ET2050

Territorial Scenarios and Visions for Europe

Project 2013/1/19

Volume 5

Land-use Trends and Scenarios

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30/06/2014

EUROPEAN UNION
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This report presents a more detailed overview of the work carried out on land use trends and scenarios as part of the ET2050 ESPON project. This Applied Research Project is 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.

The approach presented in the report has been presented and discussed with the ESPON Monitoring Committee, and the indications made by the ESPON Monitoring Committee have been integrated, but still it may 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.

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1. Introduction

The aim of the ESPON ET2050 project is to support policy makers in formulating a long-term integrated and coherent vision for the development of the EU territory. This aim is twofold: content-wise, a product, namely a vision for the European Territory, has to be developed; and process-wise, those who will elaborate this product, namely policy makers, have to be supported by sound scientific knowledge. This scientific knowledge comes from various disciplines and is backed-up by a series of models. This report describes the scientific input related to land use and especially the trends and scenarios that are envisioned as part of the project.

In the ET2050 project, the required steps towards the European Territorial visions are defined as

- Present State of Europe: What is the current state of the European territorial structure?
- Baseline Scenarios for 2030 and 2050: What will be the future state of the European territorial structure based on the hypothesis that development trends and policies remain stable?
- Extreme/exploratory Scenarios 2050: What can be feasible future states of the European territorial structure in three territorially extreme/exploratory scenarios?
- European Territorial Vision 2050: What is the room for manoeuvre to politically steer (the development of) the future state of the European territorial structure and what is the range in which a realistic territorial vision can be formulated?
- Midterm targets and pathways 2010-2030: What could be sensible midterm targets in order to steer territorial development into the direction of the desired long-term vision? And what policy actions and interventions are required to meet these midterm targets?

This report provides input to each of these steps, more in particular by answering the following questions:

- How will the present land use pattern evolve over time, given the current behaviour of spatial actors?
- How will assumptions on socioeconomics and changes in behaviour influence future land use dynamics?
- How will spatial policies influence future land use dynamics?

The report starts with presenting the methodology of the land use analysis (chapter two), followed by a description of the Metronamica modelling framework used for simulating a baseline scenario and three exploratory scenarios (chapter 3). Chapter 4 describes the present land use state and ongoing developments, while chapter 4 presents and discusses the exploratory scenarios. Chapter 5 then provides input into the Vision 2050 and the Midterm targets and pathways 2010-2030.

2. Methodology

The work carried out as part of the scientific input on land use is built on a combination of literature review, data analysis and modelling. The description of the current state and ongoing development mostly relies on a literature review complemented by analysis of land use changes between 1990 and 2006 using the Corine Land Cover database with land use maps covering large parts of Europe for the years 1990, 2000 and 2006.

In the ET2050 project a suit of models is used to simulate the baseline and alternative scenarios:

- MULTIPOLES simulates demographic developments until 2030.
- MASST simulates economic developments until 2030.
- MOSAIC simulates transport developments until 2030.
- SASI simulates long-term integrated simulations until 2050.
- Metronamica simulates land use developments until 2050.

The way the models work together is shown in figure 2-1. From these figures can be seen that Metronamica uses input from the other models. For consistency purposes, two applications of Metronamica have been set up. An application working with input from MULTIPOLES, MASST and MOSAIC, which uses input from these models at NUTS-2 level and simulating land use change until 2030, and an application working with input from SASI, using input from SASI at NUTS-3 level and simulating land use change until 2050.

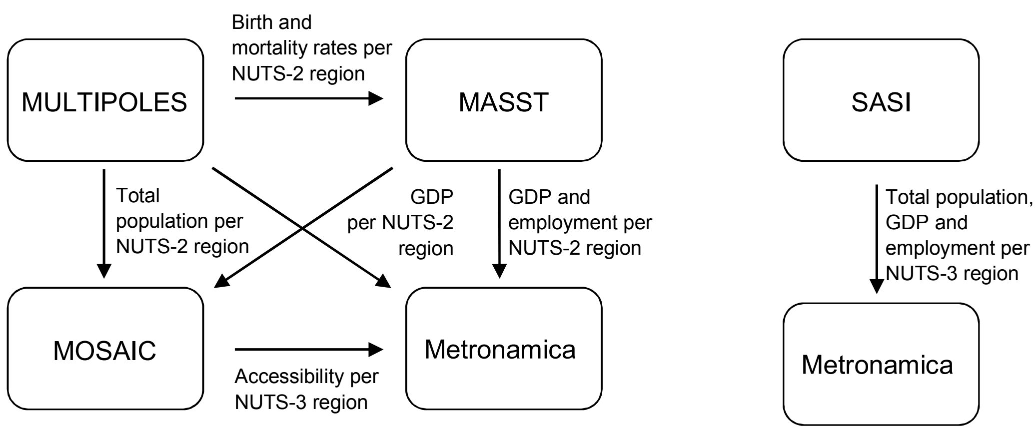

Figure 2-1 Links between models in ET2050

2.1 Land use analysis

For the analysis of historic land use changes we look at developments that have occurred between 1990 and 2006 in the Corine land cover (CLC) maps. Together with the literature review this information provides the basis for Chapter 4: Present situation and land use trends. The results of the historic analysis are also used to provide information for parameter settings of the calibration as well as the future developments in the baseline scenario. For this reason the analysis focuses on those land use classes that will be modelled explicitly in the land use model.

The selected land use model is Metronamica, which is incorporated among others in the LUMOCAP Policy Support System (PSS). This land use model is applied to EU-27 at a 1 km resolution, consistent with the resolution of this analysis. As part of the LUMOCAP project[1], it is already calibrated with a single parameter set that applies to EU-27 as a whole. From this experience we learned that there are regional differences that cannot be discarded. Therefore in a subsequent project named "Towards a green infrastructure for Europe: Developing new concepts for integration of Natura 2000 network into a broader countryside" (EC study ENV.B.2/SER/2007/0076) we had divided Europe in a few major regions (described further below) for which different parameter settings will be applied. Also in the ET-2050 project we decided to follow this approach as calibration and validation results outperformed those of the application with a single parameter set. Moreover, dividing Europe in a few major regions also has the advantage that scenarios can be interpreted differently for the different regions.

To be able to build on the existing calibration from the **LUMOCAP** project, the land use categories that will be analysed for the period 1990-2000 and that will be modelled dynamically in the land use model are:

- Residential areas;
- Industrial and commercial areas;
- Recreational areas;
- Arable land;
- Permanent crops;
- Pastures;
- Heterogeneous agricultural areas;
- Forest; and
- Natural vegetation.

Understanding land use change is more than merely looking at the total area of certain land uses that appeared or disappeared. Also the change in structure and the underlying reasons of this change are important. It is the complete picture of different elements that provides insight in land use changes. For this reason we have focused on three particular ways to measure the change:

1. Appearance and disappearance

In this part of the analysis we provide an overview of observed changes in area in the 6 classes mentioned above. Results from this analysis are:

- Total area per land use in 1990, 2000 and 2006
- Surface share per land use in 1990, 2000 and 2006
- Absolute change in area per land use from 1990-2000, 2000-2006, and 1990-2006
- Increase or decrease from 1990-2000, 2000-2006 and 1990-2006 per land use function, expressed relative to the original (resp. 1990, 2000, 1990) amount of land use for that function.
- Increase or decrease from 1990-2000, 2000-2006 and 1990-2006 per land use function, expressed as a percentage of the total land area.

[1] www.riks.nl/projects/lumocap

2. Analysis of the neighbourhood of changed land uses

Here we analyse the observed changes between maps of two different years (1990-2000, 2000-2006, 1990-2006). In particular we look for locations where each of the 8 classes mentioned above appear in the latest map and analyse what land use this location had in the previous map and what the neighbouring land uses of this location were in this map. This helps us to understand the local land use dynamics.

3. Cluster size change of different land use categories

We use two different measures for analysing the cluster size change:

- For the residential clusters we calculate the cluster size – frequency distribution which shows the distribution of the different residential cluster sizes in a certain area.
- For all above mentioned land uses we calculate the clumpiness index[2] as landscape metric, which can be used to characterize the landscape pattern in an area.

We carry out this analysis at two different spatial scales, at NUTS-2 level (for those analyses for which this is relevant) and at the level of groups of countries that we expect to have similar behaviour (and which have shown similar behaviour in previous studies for DG Environment). Based on geographical location and history we have selected the following groups of countries[3]: Western Europe (Austria, Belgium, Denmark, France, Germany, Ireland, Luxembourg, the Netherlands, United Kingdom); North-eastern Europe (Czech Republic, Estonia, Finland, Latvia, Lithuania, Poland, Sweden, Slovakia); South-eastern Europe (Bulgaria, Hungary, Romania, Slovenia); Mediterranean (Cyprus, Italy, Greece, Malta, Portugal, Spain).

2.2 The Metronamica land use model

Metronamica (White and Engelen, 1993; Van Delden and Hurkens, 2011; RIKS, 2014) is a generic forecasting tool for planners and policy analysts to simulate and assess the integrated effects of policy measures on land use developments. The system interactively simulates the impact of a variety of external influences (e.g. macro-economic changes, population growth, etc.) and policy measures (e.g. land use zoning, conservation policies, densification policies, etc.) on the regional development of a city, region, country or continent. With the integrated scenario support what-if analyses can be performed that help evaluate alternative plans under various external conditions. At present there are Metronamica applications in more than 30 countries worldwide, both inside and outside the European Union (see for an overview of Metronamica and MOLAND applications www.metronamica.nl).

Metronamica is developed using the Geonamica software environment (Hurkens et al.,2008) and includes a model library containing a range of models from various disciplines: land use, regional interaction, transport, economics and demographics. Applications can be set up with one or more models and one, two or three spatial levels depending on their scope. Spatial resolution at local level varies for current applications between 25 m. and 1000 m. Temporal resolution is a year. Temporal horizon is 20 to 50 years into the future. For the ESPON-ET2050 project to model is set up with the local land use component and the indicator component, both operating at a 1 km grid.

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[2] More information about the clumpiness indicator can be found on: http://www.umass.edu/landeco/research/fragstats/documents/Metrics/Contagion%20-%20Interspersion%20Metrics/Metrics/C115%20-%20CLUMPY.htm.

[3] Originally we had planned to have UK and Ireland as a separate category as well as Scandinavia (Denmark, Finland and Sweden) and the Baltic States. Moreover we had planned to divide the Mediterranean in an Eastern and a Western category. However, because CLC90 data was not available for Cyprus, Finland, Malta, Sweden and the United Kingdom, and CLC06 not for Greece, the remaining countries in those groups were too limited to be used as a representation for the intended categories.

The modelled area is EU-27. The remainder of this document will focus on the specifics of the ESPON-ET2050 application.

The Local model

The land use model operates at local level and uses a grid of cells. A cellular automaton (CA) based land use model is used to determine the state of a cell within the overall growth for each of the regions calculated by the regional model (White and Engelen, 1993) or – in the case of ESPON-ET2050 – provided by the MASST, MULTIPOLES and SASI models. Changes in land use at the local level are driven by four important factors that determine the potential for each location for each actor (see also Figure 1):

- Physical suitability, represented by one map per land use function modelled. The term suitability is used here to describe the aptness of a cell to support a particular land use function and its associated activity.
- Zoning or spatial planning, represented by one map per land use function modelled. For different planning periods the map specifies which cells can and cannot be taken in by the particular land use and how strict or flexible the various plans are.
- Accessibility, represented by one map per land use function modelled. Accessibility is an expression of the ease with which an activity can fulfil its needs for transportation, mobility and other facilities in a particular cell, based on the proximity to infrastructure networks.
- Interaction rules, simulating the preferences of various actors for certain locations based on the land uses in the area surrounding the location, including their power to actually occupy the most desirable locations. For each land use function, a set of spatial interaction rules determines the degree to which it is attracted to, or repelled by, the other functions present in its surroundings.

If the potential is high enough, the function will occupy the location, if not, it will look for more attractive places. New activities and land uses invading a neighbourhood over time will thus change its attractiveness for activities already present and others searching for space. This process constitutes the highly non-linear character of this model.

