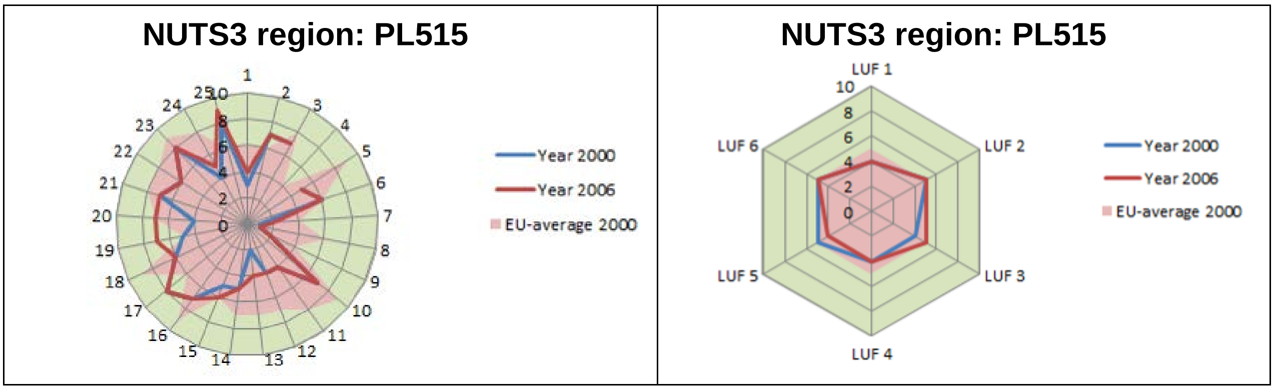


Figure 34: Results of the LUF assessment and the individual indicators for PL515 Jeleniogorski

The results are summarised in Table 13.

Table 13 Summary of changes in LUFs values between 2000 and 2006 for the NUTS 3 region PL515 Jeleniogorski

LUF	2000	2006	Change
LUF1 work	4	4	=
LUF2 Leisure	5	5	=
LUF3 Food & Bioenergy	4	5	+
LUF4 Housing & Infrastructure	4	4	=
LuF5 Abiotic conditions	5	4	-
LUF6 Biotic conditions	5	5	=

According to them, the changes in the Jeleniogorski region between 2000 and 2006 are similar to the European average. However there are some differences. For example, there is an increase in the performance of *LUF3 Provision of food and bioenergy* (score increases from 4 to 5 between 2000 and 2006). Concerning *LUF5 Abiotic conditions*, the situation has slightly deteriorated (score from 5 to 4).
A more detailed analysis based on the individual indicators (Table 14) shows that the situation has improved for Multimodal potential accessibility (Multimod00) and Gross domestic product (PPS) (Gross_Do06), but has deteriorated the indicators: ammonia emissions (NH3_emis12), net migration (Net_migr14), phosphorus surplus (P_surplu19), urban fabric (Urban_fa23) and nitrate

concentration(NO3_conc24). These indicator trends suggest a significant urban growth and in rural areas a larger use of fertilizers in agriculture.

Table 14 Changes in indicator values between 2000 and 2006 for the NUTS 3 region PL515 Jeleniogorski

Indicators	2000	2006	Change	Interpretation
Multimod00	3	4	+1	Improvement
Gross_Do06	1	2	+1	Improvement
NH3_emis12	2	4	+2	Deterioration
Net_migr14	5	6	+1	Deterioration
Natural_18	5	7	+2	Improvement
P_surplu19	4	7	+3	Strong Deterioration
Urban_fa23	4	5	+1	Deterioration
NO3_conc24	8	9	+1	Deterioration

7.2 Comparison of LUF results with case study analysis

The comparison of the LUFs results with the outcomes of the case study area based on in depth analysis of national data, provides a first validation of the LUF methodology. The summary of the comparison are presented in Table 15.

Table 15 Comparison of case study results with the LUFs results for the NUTS 3 region PL515 Jeleniogorski

Nr	Case Study PL515 Jeleniogorski	LUFs/indicator assessment	Matching
1	Overall socio-economic situation in this subregion is very much below the average level that is noted in the Dolnośląskie Region.	According to spider diagram situation PL515Jeleniogorsk is more or less on European average	
2	Outmigration from the subregion, with only few exceptions such as the suburban areas (especially around Jelenia Góra). However these zones are very narrow. Also, on the areas of great touristic and cultural value, people are migrating from bigger towns (mostly from outside of the subregion). New settlements are much more scattered. It leads to the chaotic development of spatial structures.	According to spider diagram Net migration goes from 5 to 6, i.e. is high and became even higher.	
3	There is a dichotomous process in settlement development. There are some villages, which are almost inhabited, in contrast with other villages well located and with attractive landscape surroundings that have noted a considerable share of newcomers in last two decades.	Indicator 23 Urban fabric shows an overall increase in acreage.	

4	There is one principal and basic reason for outmigration – collapse of industrial functions which were dominating on these areas in the past.	According to spider diagram Net migration goes from 5 to 6. In addition, indicator industrial areas is decreasing.	
5	High level of unemployment – collapse of many industrial activities; reduction in the previous employment in industrial factories cannot be compensated by employment offered by tourism institutions.	According to indicator 22 unemployment stays very high (score 8 in 2000 and 8 in 2006).	
6	In the lowland part of the subregion, the big agricultural enterprises have appeared – process of consolidation of land can be observed. In the upland and mountainous part, the agriculture plays less and less important function in spatial organization and economical structures.	LUF3 food an bioenergy increases and linked to this the abiotic conditions decrease	
7	The biggest tourist investments are now located in the touristic areas.	Indicator 15 nights spend is high (score 7 in 2000 and 2006)	
8	There still persists a stereotype that that region is very polluted and ecologically destroyed – the so-called “Black Triangle”. In the past, a number of large industrial factories did really produce a lot of pollutions – right now this situation has changed for the better. Now the quality of environment is much better.	According to LUF5 the environmental conditions are deteriorated, which is supported by the indicators on emissions and fertilizers that have strongly increased (due to intensification agriculture)	

In summary: only two conclusions from the case study are not in line with the LUF/ indicator analysis.

8. Conclusions

This report describes the methodology of the LUFs as adapted for the EU-LUPA project, and its implementation to The Netherlands (considering specific regional differences) and to Europe. The results at pan European level have been validated for one of the Polish case study areas, comparing the LUFs results to the detailed information gathered at national level. The results indicate that the application of the LUFs methodology is feasible and the results are plausible. Finally, the application of the LUFs concept to assess the Land Use Performance and Land Use Efficiency seems an useful approach to get deeper insight in the complexity of the multi-functionality of the land in the European regions.

It can be concluded that the three main objectives defined for the LUFs framework in EU LUPA, as defined in chapter1, have been achieved. Specifically:

- the degree of multi-functionality of regions has been assessed quantitatively for the period 2000-2006 by applying the LUF methodology to the 12 NUTS 2 regions of the Netherlands, and to the 635 NUTS 2/3 regions of EU27. The LUF multi-criteria analysis calculates a functionality score for each of the six land use functions, by integrating weighing of the normalised values of a set of meaningful indicators contributing to each LUF. The six functionality scores measure the functional performance of a region, i.e. the degree of multi-functionality;
- the impacts of land use change have been assessed in a comprehensive way by applying the LUF methodology to calculate the changes in the performance of six land use functions. The LUF performance integrates the changes in the underpinning indicators and therefore provides a comprehensive assessment and not based on the partial views provided by individual indicators;
- the impact of land use changes on the economic, social and environmental dimensions, are assessed by linking the results of the changes in the performance of the six LUFs to the changes in the three sustainability dimensions. The LUF methodology defines the LUFs considering main links to the economic, environmental and social dimensions (see chapter 1), noting that 'the LUFs do not refer uniquely to a dimension of sustainability, but have a ''prevalent'' social, economic or environmental character, acknowledging that the pillars of sustainability are not isolated, but involve numerous cross-linkages'. In this way sustainable development, when considered as the interface between socio-economic development and the environment, is addressed. For example, the performance of the LUF 'housing and infrastructure' (associated with socio-economic development) is not only underpinned by socio-economic indicators but as well by soil sealing and the percentage of green areas close to residential areas, representing the environment.

Regarding the implementation of the LUFS methodology and its further use as tool to support regional policy assessments (ex-ante and ex-post), it can be concluded:

- The Land Use Functions (LUFs) provide a useful approach by focusing on a fixed set of cross-cutting issues linked to the mains sectors involved in the use of the land, including the economic, environmental and societal dimensions. Therefore LUFs may be relevant for the design of policies addressing the interface between socio-economic development and the environment, i.e. sustainable development.

- These issues are in line with several EU policies that affect directly or indirectly the use of the land, e.g. employment, agriculture, resource efficiency, transport, urban areas, biodiversity, etc. The LUF methodology could turn into a workable tool for policymakers at different spatial scales ranging from European, national to sub-national level.

- LUFs provide an integrated assessment of the economic, environmental and social aspects of the land used, providing a good basis for trade-off analysis between the different main land functions.

- The two environmental LUFs and their respective indicators are linked to non-marketed environmental services (e.g. “Status of quality of bathing water”, “natural leisure”) and help showing how areas contribute to the overall well-being of Europe. The potential link to policy targets, as shown in the project, can help to indicate how may such ecosystem services be at risk, and how can policies take these aspects into account considering the interaction with marketed goods and services.

- LUFs and the indicators used to build them can be used to estimate land use performance using different references. Firstly, LU performance when compared to specific policy targets. And secondly, LU performance of a specific region when compared to others (EU, national and sub-national level).

- The six LUFs identified in EU LUPA offer a consistent and broad basis to approach the complex concept of LU efficiency. For example, it allows identifying regions that may be very efficient in terms of agricultural production whereas inefficient in maintaining natural resources.

- The LUFs approach may help to approach a multi-level governance by identifying diverse patterns and trends, not only within each LUF category but among the full set of categories as well, on the basis of NUTS 2/3 data (and case studies?). The LUFs help to identify common issues (both concerning performance and efficiency) that support the finding of similar solutions. Therefore the LUFs approach is also useful as a basis for pan-European dialogue, insofar as territories with the same LUFs profile are relatively more prone to develop cooperation. =

- The LUFs approach demonstrates that the designation of territorial policies needs to be integrated, considering the heterogeneity and dynamics of, and trade-offs between, the economic, environmental and social profiles within each type of areas. At the same time, the LUFs categories can be a useful tool to deal with the individuality of territories, insofar as they make it possible to categorise states and processes in a consistent way across the European regions.

- The LUFs methodology has been consistently applied at NUTS 2/3 level, based on a shared set of indicators available at pan European level. Unfortunately some key indicators were not available for all regions or their quality did not suffice to be used. This lack of relevant indicators represents a major constrain in the implementation of the methodology, as it has been explained in the report and pleas for further work on gathering new data at higher spatial resolution by the appropriate European institutions (e.g. Eurostat, EEA, JRC). The methodology is flexible and can be applied at all spatial levels (European, national and sub-national).

Regarding the implementation of the LUFs concept to the Land Use performance and LU efficiency can be concluded:

- Visualisation of the LU performance results with maps and spider diagrams brings complementary information. The maps show the spatial distribution of the calculated values and help to identify hot spots, however it is difficult to get the full picture (i.e. addition of all the LUFS and indicator maps) for one region. The spider diagrams provide this by visualising at once all the indicators or the LUFs for a single region, displaying their distance to the EU average. Being able to analyse simultaneously the spider diagrams of the indicators and the LUFs, also helps to understand the role that the indicators play in underpinning the values of the LUFs. The spider diagrams show as well the large differences between the Nuts 2/3 regions and highlight their main functional specificities.

- The approach to assess LU efficiency is in principle quite coarse. However it helps to show how relatively efficient works out multi-functionality in each region. For example, the land of a region can be used very efficiently to provide food, while at the same time being inefficient in providing housing and abiotic resources (e.g. some North provinces of the Netherlands). The LU efficiency approach also helps to find out the degree of current use regarding the maximum (e.g. provision of food and bioenergy) or the potential use (e.g. in provision of abiotic resources).

Annex 1: Description of selected indicators for the European assessment

Indicator	Definition	Source
Areas harvested - Total crop area	Harvested area includign ALL crops. Areas refer to the area under cultivation. Area under cultivation means the area that corresponds to the total sown area, but after the harvest it excludes ruined areas (e.g. due to natural disasters). If the same land parcel is used twice in the same year, the area of this parcel can be counted twice.	Eurostat (agr_r_crops) and national statistics
Landcover - Artifical non-agricultural vegetated areas	Class 14 of CLC	CLC v 15
Landcover - Forests and semi-natural areas	Class 3 of CLC	CLC v 15
Landcover - Green urban areas	Class 141 of CLC	CLC v 15
Gross domestic product (Purchasing Power Standard)	Gross Domestic Product at current market prices (Purchasing Power Standard)	Eurostat (nama_r_e3gdp)
Gross value added at basic prices - Agriculture and Fishing	Gross Value Added at Basic Prices: Agriculture and fishing	Eurostat (nama_r_e3vabp95)
Gross value added at basic prices - Total	Gross Value Added at Basic Prices: all NACE activities	Eurostat (nama_r_e3vabp95)
Landcover - Industry and Commercial areas	Class 121 of CLC	CLC v 15
Monuments and other tourist sights (index)	Monuments and other tourist sights valued 2 stars in TCI "green guides series". The final value is a weighted average of "stars" in TCI guidebook series in each NUTS area (assigning weight 3 to "conjunts" and 1 to individual momuments and objects)	ESPON ATTREG
Multimodal potential accessibility	Potential accessibility describes how easy people in one region can reach people located in other regions. Within the accessibility model used by ESPON potential accessibility is based on two elements: (1) population in NUTS 3 regions and (2) the effort in time to reach them.The accessibility model measures the minimum travel time between all NUTS 3 regions for rail, road and air separately. For multimodal accessibility the accessibility by road, rail and air are integrated into one indicator expressing the combined effects of these modes for each NUTS 3 region.The potential accessibility of a NUTS 3 region is calculated by summing up the population in all other European regions, weighted by the travel time to go there. In order to avoid “edge” effects, European regions just outside the territory covered by ESPON are also included in this calculation, in particular Eastern European regions and the Western Balkan.	ESPON db (Air and Multimodal Accessibility)
Landcover - Natural leisure	Classes 331 +335 + 511 + 512 of CLC	CLC v 15
Navigable rivers and canals	Navigable rivers and canals	Eurostat
Net migration	Derived from LAU2 population development as collected for the ESPON GEOSPECS project database: “Change in LAU2-population from 2001 and 2006”	Eurostat, National statistical agencies, ESPON GEOSPECS project
NH3 emission	The NH3 emission in groundwater is calculated with the MITERRA-Europe model, a deterministic and static model, which calculates N, P and C budgets. Within CCAT, the model is expanded by including metal budgets as well. In case of N, the model also calculates N emissions and N leaching on an annual basis using N emission factors and N leaching fractions. MITERRA-Europe is based on the existing models GAINS and CAPRI, supplemented with an N cycle and leaching module, P and metal inputs and P and metal uptake. GAINS estimates current and future gaseous N and C emissions from agriculture (and other sectors) in Europe. CAPRI is an agricultural sector model at NUTS 2 level in the EU-27, with a global market model for agricultural products.	MITERRA model (ALTERRA)
Nights spent in tourist accomodations	Nights spent in tourist accomodations	Eurostat

