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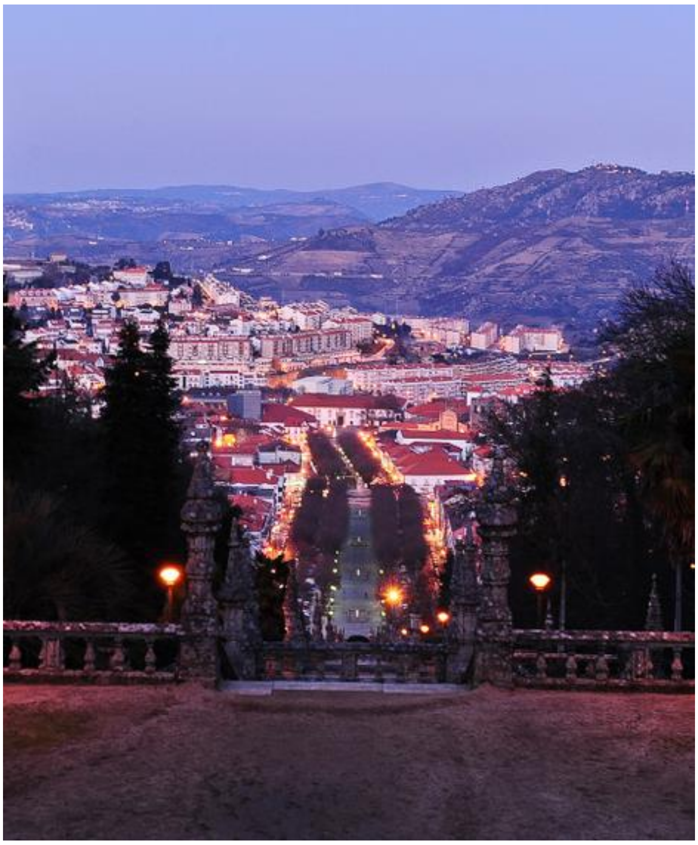
Direct and Indirect Land Use Impacts of the EU Cohesion Policy

Assessment with the Land Use Modelling Platform



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Lamego, Portugal. By: Daniel Bastos.

Contents

1. Introduction

1.1 Scope and objectives

The Cohesion policy is one of the most important policy instruments of the European Union (EU), implicating a substantial share of the EU budget and involving every region from each Member State. Also known as Regional policy, it is essentially a regional investment program, expected to "kick-start growth, employment, competitiveness, and development on a sustainable basis" (Brandsma et al. 2013: 3).

The Cohesion policy for the programming period 2014-2020 represents approximately 1/3 of the EU budget, totalling circa 322 billion euros[1] of Cohesion and Structural funds. Like in previous programming periods, Cohesion policy investments will be channelled to EU's regions in order to promote competitiveness, economic growth and job creation, while reducing economic, social and territorial disparities between regions[2], thus contributing to the 'Europe 2020' growth strategy. The main investment compartments are research and development (12%), aid to the private sector (12%), environment (17%), infrastructure (32%), human resources (22%) and technical assistance (5%).

As the manager of the Cohesion policy, the mission of the Directorate-General for Regional and Urban Policy of the European Commission (DG REGIO) is, first, to ensure that the available financial instruments contribute to a sustainable economic, social and territorial cohesion by reducing disparities between the levels of development of regions and countries of the European Union, and furthermore to ensure that these objectives are not met at high environmental cost, and that potential negative impacts are foreseen and minimized.

Ex-ante economic impacts of the new Cohesion policy on EU's regions were evaluated by the European Commission's services using the Computable General Equilibrium (CGE) model 'RHOMOLO' (Brandsma et al. 2013). Along with the desired economic impacts, the investment induced by the Cohesion policy is, as well, likely to produce impacts on local environmental conditions and land use. Despite the appreciable investment in actual physical capital across the EU, their potential aggregate impacts on local land use and environment have never been analysed in a systematic fashion. This report is the result of a first 'pilot' assessment of such

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[1] 2011 prices.

[2] 'What's the regional policy', http://ec.europa.eu/regional_policy/what/index_en.cfm, consulted in November 2013.

potential impacts. It was conducted by the Joint Research Centre (JRC)[3], as requested by the DG REGIO, in the context of the collaboration between the two European Commission bodies. The following questions and concerns motivated this study:

- *Could the Cohesion policy amplify unexpected and unwanted detrimental land use and environmental impacts?*
- *Could those impacts be avoided or mitigated with the correct set of land use/spatial planning policies?*
- *Can environmental friendly options contribute to Cohesion objectives like the reduction of social and territorial disparities between regions?*

While it would be pretentious to provide definite answers to these very broad and fundamental questions, with this study we do intend to explore the trade-offs between EU's investments and land use, and provide insights on specific land use impacts, and how negative impacts can be minimized. The inclusion of ecosystem services in this study comes as a way to address environmental impacts of land use changes in a broader and integrated manner. The ecosystem service framework of analysis takes into account the goods and services delivered by nature and their benefits to the society as a whole. The maintenance of sustainable provision levels of ecosystem services is becoming a major concern in Europe (Maes et al. 2012; Maes et al. 2013).

1.2 A modelling-based approach to assess Cohesion policy's land use impacts

Because the nature of this assessment is 'ex-ante', we rely on a modelling approach that assumes that future physical capital investments will have similar land use effects as those observed in the past. In addition, we designed two main scenarios for future land use change: a reference scenario, which serves as baseline and does not include Cohesion policy; and a scenario which includes the Cohesion policy. The scenarios were implemented through the Land Use Modelling Platform (LUMP), which is developed and run by the JRC. The LUMP can be described as a statistically calibrated cellular automata land change model. It is an adequate tool for this assessment because it integrates top-down and bottom-up drivers of land use change, while being aware of policies in different thematic domains (see figure 1).

The LUMP has already been used to assess land use impacts of key environmental EU policies, such as the integrated management of coastal zones[4], the greening of the Common Agricultural

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[3] JRC, Institute for Environment and Sustainability, Sustainability Assessment Unit.

Policy (CAP)[5], the Blueprint to Safeguard Europe's Waters[6,7] and, more recently, the assessment of potential land use impacts of the development of shale gas extraction in Europe.

The herein assessment is, in many ways, more challenging and whole than the ones carried out previously, as it needs to consider a myriad of domains addressed by the Cohesion policy. In fact, to make a comprehensive assessment and produce sensible and meaningful results, the aspects of the Cohesion Policy that are likely to impact (directly or indirectly) the land use have to be taken into account.

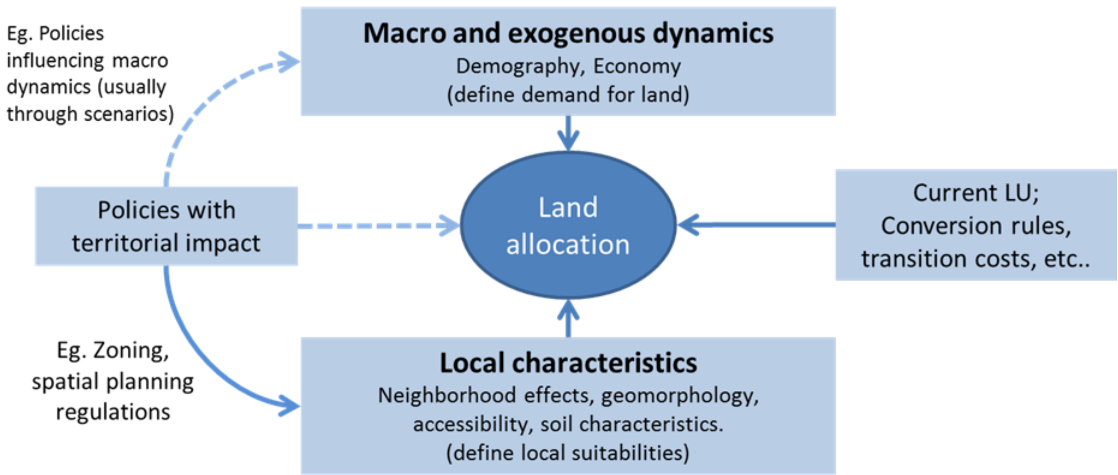

Figure 1. The LUMP merges top-down and bottom-up dynamics to simulate land use changes.

The main purpose of this document is to describe the overall assessment methodology (chapter 2), and how the LUMP has been configured to simulate the different scenarios and policy alternatives (chapter 3). Results come in chapter 4, mainly focusing on land use changes and their implications in terms of future urbanization patterns and potential cascading effects on

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[4] Lavalle C, Rocha Gomes C, Baranzelli C, Batista e Silva F (2011). Coastal Zones - Policy alternatives impacts on European Coastal Zones 2000-2050. EUR 24792 EN. Luxembourg (Luxembourg): Publications Office of the European Union.

[5] Lavalle C, Baranzelli C, Mubareka S, Rocha Gomes C, Hiederer R, Batista e Silva F, Estreguil C (2011) Implementation of the CAP Policy Options with the Land Use Modelling Platform - A first indicator-based analysis. EUR 24909 EN. DOI: 10.2788/45131. Luxembourg (Luxembourg): Publications Office of the European Union.

[6] De Roo, A et. al (2012) A multi-criteria optimisation of scenarios for the protection of water resources in Europe - Support to the EU blueprint to safeguard Europe's waters. EUR 25552 EN. DOI: 10.2788/55540. Luxembourg: Publications Office of the European Union.

[7] Burek P, Mubareka S, Rojas R, de Roo A, Bianchi A, Baranzelli C, Lavalle C, Vandecasteele I, (2012) Evaluation of the effectiveness of natural water retention measures- Support to the EU blueprint to safeguard Europe's waters. EUR 25551 EN. DOI: 10.2788/5528. Luxembourg: Publications Office of the European Union.

key ecosystem services relevant to human health. Some concluding remarks and guidelines for future work are drawn in the last chapter. A brief non-technical description of the LUMP model is provided as appendix to this document (Appendix 1). A more exhaustive description of the LUMP, in particular of its land allocation module can be consulted in Lavalle et al. (2011a).

1.3 Cohesion policy: the context

The basis for the current model of the Cohesion policy was laid in the 1988 reform. Since then, the structural funds were integrated into an overarching policy, with strategic guidelines defined by the Commission and strong involvement of Member States and regions that drafted operational and regional development plans on a multi-annual basis. Different strategic objectives were set for regions depending on their economic situation, but with particular emphasis on the lagging regions of the community (Manzella and Mendez 2009). Since then, a total of four multi-annual programs have been implemented: 1989-1993, 1994-1999, 2000-2006 and 2007-2013. A new multi-annual program is under preparation for the period 2014-2020.

In the 2007-2013 programming period, the Cohesion policy was operationally structured in three different funds, each with specific objectives: The Cohesion Fund (CF), the European Social Fund (ESF), and the European Regional Development Fund (ERTF). The latter aims at strengthening economic and social cohesion in the European Union and specific measures consist of direct aid to small and medium enterprises (SMEs), co-financing of infrastructure linked to research and innovation, information and telecommunication, environment, energy and transport, and technical assistance measures. Actors in all regions of the EU can be funded by the ERTF. The European Social Fund supports actions that contribute to improve human capital and social integration in order to increase access to the labour market and create opportunities for employment. Only the most developed EU regions (GDP/capita >90% of the EU average) are not eligible for ESF funding. Finally, the Cohesion Fund invests in key trans-European transport and energy networks, while improving the environment by increasing energy efficiency, renewable energy production, inter-modality and mass public transportation. Only the regions under the ‘Convergence’ objective (GDP/capita <75% of the EU average) are eligible for the CF.