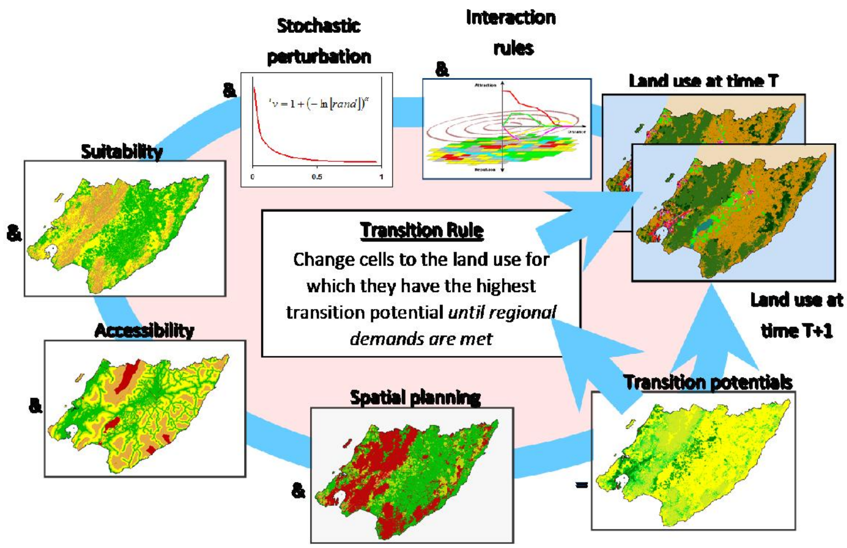


Figure 2-2 Main drivers of the Metronamica land use model

Indicators

Metronamica includes a range of socio-economic and environmental indicators which can be selected and configured based on a selection of algorithms. A set of generically applicable indicators is predefined using a categorisation of the land use classes (e.g. urban, natural, etc.) to set reasonable parameter values. These parameters can be fine-tuned to provide better results. Indicators can be added on demand by selecting one from a set of available algorithms, providing additional input data and adjusting model parameters. For the ET-2050 project the indicators Increase in urban surface (land take), Urban encroachment on agriculture and Agriculture in High Nature Value farmland have been selected.

2.3 Model adaptation, application and calibration

As part of ET2050 and the land use analysis carried out in this project, the Metronamica model has split Europe in several large regions (see also section 2.1 for an overview of these regions and the countries included) to allow for different (social) behaviour in those regions.

As mentioned in the introduction to this chapter and shown in Figure 2-1, two separate Metronamica applications have been set up. One operating at NUTS-2 level and using input from MASST, MULTIPOLES and MOSIAC and one operating at NUTS-3 level and using input from SASI. The NUTS-2 application runs until 2030 as the input from the other models is provided until this year. The NUTS-3 level application runs until 2050.

Input from MULTIPOLES, MASST and SASI at NUTS-2 and NUTS-3 level respectively are population and GDP figures. The Metronamica model converts these figures into demands for residential land and industrial & commercial land based on historic regional trends and – in case of the scenarios – assumptions for the future. Inputs for agricultural and forested areas are taken from the LUMOCAP model which has been developed in the FP6 LUMOCAP project and which includes the Metronamica land use model. For the ET-2050 project two runs with the LUMOCAP model have been carried out – a baseline run and an alternative scenario – and results for agricultural and forested land use demands are used as input into Metronamica (at NUTS-2 and NUTS-3 level).

Exogenous input at local level includes the Corine Land Cover map, base maps for suitability (agricultural limitation, aspect, elevation, maximum soil water capacity, rooting depth, slope, soil texture), base maps for zoning (Less Favoured Areas and Natura 2000) and transport networks and accessibility information provided by MOSAIC. Base maps for suitability and zoning have been taken from the LUMOCAP model for which they have been provided by JRC.

The starting year of the model is based on the Corine Land Cover data and hence 2006. CLC 1990 and 2000 maps are used for data analysis and calibration.

As part of the calibration of the model, parameter values are set and fine-tuned and subsequently the model is assessed on its behaviour and results, over the period 1990-2000. Difficulties in calibrating CA-based land use models mainly relate to the large number of parameters that need to be set, the limited availability of time series of land use maps, and finding objective ways to assess the quality of the calibration. For this reason we use a neutral model to act as a benchmark for quality assessment, together with objective measures to complement the more subjective visual assessment. To assess the quality of the calibration we take into account the predictive accuracy, which is the ability of the model to accurately simulate actual land use patterns; and the process accuracy, the extent to which the modelled processes are consistent with real world processes. Indicators used for assessing the quality of the calibration are indicators for location agreement (Fuzzy Kappa and Kappa Simulation), indicators for landscape structure agreement, (clumpiness index and rank size distribution), the enrichment factor (also used for land use analysis) and visual inspection.

During the validation, the model's behaviour and results, based on the parameters settings obtained during the calibration, are assessed over a data set independent from the one used as part of the calibration, in our particular case 2000-2006. Assessment criteria are the same as for the calibration.

Once the calibration parameters were set in such a way that the model outperformed the benchmark for all indicators mentioned above, it was tested and evaluated on its long-term behaviour, which includes a long-term simulation with the calibration parameters, a number of tests with extreme scenarios to assess the robustness of the model and a number of tests to assess the sensitivity of model results on small changes to the parameter settings.

3. Present state and trends

The *land use change analysis* shows that there was an increase in residential and industrial & commercial locations in the period 1990-2006 in all 5 groups of countries. On the other hand, there was a large decrease in agricultural areas in the same period. The only exceptions are the Baltic States, where we observe a large increase. This increase comes at the cost of forested areas, which indicates that forests are being cleared for agriculture. In this region we also see an emergence of natural vegetation which could be the result of forest harvesting.

Some new forest appears during the 2000-2006 period in North-eastern Europe and South-eastern Europe, while there is a small decline in the Mediterranean and Western Europe. But more than that, we see a large relocation of forests in these countries. For example, the Mediterranean had a net loss of only 28 km² of forest between 1990 and 2000. But in the same period, there was 8865 km² of forest reallocated. Since changes of a similar extend are visible for natural vegetation, it could very well be that these changes are due to classification errors, since there is a thin line between forest and natural vegetation. Finally, we see an increase of tourism & recreation over the period 1990-2006 in most countries, with Western Europe and the Mediterranean the countries where we observe the largest growth.

From the analysis we find an increase of all urban land uses (residential, industry & commerce and tourism & recreation) in all groups of countries, but we see large differences between the groups of countries. Western Europe –and even more so the Mediterranean– show the largest relative increase (see also Figure 3-1). Agriculture shows exactly opposite changes. It experiences the largest decreases, both relatively and absolutely, in Western Europe followed by the Mediterranean. It is very likely that this will partly be the result of urban expansion.

The *cluster analysis* shows that there are strong regional differences between the groups of countries in which we divided Europe. There were relatively many small cities in South-eastern Europe compared with other group of countries, and there were many big cities in Western Europe and Mediterranean in compared with other group of countries.

Regarding the trend over time, we observed that in Western Europe cluster size distribution remained largely unchanged between 1990 and 2006. That can be explained because Western Europe is already very urbanized in 1990. In the Mediterranean, the difference in urban clusters is largest over time: cities tend to increase into larger urban areas.

In general, all groups of countries show an increase in urban fabric over the analysis period, but in South-eastern Europe the number of small cities increases and in the Mediterranean this is true for the metropolitan areas.

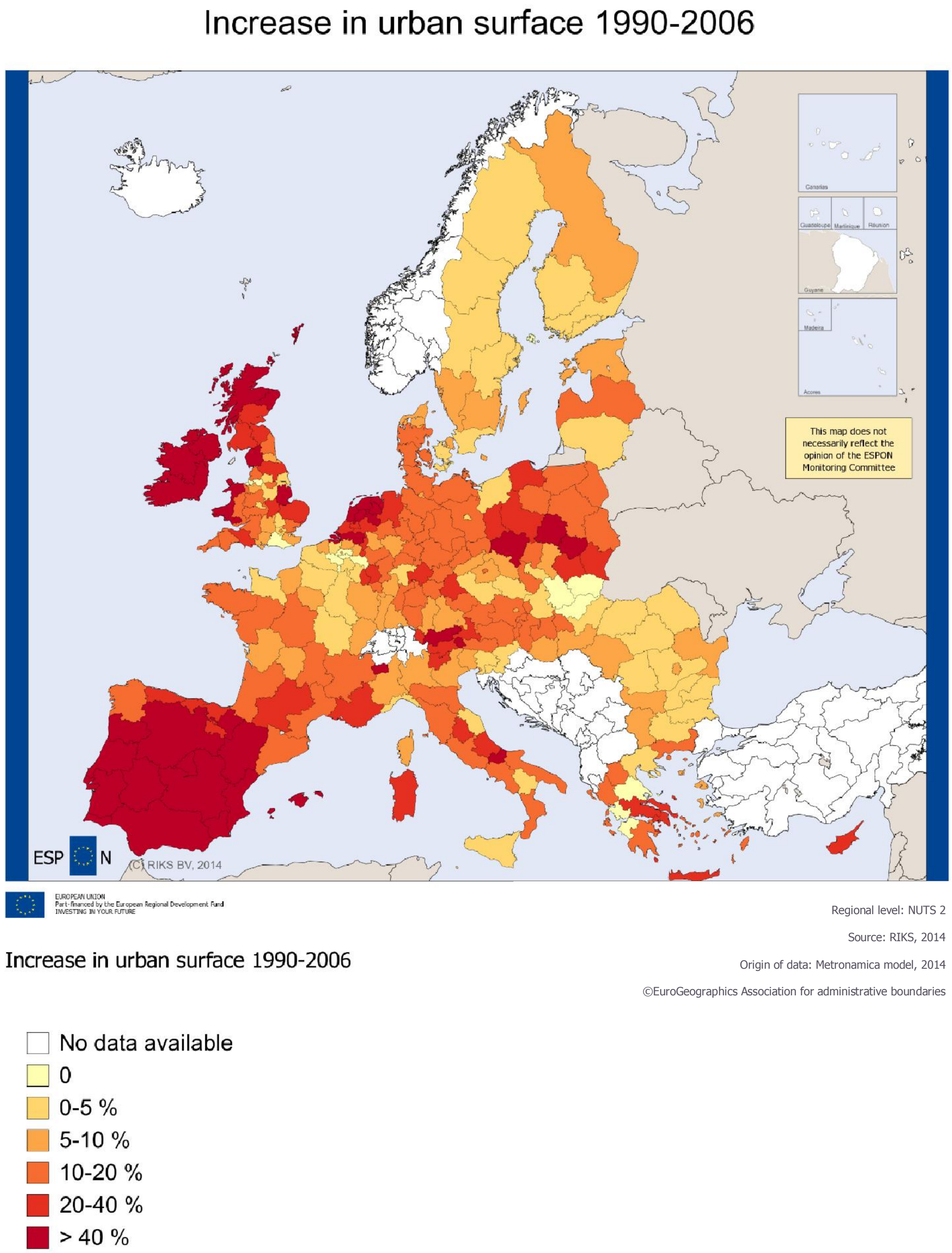


Figure 3-1 Increase in urban surface 1990-2006, based on Corine Land Cover data.

From the *neighbourhood analysis* we see that in general, new residential land uses have replaced industry & commerce, recreation and agriculture in all groups of countries. The latter is the strongest in the Mediterranean and Western Europe and indicates urban expansion at the cost of agriculture. From the graphs (see e.g. Figure 3-2) we see no attraction of new residential areas (2006) to allocate on areas occupied by natural vegetation or forest in 1990.

The observed values for industry & commerce and tourism & recreation could be the result of classification differences, since both are urban fabric. Minor changes can cause the classification to change from the one in the other. Very often urban land uses are difficult to distinguish and it happens that in one year a location is classified as residential and in the next as tourism & recreation. To make hard statements on the allocation of residential areas in 2006 on locations previously occupied by industry & commerce and recreation we would have to carry out more research. From experience we know that in some countries (especially in Western Europe) industry is relocated away from city centres and the space that becomes available is taken in by other urban classes (very often residential). But, as said, this knowledge is not sufficient to make overall statements on the observed conversion.

We should also take into account in this analysis the fact that recreation covers a very small share of surface of the whole region. Therefore very few cells of that land use can cause a relatively strong effect in the overall figures.

The graphs indicate that recreation, industry & commerce and residential areas have a higher than average attraction on new residential land use to allocate in their surroundings. This effect becomes clear because of the positive value for the urban land uses at x=1 to x=8. Forest and natural vegetation seem to provide an attraction less than average and agriculture around the average. From this we can conclude that people prefer to build new residential locations close to existing urban land clusters. Forest and natural areas do not seem to have a special attraction and this can be because of a lack of infrastructure, accessibility and services, or because of zoning regulations that prohibit new residential development in certain locations and stimulate them in other locations.

The results include the attraction of inland water bodies and marine water bodies. They show various attractions per group of countries. In South-eastern Europe and Western Europe, inland water bodies were attractive for new residential land in 2006. In all groups of countries marine water bodies were attractive for new residential land in 2006, but this is by far the strongest in Western Europe (see also Figure 3-5).

New industrial and commercial land uses can mainly be found next to other urban land uses and in particular orther industrial and commercial land uses. An example for Western Europe is shown in Figure 3-3 which also shows an attraction to inland waters, similar to South-eastern Europe. In the Mediterranean and North-eastern Europe, there is a strong attaction to the coast, which can to a lesser extent be observed in other regions as well.