N-surplus	The N-surplus in groundwater is calculated with the MITERRA-Europe model, a deterministic and static model, which calculates N, P and C budgets. Within CCAT, the model is expanded by including metal budgets as well. In case of N, the model also calculates N emissions and N leaching on an annual basis using N emission factors and N leaching fractions. MITERRA-Europe is based on the existing models GAINS and CAPRI, supplemented with an N cycle and leaching module, P and metal inputs and P and metal uptake. GAINS estimates current and future gaseous N and C emissions from agriculture (and other sectors) in Europe. CAPRI is an agricultural sector model at NUTS 2 level in the EU-27, with a global market model for agricultural products.	MITERRA model (ALTERRA)
Population density	Population density	
Pre-primary education	Pre-primary education is defined as the initial stage of organised instruction, designed primarily to introduce very young children to a school-type environment, that is, to provide a bridge between home and a school-based atmosphere.	Eurostat
Natural protected areas - CDDA and Natura2000	Protected areas includes nationally designated areas (CDDA) and Natura 2000 sites. When there is an overlap the area is only counted once.	CDDA, Natura2000
P-surplus	The P-surplus in groundwater is calculated with the MITERRA-Europe model, a deterministic and static model, which calculates N, P and C budgets. Within CCAT, the model is expanded by including metal budgets as well. In case of N, the model also calculates N emissions and N leaching on an annual basis using N emission factors and N leaching fractions. MITERRA-Europe is based on the existing models GAINS and CAPRI, supplemented with an N cycle and leaching module, P and metal inputs and P and metal uptake. GAINS estimates current and future gaseous N and C emissions from agriculture (and other sectors) in Europe. CAPRI is an agricultural sector model at NUTS 2 level in the EU-27, with a global market model for agricultural products.	MITERRA model (ALTERRA)
Status of coastal bathing water	Quality of coastal bathing waters is provided in four categories (from better to worst): • CG - compliant with the mandatory and the guide values of the Water Framework Directive • CI - compliant with the mandatory values of the Directive • NC - not compliant with the mandatory values of the Directive • B - banned or closed (temporarily or throughout the season) These categories were transformed in a numeric scale (5,4, 2,1 –to give more weight to good quality), and average computed for NUTS region.	WaterBase
Status of inland bathing water	Quality of inland bathing waters is provided in four categories (from better to worst): • CG - compliant with the mandatory and the guide values of the Water Framework Directive • CI - compliant with the mandatory values of the Directive • NC - not compliant with the mandatory values of the Directive • B - banned or closed (temporarily or throughout the season) These categories were transformed in a numeric scale (5,4, 2,1 –to give more weight to good quality), and average computed for NUTS region.	WaterBase
Unemployment rates (age >=15)	Unemployed persons are persons: aged 15-74 (in ES, SE (1995-2000), UK, IS and NO: 16-74), who were without work during the reference week, but currently available for work, who were either actively seeking work in the past four weeks or who had already found a job to start within the next three months.	Eurostat
Landcover - Urban fabric area	Class 11 of CLC	CLC v 15

Annex 2: Statistical correlations between indicators per LUF

Correlation >= 0.8
Rejected indicator

LUF 1	Indicator 0: Multimodal potential accessibility	Indicator 4: Pre-primary education	Indicator 8: Gross value added at basic prices - total	Indicator 10: Industry and commercial areas	Indicator 14: Net. Migration	Indicator 15: Nights spent in tourist accommodations	Indicator 17: Population density	Indicator 18: Natural protected areas - CDDA and Natura2000	Indicator 21: Number of tourist sights	Indicator 22: Unemployment rates > 14 years old
0	1	0.37	0.56	0.5	0.17	0.19	0.41	0.07	0.19	0.34
4	0	1	0.28	0.59	0.03	0.84	0.94	0.04	0.13	0.95
8	0	0	1	0.32	0.01	0.21	0.25	0.05	0.15	0.29
10	0	0	0	1	0.03	0.21	0.87	0.05	0.07	0.64
14	0	0	0	0	1	0.13	0.04	0.04	0.04	0.01
15	0	0	0	0	0	1	0.52	0.04	0.15	0.78
17	0	0	0	0	0	0	1	0.05	0.04	0.91
18	0	0	0	0	0	0	0	1	0.04	0.04
21	0	0	0	0	0	0	0	0	1	0.11
22	0	0	0	0	0	0	0	0	0	1

LUF 2	Indicator 0: Multimodal potential accessibility	Indicator 3: Status of bathing water	Indicator 5: Forests and semi-natural areas	Indicator 8: Gross value added at basic prices - total	Indicator 9: Green urban areas	Indicator 11: Natural leisure	Indicator 13: Navigable rivers and canals	Indicator 15: Nights spent in tourist accommodations	Indicator 18: Natural protected areas: CDDA and Natura2000	Indicator 20: Artifical leisure areas	Indicator 21: Number of tourist sights
0	1	0.07	0.36	0.56	0.43	0.09	0.32	0.19	0.07	0.46	0.19
3	0	1	0.18	0.1	0.09	0.09	0.01	0.02	0.07	0	0.06
5	0	0	1	0.07	0.28	0.23	0.25	0.08	0.15	0.38	0.01
8	0	0	0	1	0.34	0.13	0.2	0.21	0.05	0.41	0.15
9	0	0	0	0	1	0.03	0.13	0.52	0.03	0.63	0.08
11	0	0	0	0	0	1	0.37	0	0.07	0.02	0.05
13	0	0	0	0	0	0	1	0.03	0.04	0.23	0.03
15	0	0	0	0	0	0	0	1	0.04	0.22	0.15
18	0	0	0	0	0	0	0	0	1	0.05	0.04
20	0	0	0	0	0	0	0	0	0	1	0
21	0	0	0	0	0	0	0	0	0	0	1

LUF 3	Indicator 1: Harvested agricultural areas	Indicator 2: Landcover - Artificial non-agricultural vegetated areas (0/000)	Indicator 5: Forests and semi-natural areas	Indicator 7: Gross value added at basic prices - agriculture and fisheries	Indicator 9: Green urban areas	Indicator 10: Industry and commercial areas	Indicator 16: N-surplus	Indicator 18: Natural protected areas - CDDA and Natura 2000	Indicator 19: P-surplus
1	1	0.13	0.53	0.01	0.17	0.13	0.06	0.13	0.06
2	0	1	0.36	0.29	0.92	0.81	0.1	0.05	0
5	0	0	1	0.14	0.28	0.35	0.37	0.15	0.14
7	0	0	0	1	0.25	0.33	0.03	0.06	0.15
9	0	0	0	0	1	0.79	0.01	0.03	0.06
10	0	0	0	0	0	1	0.09	0.05	0.01
16	0	0	0	0	0	0	1	0.03	0.84
18	0	0	0	0	0	0	0	1	0.02
19	0	0	0	0	0	0	0	0	1

LUF 4	Indicator 0: Multimodal potential accessibility	Indicator 4: Pre-primary education	Indicator 6: Gross domestic product (PPS)	Indicator 10: Industry and commercial areas	Indicator 14: Net. Migration	Indicator 15: Nights spent in tourist accommodations	Indicator 17: Population density	Indicator 18: Natural protected areas - CDDA and Natura2000	Indicator 23: Build up areas
0	1	0.37	0.4	0.5	0.17	0.19	0.41	0.07	0.57
4	0	1	0.24	0.59	0.03	0.84	0.94	0.04	0.71
6	0	0	1	0.33	0.01	0.17	0.24	0.02	0.32
10	0	0	0	1	0.03	0.21	0.87	0.05	0.86
14	0	0	0	0	1	0.13	0.04	0.04	0.04
15	0	0	0	0	0	1	0.52	0.04	0.38
17	0	0	0	0	0	0	1	0.05	0.91
18	0	0	0	0	0	0	0	1	0.07
23	0	0	0	0	0	0	0	0	1

LUF 5	Indicator 1: Harvested agricultural areas	Indicator 3: Status of bathing water	Indicator 5: Forests and semi-natural areas	Indicator 12: NH_3 emission (Kg N/ha)	Indicator 13: Navigable rivers and canals	Indicator 16: N-surplus	Indicator 17: Population density	Indicator 18: Natural protected areas - CDDA and Natura2000	Indicator 19: P-surplus
1	1	0.11	0.53	0.08	0.08	0.06	0.15	0.13	0.06
3	0	1	0.18	0.19	0.01	0.15	0.03	0.07	0.06
5	0	0	1	0.29	0.23	0.37	0.26	0.15	0.14
12	0	0	0	1	0.28	0.83	0.01	0.03	0.79
13	0	0	0	0	1	0.49	0.23	0.04	0.27
16	0	0	0	0	0	1	0.07	0.03	0.84
17	0	0	0	0	0	0	1	0.05	0
18	0	0	0	0	0	0	0	1	0.02
19	0	0	0	0	0	0	0	0	1

Annex 3: The indicators and their contributions to the six Land use Functions

Table a: Impact indicators contributing to LUF1 *Provision of work*

Indicator	Impact issue	Score	Justification for score	Confidence of expertise
Value added per sector (80/ESTAT)	ECO8.1	1	Medium positive link: positive returns on investments;	High
GDP ppp (1/ESTAT)	ECO11.1	2	Strong positive link: high growth rate of real GDP purchasing power parties per inhabitant are beneficial to the economy and to the society and means better preconditions to strengthen potentials in all economic and social LUFs;	High
Unemployment rate (125 ESTAT)	SOC1.1	-2	Strong negative link: increase in unemployment rate means more tensions in labour markets and more problematic access to employment opportunities;	High
Net migration (137/ESTAT)	SOC9.1	2	Strong positive link: positive migration balance means attractiveness for workers;	High
Agricultural area within protected areas[1]	SOC11.1	+1	Medium positive link: increase in agricultural area within protected areas means more jobs in the agricultural sector;	High
Soil sealing (CLC or HRSS layers)	ENV3.2	1	Medium positive link: Soil sealing occurs as a result of construction, which means provision of work in the construction sector. BE AWARE IN REGIONS WITH HIGH AGRICULTURAL AREA BECAUSE RURAL MIGRATION TO CITIES TO WORK IN THE CONSTRUCTION? Decrease in employment in agriculture due to increase in SS?.	Medium
Nights spent (Total/ 103 ESTAT)		2	Strong positive link: high number of nights means more jobs in the area;	High
Transport networks (105/ESTAT or ESPON accessibility indicator)		2	Strong positive link: higher accessibility means more jobs in the area;	High
Services of general interest (hospitals, schools, universities)		1	Medium positive link: higher nr of SIG means more jobs in the area; it could be also for people living there but not working;	High

Gross expenditure on research and development (GERD)(88/ESTAT)		1	Medium positive link: higher investments resulting in more direct jobs and spin-off;	

[1]Perhaps ESTAT/55 'Agricultural areas in less favoured areas'

Table b: Impact indicators contributing to LUF2 *Provision of leisure activities*

Indicator	Impact issue	Score	Justification for score	Confidence of expertise
Value added per sector (80/ESTAT)	ECO8.1	1	Medium positive link: positive returns on investments;	High
GDP ppp (1/ESTAT)	ECO11.1	1	Medium positive link: high growth rate of real GDP per capita means that more money is available for leisure; however, it also often means more congestion (bad for recreation);	High
Green areas	SOC11.1	+2	High positive link: increase in green areas means more areas for leisure;	High
Cultural heritage sites (UNESCO)		+2	High positive link: increase in green areas means more areas for leisure;	High
Cultural (cinemas, theaters, pubs, restaurants, SERGENI)		+2	High positive link: increase in green areas means more areas for leisure;	High
Nights spent (Total/ 103 ESTAT)		2	Strong positive link: high number of nights means more jobs in the area;	High
Livestock density (57)		-2	Strong negative link: high intensity of agriculture means less attractiveness for recreation;	High
Transport networks (105/ESTAT or ESPON accessibility indicator)		2	Strong positive link: higher accessibility has a positive impact on leisure;	High
Forest fire risks (ESPON)	ENV9.1	-1	Medium negative link: if the risk is high, it has a negative impact on landscape recreational amenities. Potential risk of death and respiratory problems.	High

Table c: M2 indicators contributing to LUF3 *Food and energy production*

Indicator	Impact issue	Scor e	Justification for score	Confidence of expertise
Value added per sector (agriculture) (ESTAT/80)	ECO8.1	2	Strong positive link: increase in value added in agriculture means better valuation of agriculture potentials, in link with more efficiency and competitiveness of the sector;	High
Value added per sector (energy) (ESTAT/80)	ECO8.1	1	Medium positive link: increase means potentials in land based renewable energy sources are more valuated;	Medium (since modeled at country level)
Renewable energy (ask Berien)				
Agriculture accounts (ESTAT 56)		2	High positive link: the higher the subsidies, the higher the stimulus for farmers to increase the use of land;	High
Unemployment rate	SOC 1.1	-1	Medium negative link as in countries with a high level of employment in the primary sector (say >= 10%) when unemployment increases the impact will fall mostly on agriculture and other sectors with land-based production;	High
Soil sealing	ENV3.2	-2	In case of good quality agricultural soils, the sealing (covering the soil with concrete, urbanization) results to rapid decrease of soil availability and thus reduces its production potential;	High
Nitrogen and P input (ask Jan-Peter Lesschen)	ENV 6.6	2	Medium positive link. Increased use of N and P generally increases yields;	High
Area harvested (ESTAT/58)		2	High positive link: the higher the subsidies, the higher the area harvested, the higher the potential agricultural production;	High
Forest fire risk (ESPON natural hazards)	ENV 9.1	-2	Forest fires strongly affect economic functions of forests such as production of timber and non-timber forest products.	High

Table d: M2 indicators contributing to LUF4 Housing and transport and energy infrastructure

Indicator	Impact issue	Score	Justification for score	Confidence of expertise
Value added per sector	ECO8.1	1	Medium positive link: positive returns on investments;	High
GDP	ECO11.1	2	Strong positive link: high growth rate of real GDP per capita are beneficial to the economy and to the society and means better preconditions to strengthen potentials in all economic and social LUFs;	High
Unemployment rate	SOC1.1	-1	Strong negative link: increase in unemployment rate has a negative impact on households income and consumer demand;	High
Net migration	SOC9.1	1	Medium positive link;	Medium
Green areas within or close to residential zones	SOC11.1	1	Proximity to green areas has weak link to residential and no link to non-land based production function. In regions where the green areas are proxime, residential areas and services have higher value on the market;	Low
Soil sealing	ENV 3.2	2	One of the definitions of soil sealing is a covering (sealing) the soil trough building or construction work, it means the urban expansion and increase of space where residential, social and productive human activities could take place;	High
Household with broadband access (ESTAT 133)		2	Strong positive link;	
Services of general interest (hospitals, schools, universities)		1	Strong positive link: higher nr of SIG means more jobs in the area; it could be also for people living there but not working;	High
Gross expenditure on research and development (GERD)(88/ESTAT)		1	Medium positive link: higher investments resulting in more direct jobs and spin-off.	

Table g: M2 indicators contributing to LUF5 *Provision of abiotic resources*

Indicator	Impact issue	Score	Justification for score	Confidence of expertise
GDP	ECO11.1	1	Strong positive link: high growth rate of real GDP per capita is beneficial to the economy and to the society with positive externalities for the environment;	High
NH3	ENV1.1	-2	Ammonia emissions affect negatively the quality of air, water and soil. Ammonia is a secondary particulate precursor affecting air quality. It can cause plant damage. In addition, deposition of nitrogen compounds from NH3 emissions can lead to increased concentrations of nitrate in ground and drinking water due to nitrate leaching. Finally, ammonia emissions increase the N deposition and can lead to eutrophication and acidification of soils (EEA 2001; Velthof et al. 2007);	High
NOx	ENV1.2	-2	Contributes directly to eutrophication of semi-natural habitats, together with NH3 emissions, and therefore loss in biodiversity and quality of habitats. Indirect effects include subsequent impacts on acidity and eutrophication of freshwaters through leach;	High
N/P surplus	ENV 2.1	-1	Could have negative impact on quality of water resources;	
Soil sealing	ENV 3.2	-2	In case of good quality agricultural soils, the sealing (covering the soil with concrete, urbanization) results to rapid decrease of soil availability. Same implies also to availability of some raw materials. In some cases, the change of surface and ground water cycle as well as pollution connected with the ongoing urbanization may result to decrease of water quality and availability;	High
Transport networks (105/ESTAT or ESPON accessibility indicator)		-2	Strong negative link: higher accessibility means more air/water pollution;	High
Pesticide use	ENV 6.6	-1	Direct negative link: pesticides impact on quality of water resources;	High
Forest fire risk	ENV 9.1	-1	Forest fires could affect non production functions of forest (maintenance of water circulation, erosion prevention, desertification mitigation, microclimate maintenance, etc.) and decrease the availability of quality water, soil or air;	High
Area harvested (ESTAT/58)		-2	High negative link: the higher the subsidies, the higher the area harvested, the higher the potential agricultural production and risk for pollution.	High

Table h: M2 indicators contributing to LUF6 *Provision of biotic resources*

Indicator	Impact issue	Score	Justification for score	Confidence of expertise
GDP	ECO11.1	2	Strong positive link: high growth rate of real GDP per capita is beneficial to the economy and to the society with positive externalities for the environment;	High
NH3	ENV1.1	-2	Ammonia emissions increase the N atmospheric deposition, which causes nitrogen enrichment (eutrophication) of soil and surface waters, which in turn can lead to excessive algal blooms in coastal waters and a decrease in faunal and floristic species diversity in natural areas (EEA 2001, Velthof et al. 2007);	High
NOx	ENV1.2	-2	Contributes directly to eutrophication of semi-natural habitats, together with NH3 emissions, and therefore loss in biodiversity and quality of habitats. Indirect effects include subsequent impacts on acidity and eutrophication of freshwaters through leach;	High
N/P surplus	ENV 2.1	-1	Negative impact on water quality with;	
Soil sealing	ENV 3.2	-2	The increment of built up areas and transport infrastructures causes fragmentation of habitats and disruption of migration corridors for wildlife species;	High
Transport networks (105/ESTAT or ESPON accessibility indicator)		-2	Strong negative link: higher accessibility means more disturbance in the area;	High
Pesticide use	ENV 6.6	-2	Strong negative impact on biodiversity;	High
Forest fire risk	ENV 9.1	-2	Fires can lead to the fragmentation of forest habitats important for species. (note. This is not the case of natural fires, which are one of the elements of ecosystem regeneration).	Medium

[1] fragmentation: Is there an indicator available?