A total of 347 billion Euros were distributed among the three funds, with 201 billion Euros allocated to the ERDF, 76 billion Euros to the ESF and 70 billion Euros to the CF. In terms of regional distribution, the regions under the ‘Convergence’ objective benefit the most, with a total of 283 billion euros allocated. While the total amount of the Cohesion policy represents a very small portions of the EU's GDP (~ 0.3%), in less developed regions, the yearly allocated investments can represent as high as 5% of their annual product.

1.3.1 Expenditure categories and the link with land use

The total investment package (ERDF + ESF + CF) for the programming period 2007-2013 was classified in 86 specific 'thematic priorities', or categories of expenditure. The categories can be as specific as 'R&TD infrastructure', 'Support for self-employment and business start-up', 'Motorways', 'Multimodal transport', 'Ports', 'Renewable energy: solar', 'Integrated projects for urban and rural regeneration', 'Promotion of natural assets', 'Education infrastructure', to mention just a few. Estimates of the allocated funding per region and per thematic priority given by DG REGIO, have been made available for this project.

With 86 areas of investment, the Cohesion policy can potentially induce many direct or indirect land use changes. Going through the different thematic priorities (see Appendix 3), it becomes evident that certain investment measures produce direct land use changes. Other investments may produce indirect land use changes, by fostering economic development, attracting people and new activities. A great deal of funding measures, however, are expected to be basically neutral in terms of land use changes, such as measures targeting human capital, social integration, or direct aid to existent SMEs. Perhaps one of the most notorious facets of the funding is related to construction or improvement of infrastructure. Such investments lead to direct land use impacts, particularly when new road/rail, new buildings or facilities are constructed, but also to indirect land use changes. Developing new transport corridors, and increasing the accessibility levels may impact on economic activities, which in turn may increase demand for additional built-up area. Moreover, the location of those investments and improvements determine in part the decisions of new residents on where to live, and developers on where to build.

In this study, a two-fold approach is used to capture the direct and indirect impact of the Structural and Cohesion funds on land use. First, we use the output of RHOMOLO to capture aggregate effects of the Cohesion policy on the economy. The aggregate economic output of regions (expressed as gross value added per sector) is then translated in terms of future requirements for additional development of industrial, commercial and services land uses (see section 3.1.1). Second, investments in specific thematic priorities are dealt endogenously in the LUMP model (see section 3.3).

2. Assessment methodology

The assessment of the potential impacts of the Cohesion Policy for the programming period 2014-2020 will mainly focus on aspects related to land use systems, ecosystem services and urbanization patterns. The nature of this ex-ante impact assessment requires an integrated and comprehensive modelling approach able to simulate the potential impacts of several interacting policies. The Land Use Modelling Platform is an adequate tool for this task because it is calibrated to replicate observed land use changes, as a function of significant bio-physical and geographical factors and determinants, while integrating several sector policies and inputs, often from external sources and models consistent with the EU framework. The model is able to respond accordingly, providing a simulation of future land use changes that respond to a given future demographic and economic outlook and policy changes. By keeping the model configuration fixed and changing only the policies under scrutiny, their potential impacts can be assessed.

To determine the potential impacts of the Cohesion policy, the LUMP was used to simulate two scenarios. One scenario that projects future land use changes ignoring the Cohesion policy (a baseline scenario), and a scenario which takes it into account. The two scenarios are essentially similar apart from the fact that the latter considers the Cohesion investments, so that the differences in the simulated land use can be attributed to the policy. The methodological workflow is thus rather straightforward, and composed of four main stages:

1. *Definition of the scenarios;*
2. *Configuration the land use model to run the scenarios;*
3. *Running of the land use model;*
4. *Comparison of the simulation results through indicators.*

Other preliminary and intermediate steps are also essential. For example, model development, calibration and testing is done preliminarily. The definition of the scenarios is done in interaction with the policy makers who want to see their policy proposals assessed. After running the model, results are inspected to check for errors and inconsistencies that need to be traced and fixed. Re-runs are required until the results are stable and plausible.

In the following section we will look at the LUMP and its main characteristics. Finally, the scenarios will be described in more detail in section 2.2.

2.1 The Land Use Modelling Platform

> *Land change models are a key means for understanding how humans are reshaping the Earth's surface in the past and present, for forecasting future landscape conditions, and for developing policies to manage our use of resources and the environment at scales ranging from an individual parcel of land in a city to vast expanses of forests around the world.*
>
> National Research Council (2013)

The LUMP is a computational dynamic spatial model which simulates future land use changes based on biophysical and socio-economic drivers. Its core was initially based on other land use models, namely the Land Use Scanner and the CLUE models (Hilferink and Rietveld 1999; Dekkers and Koomen 2007; Verburg and Overmars 2009), but its current form is the result of continuous development effort by the JRC. The core of the model is written in *GeoDMS*, an open source programming language. It functions essentially as a 'cellular automata' land change model as it integrates suitability maps for different land uses and neighbourhood relationships between land uses, as well as information about the aggregate amounts of land use change expected in the future. The suitability and neighbourhood parameters are statistically calibrated based on observations of past land use patterns.

LUMP has been specifically designed to assess land use impacts of European policies, and it is usually run for the entire EU-28, although it can also be used for more detailed case studies. It is meant to provide a vision of possible futures and indicative qualitative and quantitative comparisons between simulated scenarios and policy options at European level. It runs at high spatial resolution of 1 hectare (100 x 100 metres), and the most relevant groupings of land uses are represented (see table 2). The main characteristics of LUMP are summarized in table 1.

Linkages between LUMP and other thematic models have been constructed in order to ensure consistency of the European scenarios. The platform allows multi-policy scenarios to be accommodated, so that several interacting and complementary dimensions of the EU are represented. Often LUMP inherits policy scenarios from other sector models. For example, land demand for different agriculture commodities is taken from the CAPRI model, which takes on board the effects of the Common Agricultural Policy. The most recent demographic projections from Eurostat are used to derive future demand for additional residential areas in each region.

Energy and economic policies are also passed to LUMP through macro-economic models. Other spatially explicit land use policies, such as transport improvements or land use regulations, are configured directly in LUMP.

The LUMP is structured in three main modules. The demand module, the land use allocation module and the indicator module (see figure 2). The demand module is where demand for different land uses is defined. A range of minimum and maximum demand for each land use, for each year and for each NUTS2, is determined from outputs of exogenous thematic models. These demands, also referred as land claims, are passed onto the land allocation module. The role of this module is to spatially allocate the land claims for the simulated land use classes for each region, yearly. The allocation is based on the dynamic competition between land uses, which takes into account spatial allocation rules that stem from a combination of land demand, land use suitability, temporally-dynamic neighbourhood characteristics and scenario/policy-specific decision rules.

Table 1. Main model characteristics

Spatial extent	EU-28
Spatial resolution	100 metres
Thematic resolution	7 main land use classes (+ agricultural breakdown + 'abandoned' land uses)
Temporal resolution	Yearly
Time span	2006-2030; 2006-2050
Primary output	Land use maps, land use changes
Secondary outputs	Spatially explicit thematic indicators

Table 2. Simulated land use classes

Code	Label	CLC corresponding class-codes
1	Urban	Urban fabric (111, 112, 113); Green-urban areas (141); Sport and leisure facilities (142)
2	Industry, commerce, services	Industrial or commercial units (121)
3	Arable land	Arable land (211, 212, 213); Heterogeneous agricultural areas (241, 242, 243)
4	Permanent crops	Permanent crops (221, 222, 223); Agro-forestry areas (244)
5	Pastures	Pastures (231)
6	Forests	Forests (311, 312, 313)
7	Semi-natural vegetation	Transitional woodland-shrub (324)
11	Abandoned arable land	LUMP specific class
12	Abandoned permanent crops	LUMP specific class
13	Abandoned pastures	LUMP specific class
14	Abandoned urban	LUMP specific class
15	Abandoned industry, commerce, services	LUMP specific class
16	New energy crops	LUMP specific class

The base map for the simulation is the CORINE Land Cover 2006 – refined version (CLC-r), which provides additional detail when compared to the original CLC 2006 (improved detail from 25 ha to 1 ha minimum mapping unit for the artificial land use classes)[8]. The main direct output of LUMP is a simulated land use/cover map with the thematic detail described in table 2 and with a spatial resolution of 100 x 100 meter. A number of CLC original classes are not possible to model, and thus remain fixed in terms of their spatial extent, i.e. certain infrastructure (ports, airports, and dump/waste/water treatment sites), green urban areas, and natural classes like wetlands, water bodies, and areas covered by sand, rock or permanent snow (glaciers).

[8] The CLC-r was produced by the JRC and is the result of the combination of high resolution thematic datasets such as the CLC change map, Soil Sealing Layer, Tele Atlas® Spatial Database, Urban Atlas, and Water Bodies Data from the Shuttle Radar Topography Mission (Batista e Silva et al. (2013b)).

From LUMP's main output – and in conjunction with other modelling tools which have been coupled with LUMP – a number of relevant indicators can be computed (indicator module of LUMP). The indicators are seen as ways to capture meaningful information from the model's outputs on specific themes. When computed for various scenarios, differences in the indicators can be geographically identified, sensitive regions can be pinpointed, and impacts can be related to certain driving factors assumed in the definition of the scenarios.

As with many modelling tools, LUMP is not a forecasting model. It is designed to simulate future trends according to scenario and/or policy specifications, and to provide not only a vision of possible futures but also indicative qualitative and quantitative comparisons between the simulated options. In the appendix 1, additional background information on LUMP is provided.

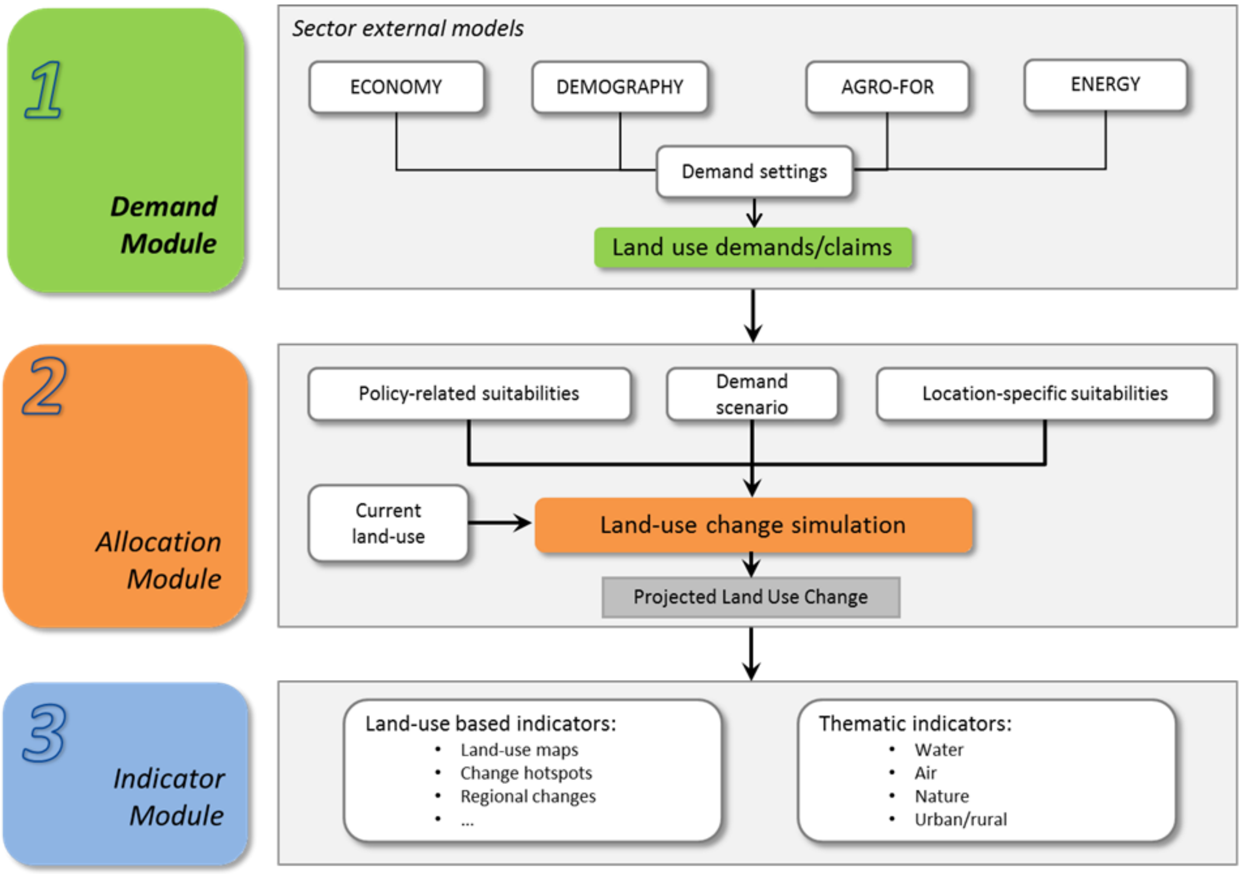


Figure 2. Modular structure of LUMP.