New agricultural areas from different types are mainly found on agricultural areas of other types. New agricultural areas can also be found close to existing agricultural areas.

New forest land can mainly be found on natural vegetation and in the surroundings of other forest or natural vegetation (see Figure 3-4). This behaviour we find throughout all groups of countries. In the Mediterranean and South-eastern Europe forested areas are also found near pastures.

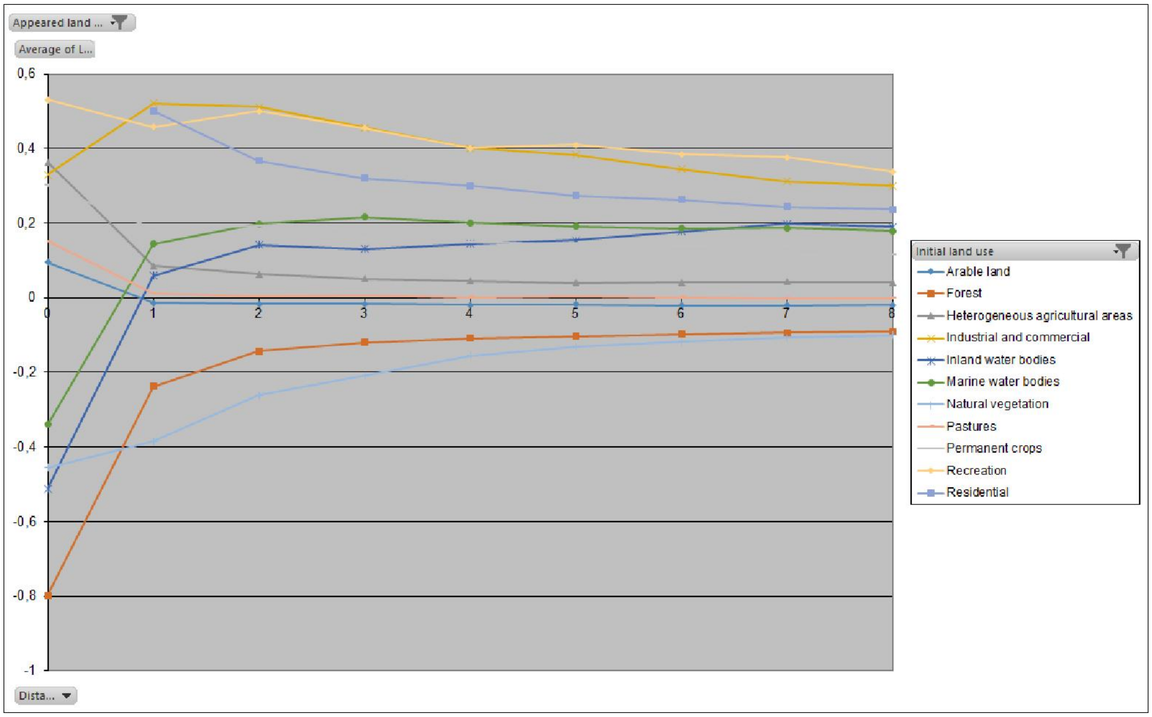


Figure 3-2 Under- and overrepresentation of land uses in the neighbourhood of new residential locations in Western Europe. On the y-axis the over- and underrepresentation is shown and on the x-axis the distance in km. Data analysis based on Corine Land Cover.

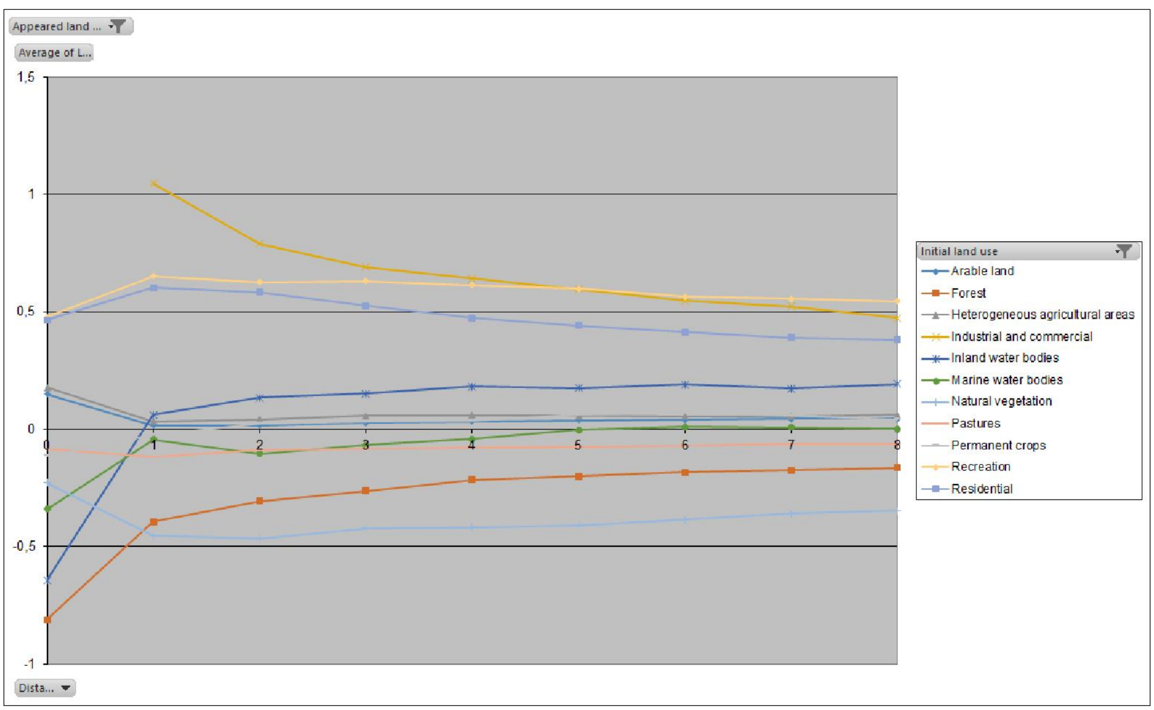


Figure 3-3 Under- and overrepresentation of land uses in the neighbourhood of new industrial locations in Western Europe. On the y-axis the over- and underrepresentation is shown and on the x-axis the distance in km. Data analysis based on Corine Land Cover.

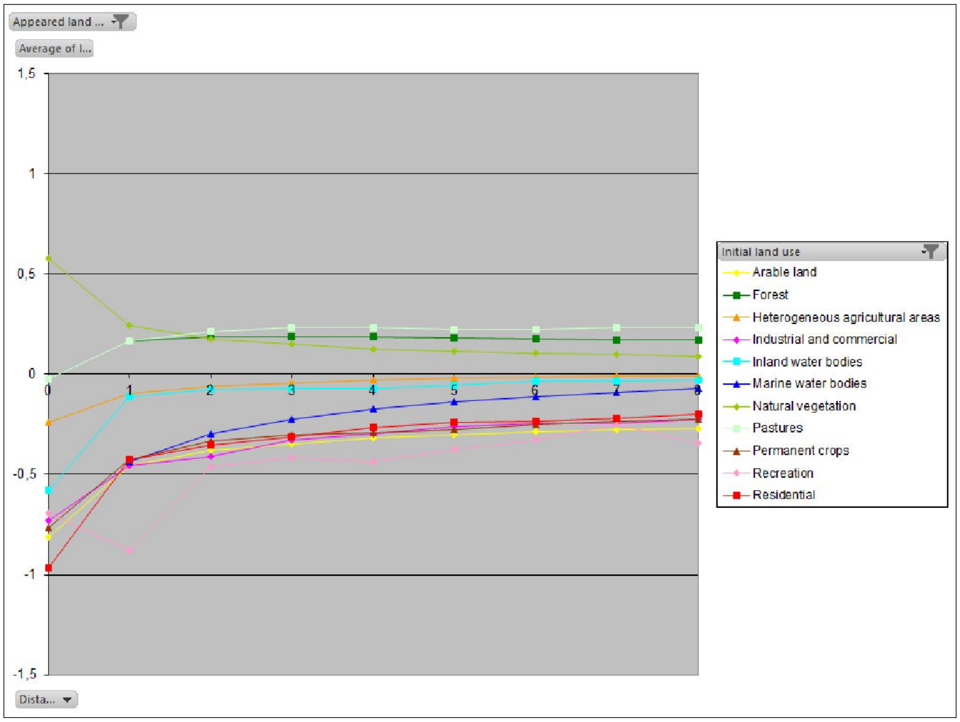


Figure 3-4 Under- and overrepresentation of land uses in the neighbourhood of new forest locations in Mediterranean Europe. On the y-axis the over- and underrepresentation is shown and on the x-axis the distance in km. Data analysis based on Corine Land Cover.

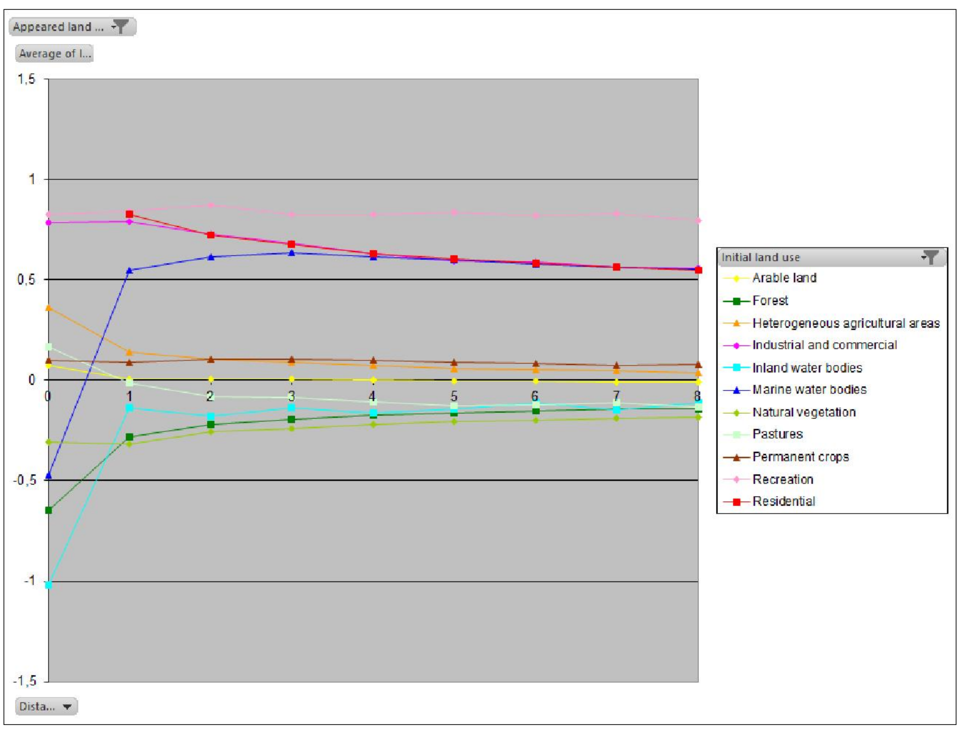


Figure 3-5 Under- and overrepresentation of land uses in the neighbourhood of new residential locations in Mediterranean Europe. On the y-axis the over- and underrepresentation is shown and on the x-axis the distance in km. Data analysis 050 Baseline scenario modelled by Metronamica

4. ET2050 Baseline scenario modelled by Metronamica

The Metronamica application as used in the ESPON ET2050 project builds on the application developed in the LUMOCAP project (Van Delden et al, 2011) and subsequently used and adapted in projects for EC-JRC, DG Environment and the EEA. For the baseline scenario it makes use of the data and calibration parameters of these projects and updates have been made where possible and relevant. The main update to the model has been to use 2006 as the starting year for the simulation.

4.1 Land use demands

For the baseline scenario general land use behaviour is assumed to be similar to that of the historic period 1990-2006. Demographic and economic developments from the respective models (MASST, MULTIPOLES and SASI) are used to provide input into the model and are used to calculate the demands for residential (MULTIPOLES and SASI) and industrial and commercial areas (MASST and SASI), with MASST and MULTIPOLES providing input until 2030 and SASI until 2050. Conversion of population and GDP to land use demands is based on historic and ongoing density developments. Although there is an overall trend for people to use more (residential) space per head (larger houses, less people per family), when looking at individual NUTS regions this assumption cannot be followed. As we could not observe an overall density trend throughout Europe, density trends have been calculated for each individual NUTS-2 and NUTS-3 region. Even though we expected to find a densification trend for industrial and commercial areas (more GDP and or employment per surface area), we did not observe this throughout all NUTS regions. For this reason we have used a similar approach to that of the residential areas and have calculated density and density trends per NUTS region. The above-mentioned trend for increasing urban areas between 1990 and 2006 is also in line with recent developments as observed by the EEA (SOER, 2010). Also for the baseline simulation we do observe this trend for the coming years as can be seen by Figures 4-1 and 4-2 and in Table 5.2 in the next chapter. Total **urban land take** is expected to be between **900-1200 km2 per year** during the period 2010 and 2030. Afterwards it is assumed to reduce to about **150 km2 per year** during the period 2030 and 2050, mainly due to population decreases.