Annex 4: Examples of Rule bases and scientific justification for deriving Regional Importance Scores (weight 3)

2.1 Environmental indicators

ENV NOx emissions

Nitrogen dioxide (NOx) can have impacts on human health (e.g. respiratory problems) (Kampa & Castanas, 2006), can damage buildings via acid rain (Butlin, 1990), and is one source of atmospheric nitrogen (the other major source is ammonia) which when deposited can lead to eutrophication of natural habitats, and nitrate leaching into waterways (Achermann & Bobbink, 2003; Bobbink *et al.*, 1998). Thus its importance was calculated based on a combination of population density in a cluster (for human health and impacts on the built environment) and the proportion of habitats potentially sensitive to eutrophication and acidification – which was taken to include all land protected under NATURA2000 designation (or similar data from CORINE Biotopes for those countries for which NATURA2000 data were not available). Population density was obtained from the description of cluster regions (Annexe 1), taken as the upper limit of the range in which the median population density occurred (median of the distribution of values for all Nuts 2/3 regions in that cluster). The proportion of land under NATURA2000 or similar designation was also calculated per Cluster region (Table 3.x).The basic rules for attributing a score in relation to these two descriptors were as follows:

- Impact on urban areas, based on Population density (Pop Dens):

IF Pop Dens < 50 THEN score 1 *(predominantly rural)*
IF Pop Dens 50 < x < 100 THEN score 2
IF Pop Dens > 100, score 3 *(large centres of population, or highly urbanised areas)*

- Impact on natural habitats, based on Proportion of protected land area (Prot Area):

IF Prot Area < 0.35 THEN score 1 *(25%ile)*
IF Prot Area 0.35 < x < 1.75 THEN score 2
IF Prot Area > 1.75 THEN score 3 *(75%ile)*

Most clusters have reasonably high population density somewhere within the region where NOx effects may occur, and all clusters will have some measure of sensitive natural habitats that should be protected from eutrophication. Therefore, these two scores were combined with a simple rule base to achieve a final score which is intended to highlight the importance of NOx in all regions except those which have very few centres of population and have very little habitat in need of protection from eutrophication. All scores are shown in Table 10 below. The rule base for calculating the final importance for NOx in each cluster was as follows:
If scores sum to 2, score 1
If scores sum to 3, score 2
If scores sum to 4 or more, score 3

Table 16 Descriptors of cluster regions used to assess the importance of NOx in the cluster regions

CR	Cluster Region name	Median population density	% of protected land area	Population density score	Protected area score	FINAL REGIONAL IMPORTANCE SCORE (NOx emissions)
1	Scandinavian mountains and valleys	10	0.07	1	1	1
2	Scandinavian Shield	10	0.39	1	2	2
3	Eastern Baltic Plains	39	1.98	1	3	3
4	Central Baltic Plains	19	1.30	1	2	2
5	South-East Baltic	79	2.28	2	3	3
6	Alpine Mountains and Valleys	149	0.11	3	1	3
7	North-West Atlantic	149	0.98	3	2	3
8	West Baltic/North Sea	299	0.30	3	1	3
9	North-Eastern Lowlands/Southern Baltic	149	0.22	3	1	3
10	North Sea Plains	299	1.95	3	3	3
11	Balkan Plains	79	3.46	2	3	3
12	Central Continental Lowlands	149	0.75	3	2	3
13	South Continental	79	1.74	2	2	3
14	Atlantic Plains	79	1.71	2	2	3
15	Central Atlantic Plains/Hills	299	0.26	3	1	3
16	Central Atlantic Hills	79	0.47	2	2	3
17	Central Atlantic Hills/Plains	79	0.28	2	1	2
18	Central Atlantic Lowlands	599	0.60	3	2	3
19	Northern Mediterranean Coastal/Hinterland	149	0.38	3	2	3
20	Central Pannonian Plains	79	3.45	2	3	3
21	East Pannonian Plains	79	1.67	2	2	3
22	North Pyrenean Margin	79	0.45	2	2	3
23	Atlantic Lusitanian Coast	149	0.33	3	1	3
24	West Mediterranean	149	0.52	3	2	3
25	Core Mediterranean	39	0.68	1	2	2
26	South-East Mediterranean	39	1.52	1	2	2
27	West Iberia and Mediterranean Islands	79	2.01	2	3	3

Impact issue: Water quality

2.2 Socio-economic indicators

Related to employment

Preliminary remarks

The methodology implemented in this document has been developed on the basis of the information written in the report *'The detailed description of cluster regions'* (Annexe 1). This information provided us with essential data to implement our process and finalise the framework. However, the range of socio-economic indicators and the spatial level at which these indicators were described forced us to make some simplifications both in terms of the decision rules applied and of the spatial level at which the assessment was carried out. This last point is particularly important because cluster regions are characterized by a high level of heterogeneity with regard to socio-economic indicators (Annexe 1). Our rationale is based on the recognition of two different kinds of indicators: general indicators and specific ones.

General indicators

ECO6.1; ECO11.1; SOC1.1; SOC 3.1 and SOC 3. 2
They cover socio-economic contextual characteristics of the cluster regions that can favour (or hinder) the performances of the LUFs. Thus, they help examining the overall potentials of the LUFs based on the assumption that good economic and social conditions mean high potentials in terms of LUFs. General indicators are considered relevant for all the clusters and a score 2 is automatically assigned to general indicators in all the clusters.

Specific indicators

ECO8.1a and ECO8.1b
They assess the performances of the LUFs with regard to particular aspects which importance for each cluster has to be assessed. In order to identify the importance of the indicators in the 27 cluster regions we made use of a two-step assessment that starts with general indicators and then evaluates specific indicators. Consistently with what we have assumed, general indicators are considered relevant for all the clusters. Thus, score 2 was assigned to general indicators in all the clusters. Then, in those clusters where the level of the general indicator does not pass the threshold, as defined in table 10 of the Deliverable 3.2.2b (socio-economic aspects), we moved to examine specific indicators which may revel *'hidden'* problems. Otherwise, when the indicator passes the threshold we did not evaluate the importance of the specific indicators because a negative general assessment cannot be compensated by a positive assessment referred to particular aspects.

In order to assess the importance of specific indicators in cluster regions, it was assumed that they would be relevant when the sector they refer to is important for the economic structure of the cluster. This importance was evaluated with the following descriptors of cluster regions:

- The degree of relevance of the agricultural sector was assessed by using the proportion of arable cover in the cluster region;
- The degree of relevance of the energy sector was assessed by using GDP per capita, assuming the existence of a positive link between GDP and energy demand.

The Descriptor *'arable land'* was available in absolute terms. Thus, in order to identify decision rules, the statistical distribution of this descriptor was analysed and the criteria for the selection of the regions where agriculture is important sectors were defined with regard to the quartiles values. The importance of the sector was considered to be 0 when descriptor value was less than the first quartile, to be 1 when the descriptor value was comprised between the first and third quartile and to be 2 when the descriptor value was above the third quartile. The cut off values for each descriptor are presented below:

- Importance of the agriculture sector:

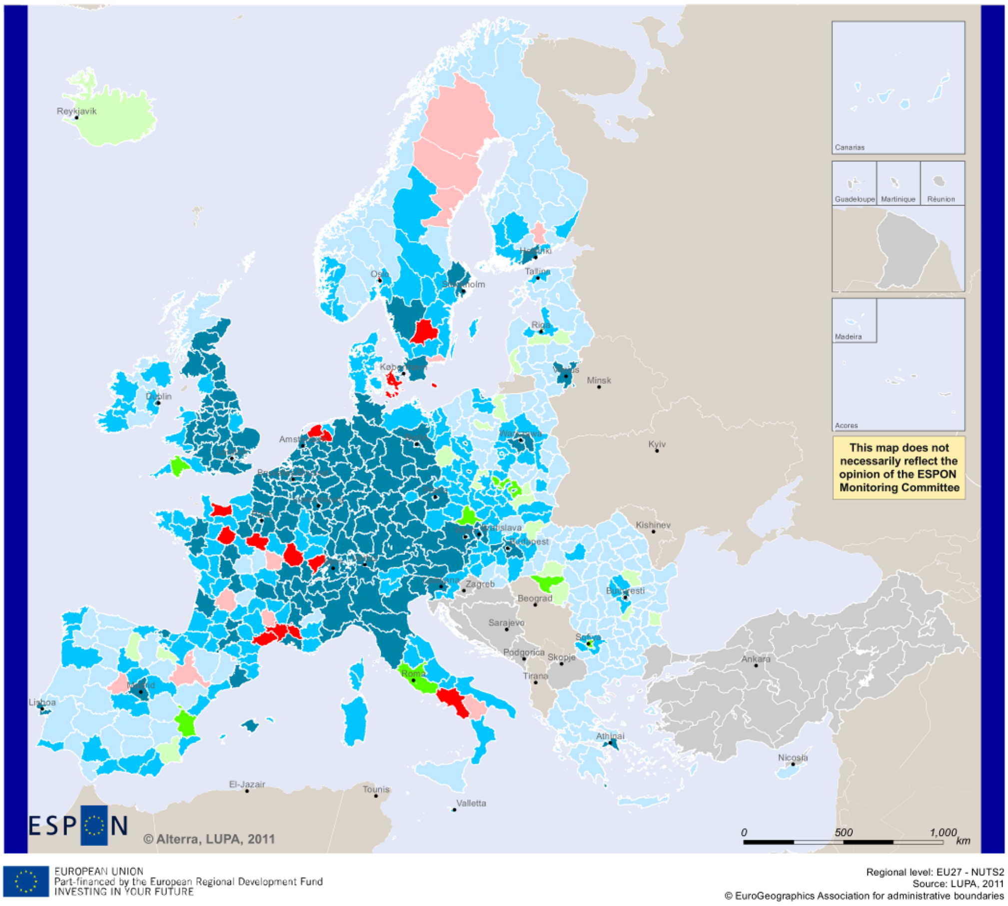
IF arable cover <13 THEN A = 0
IF 13 < arable cover < 38 THEN A = 1
IF arable cover > 38 THEN A = 2

As for the descriptor GDP per capita, rules for deciding on the importance of the indicator were as follows:

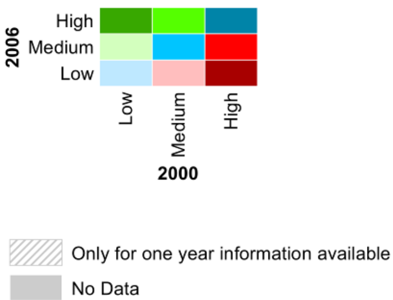
- Importance of energy sector:

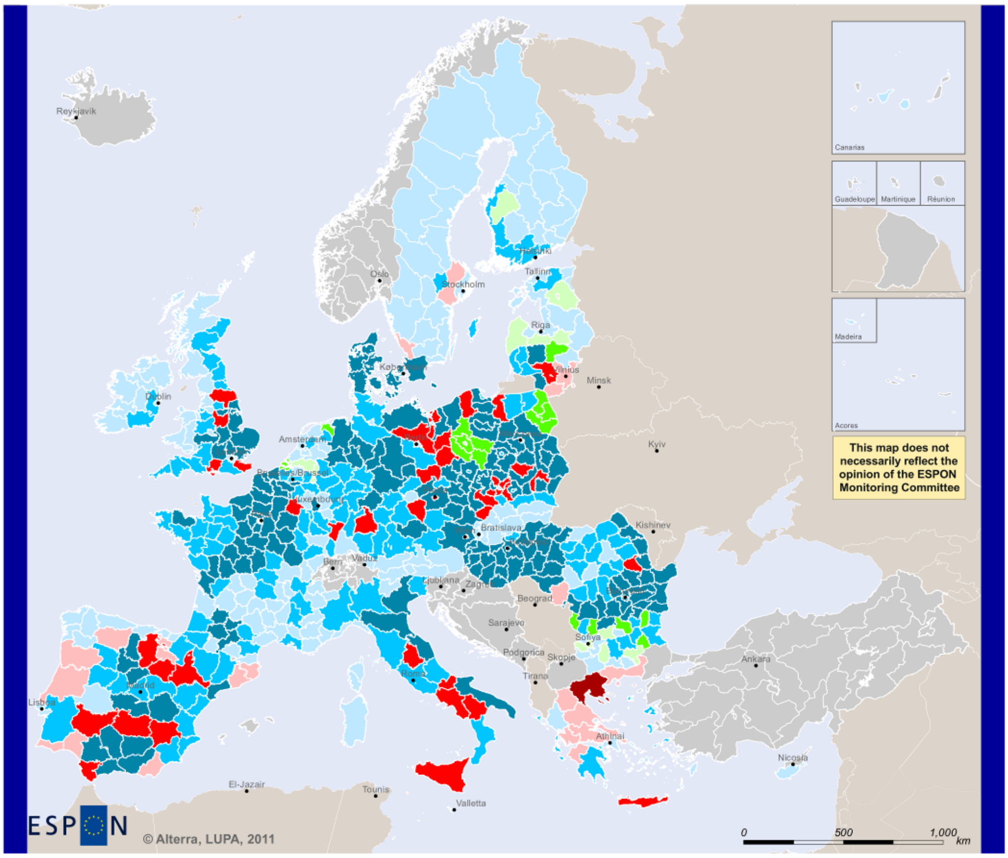
IF % area of cluster is in class 'below 16000 $PPP per capita' < 50 THEN A = 0
IF % area of cluster is in class 'over 20000 $PPP per capita' > 50 THEN A = 0
ELSE A = 1

Annex 5: Indicator maps for the European assessment



Indicator 0: Multimodal potential accessibility





EUROPEAN UNION
Part-financed by the European Regional Development Fund
INVESTING IN YOUR FUTURE

Regional level: EU27 - NUTS2
Source: LUPA, 2011

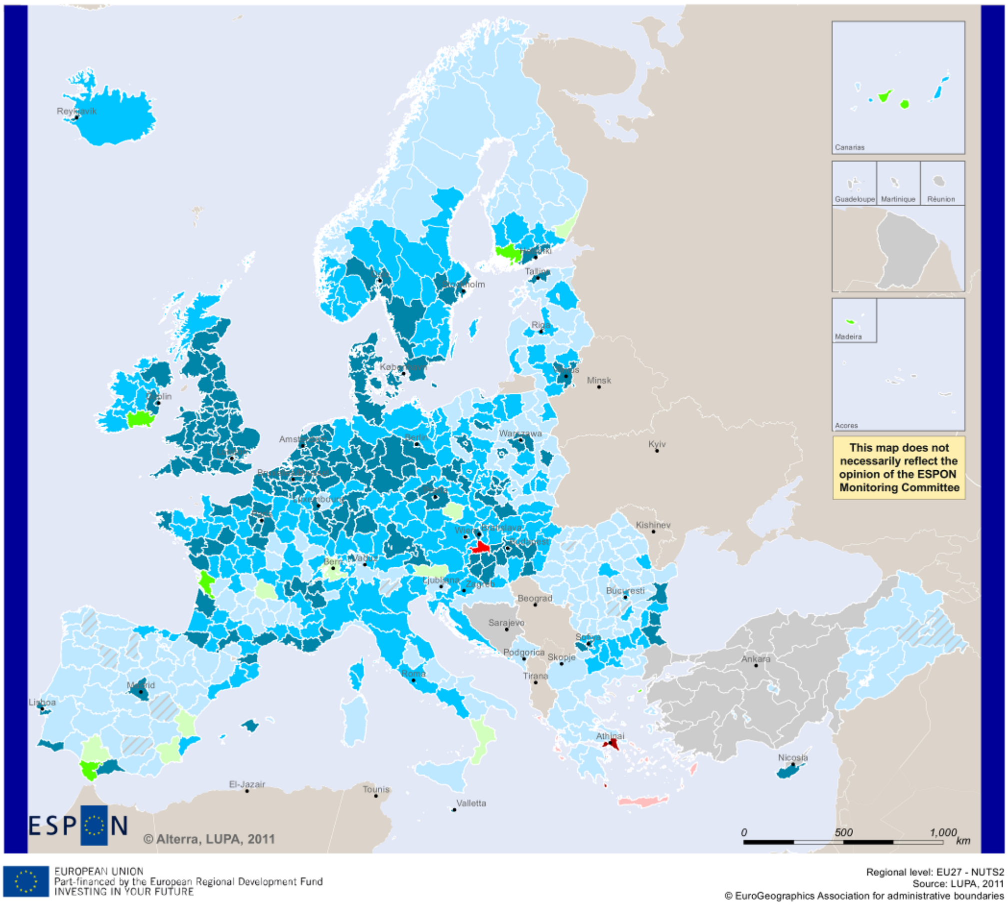
Indicator 1: Harvested agricultural areas