2.2 The 'Reference' and the 'Policy' scenarios

The assessment is based on the comparison of two scenarios: the 'Reference scenario' and the 'Policy scenario'. The Policy scenario is further broken down in two variants, which will be detailed later on in this section. The Reference scenario and its implementation in LUMP is described in a dedicated report by Lavalle et al. (2013).

The two scenarios have some common aspects, but also important differences. The Reference scenario describes the future as it is likely to develop according to historical trends, current legislation, and the Europe 2020 strategy, namely in terms of the climate and energy objectives. It assumes a total population growth of 4.6% in the period 2010-2030 in the EU27 (Eurostat's population projections 'EUROPOP 2010'). The GDP grows a yearly average of 1.5% in the same period (GEM-E3 model's simulations, where GDP growth rates are taken as targets, specified according to DG ECFIN/Economic Policy Committee agreed short and medium term GDP projections and the European Commission/Economic Policy Committee Ageing Report 2012 assumptions). The future forest and agricultural land uses are given by the G4M/GLOBIUM and the CAPRI models, respectively. Finally, the EU's Cohesion Policy is not taken into consideration. As such, improvements to the current transport network are not implemented. Urbanization reflects a 'business as usual' situation, whereby past trends are projected into the future, and specific urban land use policies are not put in place.

On the other hand, the policy scenario simulates the future as it is likely to develop taking into account the Cohesion policy. The baseline economic growth is influenced by financial transfers to regions due to the EU Cohesion Policy (according to RHOMOLO model). Other effects of the Cohesion policy are considered, such as improvements to the transport infrastructure which result in improved accessibility levels for citizens and businesses. Cohesion policy investments in regions on specific thematic areas are also considered (e.g. investment and construction of R&D facilities, health and education facilities, waste and water treatment facilities, and urban regeneration). Environmental legislation, demographic trends and the agriculture and forestry sectors are equivalent in the Reference and Policy scenarios. Table 3 summarizes the main assumptions and input models used in each of the scenarios.

Both scenarios were run by LUMP, generating comparable outputs. Even though the Cohesion Policy targets directly the period 2014-2020, its impacts in the Economy and the territory are expected to fade out beyond 2020. Therefore, the chosen modelling time span ranges from 2006 to 2030.

2.2.1 Policy alternatives – story lines

As already mentioned, the Policy scenario has two variants, which we labelled as 'Policy-BAU' and 'Policy-Compact. In the 'Policy-BAU', urbanization reflects a 'business as usual' situation, whereby past urbanization trends are projected into the future, and specific urban land use policies are not put in place. Often this means that sprawling trends may continue, with low population density and disperse urbanization patterns. This set up is also used in the Reference scenario.

In the 'Policy-Compact' variant, new urbanization follows more strict rules, thus enforcing densification of urban areas and more compact development. In addition, Cohesion policy is also assumed to give emphasis to environmental conditions of urban areas, encouraging the maintenance and/or the expansion of green/forest areas within large urban zones.

Table 3. Summary of main assumptions for the Reference and Policy scenarios.

Sector / Theme	Land use classes directly impacted	Reference Scenario	Policy Scenario
Agriculture	Arable land, permanent crops, cereals, maize, root crops, new energy crops + abandoned agricultural land	Upstream model: CAPRI (University of Bonn / EuroCARE, Bonn). Relevant outputs: Agriculture land use per commodity (NUTS2). Run: 2020 energy targets met (reference scenario for DG CLIME, driven by the PRIMES model)	
Forestry	Forest	Upstream model: G4M/GLOBIOM Relevant outputs: afforestation/deforestation rates. Run: EUCLIMIT Project (DG CLIMA)	
Economy	Industry/commerce/services + abandoned industry/commerce/services	Upstream model: GEM-E3 (E3M Lab, National Technical University of Athens). Relevant outputs: GDP and GVA per sector, national disaggregation. Run: GDP growth rates are taken as targets, specified according to DG ECFIN/Economic Policy Committee agreed short and medium term GDP projections and the European Commission/Economic Policy Committee Ageing Report 2012 assumptions.	Upstream model: Rhomolo (JRC-IPTS, Seville) Relevant outputs: GDP and GVA per sector, regional disaggregation (NUTS2). Run: Simulation with Cohesion funds, and TEN-T.
Demography	Urban/residential fabric + abandoned urban/residential fabric	Upstream model: EUROPOP 2010 (ESTAT). Relevant outputs: Regionalized population projections (NUTS2). Run: Convergence scenario	
Transportation	All land uses influenced by accessibility patterns.	Current transport network only (until 2030). TEN-T network in place from 2030.	Upstream model: TRANS-TOOLS (JRC-IPTS, Seville) Current transport network and full implementation of TEN-T + simulated road improvements by Cohesion

<table>
<tr><td></td><td></td><td></td><td>funds.</td></tr>
<tr><td>Cohesion policy 2014-2020 (thematic priorities)</td><td>All</td><td>No</td><td>Yes</td></tr>
<tr><td>Urban specific policies</td><td>Urban/residential fabric, abandoned urban/residential fabric</td><td>No</td><td>Yes
(Simulation of BAU and Compact urban expansion variants)</td></tr>
<tr><td>Legislation</td><td>All</td><td colspan="2">Directly within LUMP:
- Cross-compliance, as defined in annex III of COM(2008)306;
- Support schemes, as defined in annex VI of COM(2008)306 and 1257/1999, Chapter V;
- Health Check 2008 COM(2008)306;
- Rural development regulation 1698/2005, Axis 2 measures:
  - Agriculture specific: Natural handicap payments, (art. 37) and Natura 2000 payments for agriculture (art. 38); Agri-environmental schemes (art. 39);
  - Forest specific: Natura 2000 payments for forests (art. 46)
- Renewables directive 2003/30 and 2009/28
- Habitat/birds directive (N2K)
Upstream from LUMP:
- Nitrates Directive 91/676 (CAPRI)
- Biofuel Directive (CAPRI)
- Energy Efficiency packages (PRIMES)
- Energy markets and power generation (PRIMES), including the Water Framework Directive
- Transport packages (PRIMES)</td></tr>
</table>

3. Defining and implementing the Policy scenario

In the previous section we have summarized the main assumptions behind the two scenarios that are the focus of this study. In this section we will concentrate on the aspects that are specific mainly to the policy scenario. Figure 3 depicts the overall workflow used in this project, and identifies the three main elements that characterize the Policy scenario: 1) the input from Rhomolo (Economy); 2) the population projections (Demography); and 3) the regional and thematic allocation of the cohesion funds (Thematic priorities). Finally, the legislation is configured similarly in both Reference and Policy scenarios, and it is covered in the report by Lavalle et al. (2013).

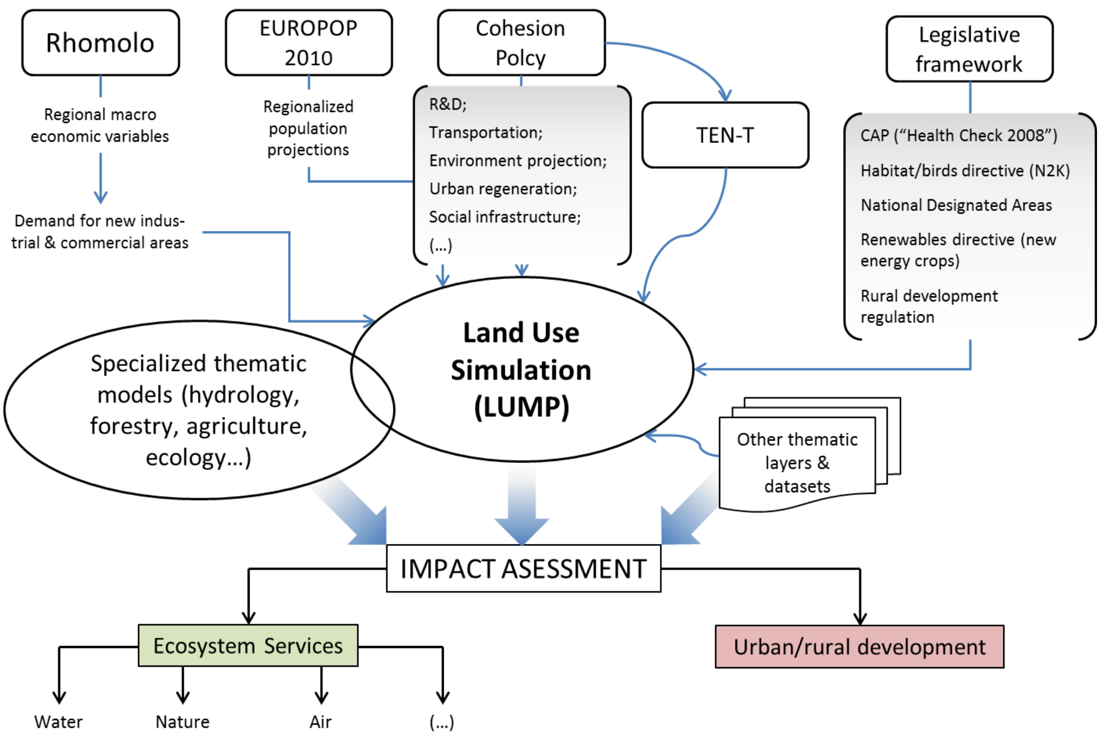


Figure 3. Definition of the policy scenario: main inputs and overall workflow.

Economy can be integrated in LUMP by using the sectoral gross value added (GVA) from any macro-economic model. The GVA is used to derive demand for industrial, commercial and services land uses (see section 3.1.1), which is then spatially allocated using the allocation model of the LUMP. As depicted in the figure 4, the base year for the land use modelling is 2006. Between 2006 and 2009, the model is driven by the sectoral GVA values reported by Eurostat (in constant prices). From 2009 onwards, the land use model is driven by the computable general equilibrium (CGE) macro-economic model 'GEM-E3' (General Equilibrium Model for Energy-Economy-Environment), run by the National Technical University of Athens, and which provides annual GVA growth rates with national and sectoral detail. The growth rates from GEM-E3 are used to project GVA from 2009, and generate a trajectory of future GVA that describes the Reference scenario (baseline). The GVA projection for the Policy scenario is created by modifying the baseline GVA growth according to results from the Rhomolo model. The Rhomolo run that was used takes into account the Cohesion policy and its economic repercussions within each region, but also how the economy of neighbouring regions may be influenced through spill over effects of certain major investments.