Agriculture is the land use expected to show the largest decline in surface area in the European territory. Although some agricultural areas will be taken over by urban development, the strongest declines are expected on marginal lands. Conversion from agriculture to all other land uses is expected throughout Europe, with large changes from low productive lands to natural vegetation. Demand for agricultural land is calculated with the LUMOCAP system which includes an econometric model for assessing the impacts of the Common Agricultural Policy on Europe's agriculture. Baseline results of this model show a decrease in Utilized Agricultural Area (UAA) of 3,3% in EU-15, 17,5% in NMS-10 and 15,5% in NMS2 over the period 2000-2030. A comparative scenario study carried out as part of the State of the Environment Report 2010 shows that this is in line with other agricultural land use studies (e.g. SCENAR, Land Use Modelling Implementation and EURURALIS).

Forested areas are expected to slightly increase in the first years of the baseline scenario based. The expansion in the earlier years will mainly take place by the growth of existing forests. During these years competition for productive land and land at good locations is expected to increase, due to a further urbanization, an increasing demand for meat and dairy products and the need to maintain a sufficient agricultural production, together with an increasing demand for bio-energy crops, all while meeting ambitious environmental goals, such as the GAEC standards for permanent pastures, the nitrate and water framework directive and the biodiversity action plan BAP). This increasing demand for land is likely to slow-down the expansion of the forests that Europe experienced over the past decades and by 2030 the forested area is expected to be similar to that at present, or slightly less in the high pressure regions. Demand for forested areas is also taken from the LUMOCAP system.

4.2 Land use allocation

The Metronamica model takes as input the demands for land and subsequently tries to allocate this to the local grid cells (1x1 km). If there is sufficient space of good quality (physical characteristics, accessibility) and there are no policy restrictions to occupy this land, than the demands will be allocated. In case there is insufficient space of good quality or there are spatial plans that limit the development, a local competition for space will determine which demands will be fulfilled.

As discussed in the previous chapter baseline parameters have been set based on a calibration using Corine land use maps. The following characteristics have been incorporated: a continuation of the urbanization process and the development towards larger urban centres. The exception to this is Western Europe, where the distribution remains largely constant. New residential land use will mostly be allocated on areas that were agricultural land before. Moreover, urban land use classes show a stronger dependency with other urban land uses in their allocation then agriculture, forest and natural vegetation. In South-eastern Europe and Western Europe, inland water bodies will remain attractive for new residential development; in Mediterranean and Western Europe, marine water bodies will remain attractive for the allocation of new residential land uses.

The local allocation shows if there is enough space in a region to allocate demands and what land uses are being replaced when new land uses are allocated. A particular interest is to see to what extent new urban land is taking over agricultural land uses. Figures 4-3 and 4-4 show the urban encroachment of the agricultural areas, meaning that they show how much agricultural area available in 2010 is taken over by urban land uses in 2030 and 2050. What can be observed is that especially the stronger agricultural countries and regions (Eastern countries, but also France and Spain) have the risk of land take taking place on agricultural areas. Looking at this issue in more detail we see that most of the agricultural areas at risk are located near existing urban developments, so with (uncontrolled) urban sprawl these are occupied with residential, industrial and commercial areas.

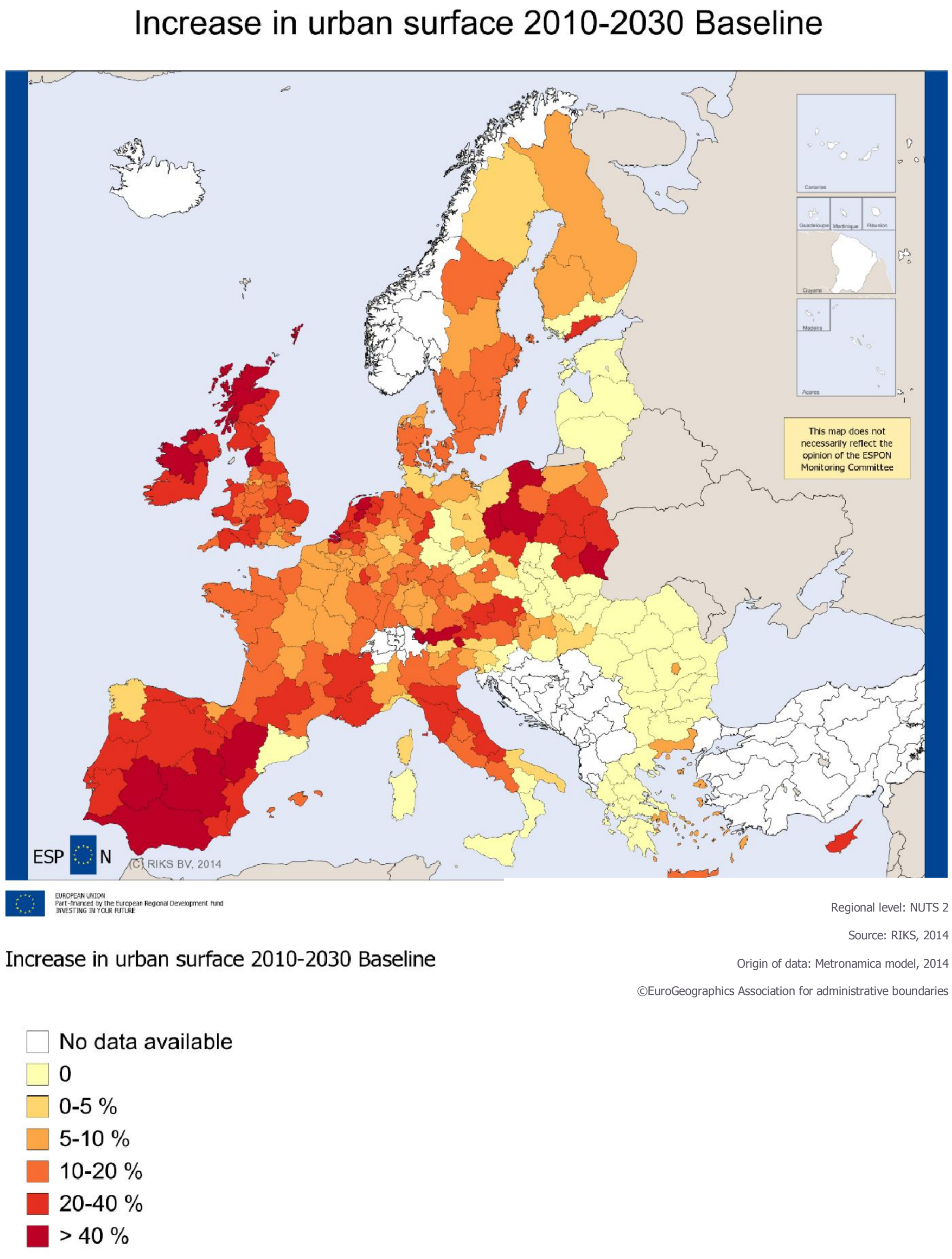
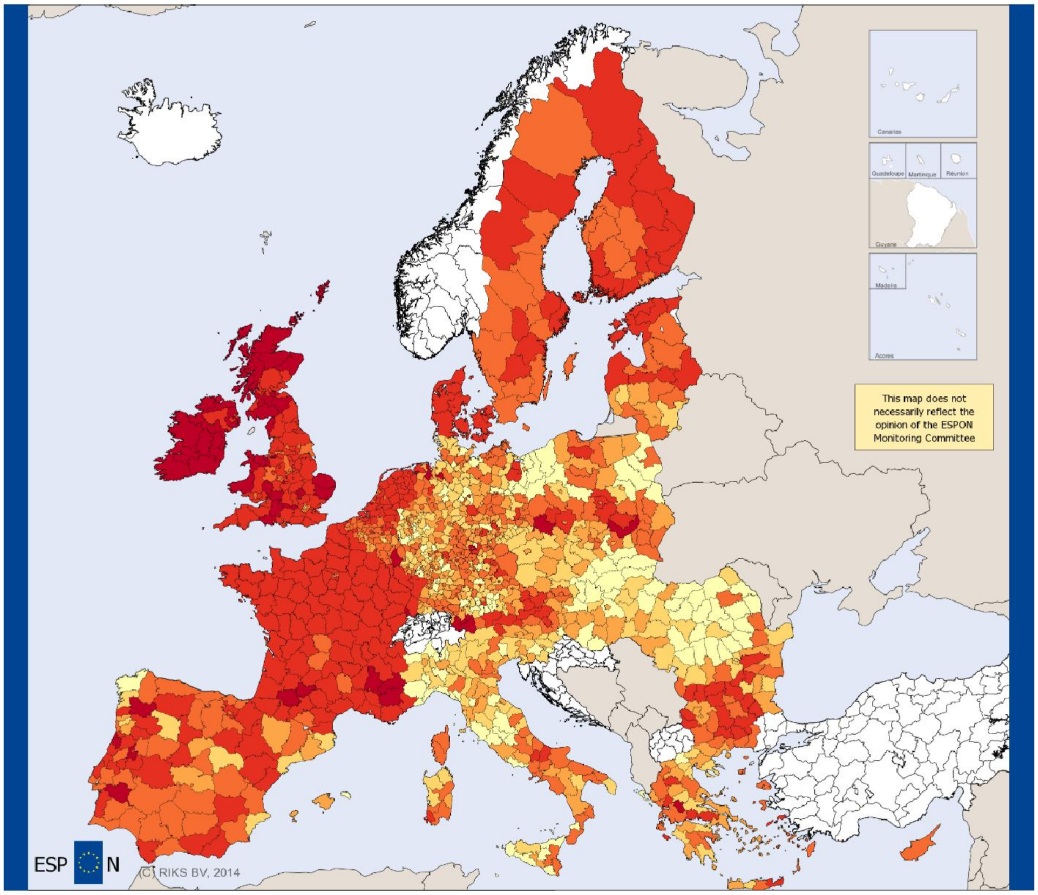


Figure 4-1 Increase in urban surface 2010-2030 as calculated by the Metronamica model and based on socio-economic forecasts by MASST and MULTIPOLES.

Increase in urban surface 2010-2050 Baseline



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Regional level: NUTS 3

Source: RIKS, 2014

Origin of data: Metronamica model, 2014

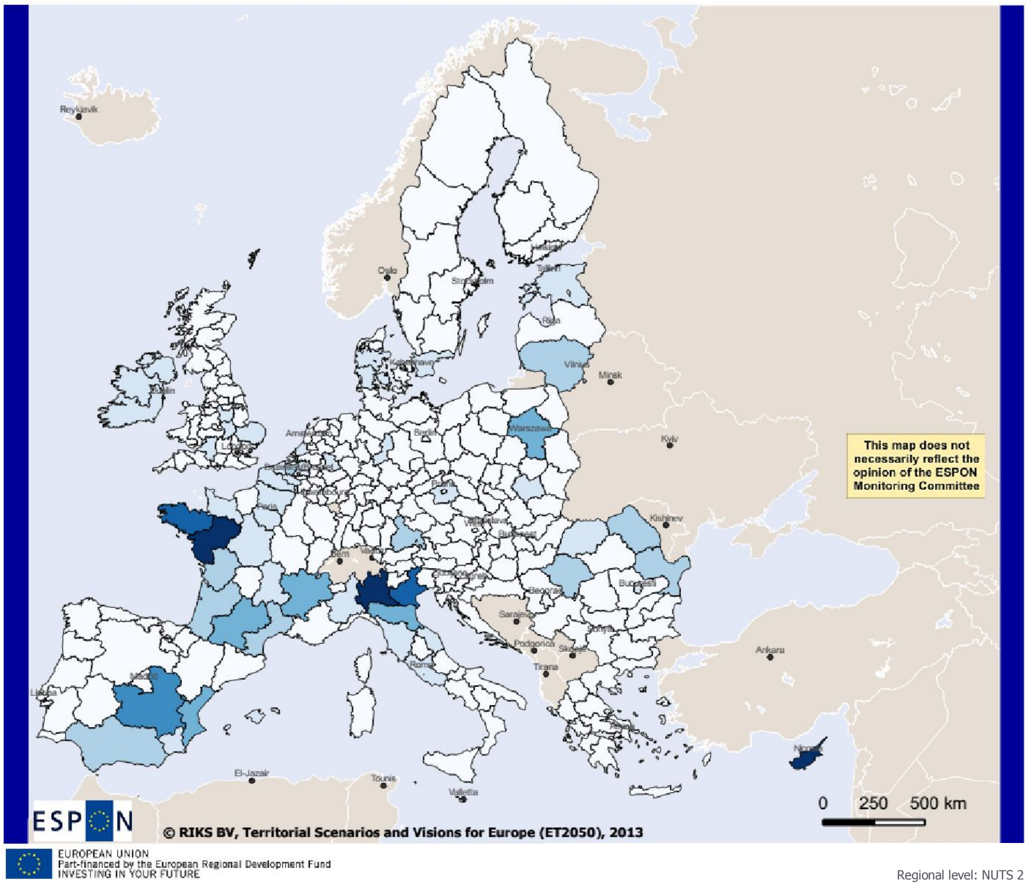
©EuroGeographics Association for administrative boundaries

Increase in urban surface 2010-2050 Baseline

- No data available
- 0
- 0-5 %
- 5-10 %
- 10-20 %
- 20-40 %
- > 40 %

Figure 4-2 Increase in urban surface 2010-2050 as calculated by the Metronamica model and based on socio-economic forecasts by SASI.