2006: High / Medium / Low

2000: Low / Medium / High

Only for one year information available

No Data



Indicator 2: Landcover - Artifical non-agricultural vegetated areas (0/000)

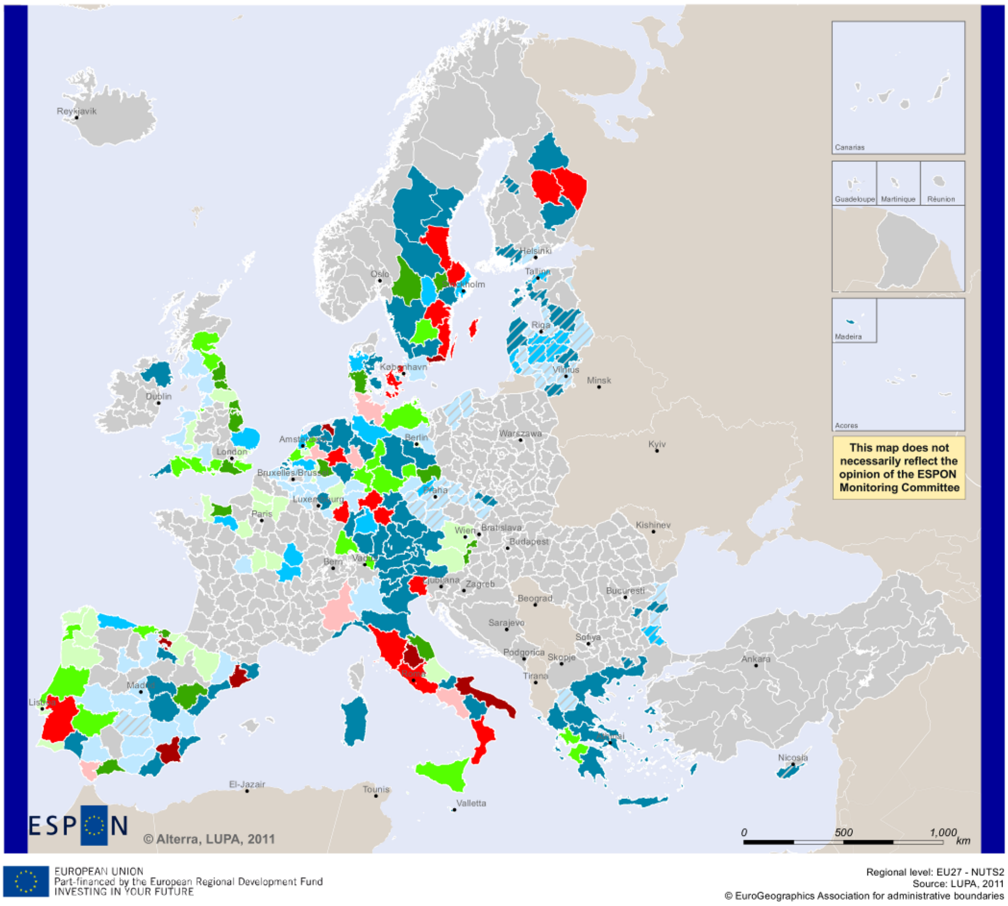
2006: High, Medium, Low

Low, Medium, High

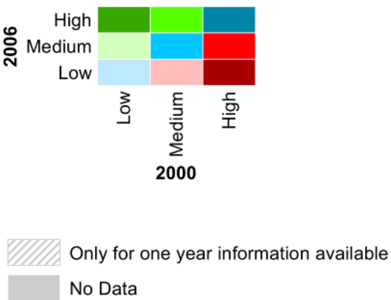
2000

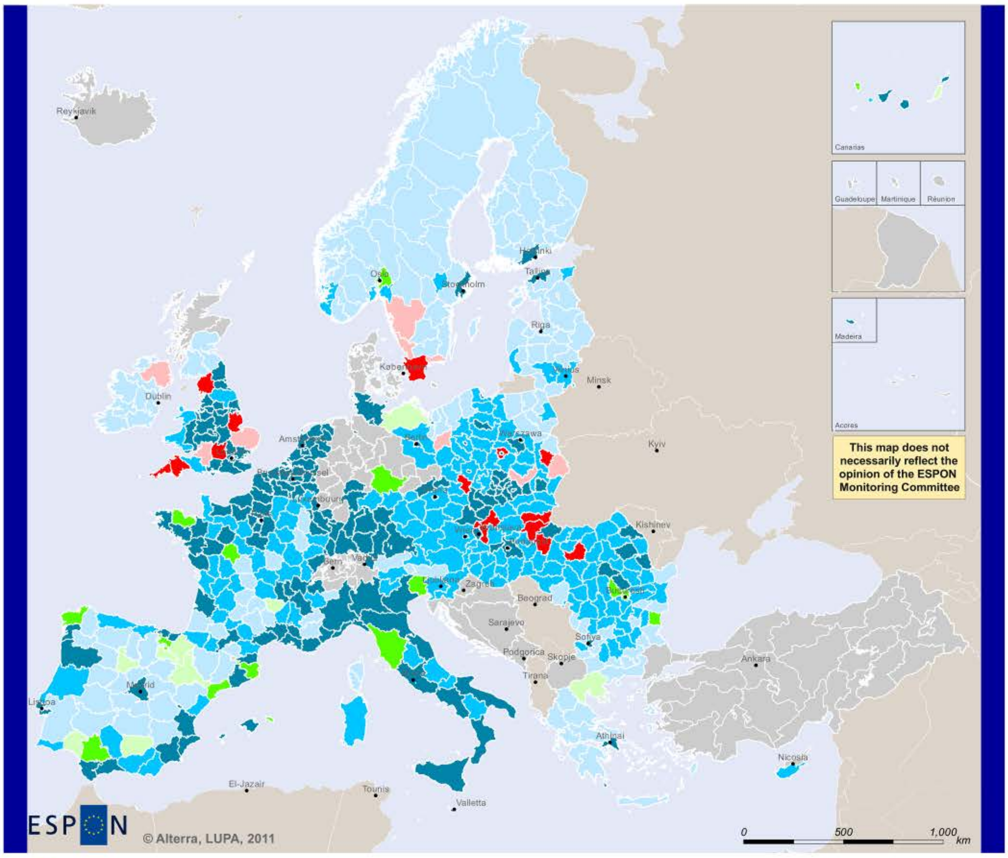
Only for one year information available

No Data



Indicator 3: Status of bathing water

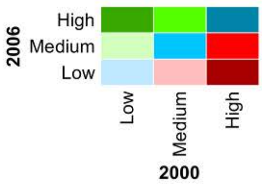




EUROPEAN UNION
Part-financed by the European Regional Development Fund
INVESTING IN YOUR FUTURE

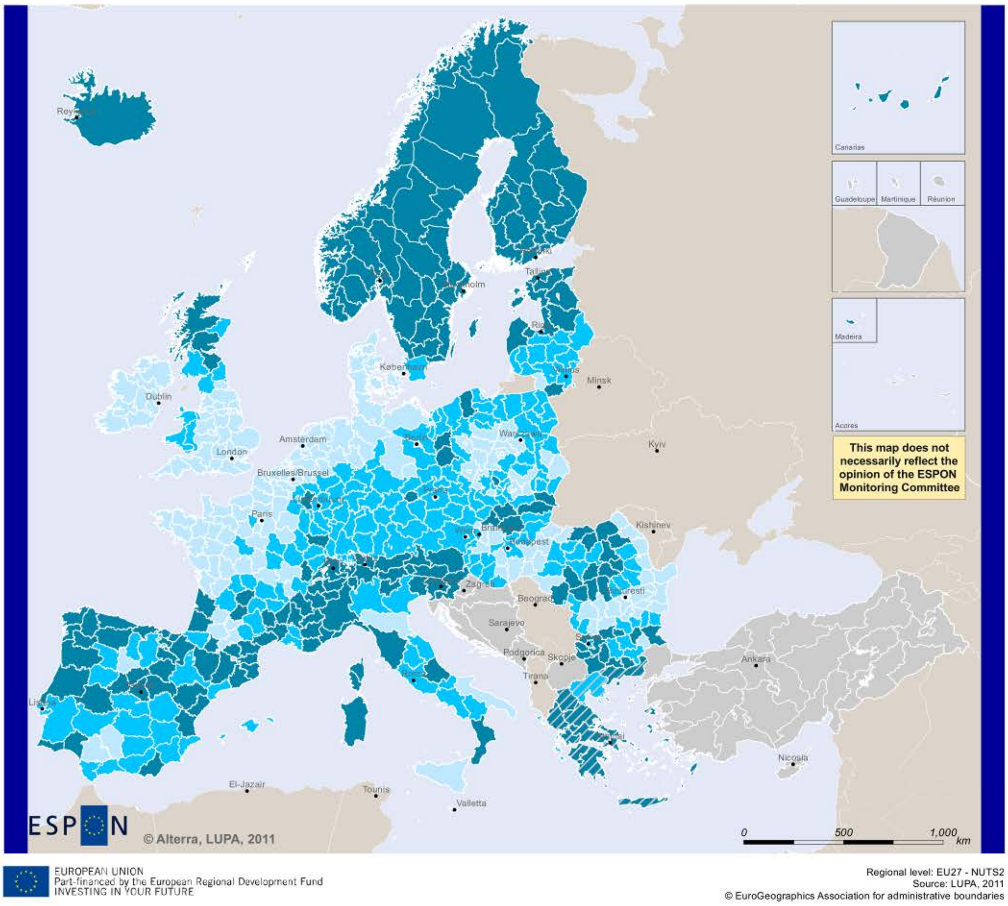
Regional level: EU27 - NUTS2
Source: LUPA, 2011
© EuroGeographics Association for administrative boundaries

Indicator 4: Pre-primary education

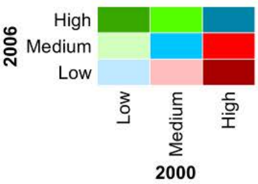


Only for one year information available

No Data

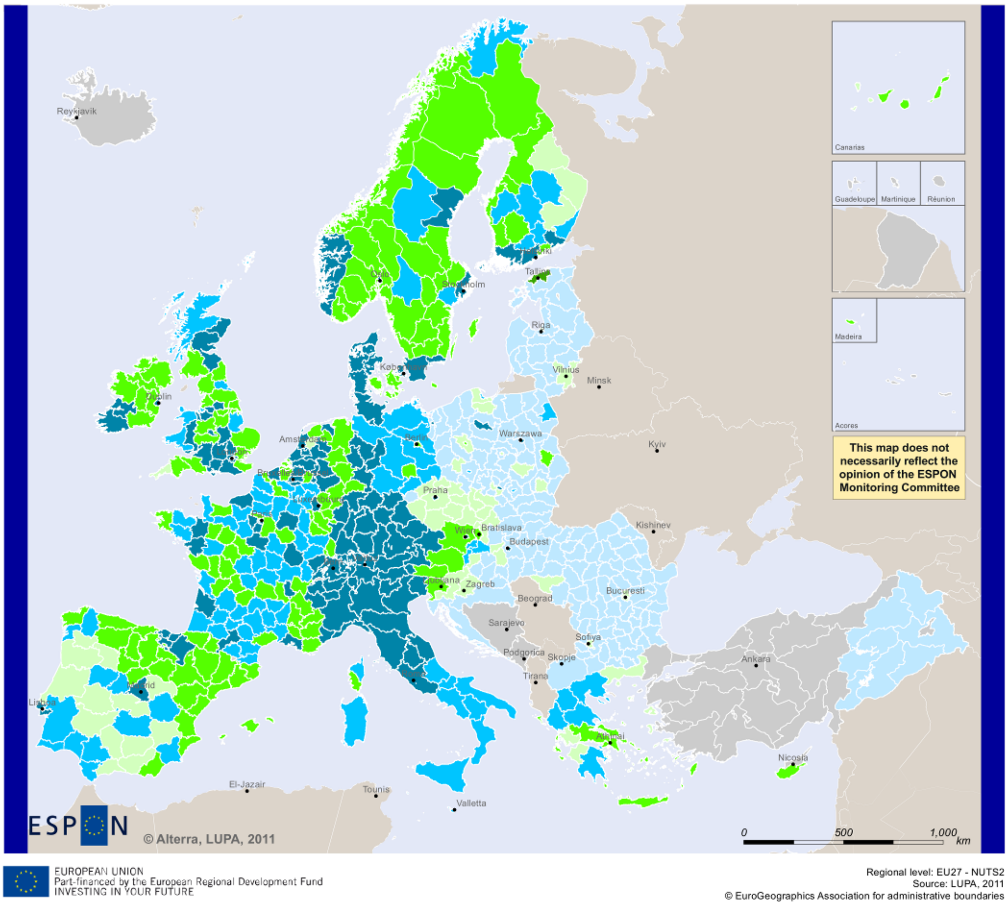


Indicator 5: Forests and semi-natural areas

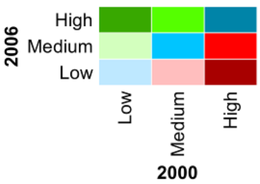


Only for one year information available

No Data

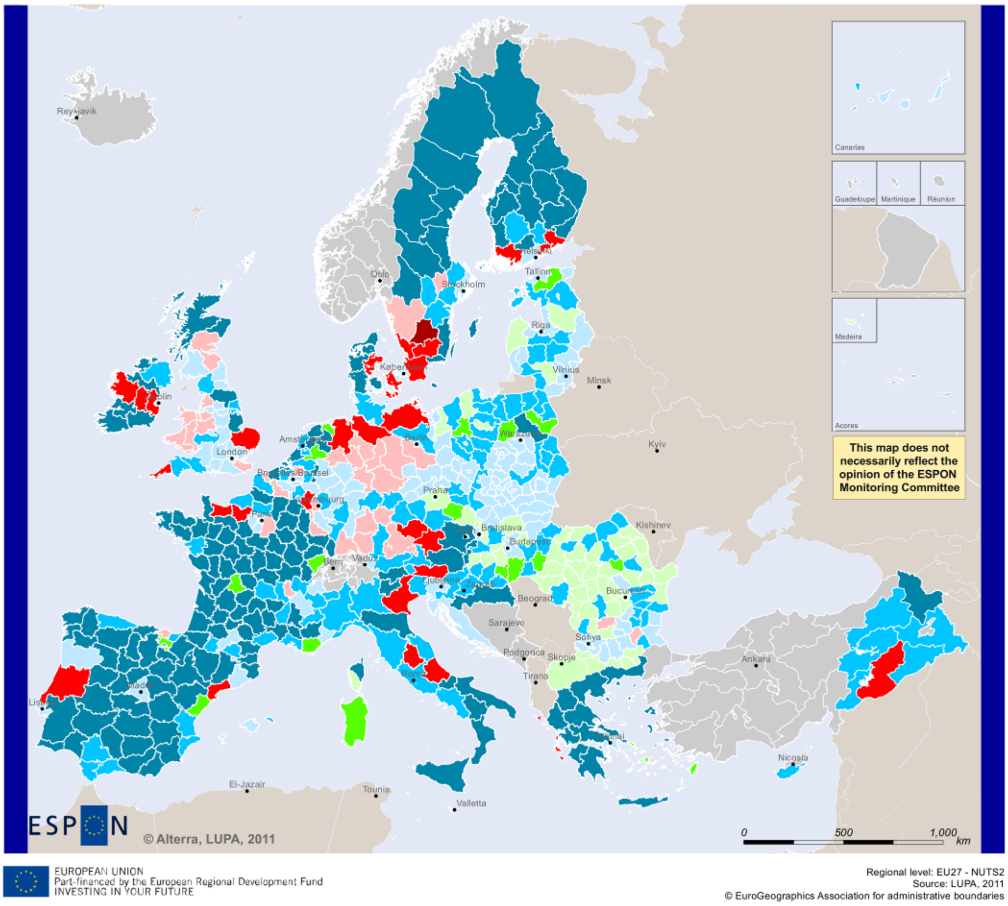


Indicator 6: Gross domestic product (PPS)