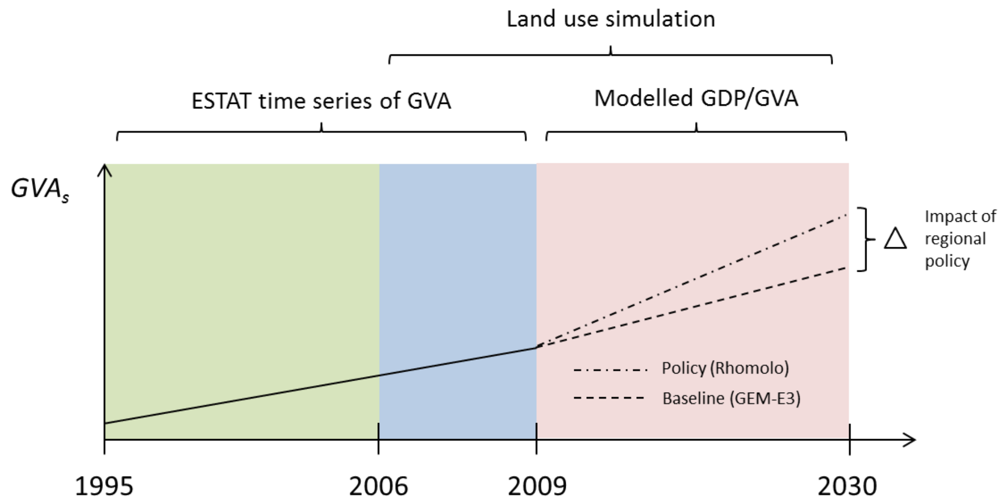


Figure 4. Main assumptions for GDP and GVA in the simulation period (2006-2030)

With regard to Demography, although both Reference and Policy scenarios use the same population projections, the dynamic population allocation sub-model, described in section 3.2.1, contains certain parameters that can be set to reflect policy orientations towards urban development.

Finally, as already discussed, the thematic priorities reflect the allocation of the Cohesion funds by category of expenditure and NUTS2 region of the EU. This aspect is specific of the Policy scenario and is ignored in the Reference scenario. Investments in regions are integrated in the modelling platform by looking at potential direct/indirect land use impacts of typical investments under each thematic priority. The technical approaches used to integrate these investments vary considerably between thematic priorities.

In the following sections we will focus on three main elements that define and characterize the policy scenario, and how we configured the LUMP to best integrate and simulate it. We will start with the linkages between Rhomolo and LUMP (section 3.1), continue with integration of the population projections and the dynamic population allocation (section 3.2), and conclude with a detailed description of how certain expected thematic investments were integrated in LUMP (section 3.3).

3.1 Integrating the regional economic scenarios

Rhomolo is a macro-economic, spatial equilibrium model built for 27 European Member States[9]. Contrary to most macro-economic models at European level, Rhomolo deals and provides solutions for all the European NUTS2 regions. It was specifically designed to carry both ex-ante and ex-post impact assessments of the European Cohesion policy. Rhomolo is not suited to produce forecasts, but is rather a tool to give insights on the economic implications of different policy scenarios. The model's equations and equilibrium solution are calibrated on data for the year 2007 and then solved for each period of the simulation time horizon, which can potentially go up to 2050.

Rhomolo takes into account factors of production like labour, capital and commodities. It includes a government sector, which collects taxes and pays subsidies, as well as households and firms. It dynamically links time periods through savings and investments and models inter-regional trade (exports and imports), thus allowing to analyse spill over effects between regions. Typical outputs of Rhomolo include Gross Domestic Product (GDP), Gross Value Added (GVA) per sector and employment and unemployment rates. The included sectors are as listed in table 4.

As requested by EC DG REGIO, Rhomolo is being used to simulate the impact of the regional investments of the European Cohesion Policy, as defined by the Multiannual Financial Framework (MFF) of the European Union for the programming period 2014-2020 (EUCO 37/13).

Due to its regional and sectoral detail, Rhomolo's simulations can be used by LUMP in order to estimate demand for industrial, commercial and service land uses (ICS). The workflow to link Rhomolo and LUMP is generally described below:

1. *Annual growth rates from an economic projection (GEM-E3) are used to generate a baseline scenario estimate of the GVA (2009 onwards);*

[9] At the time of the writing, Croatia was still not modelled by Rhomolo.

2. *Rhomolo outputs consist of two separate results: a baseline (no policy is applied), and simulation (the policy is applied);*
3. *A 'policy effect' parameter is obtained by calculating the ratio between the baseline and the policy outputs, and it can be interpreted as the effect of Cohesion policy in regional economy;*
4. *The 'policy effect' parameter is used to modify the GEM-E3 baseline and obtain a policy scenario estimate of the GVA (region and sector specific);*
5. *The GVA per sector is 'translated' into demand for additional industrial, commercial and services (ICS) land use, by means of an 'intensity approach';*
6. *An interval of minimum and maximum land demand is generated per region, based on variance of observed past trends;*
7. *Land demand for new ICS land use is allocated using the discrete allocation module of the LUMP. The allocation is resolved regionally, and it is determined essentially by the overall suitability for ICS areas and competition between land uses.*

Table 4. Economic sectors considered in Rhomolo.

Sector	NACE (rev. 1.1) section	Description	Sectors and labels used in LUMP
1	A + B	Agriculture, hunting and forestry	-
2	C + D + E	Mining and quarrying + Manufacturing + Electricity and Gas	Industry
3	F	Construction	-
4	G + H + I	Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods + Hotels and restaurants + Transport and Communications	Commerce and private services (Commerce)
5	J + K	Financial and Business Services	
6	L + M + N + O + P	Non-Market Services	Public services and administration (Services)

3.1.1 Estimating demand for industrial, commercial and services land uses (ICS)

'Land use demand' is defined as the additional land use required to meet future economic and societal needs. Land demand can refer to any land use typology, and the macro drivers for demand vary accordingly. The approach to estimate demand for ICS areas was developed by Batista e Silva et al. (2013c), and it is currently part of the demand module of LUMP. ICS land demand is essentially dependent on scenario-based economic outlooks, and it is estimated through a 'land use intensity' approach.

The land use intensity is the ratio between the economic output (GVA) of a given sector 's' and the land acreage 'A' known to be used by sector 's' in t_0 (eq. 1). The observed land use intensity per sector can then be used to estimate the total ICS land for any given t_1 (eq. 2). Conceptually, this formulation allows the integration of land use intensities specific to an n number of sectors. In this study, the considered sectors are three: industry, commerce and service areas, as defined in table 4. The sectoral GVA for t_0 is taken from the Eurostat online database (year 2006), whereas the sectoral GVA for t_1 is derived from the procedure described above.

$$LUI_{s,t_0} = \frac{GVA_{s,t_0}}{A_{s,t_0}}, with\ s \in \{1 = \text{"industry"}, 2 = \text{"commerce"}, 3 = \text{"services"}\} \qquad \text{eq. 1}$$

$$A_{t_1} = \sum_{s=1}^{n} \left(\frac{GVA_{s,t_1}}{LUI_{s,t_0}} \right) + \varepsilon \qquad \text{eq. 2}$$

An empirical exercise conducted for Spain and the Netherlands using detailed national land use datasets for circa 2006 showed that $LUI_{commerce} > LUI_{services} > LUI_{industry}$ consistently for all NUTS2 regions. In fact, on average, it was found that $LUI_{commerce} = LUI_{industry} * 27.6$ and that $LUI_{services} = LUI_{industry} * 6.7$. These empirical factors allowed us to disaggregate the CORINE Land Cover class 1.2.1 ("industrial and commercial units") in "industrial areas", "commercial areas" and "service areas", thus obtaining, for each region, the term $A_{s,t0}$ of equation 1.

The main assumption of this approach is that the intensity of ICS land, measured in economic terms for a given year in the past, remains unchanged in time. Therefore, the predicted demand for ICS land is driven directly by the predicted changes in the economic output of the respective sectors. This approach is regional and sector specific, and thus sensitive to differences in the production structure between regions, as well as to the changes in time in the production structure within each region. To illustrate, if the 'commerce' sector in a given region is predicted to grow while the 'services' and 'industry' sectors are predicted stagnate, the estimated impact on land use will be relatively small due the high intensity of commercial land (or, in other words, due to the low land take per unit of economic output). On the other hand, a region where considerable growth is estimated for the industrial sector should require a more significant amount of land use, because each additional unit of output requires a large amount of land.

This approach can be easily adapted to incorporate policy and technological aspects. For instance, land use intensities of the industrial sector can be set to increase in time in order to reflect expected technological improvements and/or policy targets in terms of improving land use efficiency.

Figure 5 shows the EU-aggregated land use demand figures obtained from this approach (Policy scenario).

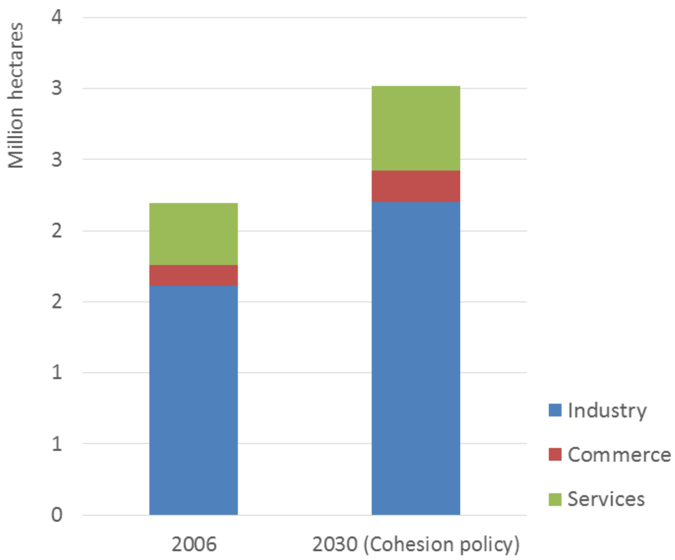


Figure 5. Historical land use and projected land use demand, broken down by sector (2030, Cohesion policy scenario)

3.2 Integrating demographic projections

Eurostat produces population projections approximately every two to three years. The latest version of population projections is denominated 'EUROPOP 2010' (Eurostat Population Projections 2010-based) and was produced "in the framework of the invitation of the Council (ECOFIN) to the Economic Policy Committee to update its analysis of the economic and budgetary implications of ageing". The projections are originally provided at national level, covering both EU27 and EFTA countries for the period 2010-2060, by 5-year intervals, with estimates referring to 1st January of each available year. Population figures are further provided with age and gender breakdown. The projections assume that socio-economic differences between EU27 and EFTA countries will fade out in the long term. This was implemented by imposing the convergence of fertility rates, life expectancy, and net migration "in the very long run".

For the purpose of this study, the EUROPOP 2010 projections had to be disaggregated from national to regional level (NUTS2). This was done by using regional population shares obtained from the previous version of the Eurostat's population projections, the 'EUROPOP 2008'.