Urban encroachment on agriculture
Baseline scenario 2030



Regional level: NUTS 2

Source: RIKS, 2014

Origin of data: Metronamica model, 2014

©EuroGeographics Association for administrative boundaries

Urban encroachment on agriculture (km2)
Baseline scenario 2030

- 0 - 100
- 100 - 200
- 200 - 300
- 300 - 400
- 400 - 500
- 500 - 600
- > 600

Figure 4-3 Urban encroachment on agriculture as calculated by the Metronamica model and based on socio-economic forecasts by MASST and MULTIPOLES. Baseline scenario 2030, showing the land take on agricultural areas that has taken place in the 2010-2030 period.

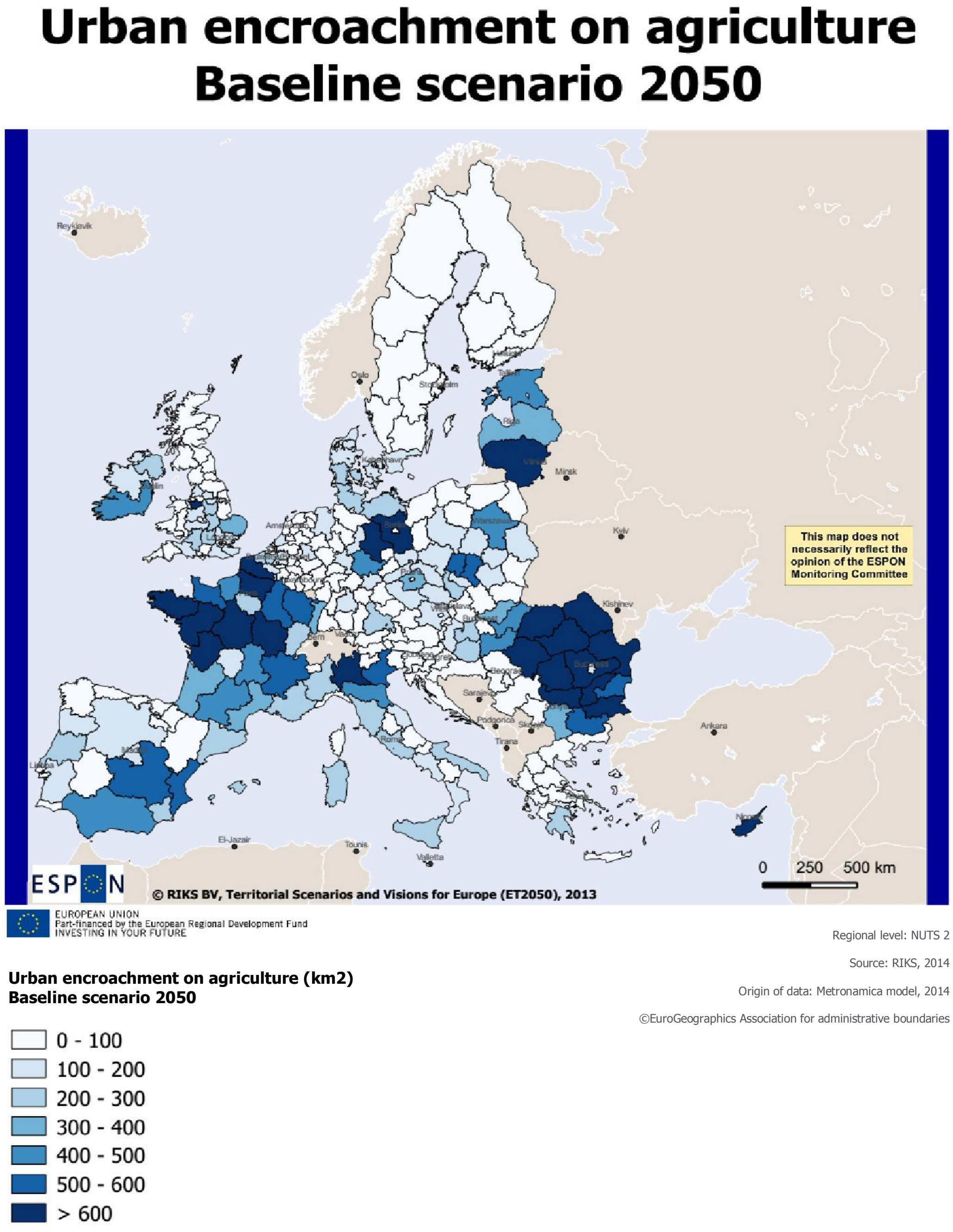


Figure 4-4 Urban encroachment on agriculture as calculated by the Metronamica model and based on socio-economic forecasts by SASI Baseline scenario 2050, showing the land take on agricultural areas that has taken place in the 2010-2050 period.

5. ET2050 Explorative scenarios modelled by Metronamica

5.1 Scenario assumptions

For the exploratory scenarios a set of assumptions have been made which are provided in the table below. Input for the exploratory scenarios are the results (population and GDP figures) from the MASST and MULTIPOLES models for the modelling until 2030 and from SASI until 2050. Accessibility information per NUTS-3 regions come from the MOSAIC model, and is complemented with local accessibility based on the infrastructure networks (also from the MOSAIC model). Input for agricultural areas is taken from the LUMOCAP model and figures for this are provided below in table 5-1.

	Baseline	**Scenario A: MEGAs**	**Scenario B: Cities**	**Scenario C: Regions**
Focus	Business-as-usual	Global and economic oriented	National and more social oriented	Local and more ecological
Densification	Ongoing developments based on CLC and Eurostat data	Development in larger urban zones. High-rise centres with sprawled sub-urbs. Density in MEGA regions less than baseline, in other regions as in baseline	Compact development around large and middle size cities. Extension and infill of brownfields. Density in regions with secondary cities higher than in baseline	Diffused development based on pre-existing rural centres. Density in rural regions lower than in baseline, in other regions as in baseline
Accessibility	Based on calibration	Focus on main transport networks	Focus on main transport networks	Also focus on more local transport
Natura 2000	Limited developments in Natura sites allowed	Same as in baseline	Stricter protection of Natura sites than in baseline	No developments in Natura sites allowed
Open spaces	No protection of open spaces (outside of Natura 2000)	No protection of open spaces (outside of Natura 2000)	Protection of open spaces also outside Natura 2000 areas	No developments open spaces allowed.
CAP	Baseline scenario as calculated by the LUMOCAP model.	Liberalisation scenario as calculated by the LUMOCAP model, decreasing CAP subsidies by 50%	Liberalisation scenario as calculated by the LUMOCAP model, decreasing CAP subsidies by 50%	Baseline scenario as calculated by the LUMOCAP model, but with extra focus on Less Favoured Areas (LFAs).
Landscape structure	Based on historic developments	More clustered urban development, especially around important transport nodes	More clustered urban development	Promotion of mixed land uses in small and medium size towns

Table 5-1 Scenario assumptions.

5.2 Scenario results

Model results of the three different scenarios can be found on the following pages. Figures 5-1, 5-2 and 5-3 show the increase in urban surface over the period 2010-2030 based on socio-economic input from MASST and MULTIPOLES (M/M), while Figures 5-1, 5-2 and 5-3 show the figures based on socio-economic input from SASI. The table below summarizes the total land take in various scenarios.

Annual land take (km2)	Residential areas	Areas for industry and commercial activities	Total urban land
1990-2006	906	302	1208
1990-2000	700	274	973
2000-2006	1249	349	1598
Baseline 2010-2030 (M/M)	605	293	898
Scenario A 2010-2030 (M/M)	628	251	879
Scenario B 2010-2030 (M/M)	445	283	728
Scenario C 2010-2030 (M/M)	796	284	1080
Baseline 2010-2030 (SASI)	755	408	1163
Scenario A 2010-2030 (SASI)	841	253	1093
Scenario B 2010-2030 (SASI)	673	261	934
Scenario C 2010-2030 (SASI)	1005	421	1426
Baseline 2030-2050 (SASI)	-208	362	154
Scenario A 2030-2050 (SASI)	-215	332	117
Scenario B 2030-2050 (SASI)	-207	335	128
Scenario C 2030-2050 (SASI)	-215	371	155

Table 5-2 Annual land take.

From the table we see that the general trend as already observed in the baseline is by far the strongest. In the coming decades high land take can be expected, but in future, mainly due to a decreasing population in quite a few NUTS regions throughout Europe land take is expected to be much less.

From the maps below we see that in all scenarios the increase in land take is very large in Western Europe, including Spain. All land take maps, but especially those based on the MASST/MULTIPOLES models show very little land take in the Eastern countries, which is due to the population decline in these countries, because residential development is a major driver of land take.

Both maps representing scenario A show a higher land take in the metropolitan cities around Europe, as can be expected in this scenario, due the higher expected socio-economic growth in the metropolitan regions and the type of land take assumed in this scenario (an American-Australian type of metropolitan development). Not all metropoles show an additional land take compared to the other scenarios. Especially some of the more Western and Spanish metropoles are not expected to have any additional land take compared to the other scenarios as they are currently already densifying. Furthermore, in some regions (especially NUTS-3) regions, but also in the London region in the NUTS-2 calculations, the area is already completely occupied with urban land uses, so there is simply no space to expand.

Differences in land take in scenarios A and B are minor in the way the land take is divided over Europe, although there is a bit more balance in scenario B. As can be seen from the table, land take in scenario B shows the lowest overall land take. Scenario C shows big differences in the way the land take is taking place throughout Europe. The runs based on SASI input (Figure 5-6) shows a much more balanced land take than the other scenarios, both due to socio-economic differences compared to the other scenarios, but also density differences, as in this scenario people tend to take up more space per person in the stimulated regions (the smaller regions). However, it should be noted that in this case it means that there is more land take in Eastern Europe compared to the other scenarios, not that land take takes place in the East instead of in the other regions of Europe. Scenario C has the highest land take overall. However, due to the stricter protection in this scenario, there is less urban encroachment on agricultural areas compared to the other two scenarios. Due to the more diffuse development in this scenario there is however more habitat fragmentation.

Looking at Figures 5-7, 5-8 and 5-9 we see that scenario C has the highest amount of agriculture in High Nature Value farmland areas. This is due to the strong protection on valuable landscapes in this scenario. This means that although land take is higher in scenario C, the impact on valuable landscapes is likely to the less.