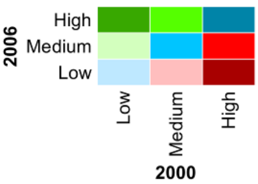


Only for one year information available

No Data

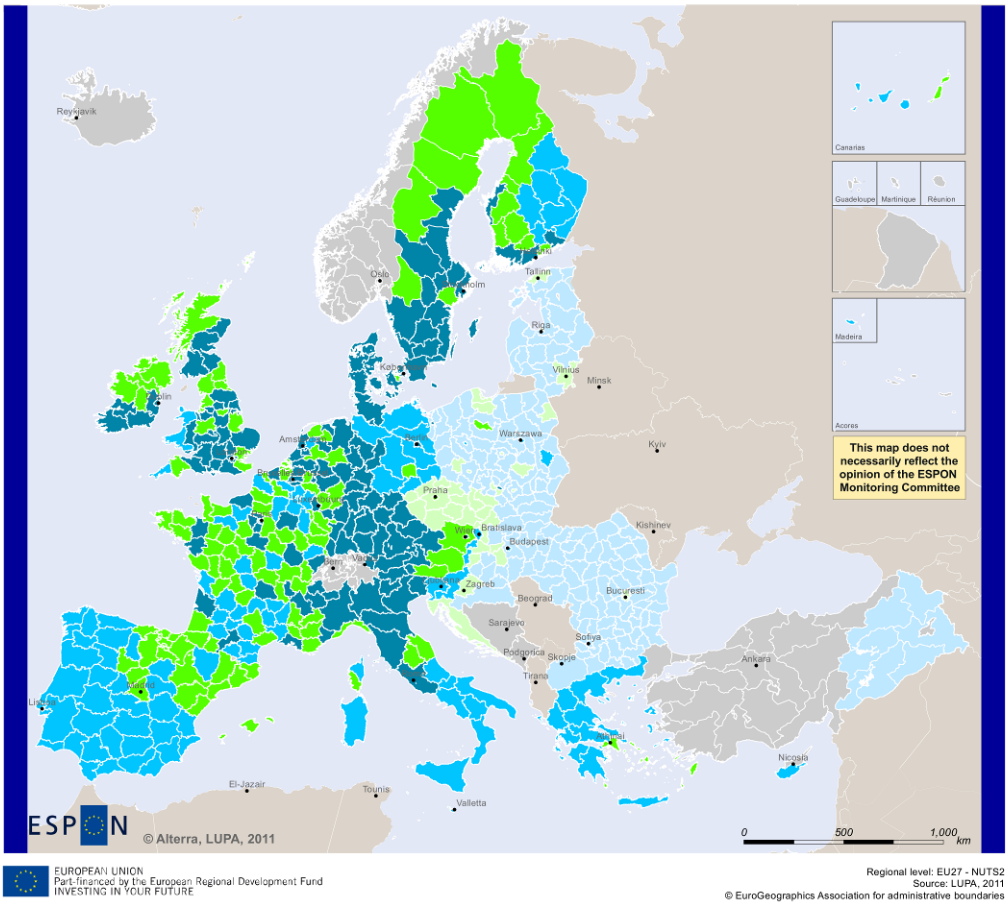


Indicator 7: Gross value added at basic prices - agriculture and fisheries

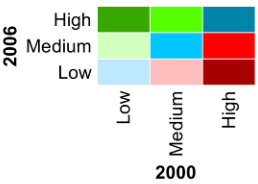


Only for one year information available

No Data

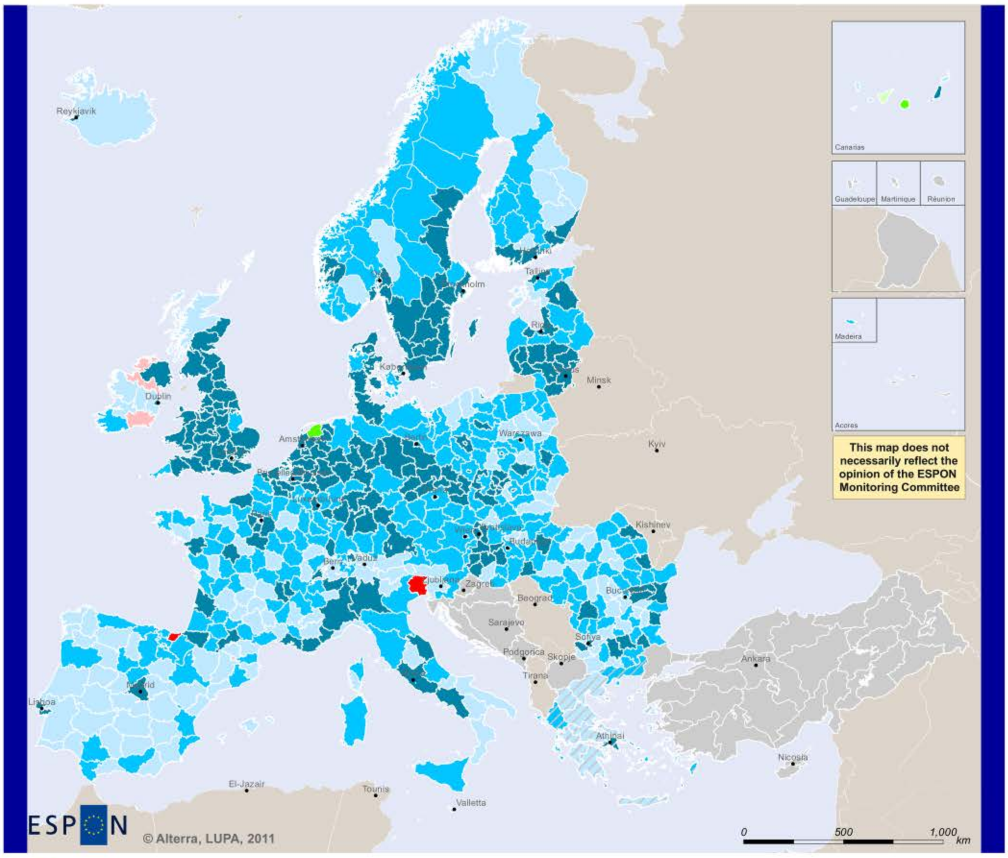


Indicator 8: Gross value added at basic prices - total



Only for one year information available

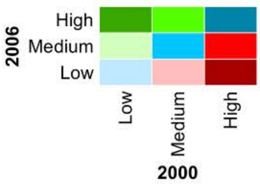
No Data



EUROPEAN UNION
Part-financed by the European Regional Development Fund
INVESTING IN YOUR FUTURE

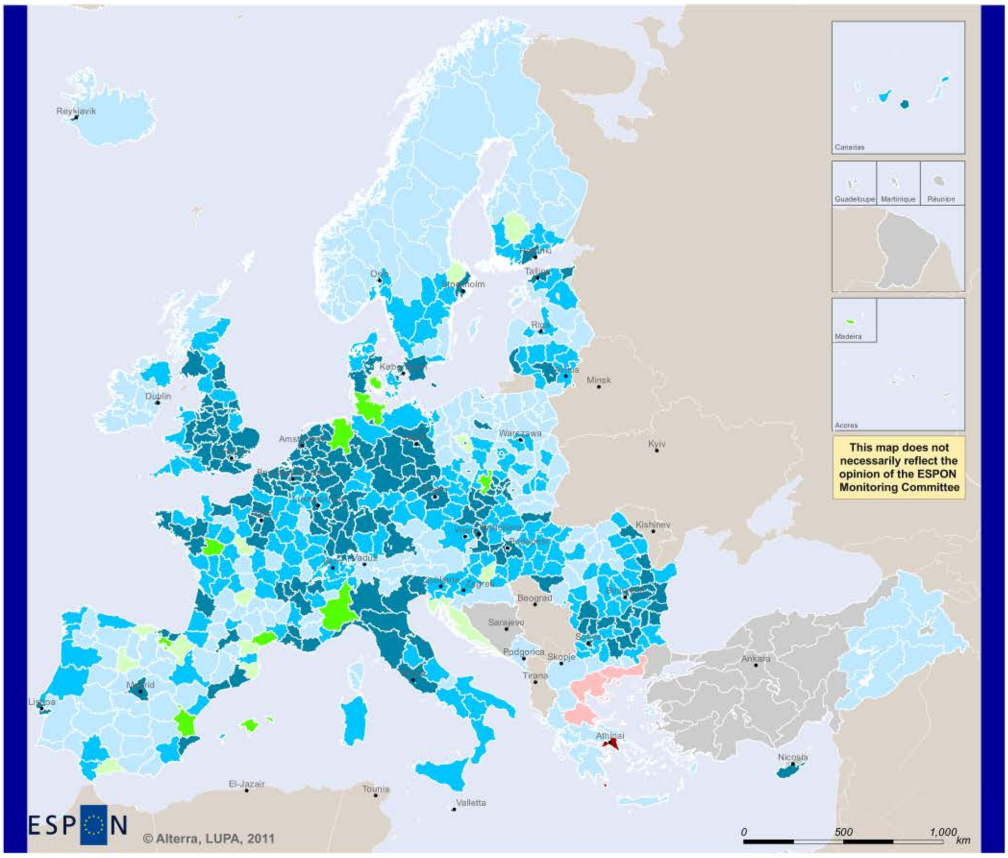
Regional level: EU27 - NUTS2
Source: LUPA, 2011
© EuroGeographics Association for administrative boundaries

Indicator 9: Green urban areas



Only for one year information available

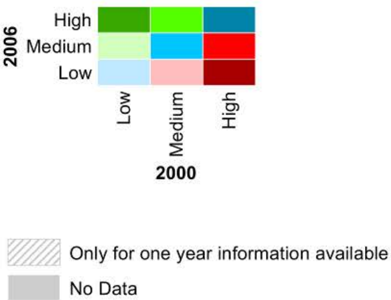
No Data

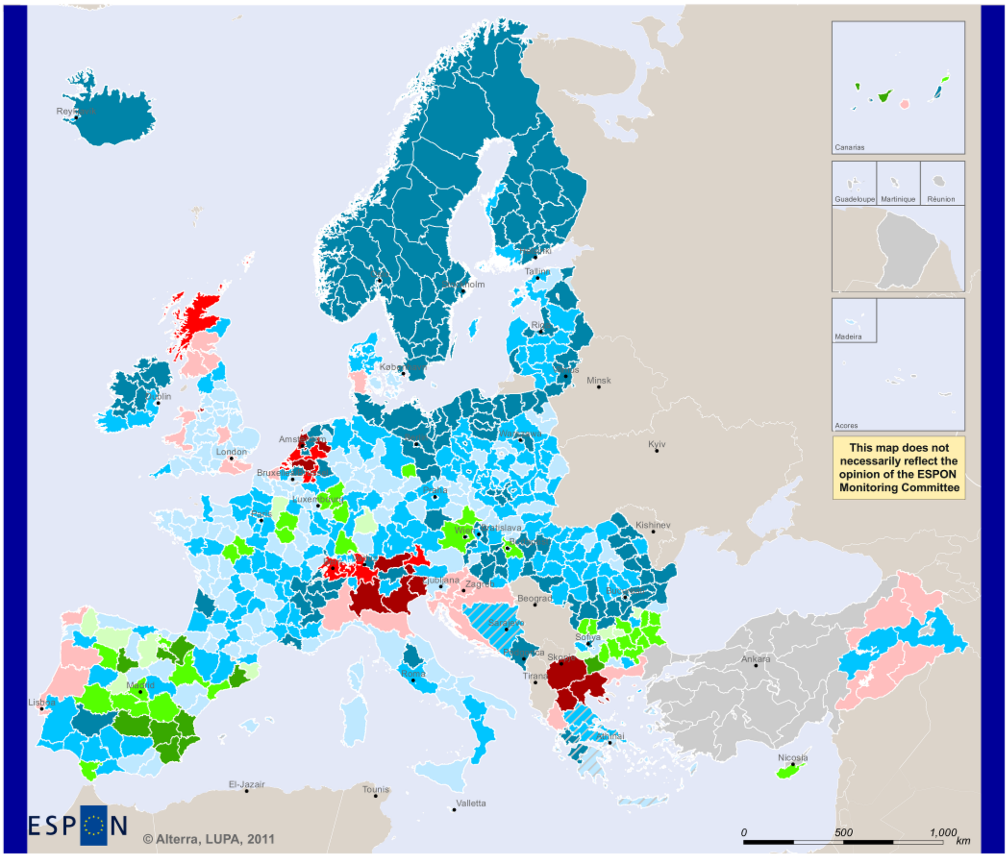


EUROPEAN UNION
Part-financed by the European Regional Development Fund
INVESTING IN YOUR FUTURE

Regional level: EU27 - NUTS2
Source: LUPA, 2011
© EuroGeographics Association for administrative boundaries

Indicator 10: Industry and commercial areas

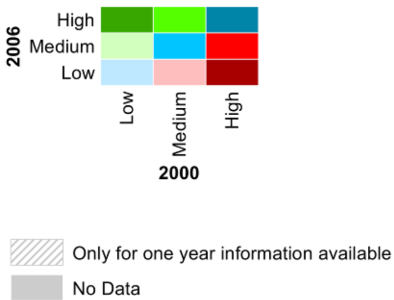


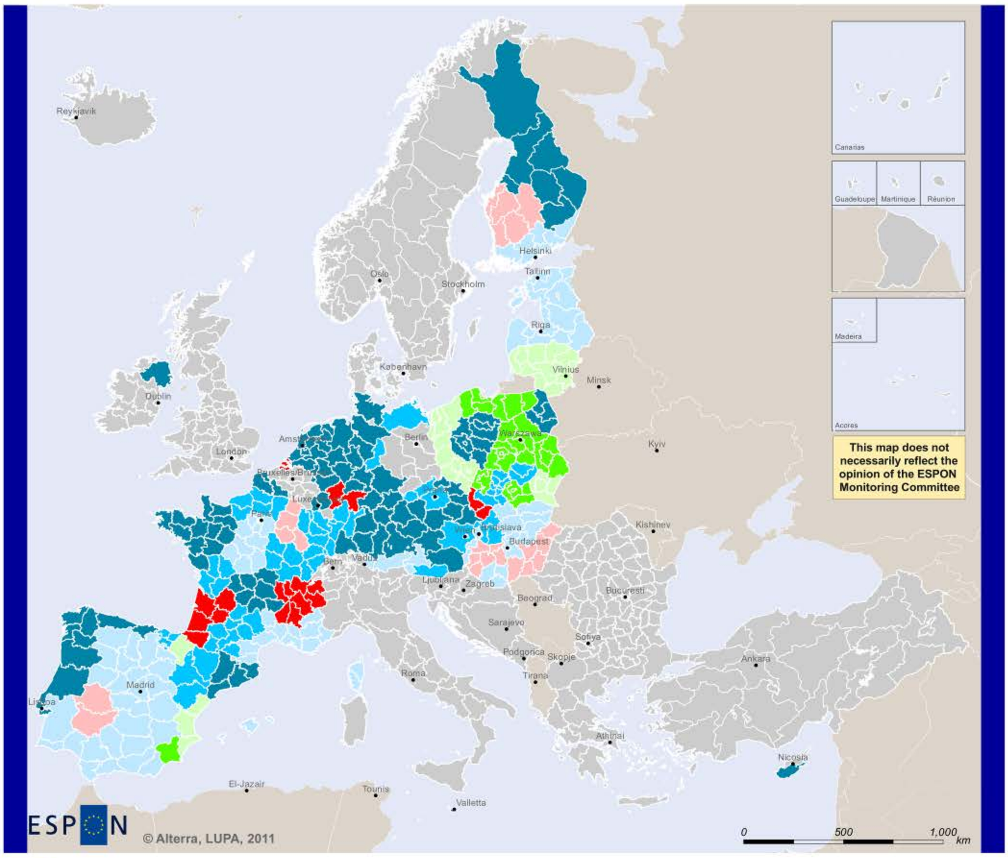


EUROPEAN UNION
Part-financed by the European Regional Development Fund
INVESTING IN YOUR FUTURE

Regional level: EU27 - NUTS2
Source: LUPA, 2011
© EuroGeographics Association for administrative boundaries

Indicator 11: Natural leisure

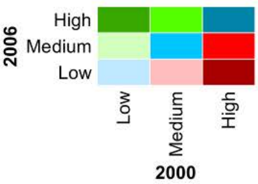




EUROPEAN UNION
Part-financed by the European Regional Development Fund
INVESTING IN YOUR FUTURE