Similarly to EUROPOP 2010, its precedent version assumed a converge hypothesis between countries in the future, and estimates were produced for EU27 plus EFTA countries until 2030. The level of spatial detail provided by EUROPOP 2008 allowed us to derive regional population shares up to 2030. In order to disaggregate the whole EUROPOP 2010 dataset, the regional shares derived for 2030 from EUROPOP 2008 were kept constant up to 2060. Equation 3 shows how the disaggregation was performed:

$$P'_{t,i} = P'_{t,j} * \left(\frac{P''_{t,i}}{\sum_{i=1}^{n} P''_{t,i}} \right) \qquad \text{eq. 3}$$

where:

P' and P''= population value reported by EUROPOP 2010 and EUROPOP 2008, respectively

t = a given year, with t ∈ [2010, 2060] for EUROPOP 2010, and with t ∈ [2010, 2030] for EUROPOP 2008

j = a given EU27 or EFTA country

i = a given NUTS2 region of the country j

n = the total number of regions i belonging to the country j

3.2.1 Simulating urban growth and abandonment with a dynamic population allocation module

The regionalized population projections are an exogenous input for the LUMP, and are used as a main driver for expansion of urban/residential land. In the LUMP, the development of urban/residential land is the result of a process by which incoming or moving residents within each region are allocated dynamically in space in each time step. The basic spatial unit for the allocation corresponds to cells of 100 x 100 meter size (1 hectare), and the temporal resolution is yearly. For time step t+1, the population to be allocated spatially, ‘K’, within each region ‘j’ corresponds to the population surplus plus a fraction of the already existing population (eq. 4).

$$K_{j,t+1} = (Q_{j,t+1} - Q_{j,t}) + (u * Q_{j,t}), \qquad \text{eq. 4}$$

in which the term ‘Q’ refers to inhabitants and ‘u’ corresponds to the proportion of existing inhabitants that will move within the region between ‘t’ and t+1. This proportion is currently assumed to be 0.1. The allocation of ‘K’ is determined by the factors/parameters listed in table 5, which contribute to the overall potential population, ‘P’ of each cell ‘i' in each region ‘j’ (eq. 5). The actual allocation is done by disaggregating ‘K’ amongst the existing cells within region ‘j’, as formulated in equation 6. A new population distribution is thereafter created for t+1, as shown in equation 7. As a result of this allocation algorithm, existing urban areas can either become denser, maintain or lose residents. On the other hand, non-artificial land uses can host new residents as well, if their overall potential population is sufficiently high.

$$P_{i,j,t+1} = f(A_{i,t+1}, N_{i,t+1}, H_{i,t+1}, L_{i,t}, D_i, S_i)^{\lambda} R_i \qquad \text{eq. 5}$$

$$K_{i,t+1} = K_{j,t+1} * \left(\frac{P_{i,j,t+1}}{\sum_j P_{i,j,t+1}}\right) \qquad \text{eq. 6}$$

$$Q_{i,t+1} = K_{i,t+1} + \left[Q_{i,t} * (1-u)\right] \qquad \text{eq. 7}$$

Table 5. Factors/parameters used in the allocation of incoming and moving residents.

Factor / parameter	Label	Description	Notes
A	Potential accessibility	Captures the relationship between development and accessibility levels.	Takes into account the major programmed changes in the network as well as other smaller investments in road infrastructure. Statistically calibrated.
N	Neighbourhood population	Influence of population in neighbouring cells.	Function of the sum of existing population within a pre-defined neighbourhood range. Statistically calibrated.
H	Housing supply	Accounts for the inelastic supply of housing at the scale of the pixel.	Housing supply is the same as of 2006, and it is updated every 10 years.
L	Land use	Suitability of the land use in t to host population.	Statistically calibrated.
D	Distance to roads	Captures the relationship between development and proximity to existing road network	Statistically calibrated.
S	Slope	Captures the relationship between development and slope	Statistically calibrated.
R	Restrictions	Top-down restrictions to built-up land use.	Boolean map with legal and/or physical restrictions to built-up. It can be used as a ‘policy parameter’.

λ	Power parameter	Optional parameter that can be used to stretch or shrink the variance of the potential population. Reflects the possibility that housing preferences are not linear to suitability.	p = 1 has a neutral impact; p > 1 stretches the variance by amplifying higher values; p < 1 shrinks the variance by diminishing more the higher values. Calibrated to best represent population distribution in the base year (typically ~ 1.5). It can be modified to enforce compact or dispersed growth.

After solving equations 4 to 7, non-artificial land uses are converted to urban/residential if a minimum population is reached. At the same time, urban/residential cells which had their population reduced between t and t+1 to a level below a given threshold are classified as 'urban abandoned'. The resulting distribution of urban and abandoned urban land uses is used in the subsequent time step. The conversion thresholds are based on the statistical distribution of population over cells, which is collected from high resolution ground truth population data (see figure 6 for an example). Statistical analyses indicated that the threshold for the conversion to urban residential should be set to 6 inhabitants/ha, and to 2 inhabitants/ha for abandonment (table 6). The gap between the two thresholds creates a certain degree of hysteresis between the amount of people and the status of the urban land.

The quantitative allocation of inhabitants, and the subsequent rule-based conversion of urban and abandoned urban land uses is a novelty recently introduced in the LUMP, and replaces a purely discrete allocation of urban land use.

Table 6. Thresholds to be used for conversions to urban and urban abandoned

Conversion type	**Criteria**
Conversion to Urban	$(Q_{i,t+1} \geq 6)\ AND\ (L_{i,t} \neq "Urban")$
Conversion to Urban Abandoned	$(Q_{i,t+1} < 2)\ AND\ (L_{i,t} = "Urban")\ AND\ (Q_{i,t+1} < Q_{i,t})$

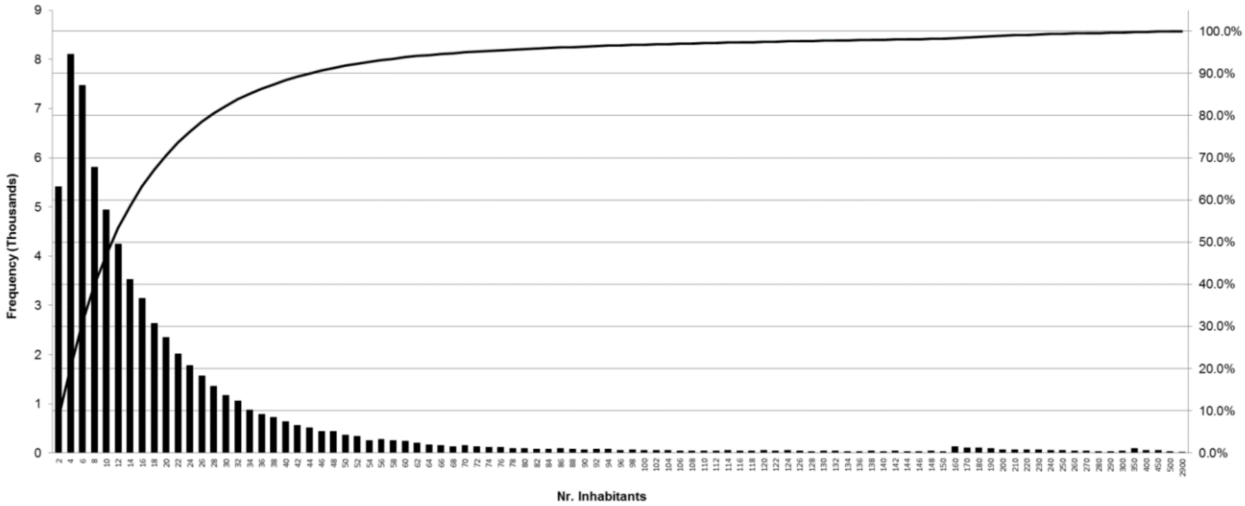


Figure 6. Frequency (bars) and cumulative frequency (line) of urban cells per number of inhabitants, ground-truth data for 2006, Slovenia (Slovenia Statistical Office).

In the results computed for this assessment, the amount of urbanization is however constrained by a range of minimum and maximum urban land use demand estimated for each region. As such, the population allocation module is forced to allocate at least 6 people to a minimum amount of cells in regions where the minimum area of urban land-use is not met, and similarly is forced to reduce population counts below 2 in urban cells that are overabundant. The method to allocate minimum and maximum urban areas depends on population potential P, so that non-urban cells with the highest population potential are forced to become urban when a minimum claim needs to be fulfilled, and built-up cells with the lowest potential population are forcibly abandoned if the number of urban cells exceeds the regional maximum.

The population allocation method is constrained to exogenous minimum and maximum claims to ensure that, within regions, areas of urban land also follow regionally relevant trends concerning household size and land consumption per capita. The method to compute future land-use claims is based on methods developed in the context of the FP-7 project VOLANTE (Lotze-Campen 2013). The allowed estimated amounts are based on a number of regionally varying trends: these are, besides the projected population numbers: 1) a general trend of household size development in which average regional households in Europe are expected to converge to 1.8 persons per household by 2100; and 2) region-specific trends of urban land use per capita, in which the historical development of regional urban land use per capita is extrapolated to future years. The relative accuracy with which the fitted equation can reproduce historical levels of per-capita land consumption is used to generate an interval of minimum and maximum areas of urban land.

3.3 Simulating land use impacts of the Cohesion Policy investments

The Cohesion Policy is a major part of the total EU multiannual financial framework (MFF). In the programming period of 2007-2013, it represented about 1/3 of the total financial commitments of the EU. In the beginning of 2013, the European Council agreed on a total of ~ 322 billion EUR (in 2011 prices) committed to the Cohesion Policy for the programming period 2014-2020. Despite the slight decrease of funding in real terms, the share of the Cohesion Policy in respect to the total EU budget is expected to remain around 1/3. These funds will be distributed among countries and regions during the time horizon of the MFF with the objective of promoting economic, social and territorial cohesion within the EU28, and based on solidarity among Member States. As stated in EUCO 37/13 (p 10), "cohesion policy is (…) the main tool to reduce disparities between Europe's regions and must therefore concentrate on the less developed regions (…). Furthermore, [it] shall contribute to the Europe 2020 Strategy for smart, sustainable and inclusive growth throughout the European Union".

The funds made available through the Cohesion Policy are allocated to regions (according to an eligibility scheme favouring less developed regions) and thematic priorities. With regards to the programming period 2007-2013, DG REGIO produced a matrix reporting the total financial resources allocated to each NUTS2 region by each thematic priority. The thematic priorities considered in the previous programming period are 86 in total, grouped into 17 headings. A preliminary matrix for the new programming period is being generated by DG REGIO based on the available budget, eligibility criteria and the foreseen thematic objectives.

In order to integrate the Cohesion policy directly in the LUMP, an internal consultation process was initiated in the last quarter of 2012. All 86 thematic priorities were analysed and, as a result of this process, which involved all members of the Land Use Modelling Group at JRC, a short list of thematic priorities was achieved. The short list contained thematic priorities which comply with the following criteria:

- *The thematic priority is expected to produce direct or indirect impacts on at least one land use type;*
- *The expected impacts can be captured by the thematic and spatial resolution of LUMP.*

This evaluation was done through a systematic survey, followed by a meeting where all participants discussed the results. In a second stage of the consultation process, examples of projects financed by each of the short-listed thematic priorities were sought. Based on the project examples, a clearer idea of the probable direct and indirect land use impacts was obtained for each thematic priority. This investigation was followed by internal meetings in which a further filtering of the thematic priorities was made, based on the feasibility of modelling the impacts of each thematic priority.

At the end of this process, and given the technical feasibility plus time restrictions, the thematic priorities that were chosen to integrate directly in LUMP are listed in table 7. In the following sub-sections, more details are given about the implementation of the investments in LUMP.

Table 7. Final list of thematic priorities to model within the LUMP.

Grouping label	Thematic priority code	Thematic priority name	Main land use classes impacted
R&TD + information society	2	R&TD infrastructure (including physical plant, instrumentation and high-speed computer networks linking research centres) and centres of competence in a specific technology	Industrial, Commercial, Services
	13	Services and applications for the citizen (e-health, e-government, e-learning, e-inclusion, etc.)	
	14	Services and applications for SMEs (e-commerce, education and training, networking, etc.)	
Road networks	16-17	Railways / Railways (TEN-T)	Urban areas; Industrial, Commercial, Services
	18-19	Mobile rail assets / Mobile rail assets (TEN-T)	
	20-21	Motorways / Motorways (TEN-T)	
	22-23	National, regional and local roads	
Multimodal transport	24	Cycle tracks	Urban areas
	25	Urban transport	
	26-27	Multimodal transport / Multimodal transport (TEN-T)	
Airports & Ports	29	Airports	Urban areas; Industrial, Commercial, Services
	30	Ports	
Culture, urban and rural regeneration	58	Protection and preservation of the cultural heritage	Urban areas
	59	Development of cultural infrastructure	
	61	Integrated projects for urban and rural regeneration	
Social infrastructure	75	Education infrastructure	Services (public)
	76	Health infrastructure	
	77	Childcare infrastructure	
	79	Other social infrastructure	

3.3.1 Investment in road network and multimodal transport

A considerable part of the cohesion funds is allocated to transport infrastructure projects. These will possibly affect 1) regional economic growth and 2) the intra-regional distribution of human activities. Regional economic effects are taken into account by the Rhomolo model and are taken as exogenous in LUMP's modelling effort. In Rhomolo, improvements in the network lead to improved accessibility and thus reduced costs for inter-regional trading. The intra-regional distribution of human activities will be modelled in the LUMP, by methods described further below in this section.