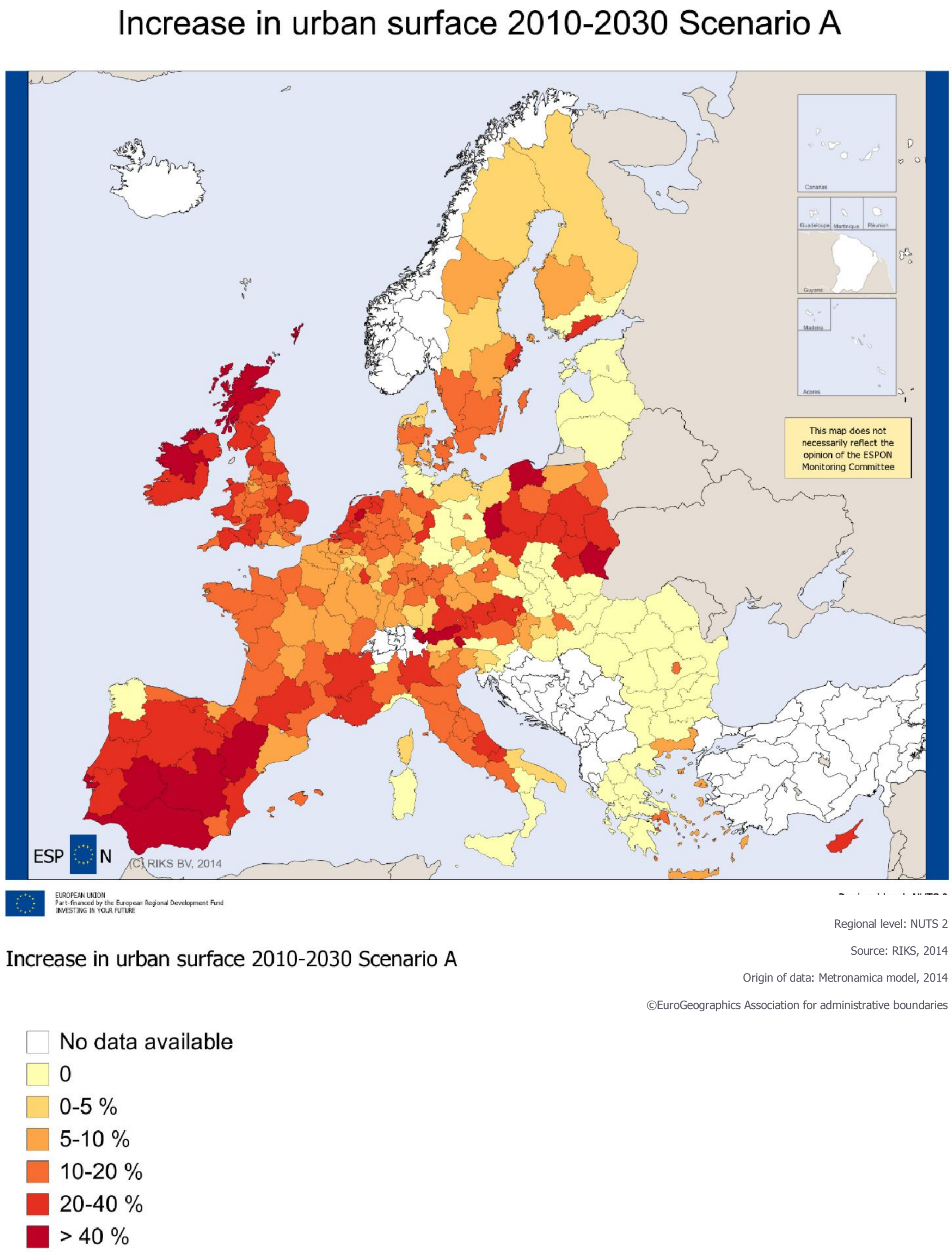
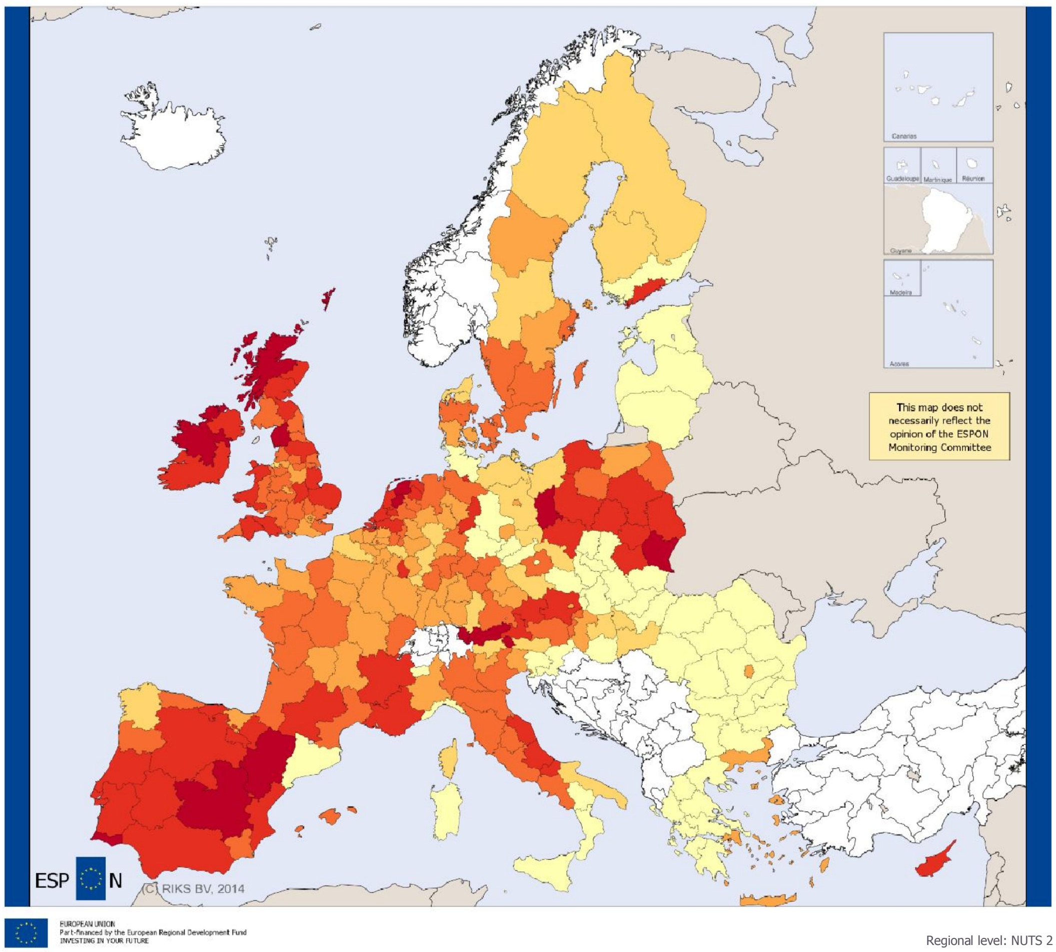


Figure 5-1 Increase in urban surface 2010-2030 Scenario A, as calculated by the Metronamica model, using input from MASST, MULTIPOLES and MOSAIC

Increase in urban surface 2010-2030 Scenario B



Regional level: NUTS 2

Increase in urban surface 2010-2030 Scenario B

Source: RIKS, 2014

Origin of data: Metronamica model, 2014

- No data available
- 0
- 0-5 %
- 5-10 %
- 10-20 %
- 20-40 %
- > 40 %

Figure 5-2 Increase in urban surface 2010-2030 Scenario B, as calculated by the Metronamica model, using input from MASST, MULTIPOLES and MOSAIC.

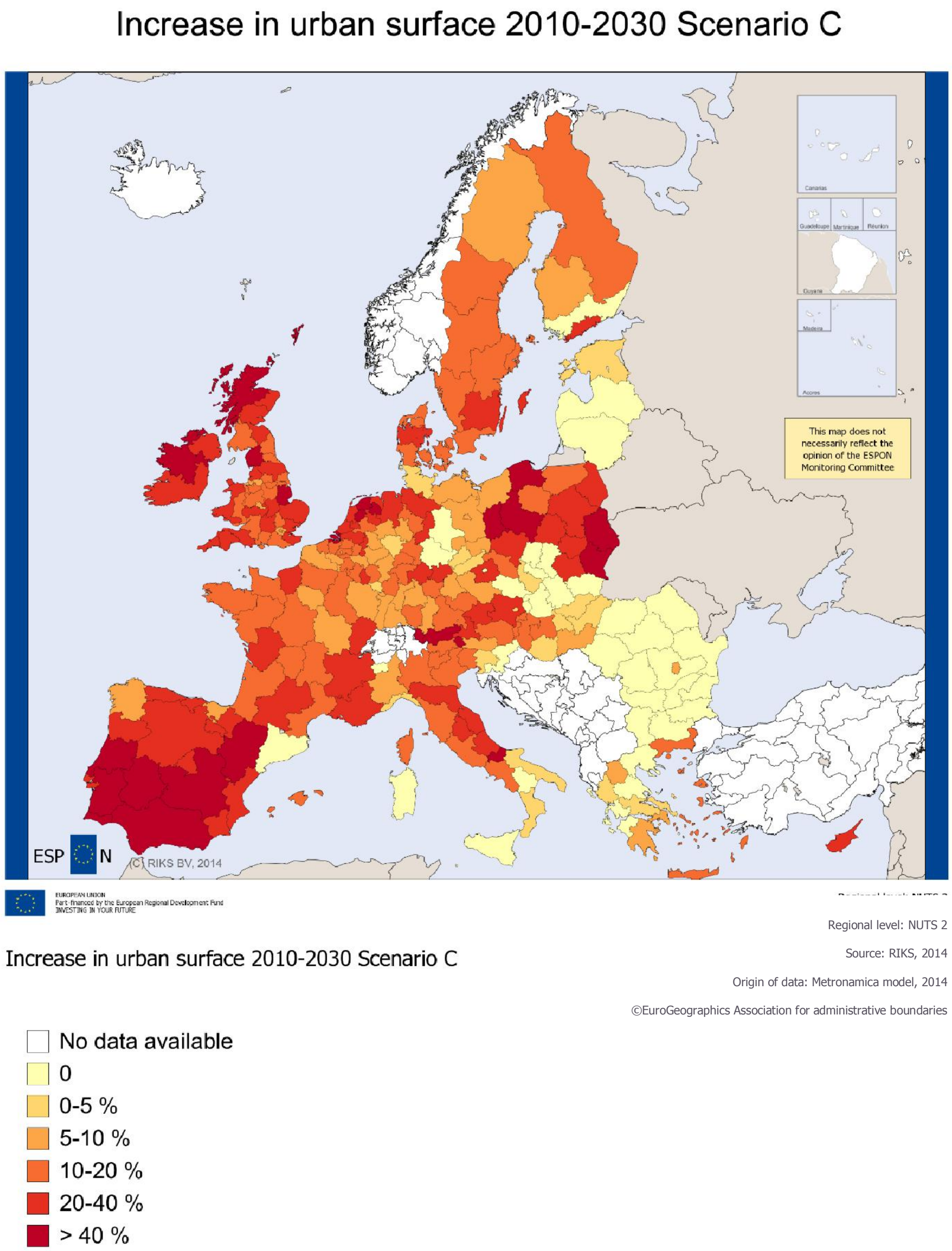


Figure 5-3 Increase in urban surface 2010-2030 Scenario C, as calculated by the Metronamica model, using input from MASST, MULTIPOLES and MOSAIC.

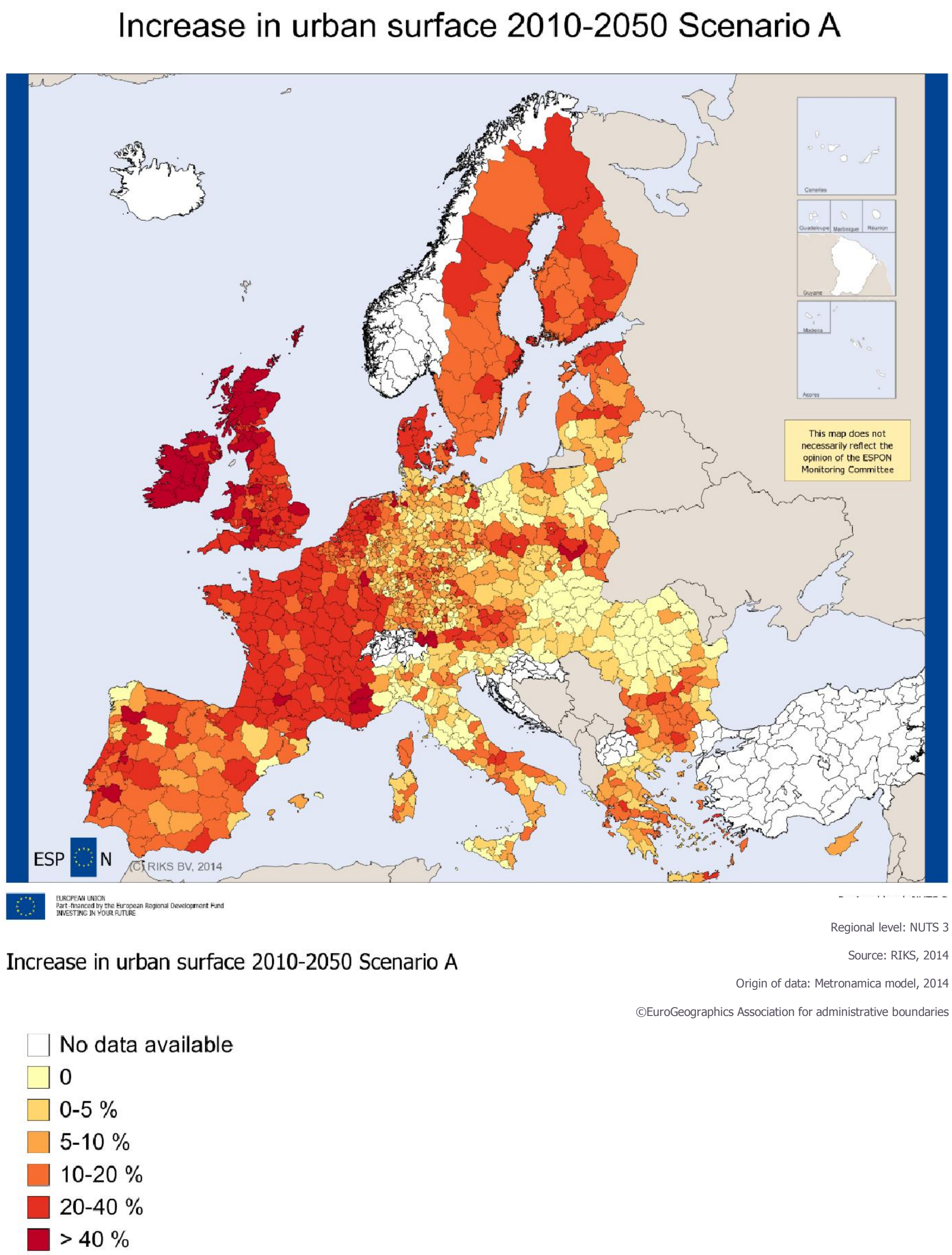


Figure 5-4 Increase in urban surface 2010-2050 Scenario A, as calculated by the Metronamica model, using input from SASI.