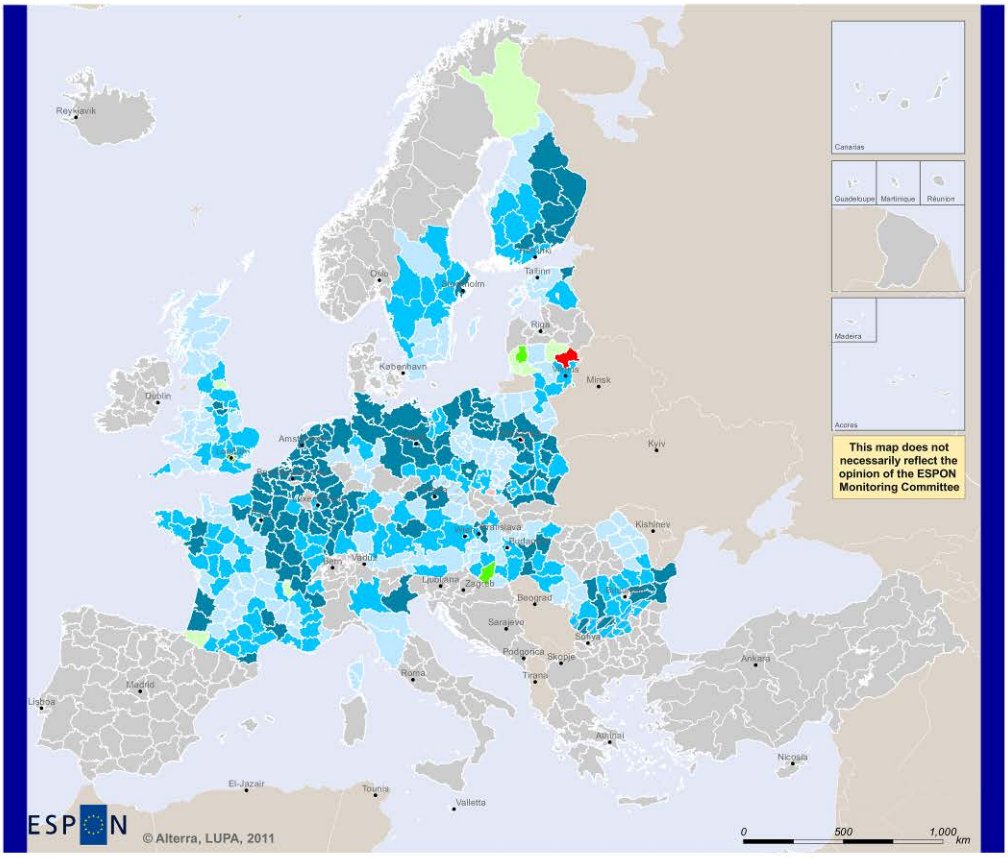
Regional level: EU27 - NUTS2
Source: LUPA, 2011
© EuroGeographics Association for administrative boundaries

Indicator 12: NH_3 emission (kg N/ha)



Only for one year information available

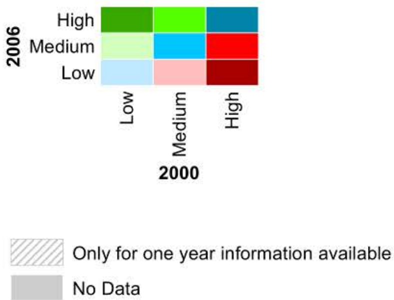
No Data

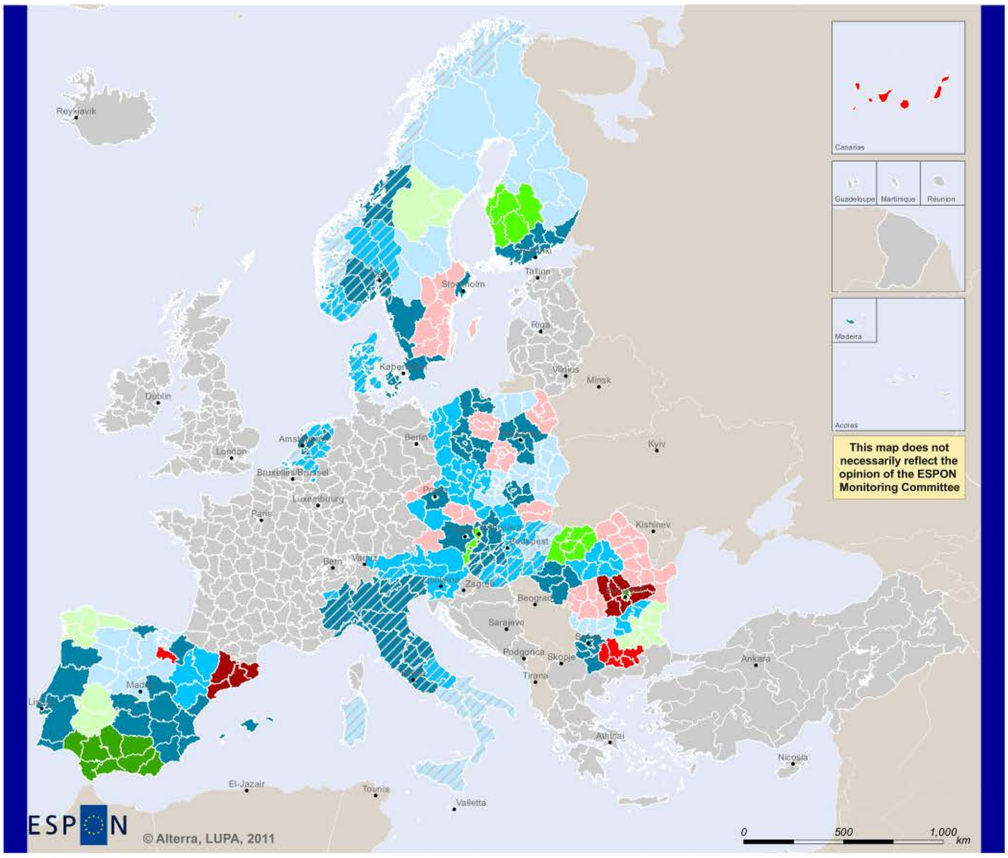


EUROPEAN UNION
Part-financed by the European Regional Development Fund
INVESTING IN YOUR FUTURE

Regional level: EU27 - NUTS2
Source: LUPA, 2011
© EuroGeographics Association for administrative boundaries

Indicator 13: Navigable rivers and canals

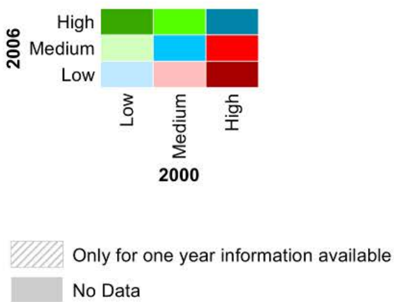


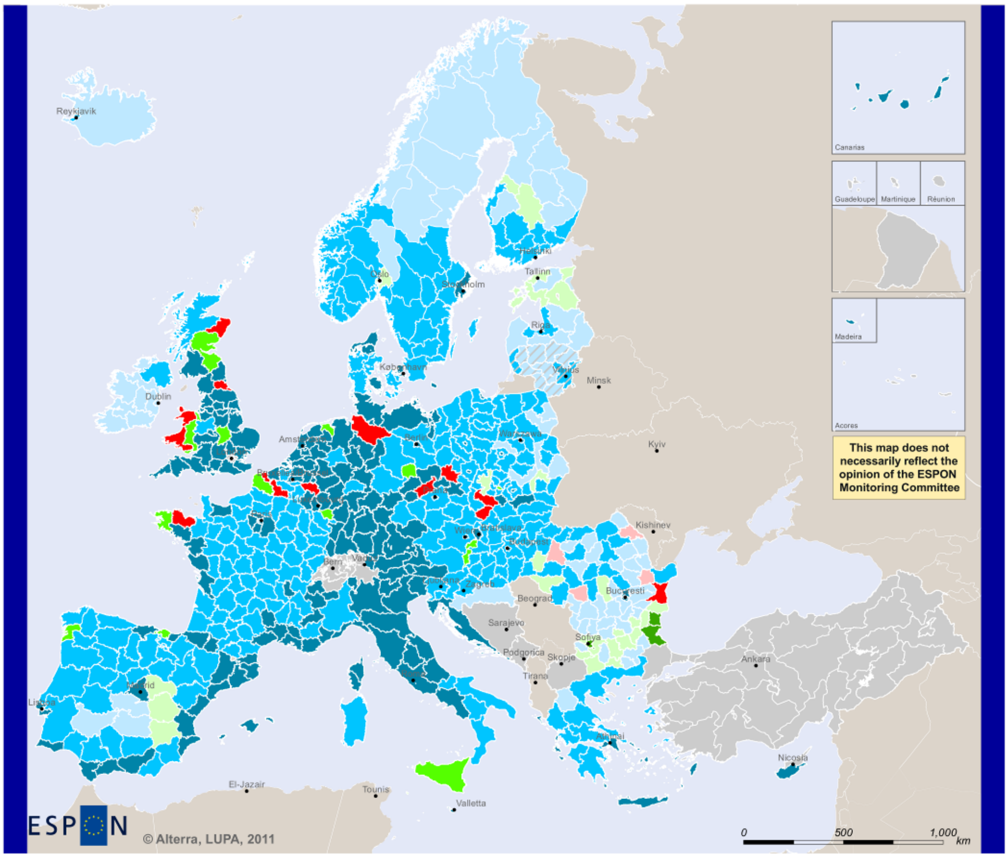


EUROPEAN UNION
Part-financed by the European Regional Development Fund
INVESTING IN YOUR FUTURE

Regional level: EU27 - NUTS2
Source: LUPA, 2011

Indicator 14: Net. migration

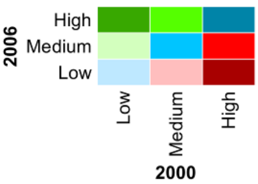




EUROPEAN UNION
Part-financed by the European Regional Development Fund
INVESTING IN YOUR FUTURE

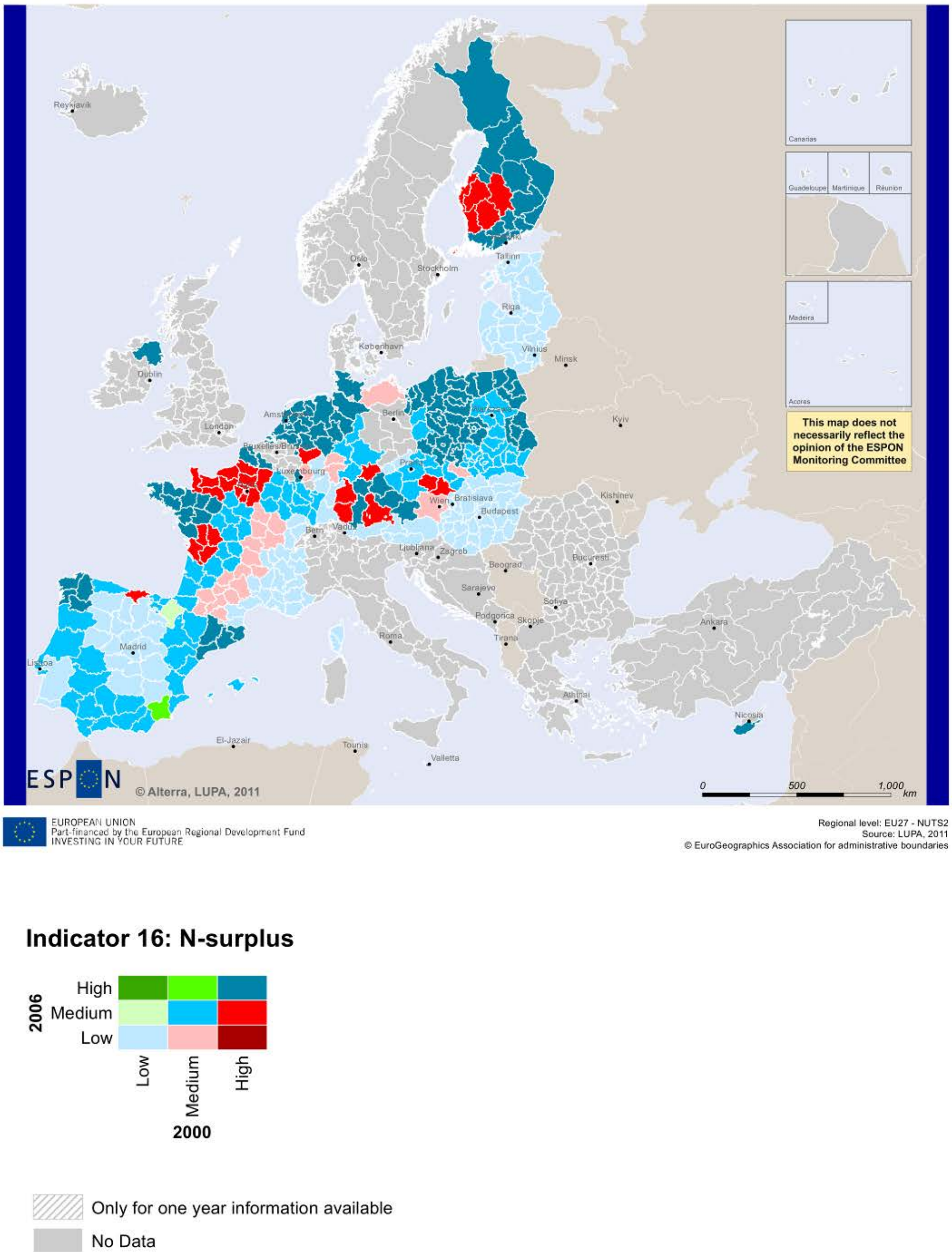
Regional level: EU27 - NUTS2
Source: LUPA, 2011
© EuroGeographics Association for administrative boundaries

Indicator 15: Nights spent in tourist accommodations

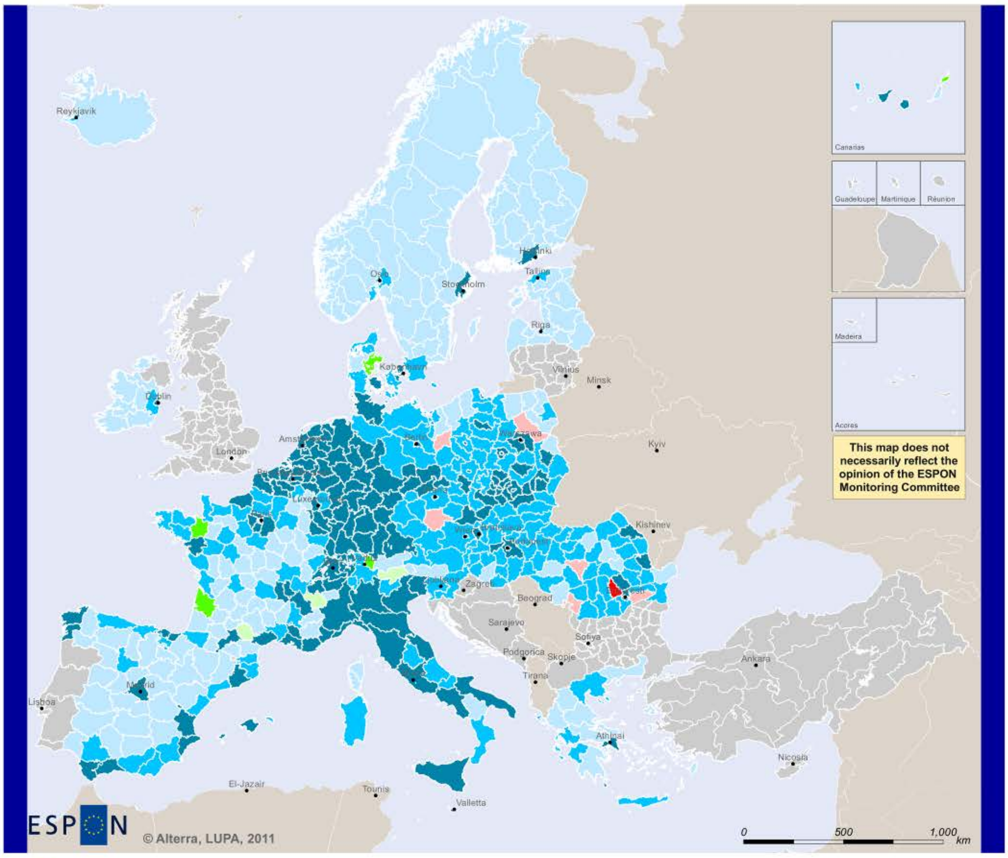


Only for one year information available

No Data



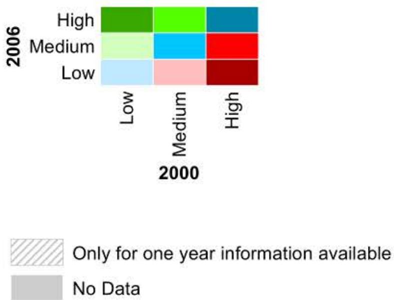
Reykjavik
Dublin
London
Berlin
Wien
Bratislava
Budapest
Bern
Vaduz
Ljubljana
Zagreb
Beograd
Sarajevo
Podgorica
Skopje
Tirana
Sofiya
Bucuresti
Kishinev
Kyiv
Minsk
Vilnius
Riga
Tallinn
Stockholm
Oslo
København
Madrid
Roma
Athinai
Ankara
Nicosia
Valletta
Tounis
El-Jazair
Canarias
Guadeloupe
Martinique
Réunion
Madeira
Acores
This map does not necessarily reflect the opinion of the ESPON Monitoring Committee
ESPON
© Alterra, LUPA, 2011
0
500
1,000
km
EUROPEAN UNION
Part-financed by the European Regional Development Fund
INVESTING IN YOUR FUTURE
Regional level: EU27 - NUTS2
Source: LUPA, 2011
© EuroGeographics Association for administrative boundaries
Indicator 16: N-surplus
2006
High
Medium
Low
Low
Medium
High
2000
Only for one year information available
No Data