Accessibility is a measure of the opportunities that a place offers the people or businesses residing there: for example expressed in the amount of jobs that jobseekers can reach, or the amount of customers that may visit a shop. It defines the possible amount of physical interactions and transactions in an economic system, and is considered a key determinant of local economic and urban development (Hansen 1959; Vickerman et al. 1999; Koopmans et al. 2012). Two factors determine how accessible a location is: the amount of opportunities (e.g. people, jobs, customers, services) available at various places; and the amount of difficulty involved in reaching those opportunities from a starting point. The level of accessibility grows when the amount of opportunities increases, or the costs of reaching those opportunities decreases.

As seen in table 5 of section 3.2.1, accessibility is one important factor in the population allocation model that is part of the LUMP. In that model, high resolution maps of accessibility levels are computed yearly from 2006 to 2030. A large variety of possible accessibility measures exist in the scientific literature; in the LUMP model, 'potential accessibility' measures similar to those reported by ESPON (2006) are used. They are based on the amount of people one can reach from a given place; the difficulty of reaching other places is computed as a quadratically increasing function of travel time by car over the road. Estimated numbers of people are derived from the model at pixel level and subsequently aggregated to municipality levels. Travel time by car to those municipalities is computed by the model, using the same road network data that is used in the TRANS-TOOLS model developed by the European Commission[10]. It has been found that higher accessibility levels increase the local likeliness of urbanization in Europe. Accessibility is therefore used in LUMP as a positive effect on population suitability levels. The

[10] TRANS-TOOLS, http://energy.jrc.ec.europa.eu/transtools/

actual relationship between the degree of accessibility and the suitability for urbanization has been derived country-wise through statistical calibration.

In the 2014-2020 programming period, substantial funding will be available for upgrades to transport networks in the European Union. The largest share of this funding is allocated particularly to a number of Southern European regions and the new member states. A part of the funding has a known target (for example the TEN-T priority projects); another part will be allocated to currently unknown projects. The known projects are integrated in the model's network data. Because it is unclear to what road improvements the remaining share of the available funding will be allocated, a separate transport modelling exercise has been executed to select links that will presumably be upgraded. The transport modelling exercise is based on a relatively straightforward spatial interaction model, with transport flows being attributed to the fastest paths. The rules to select links based on the outcome of that transport model are:

1. *Only upgrades to road links already used in the model are allowed; furthermore*
2. *Upgrades cause speed increases and have a fixed cost per kilometre of road. Those costs are based on the average costs of previous TEN-T projects; and*
3. *The links with the highest modelled transport flows are selected until the available funding is exhausted.*

Effective speed improvements are modelled by increasing the speed of particular links up to 130 (in case of new motorways), 100 (in case of new national roads), or 80 (in case of new local or regional roads). Based on a small survey of successful EU regional funding projects we have estimated that upgrading and/or constructing roads costs 10 million euros per kilometre in the case of four-lane motorways, 4.2 million euros per kilometre in the case of national two-lane roads and 3 million euros in the case of local or regional two-lane roads. We expect that the link upgrades are allocated based on the amount of users of links. The amount of users of a link is approximated by a simple transport modelling effort. Based on these rules, roughly 8000 kilometres of presumed road network upgrades are included in the Policy scenarios modelled with LUMP.

The presumed improvements in terms of travel-time gains are assumed to be effectuated gradually between 2007 and 2030. In practice, two accessibility maps are produced. The first reflects the current network's geometry and characteristics ($\text{Accessibility}_{t0}$), while the second reflects the improved network by 2030 ($\text{Accessibility}_{t1}$), taking into account all the expected network improvements. The two accessibility maps are used simultaneously within LUMP by a mechanism which smoothly distributes the effects of the investment in infrastructure throughout the time span of the simulation (2006-2030) (eq. 8). In the notation used below, t_0 refers to the year 2006, t_1 refers to year 2030 and t_x refers to each yearly time step between 2006 and 2030.

$$Accessibility_{t_x} = \left[Accessibility_{t_0} * \left(\frac{t_1 - t_x}{t_1 - t_0}\right)\right] + \left[Accessibility_{t_1} * \left(\frac{t_1 - t_x}{t_1 - t_0}\right)\right], t_0 < t_x < t_1 \qquad \text{eq. 8}$$

When plotting initial accessibility levels and relative accessibility improvements we find that a number of the countries that border the Baltic Sea enjoy the largest improvements in accessibility (see figure 8). Those improvements are no doubt caused by planned upgrades of roads in particular in Estonia, Latvia, Lithuania, Poland and Sweden; and by planned upgrades of the ferry services that connect those countries. Furthermore many of the European Union's other new member states enjoy substantial improvements in accessibility. When mapping relative accessibility improvements, it is clear that the accessibility effects of road upgrades are most profound in the outermost parts of the European Union. Road upgrades in the Gdansk to Vienna corridor affect central Poland and the eastern part of the Czech Republic the most. Although we find substantial increases in accessibility, those improvements do not alter the ranking concerning which member states have the highest levels of accessibility.

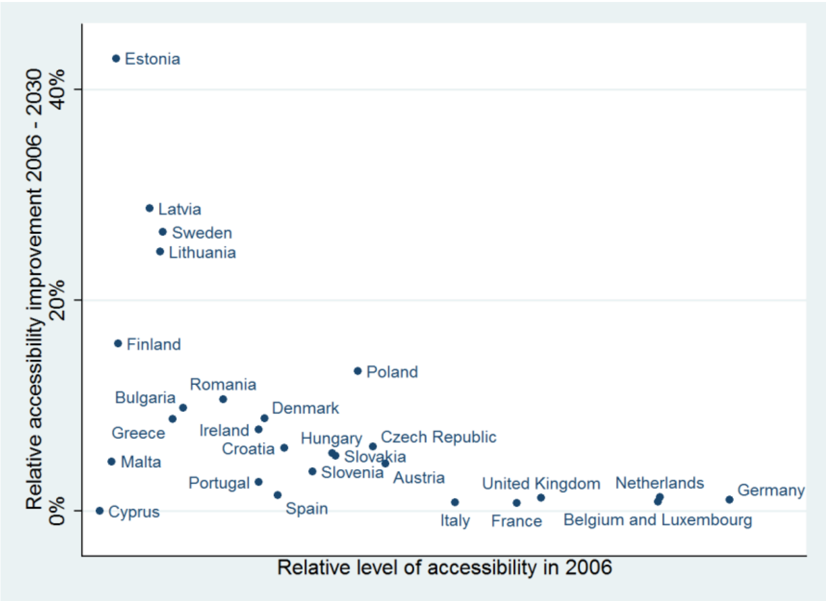


Figure 7. Initial accessibility levels and relative accessibility improvements because of modelled road network improvements in Europe.

- *Multimodal transport*

The impact of funding for multimodal transport has been modelled by assuming that investment to upgrade transport infrastructure can result in increased attractiveness to new residents and/or businesses. As a result, additional land development could be induced in the areas served by the improved infrastructures. Increases in attractiveness were assumed to be proportional to the amount of funding and the number of potential users of transport infrastructure.

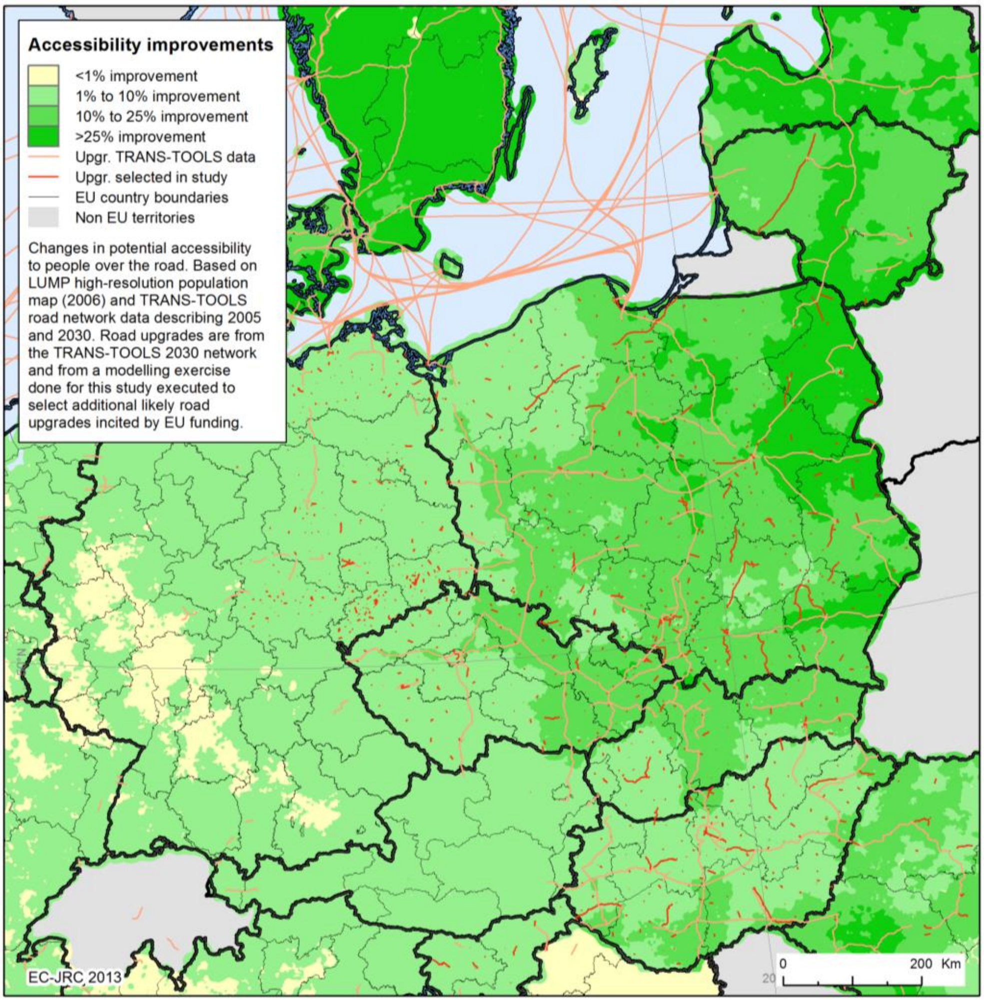


Figure 8. Accessibility changes because of modelled road network improvements in the Gdansk-Vienna corridor.

3.3.2 Ports and airports

Ports and airports are extremely important nodes of transport, allowing efficient connection of faraway regions by air and sea. Consequently, these infrastructures are extremely important for the economy and thus relevant factors for the location of economic activities.