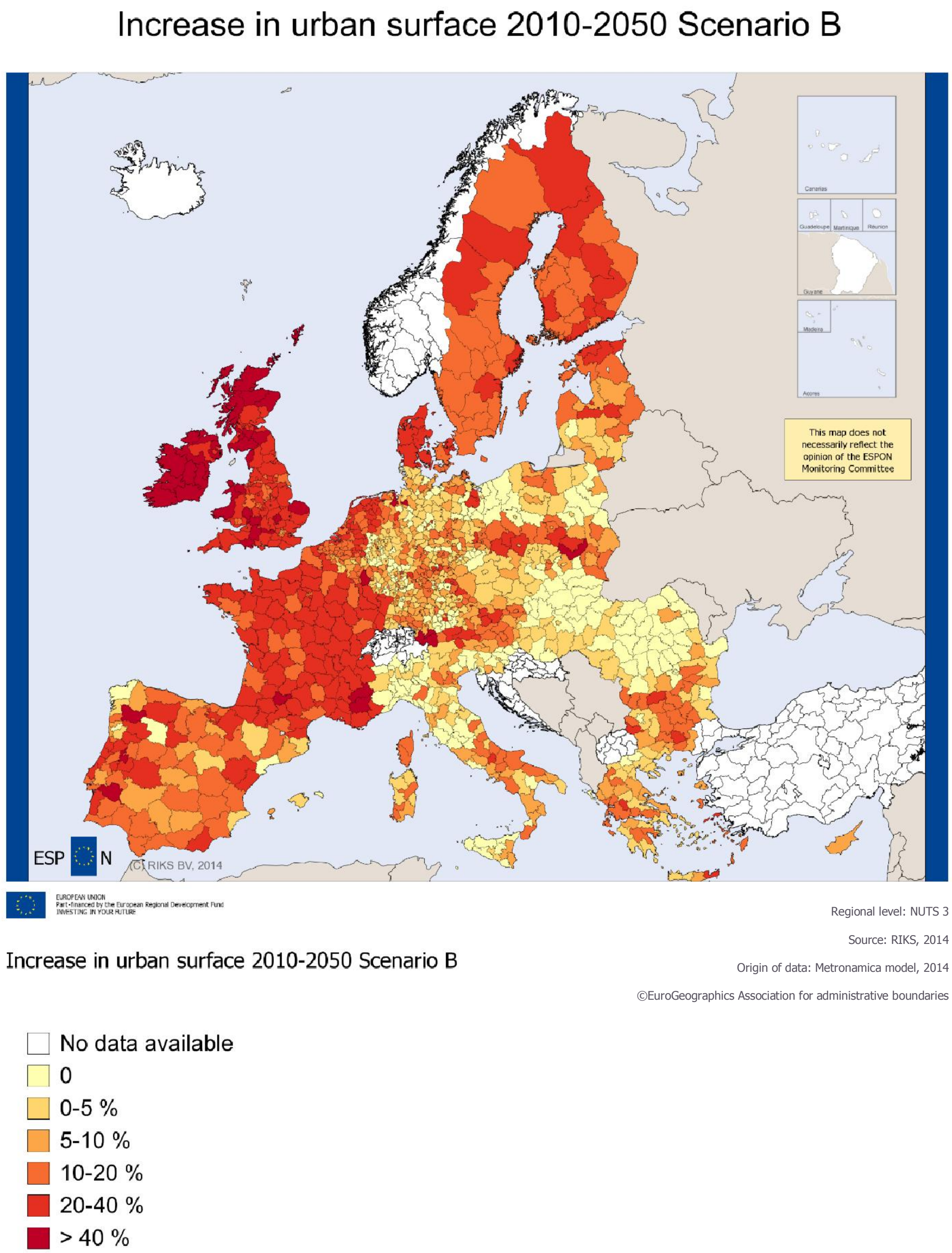


Figure 5-5 Increase in urban surface 2010-2050 Scenario B, as calculated by the Metronamica model, using input from SASI.

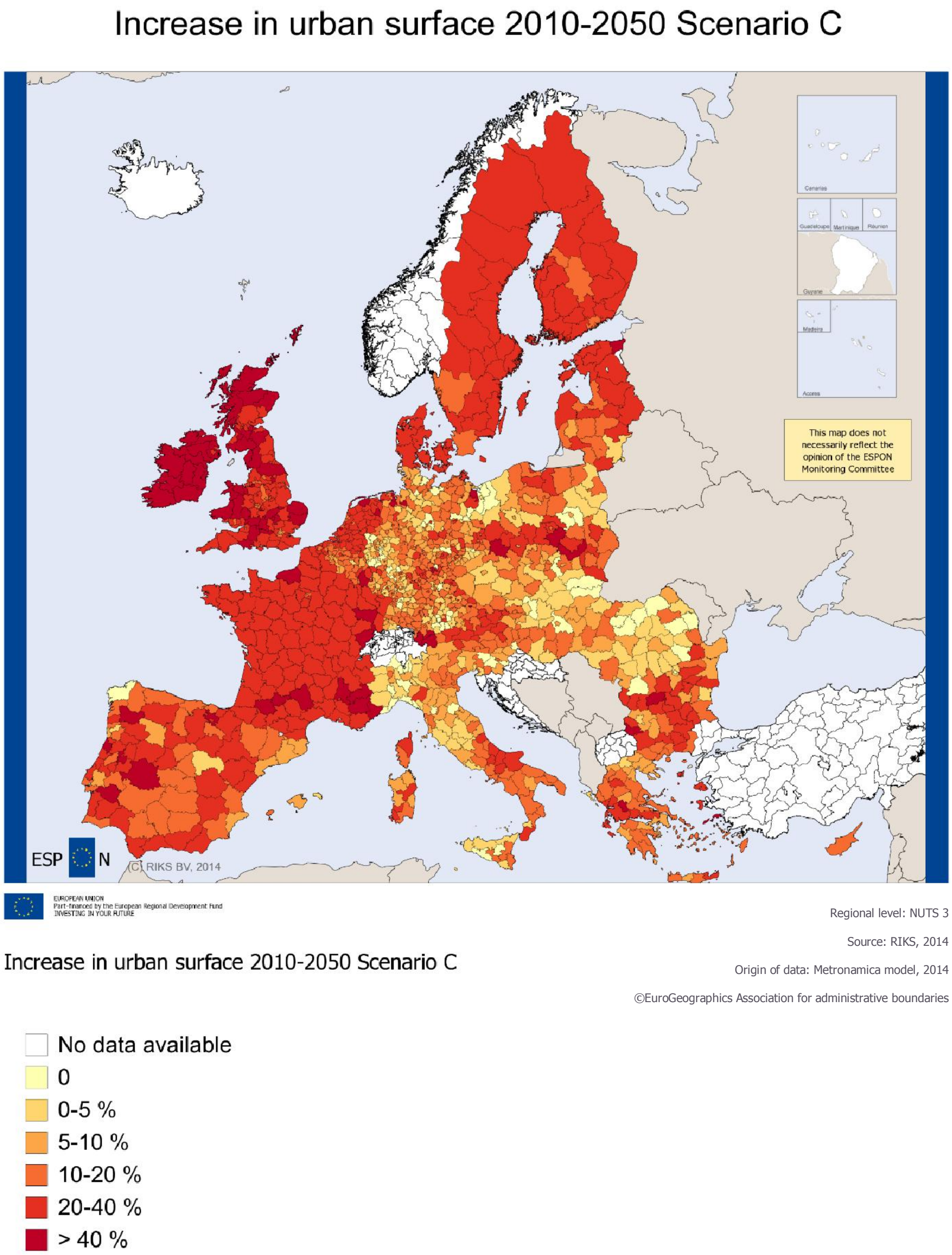


Figure 5-6 Increase in urban surface 2010-2050 Scenario C, as calculated by the Metronamica model, using input from SASI.

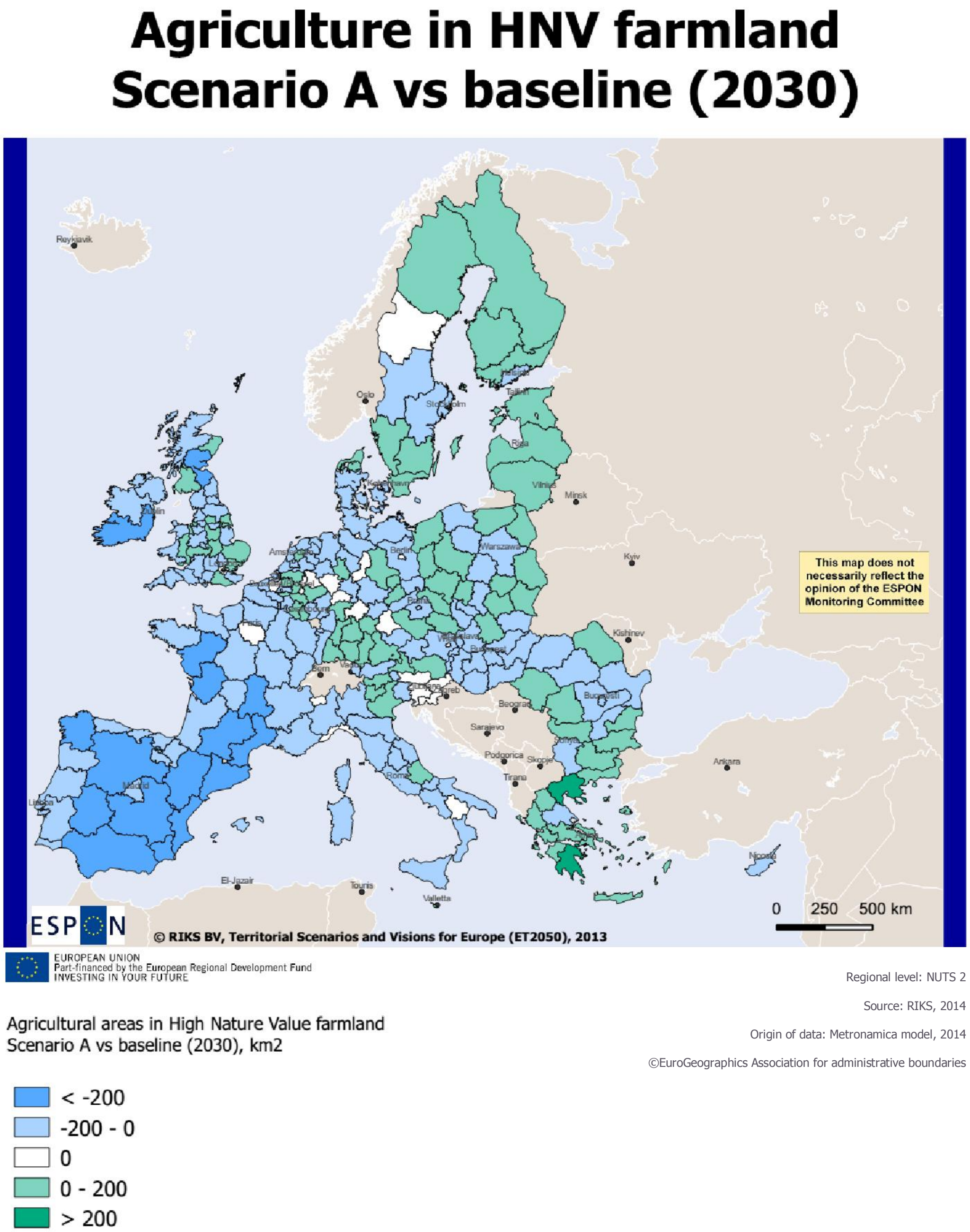


Figure 5-7 Agriculture in HNV farmland: Scenario A versus the baseline scenario in 2030, as calculated by the Metronamica model, using input from MASST, MULTIPOLES and MOSAIC.