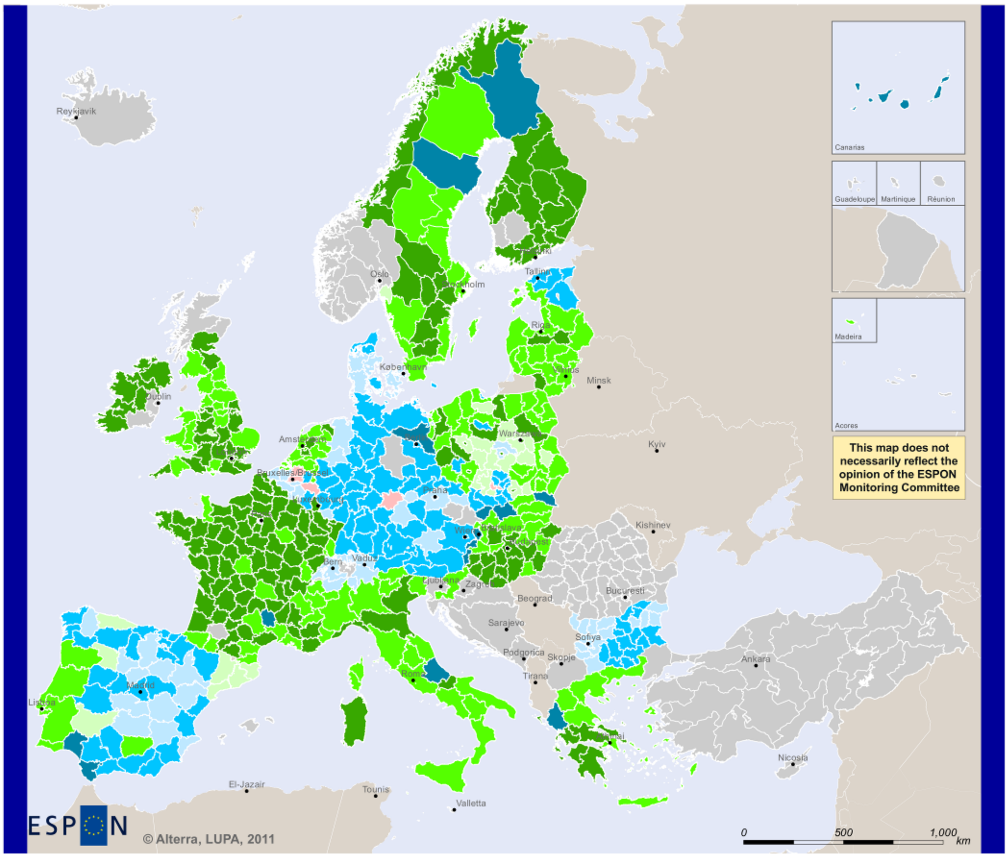


EUROPEAN UNION
Part-financed by the European Regional Development Fund
INVESTING IN YOUR FUTURE

Regional level: EU27 - NUTS2
Source: LUPA, 2011
© EuroGeographics Association for administrative boundaries

Indicator 17: Population density

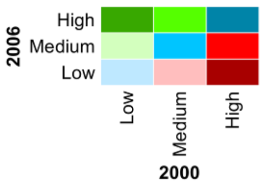




EUROPEAN UNION
Part-financed by the European Regional Development Fund
INVESTING IN YOUR FUTURE

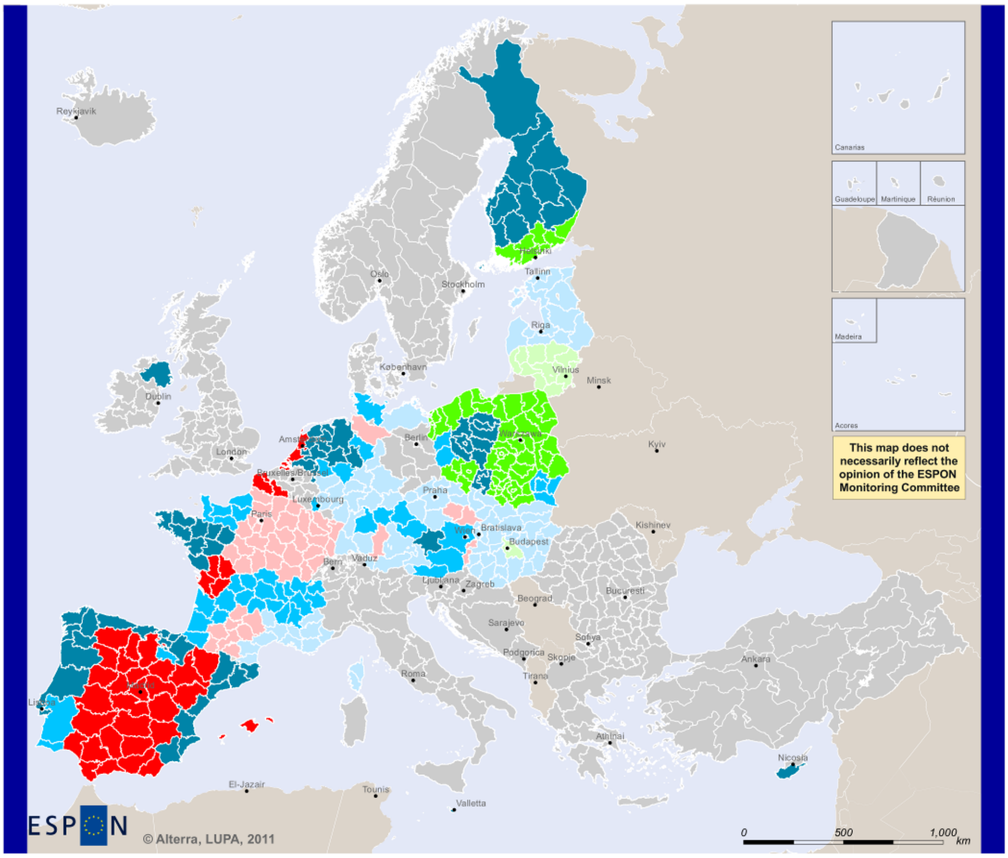
Regional level: EU27 - NUTS2
Source: LUPA, 2011
© EuroGeographics Association for administrative boundaries

Indicator 18: Natural protected areas - CDDA and Natura2000



Only for one year information available

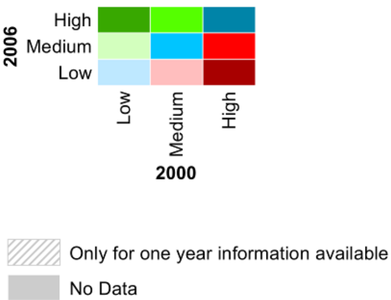
No Data

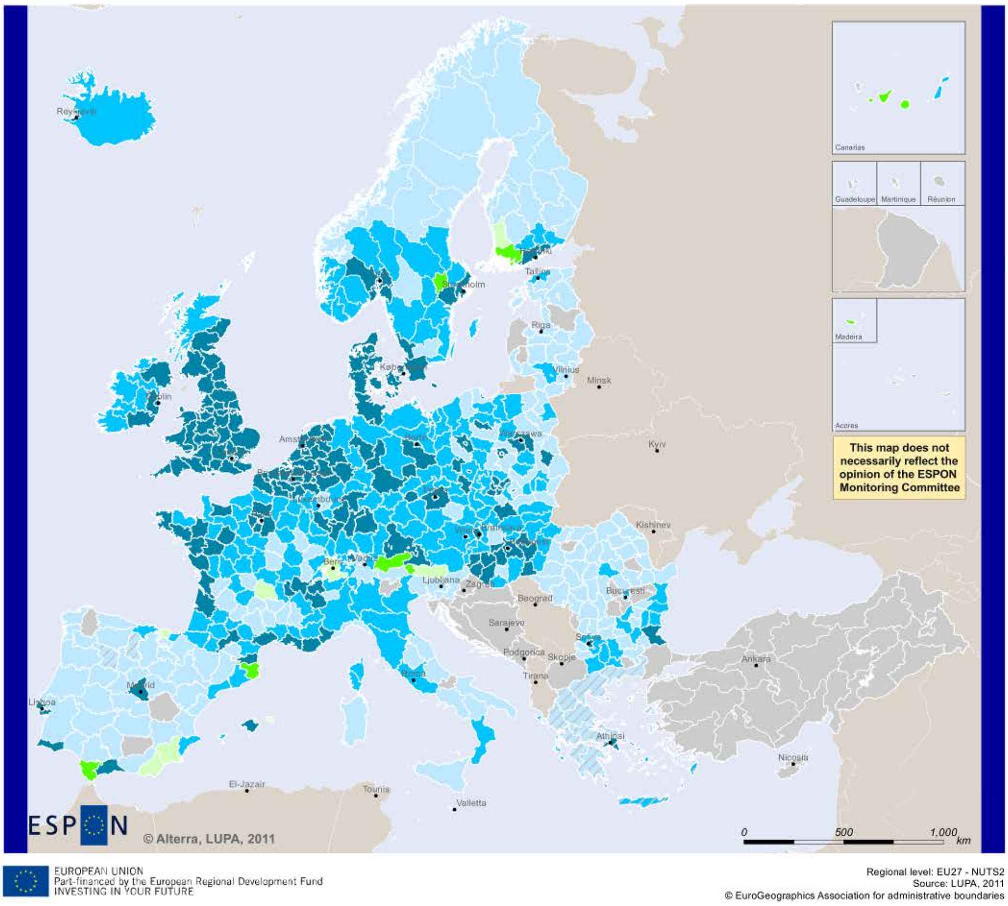


EUROPEAN UNION
Part-financed by the European Regional Development Fund
INVESTING IN YOUR FUTURE

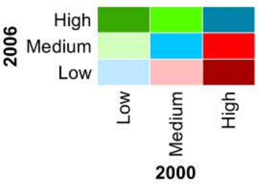
Regional level: EU27 - NUTS2
Source: LUPA, 2011

Indicator 19: P-surplus



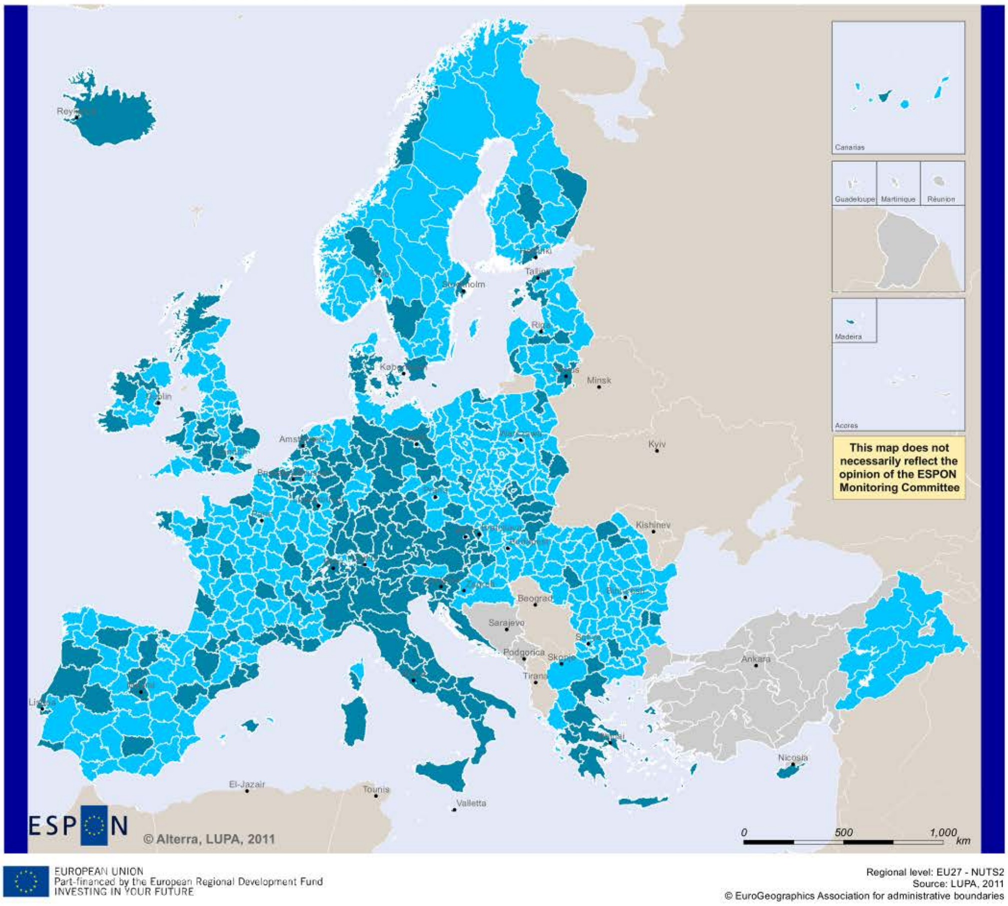


Indicator 20: Artifical leisure areas

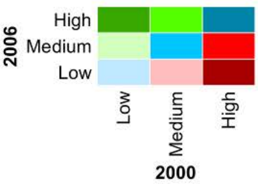


Only for one year information available

No Data

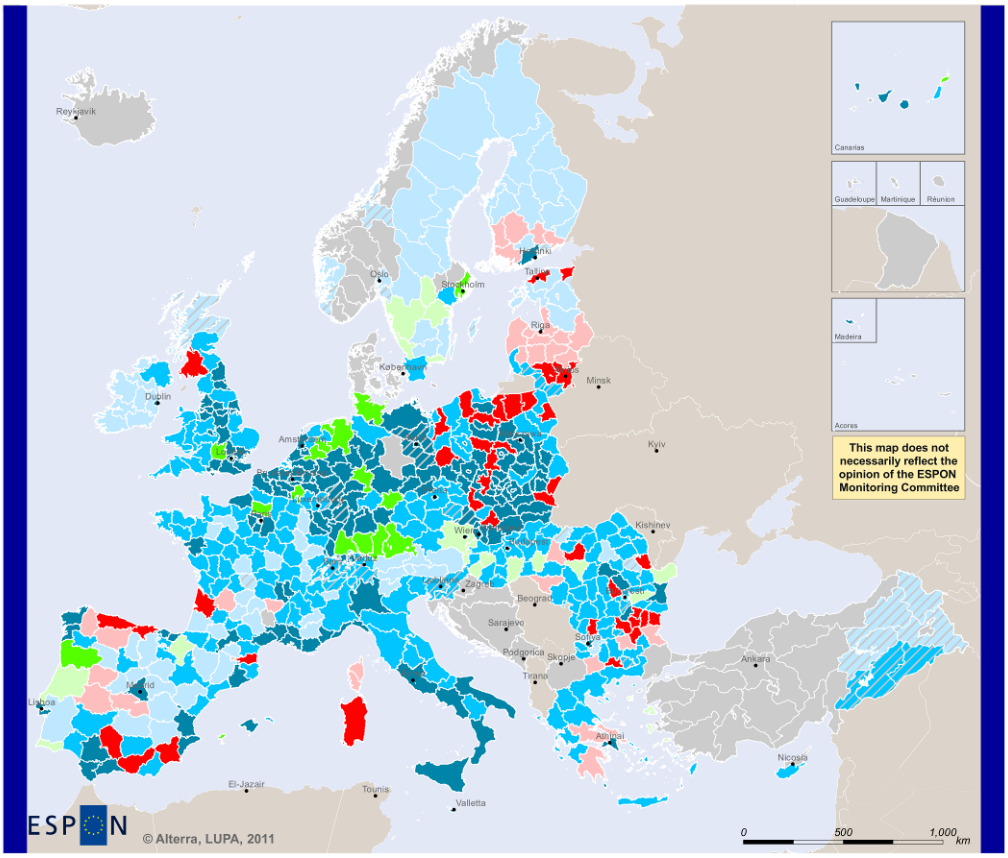


Indicator 21: Number of tourist sights



Only for one year information available

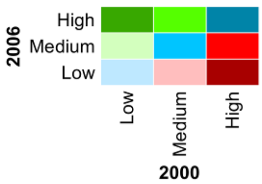
No Data



EUROPEAN UNION
Part-financed by the European Regional Development Fund
INVESTING IN YOUR FUTURE