New airports and ports are not expected to be built with Cohesion policy funds. These funds, however, are expected to be directed towards improvement of existing infrastructure. In this modelling exercise we propose to simulate the effect of investment in existing airports and ports by assuming improvements in their functionality and thus increases in the attractiveness of surrounding areas to urban, industry and commercial uses. Predefined influence radius around selected airports and ports are considered. Below we explain how airports were selected (a similar procedure was applied to select ports):

1. *Selection of the NUTS2 regions with an investment in airports greater than 10 million euros. It was assumed that investments below this threshold do not produce measurable impacts on infrastructure and, therefore, on land use;*
2. *The CORINE Land Cover was used to find the location of airports EU-wide for the NUTS2 regions selected above;*
3. *Selection of airports classified by Eurostat as 'main airports'. Airfields or very small regional airports were thus filtered out;*
4. *The Eurostat statistics on "Airline traffic data by main airport" were used to determine whether airports showed an increase or decrease trend in total number of passengers/year during the period 2003-2011 (slope of linear trend). Only those with positive trends were taken as potentially objects of investment, thus potentially leading to land use impacts.*

Each of the selected airports was then used to construct a multi-ring buffer of 5, 10, 15 and 20 Kilometres around it. The buffers are intersected with CORINE Land Cover classes 'continuous urban fabric',' discontinuous urban fabric', and 'industrial or commercial units', and a characterization of the land use composition of each airport's surroundings is obtained. By calculating the percentage of urban and industrial/commercial land within each ring buffer, it is possible to evaluate within which distances each airport might have a higher positive impact.

The funding allocated to each region can then be disaggregated among the rings. These values can be finally transformed through a normalization procedure in order to derive an indicator representing the positive impact on the suitability for urban, industrial and commercial uses. The indicator is spatially explicit through a 'locspec' layer (location specific map), and is independent of administrative regions. In LUMP, the 'locspec' layer has the effect of increasing the overall suitability of areas around which port and airport improvements are expected to exist.

The methodology followed for the investment in ports is very similar to the one described for airports. One of the differences is related to the potentially impacted land-uses, which in this case only industry and commercial areas were considered. Instead of passengers, freight statistics from Eurostat were be used to determine the importance of the ports and their growth trends.

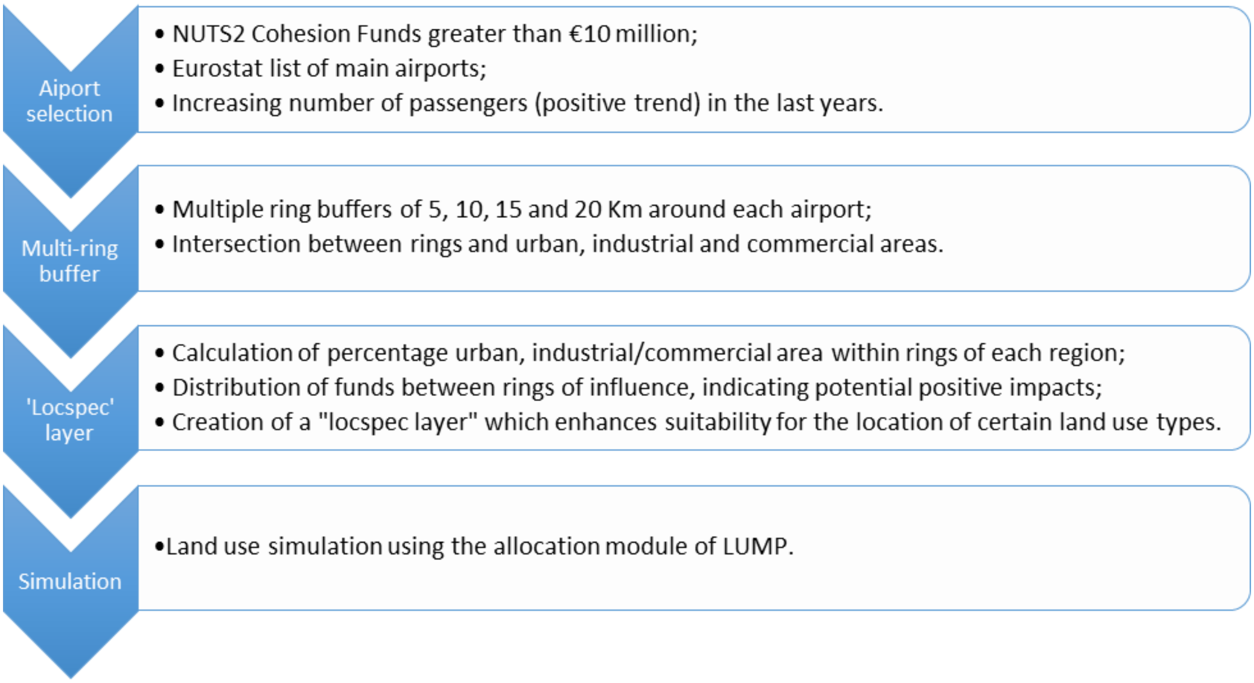


Figure 9. Overall workflow for considering investment in airports in the LUMP's modelling exercise.

3.3.3 Other investments

- *R&TD + information society*

The investment in R&TD infrastructure can lead to the development of new industrial and technological parks, physical facilities for scientific and technological research, incubators for small firms, etc. It involves the direct construction of new physical infrastructure requiring land take. The main land use classes impacted are industrial and business areas. Other than the direct impacts on land uptake, these investments can lead to new opportunities for businesses and jobs, therefore increasing the attractiveness of a city to new commuters and new residents. As a consequence of the increased attractiveness, the built-up of new residences could be fostered. The direct impacts can be included in LUMP through the 'demand module', where the land required by the society to develop its economic activities is estimated prior to the actual spatial allocation. The indirect impacts are, to some extent, already captured by the Rhomolo model. Investment in R&TD is, in fact, a particular feature of the Rhomolo.

The extra demand for new 'industrial land', as a consequence of the direct investment in R&TD infrastructure was implemented directly within the demand module of LUMP, particularly when sectoral GVA is translated in land demand (see section 3.1.1). The amount of land required for industrial uses is a component of the total industrial, commercial, and services demand. Therefore, we increased the demand for the industrial component alone through equation 9, where extra land demand is added as a direct result of the investment. The land use intensity of the investments (LUI) was empirically derived from a sample of European projects, where total investment and total number of constructed hectares is known.

$$A'_{industy,t_1} = \left[A_{industry,t_1} + \left(\frac{Investment\ in\ R\&TD\ infrastructure}{LUI}\right)\right] * TechFactor \quad \text{eq. 9}$$

Finally, the investments in information society (services and applications for the citizen and small and medium enterprises (e-health, e-government, e-learning, e-inclusion, e-commerce, education and training, networking, etc.), could lead to a reduction of the demand for space, thus acting in the opposite direction. This can be captured by a technological factor, which is defined in equation 10, and it is applied regionally. The constant is a parameter that cuts-off the technological factor to a maximum level of impact on the land use. The constant can be any positive integer, and was set to the value 50 in this study.

$$TechFactor = 1 - \left(\frac{scaled\left(Investment\ in\ information\ society\right)}{constant}\right) \quad \text{eq. 10}$$

- *Culture, urban and rural regeneration*

Measures funded by these investment categories may comprise two main typologies of interventions: 'Soft' measures (thematic priorities 58, 59 and 61), and 'hard' measures. The former are not likely to produce significant physical changes on the urban fabric. Example of measures may comprise the recovering of vacant and/or degraded buildings/quarters) and the installation of cultural and social services. These type of interventions are likely to increase the attractiveness of the intervened areas, such as urban cores, peripheral contexts or degraded neighbourhoods. 'Hard' measures target the regeneration of already existing buildings. Even though these measures might not foster any land use conversion or the conversion might happen at fine scale not capture by the LUMP, they can still be taken into account directly within the land use model.

To address these interventions as a whole, we produced a policy layer ('locspec') based on the regional allocation of funding in these categories. The layer is used to increase the overall suitability to attract residents and urban activities to established city cores in a selection of towns and cities. This is expected as well to counteract the abandonment process of urban centres which are prone to it.

- *Social infrastructure*

Investment in these categories is typically directed to the development of actual physical infrastructure that often result in visible impacts on the land surface. Funding under these thematic priorities has contributed the construction of numerous projects across Europe, including hospitals, health centres, maternities, kindergartens, and schools of different educational levels. It is, however, difficult to discern which share of the funding is directed to the renovation/requalification of existing facilities, and which share is directed to the actual construction of brand new facilities.

We do not expect that investment in these thematic priorities will create significant increases of the level of attractiveness of the territory, but rather fulfil already existing needs of the regional population. However, at the very local scale, we could imagine that the construction of major facility like a hospital or university campus could indeed increase local attractiveness of the territory to new commuters and residents, by creating new opportunities for jobs and improving the accessibility to public services and their quality. These aspects cannot be captured by LUMP because it does not capture such specific land use features, and predicting their exact location within a region would be too uncertain when working at European level.

We implemented a straightforward approach which relates the total funding allocated to a region with the extra land needed to develop the infrastructure. To do so, the funding allocated to the regions was added to the 'services' GVA term in eq. 2 of section 3.1.1. This way, we directly integrate the investment in social infrastructure in the 'land demand module' of LUMP.

4. Results

In the previous sections of this report we have looked at the definition of the scenarios and how these were technically configured in the Land Use Modelling Platform. The Reference scenario describes the future as it is likely to develop according to historical trends, current legislation, and the Europe 2020 strategy, namely in terms of the climate and energy objectives. Urbanization processes follow essentially the observed trends, consistent with a 'business as usual' approach. The Policy scenario represents the Cohesion policy and their interventions in regions, which co-finances specific thematic investments. The Policy scenario has two branches: one which simulates 'business as usual' urbanization processes (Policy-BAU), and another which enforces compact urbanization and densification of already built-up areas in order to reduce land consumption (Policy-Compact).

Comparisons will be made pair-wise, namely between the Reference and Policy-BAU scenarios and between the Policy-BAU and the Policy-Compact. The Reference and Policy-BAU scenarios are essentially similar apart from the fact that the latter takes on board the Cohesion policy. Differences between these two scenarios can therefore be attributed to the policy. The comparison between these scenarios can provide some clues on potential land use impacts of the Cohesion policy. On the other hand, the Policy-BAU and the Policy-Compact scenarios differ only in the assumed spatial planning policies for the urbanization processes. By comparing these two scenarios, it is possible to assess whether potentially negative land use impacts of the Cohesion policy could be avoided or minimized if urban land use efficiency is promoted.

The results shown later in this chapter should not be interpreted as predictions, but the result of a 'what-if' scenario exercise operated with a large modelling tool which, in itself, contains assumptions and sources of uncertainty. Notwithstanding these limitations, scenario exercises can provide insights that would not be available otherwise. The results concern only four countries: Austria, Czech Republic, Germany, and Poland. This is an interesting sample of neighbouring countries comprising both old and new Member States.

4.1 Cities and urbanization trends

4.1.1 Introduction

With its more than 500 Million inhabitants across 28 Member States, the EU is home to a great variety of cities which considerably differ in terms of size, social conditions, heritage, environmental and cultural amenities, and available transport infrastructure. Cities have always played an important role in human and social development over the History. They attract thousands of persons into a vibrant and culturally-rich environment, generating economies of scale and critical mass to foster creative interaction among people. Cities offer large labour pools, proximity between customers and suppliers, and opportunities for specialization and division of labour (Bai et al. 2012). This creates the conditions for economic activities to spur, which in turn drive the creation of wealth and jobs, which further attracts new migrants. It has been argued that urbanization processes are both a cause and a driver of economic growth (Bloom et al. 2008), but that extreme urbanization rates could also generate crowding, environmental degradation and other impediments to productivity (Bai et al. 2012).

- *Environmental concerns over excessive built-up expansion*

EU's cities continue to hold an ever increasing share of EU's population. As a result, cities keep expanding spatially. Recent assessments show that land take for built-up areas increases more rapidly than the population in many European countries (OECD 2012). Despite the important economic, social and cultural role of cities, their ever increasing size has been raising concerns over environmental degradation, such as increased pollution levels, disruption of ecosystem services and consumption of soil which otherwise could be used for purposes such as agriculture. The expansion of built-up area, in effect, constitutes an important change in the local environmental conditions and landscape, and these changes are often extremely costly to revert.