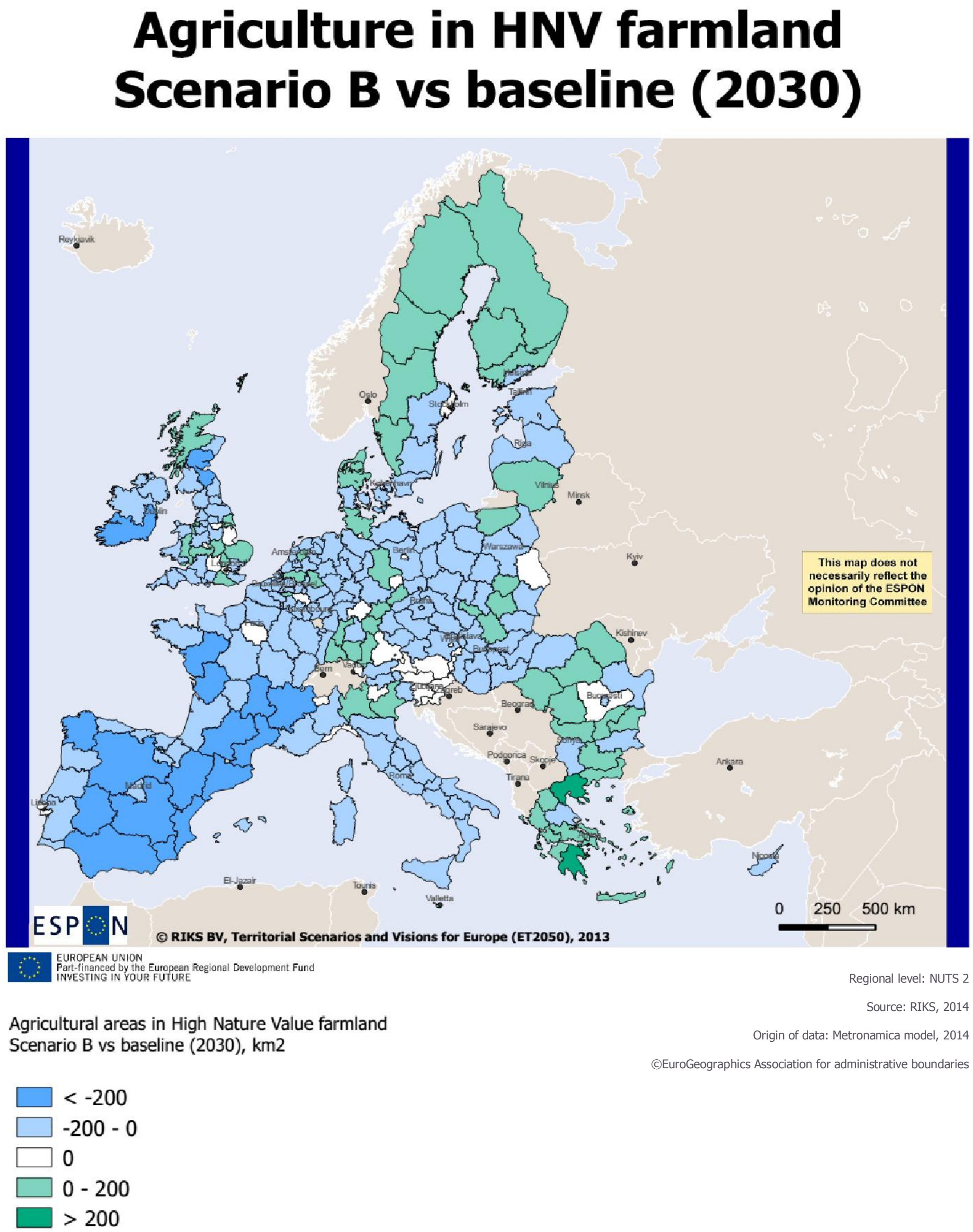


Figure 5-8 Agriculture in HNV farmland: Scenario B versus the baseline scenario in 2030, as calculated by the Metronamica model, using input from MASST, MULTIPOLES and MOSAIC.

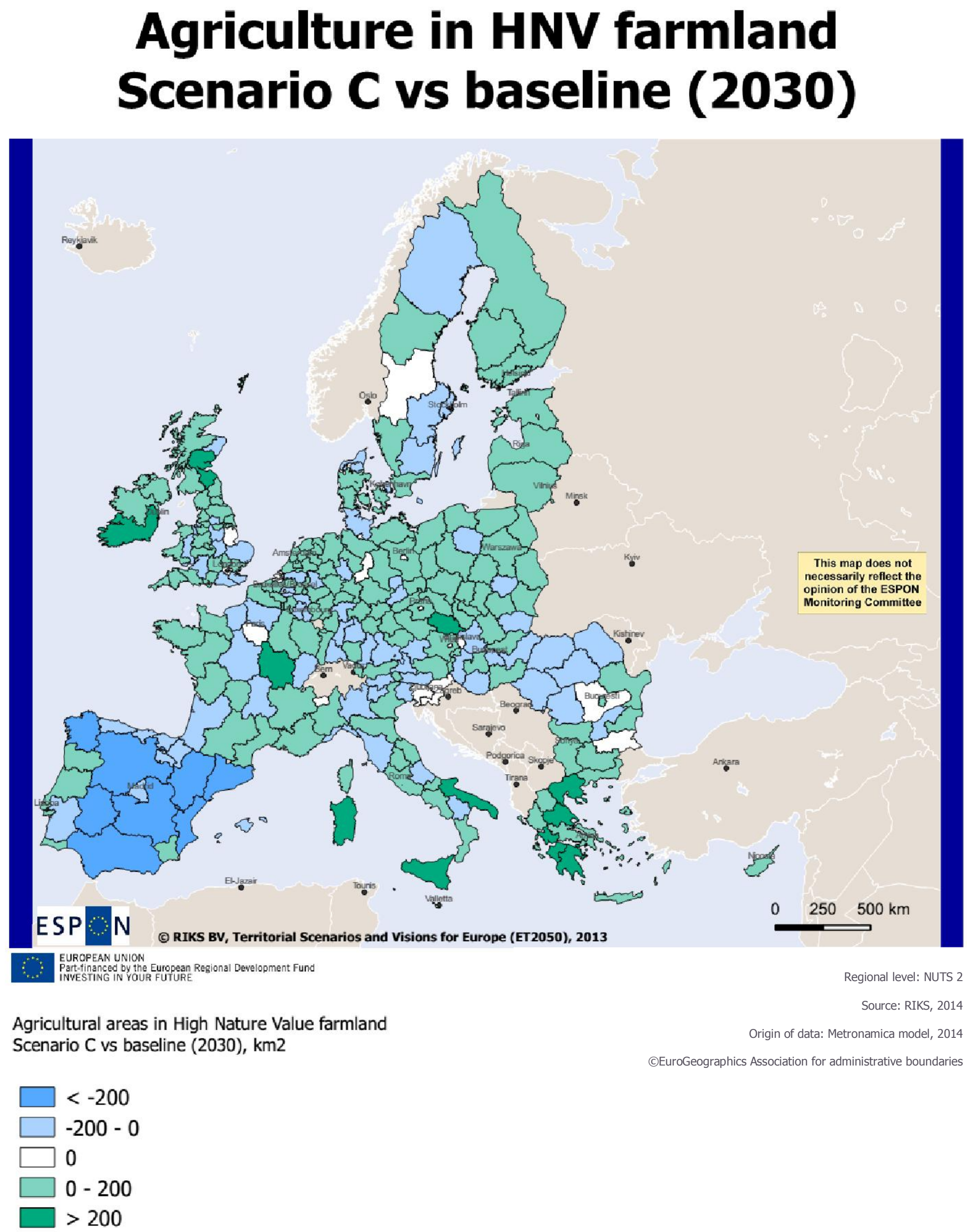


Figure 5-9 Agriculture in HNV farmland: Scenario A versus the baseline scenario in 2030, as calculated by the Metronamica model, using input from MASST, MULTIPOLES and MOSAIC.

6. Conclusion and input for the Territorial Vision

Main findings from the land use modelling that can be used as input into the vision are the following:

The urban surface is increasing rapidly often in the form of uncontrolled urban sprawl. Main drivers are people migrating from rural areas to cities and people using more (residential) space per capita (larger houses, less people per family). Although industrial and commercial land uses tend to become denser (higher GDP per surface area), this is not something that can be observed within each region and there are still big differences in density between the different regions. Also, the overall process is still one of increasing urban surface. The problem is not just the increase in sealed soil, but even more the uncontrolled element of it: where does development take place (on fertile soils, with the risk of losing these and the nature and the ecosystem services related to it?) and how does development take place. Compact development with well-planned surroundings and good accessibility, may enhance quality of life and minimize negative impacts of transport and soil sealing or uncontrolled development along the roads, within pristine natural areas (causing habitat fragmentation) or on highly productive agricultural soils.

Over the past decades there has been a large decline in agricultural areas, especially in pastures and perennial crops. This process is expected to continue for a few more years, with strongest declines expected on marginal lands. Conversion from agriculture to all other land uses is expected throughout Europe, with large changes from low productive lands to natural vegetation. This brings challenges regarding rural depopulation and good stewardship of the land, but can also be seen as an opportunity to restructure and strengthen the rural areas. Europe, its Member States and its regions are at a crossroad to decide how they want to continue with the agricultural areas. Should food security be a crucial aim or should more space be devoted to energy crops? Or does the decline in agriculture area offer possibilities to connect high value natural areas into a green infrastructure throughout Europe?

In scenario A, due to the attraction of the metropolitan areas, rural areas are not too much impacted by the expected land take. The development of high-rise buildings will compensate some of the low-rise neighbourhoods and, while causing more land take in the few metropolitan regions, less land take in many other regions is expected. Main threats of the large metropolitan regions are the diseconomies of scale, or negative consequences of size, such as mobility and quality of life issues such large developments are likely to bring, as well as a as large urban sprawl in the sub-urban environments of these metropoles if Europe was to follow an urban development similar to that of e.g. the United States or Australia. Furthermore with a main focus on the metropolitan regions, there is a risk of depopulation of the countryside (abandonment of the less productive areas) and as a result good stewardship of the land. Main benefits of Scenario B will be the balanced growth throughout Europe and the ability to keep cities manageable. Cities are expected to fulfil an important interaction with their hinterland and thus provide a balanced landscape in which both urban and rural areas can thrive. In the scenario C it is expected a bottom up approach to maintain the rural areas. Main benefit of Scenario C is the ability to maintain and protect valuable ecosystems, and enhance a vibrant hinterland. It is the scenario where most policy interventions are required. Good stewardship of the land and cohesion are promoted through stimulating Less Favoured Areas. The scenarios show that protection of valuable land will only be possible through strong zoning regulations. Otherwise stronger socio-economic uses will take over pristine natural areas and good agricultural soils Main threat of Scenario C is an increasing fragmentation of the landscape due to less dense urban developments throughout Europe.

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7.1

- Geometric/arithmetic means
- Relative convergence
- Absolute convergence

Currently cohesion indicators are calculated for accessibility and GDP per capita. With little additional programming effort, cohesion indicators for other output variables of the model can be calculated. The model documentation (Wegener, 2008, Page 28) contains a list of the about 35 population, economic and attractiveness indicators produced by the model. These include part of the indicators of the ESPON INTERCO project (ESPON INTERCO, 2011) as far as they are suitable for assessing territorial cohesion between (and not within) regions, such as demographic indicators, employment indicators, accessibility indicators and migration indicators.

<u>Polycentricity indicators</u>

Polycentricity indicators are macro indicators measuring the degree of polycentricity of the urban system in a territory. In SASI the polycentricity index developed in ESPON 1.1.1 (ESPON 1.1.1, pp. 60-84) is calculated. The polycentricity index of ESPON 1.1.1 is a weighted combination of three sub-indices:

- The Size index measures the slope and primacy of the rank-size distributions of population and GDP of cities.
- The Location index measures the Gini coefficient of the size of the service areas of cities.
- The Connectivity index measures the correlation of population and accessibility by the slope of the regression line and the Gini coefficient of accessibility of cities.

Currently the polycentricity index is calculated based on 1,588 Functional Urban Areas (FUAs) identified in ESPON 1.1.1 for the EU member states. With little additional effort the polycentricity index can also be calculated based on the 76 Metropolitan European Growth Areas (MEGAs) identified in ESPON 1.1.1 for the European Union as a whole.

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.

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ISBN-number: 978-2-919777-69-3

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