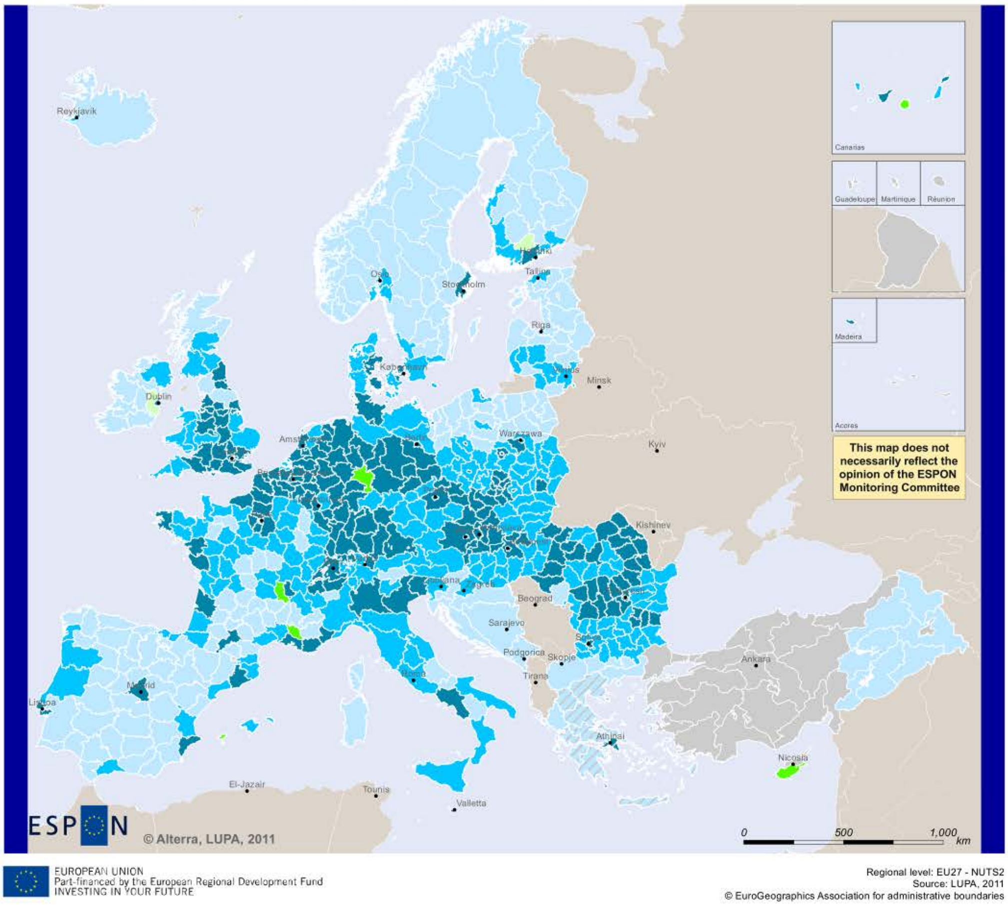
Regional level: EU27 - NUTS2
Source: LUPA, 2011
© EuroGeographics Association for administrative boundaries

Indicator 22: Unemployment rates > 14 years old

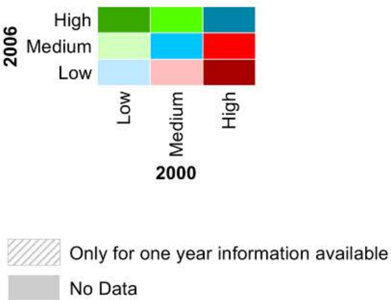


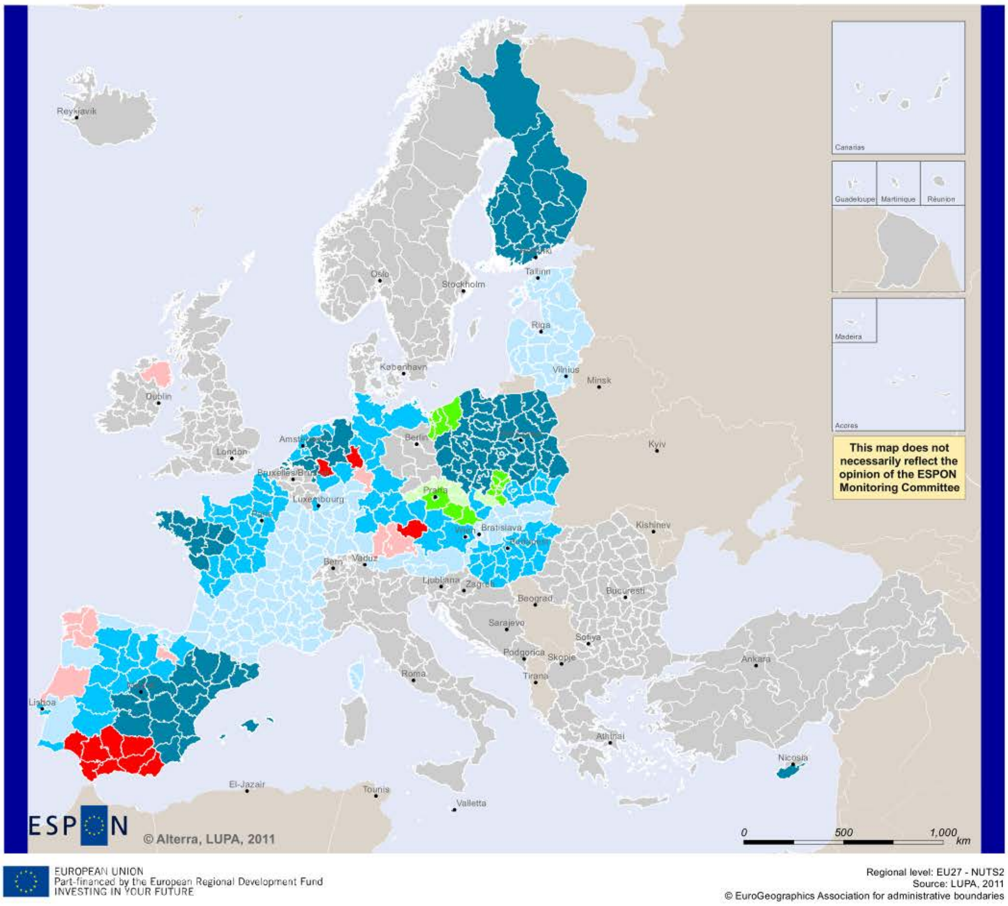
Only for one year information available

No Data

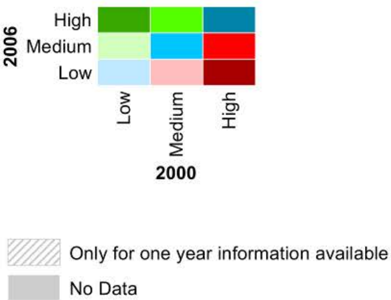


Indicator 23: Build up areas





Example Indicator: NO3 concentration of leaching (mg NO3/litre)



Annex 6: Policy targets and possible links to indicators

LUFs Indicators	Performance indicator	Policy	Policy target	Comments to policies	Efficiency
Gross domestic product (Purchasing Power Standard)	GDP per person employed, index EU27=100	Lisbon treaty and Gotteborg objetives	Social cohesion EU27 Average		Very difficult to relate to a certain land use
Gross domestic product (Purchasing Power Standard)	Growth rate of real GDP per capita	European Strategy of Sustainable Development	Socio-economic development EU27 Average		Very difficult to relate to a certain land use
Multimodal potential accessibility		Territorial cohesion	Not found		It could be feasible using lenght of roads
Net migration			Not found		It could be related to an increase in built-up/residential area.
NH3 emission		National Emission Ceilings Directive	Policy targets per country		Very difficult to relate to a certain land use
Nights spent in tourist accomodations		It does not relate to any policye			
N-surplus	NO3 level in water	Directive 91/676/EEC on pollution caused by nitrates from **agricultural** sources ("nitrate" Directive)	The Nitrates Directive requires MS to monitor surface waters and groundwater for nitrate pollution against a maximum limit of **50mg NO3**	The Directive seeks to reduce or prevent the pollution of water caused by the application and storage of inorganic fertiliser and manure on farmland. It is designed both to safeguard drinking water supplies and to prevent wider ecological damage in the form of the eutrophication of freshwater and marine waters generally. Where this level of pol-lution is reached, land draining into the affected waters (and which con-tribute to pollution) must be designated as a Nitrate Vulnerable Zone (NVZ).	As alternative indicator we could use the NVZs.
P-surplus			not found		
Status of coastal bathing water		Directive 2000/60/EC Water framework directive			It is very difficult to relate to certain land cover classes. We may assume that bathign water quality is a result of inputs (agriculture+industry+households) - treatments. The WaterBase already provides good information on water treatment plants (inputs and outputs) which is relatively independent of the land use (it has more to do with implementation at national and local level being other factors relevant -policy context, technologies,...)
Status of inland bathing water		Directive 2000/60/EC Water framework directive			It is very difficult to relate to certain land cover classes. We may assume that bathign water quality is a result of inputs (agriculture+industry+households) - treatments. The WaterBase already provides good information on water treatment plants (inputs and outputs) which is relatively independent of the land use (it has more to do with implementation at national and local level being other factors relevant -policy context, technologies,...)

Unemployment rates (age >=15)	Dispersion of regional unemployment rates	Lisbon treaty and Gotteborg objetives; no clear policy target.	Social cohesion EU27 Average		There is no link in the database betwee UNemployment and employment (per sector) therefore we don't know if somebody is unemployed in a certain sector.
Unemployment rates (age >=15)	Employment rate by gender, age group 20-64	Europe 2020 Strategy	**75 % of the population aged 20-64 should be employed**		There is no link in the database betwee UNemployment and employment (per
	Gross domestic expenditure on R&D (GERD)	Europe 2020 Strategy	3% of the EU's GDP should be invested in R&D		
CO2 emissions	Greenhouse gas emissions, base year 1990	Europe 2020 Strategy	The "20/20/20" climate/energy targets should be met (including an increase to 30% of emissions reduction if the conditions are right) EU27 target 80		
	Share of renewables in gross final energy consumption	Europe 2020 Strategy			We don't have data on area used for renewable energy. It maybe possible fo biofuels in some countries, but we have not found data covering all Europe in terms of solar energy, neither wind mill (there is only some data for offshore).
	Energy intensity of the economy (proxy indicator for *Energy savings*, which is under development)	Europe 2020 Strategy			
	Early leavers from education and training by gender	Europe 2020 Strategy	The share of early school leavers should be under 10% and at least 40% of 30-34 years old should have completed a tertiary or equivalent education		
	Tertiary educational attainment by gender, age group 30-34	Europe 2020 Strategy			
	Population at risk of poverty or exclusion *(union of the three sub-indicators below)*	Europe 2020 Strategy	Reduction of poverty by aiming to lift at least 20 million people out of the risk of poverty or exclusion		
	Persons living in households with very low work intensity	Europe 2020 Strategy			
	Persons at risk of poverty after social transfers	Europe 2020 Strategy			
	Severely materially deprived persons	Europe 2020 Strategy			
	Resource productivity	European Strategy of Sustainable Development	Sustainable consumption and production EU27 Average		
	Healthy life years and life expectancy at birth, by gender	European Strategy of Sustainable Development	Public health EU27 Average		
	Energy consumption of transport relative to GDP	European Strategy of Sustainable Development	Sustainable transport EU27 Average		
	Common bird index	European Strategy of Sustainable Development	Natural resources EU27 Average		Protected area
	Fish catches taken from stocks outside safe biological limits				
	Official development assistance as share of gross national income	European Strategy of Sustainable Development	Global partnership EU27 Average		

Annex 7: Bibliography

Helming K, H. Bach O. Dilly, R.F. Hüttl B. König, T. Kuhlmann, M. Perez-Soba, S. Sieber P. Smeets, P. Tabbush, K. Tscherning, K. Müller, D. Wascher, and H. Wiggering. 2008 Ex ante impact assessment of land use changes in European regions – the SENSOR approach. Pages 56-77 in: Helming K, Perez-Soba M, Tabbush P, editors. Sustainability impact assessment of land use changes. Springer-Verlag. Berlin, Germany.

König H., Schuler J., Suarma U., McNeill D., Imbernon J., Damayanti F., Dalimunthe S.A., Uthers S., Sartohadi J., Helming K., Morris J., 2010, Assessing the Impact of Land Use Policy on Urban-Rural Sustainability Using the FoPIA Approach in Yogyakarta, Indonesia. Sustainability, Volume 2, Issue 7, 1991-2009.

Jeffreys, I., 2004, The Use of Compensatory and Non-compensatory Multi-Criteria Analysis for Small-scale Forestry. Small-scale Forest Economics, Management and Policy, Volume 3, Issue 1, Pages 99-117.

Munda, G., 2004, Social multi-criteria evaluation: Methodological foundations and operational consequences. European Journal of Operational Research, Volume 158, Pages 662–677.

Nardo, M., Saisana, M., Saltelli, A., Tarantola, S., Hoffman, A. and Giovannini, E., 2005, Handbook on constructing composite indicators: methodology and user guide. OECD Statistics working paper, Paris.

Paracchini, M.L., Pacini, C., Jones, L., Pérez-Soba, M., 2011, An aggregation framework to link indicators associated with multifunctional land use to the stakeholder evaluation of policy options, Journal Ecological Indicators, Volume 11, Issue 1, , Pages 71-80.

Pérez-Soba, M., Petit, S., Jones, L., Bertrand, N., Briquel, V., Omodei-Zorini, L., Contini, C., Helming, K., Farrington, J. H., Tinacci Mossello, M., Wascher, D., Kienast, F., De Groot, R., 2008, Land use functions: a multi-functionality approach to assess the impact of land use changes on land use sustainability. In: Helming K., Pérez-Soba M., Tabbush P. (Eds) Sustainability impact assessment of land use changes: Pages 375-404; Berlin (Springer).

Plummer, M. L. 2009. Assessing benefit transfer for the valuation of ecosystem services. Frontiers in Ecology and Environment 7(1):38-45.

Reidsma, P., König, H., Feng, S. et al., 2011, Methods and tools for integrated assessment of land use policies on sustainable development in developing countries. Land Use Policy. Doi: 10.1016/j.landusepol.2010.11.009.

Renetzeder, C., van Eupen, M., Mücher, S., Wrbka, T. A Spatial Regional Reference Framework for Sustainability Assessment in Europe. 2008. In: Helming K, Pérez-Soba M, Tabbush P (Eds) Sustainability impact assessment of land use changes: 249-268; Berlin (Springer).

Velthof, G.L., D. Oudendag, H.P. Witzke, W.A.H. Asman, Z. Klimont & O. Oenema. 2009. Integrated Assessment of Nitrogen Losses from Agriculture in EU-27 using MITERRA-EUROPE. J Environ Qual 38 (2), 402-417.

Wiggering, H., C. Dalchow, M, Glemnitz, K. Helming, K. Müller, A. Schulz, U. Stachow, and P. Zander. 2006. Indicators for multifunctional land use – Linking socio-economic requirements with landscape potentials. Ecological Indicators 6: 238-249.

www.espon.eu

The ESPON 2013 Programme is part-financed by the European Regional Development Fund, the EU Member States and the Partner States Iceland, Liechtenstein, Norway and Switzerland. It shall support policy development in relation to the aim of territorial cohesion and a harmonious development of the European territory.

ISBN 978-2-919777-19-8