- *What is compact urban development?*

It has been widely argued that compact cities are more sustainable than dispersed and sprawled cities. Compact cities contribute to sustainability by offering important savings in terms of infrastructure and travel time, thus reducing environmental impacts due to built-up and fuel consumption. The notion of city compactness is not established definitively, and its understanding may be subjective. Moreover, there is no best urban form, but solutions should be tailored for each specific city and its geographical context. However, some characteristics are commonly attributed to compact cities. Matsumoto (2011) has systematized some key characteristics:

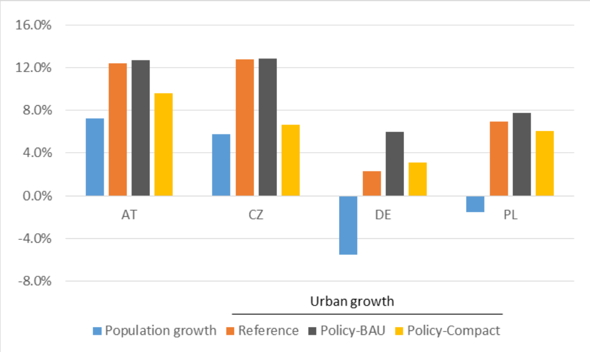
- *Contiguous development patterns. New urban development is typically located at the fringes of already existent urban areas. 'Leap-frogging' and sprawled development is avoided.*
- *Dense built-up areas. Urban land use is intensively used, with more residents and more activities per unit of built-up area.*
- *High levels of accessibility. Mass-transit linkages provides mobility within the dense urban areas and mixed land uses ensure that people enjoy fast access to services.*

4.1.2 Results of the simulation

The main aggregate results at country level are depicted in the graphs of figure 10. Results from the simulations show that the rates of urbanization are generally higher than those of population growth for all three scenarios and all countries. The "Policy-BAU" scenario generates slightly more urbanization than the Reference scenario, which can be explained by the additional incentive from the Cohesion policy, which boosts demand and helps improve accessibility levels. The Policy-Compact scenario, however, is able to effectively correct the urban growth to much more moderate levels. In figure 10 (on the right), the 2006-2030 growth of industrial/commercial/services land uses per scenario and country is shown. In Austria and Czech Republic, the Cohesion policy seems to produce a positive effect on the expansion of these land uses. Moreover, urban compact policies in these countries reduce the pressure to expand residential land use, thus decreasing competition for land. As a result, industrial/commercial/services could expand more. These kind of trade-offs and unwanted effects must be foreseen and dealt with when designing land use policies.

Because urban areas keep growing at higher rates than population in all three scenarios, the average population densities (measured as nr. of inhabitants per hectare of urban land) tend to drop between 2006 and 2030. This may indicate that some degree of sprawling is likely to continue, with more land area required per person and household on average. However, if more restrictive spatial planning policies are in force, this effect can be minimized, as the results of the simulation show (figure 11).

Another aspect of urban morphology can be captured if we count the number of urban patches. An 'urban patch' can be defined as an individual portion or urban land surrounded by non-built-up land uses such as forest, or agriculture. Increases in the number of patches over time mean that development of cities takes place by 'leap-frogging' development, as opposed to contiguous development, or edge-expansion. For all modelled countries, the number of patches increases in both Reference and Policy-BAU scenarios, sometimes substantially. However, the results of the Policy-Compact scenario show an actual reduction of the number of observed patches in 2006 (figure 12 on the left). This clearly indicates that the simulated urban expansion is done primarily by building-up in areas adjacent to pre-existent urban areas, and often filling vacant holes. As a consequence, this type of development favours the increase in the average size of the patches (figure 12 right).



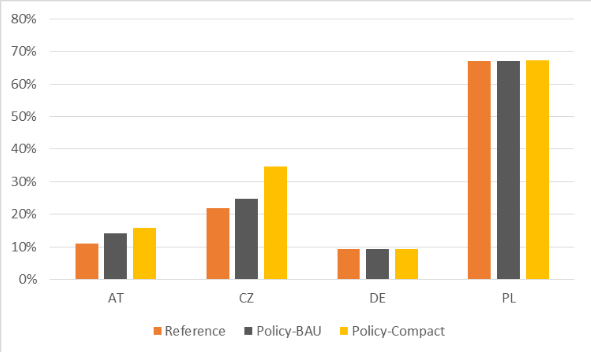


Figure 10. Left: Predicted population growth and urbanization growth between 2006 and 2030 per scenario in four EU countries. Right: Predicted growth of industrial/commercial/services land uses between 2006 and 2030 per scenario in four EU countries.

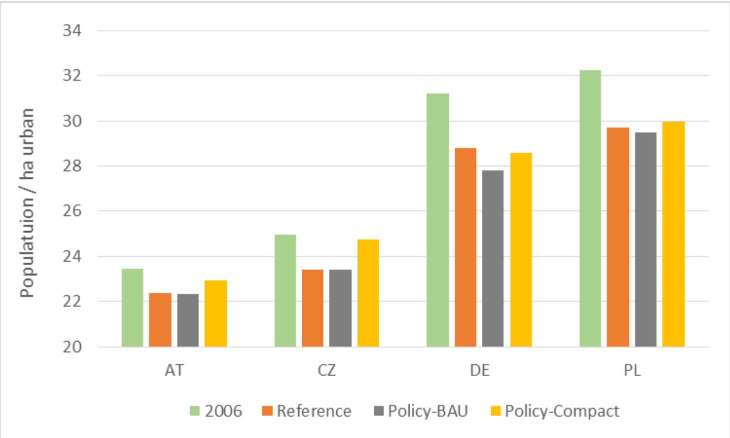


Figure 11. Population density level in 2006 and 2030 for three scenarios, in four EU countries.

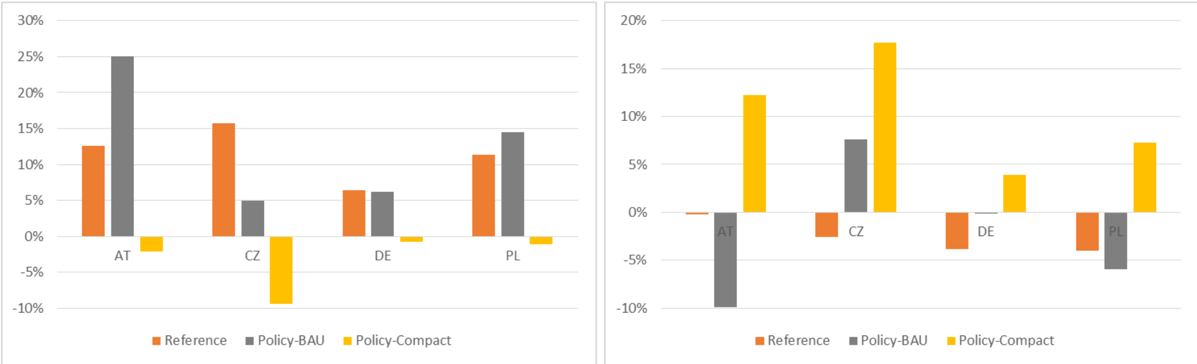


Figure 12. Left: Predicted growth of the number of urban patches in respect to 2006. Right: Predicted growth of the average size of urban patches in respect to 2006.

For illustration, figure 13 shows the absolute differences in population at pixel level between 2006 and 2030 for two scenarios. It can be seen that, in the Policy-Compact scenario, population is much more driven to city centres, whereas in the Reference scenario city centres are less attractive, and population tends to spread more. In general, the Policy-BAU scenario generates more fragmented and dispersed-like urban expansion, whereas the Policy-Compact scenario induces a more dense residential land use, less sprawl and more compact (round-shaped) urban forms. As a result, additional needs for construction are met, but leaving more space free for other non-artificial land covers and avoiding unnecessary imperviousness. Figures 14 to 16 show the Policy-Compact simulation results for Prague and Vienna, in the context of the historical records of built-up expansion.

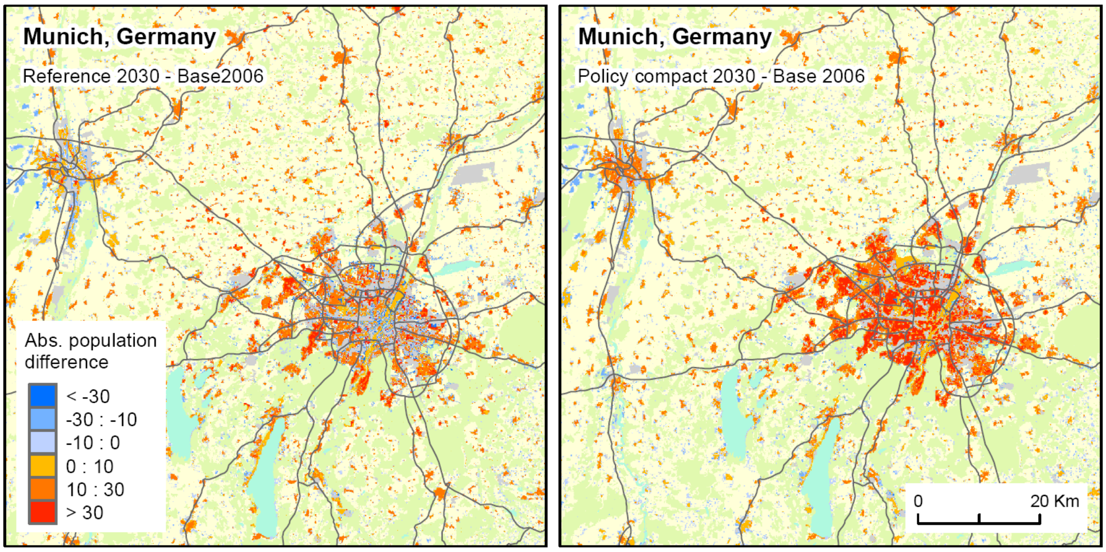


Figure 13. Predicted absolute population differences between 2006 and 2030 according to Reference scenario (left) and Policy-Compact scenario (right).

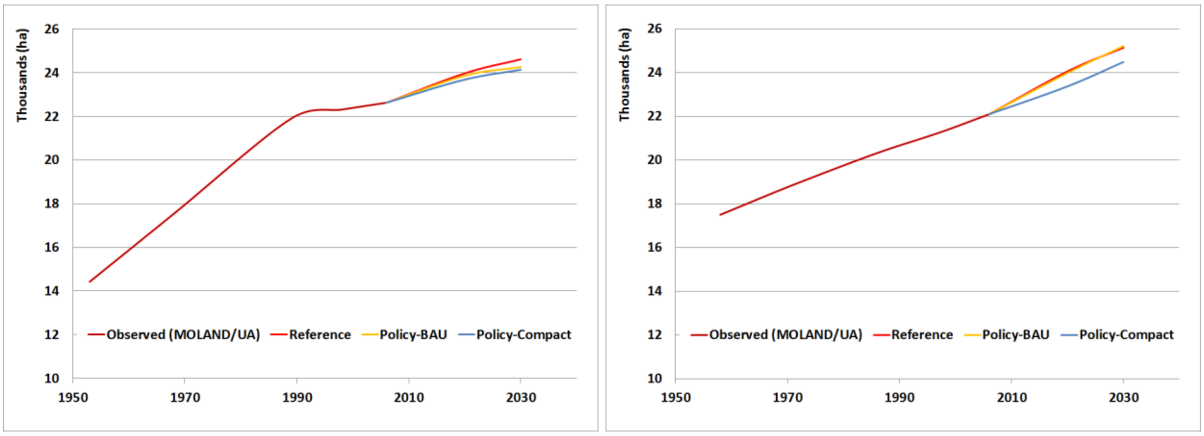


Figure 14. Total built-up growth in Prague (left) and Vienna (right). Historical time series (1950's – 2006) and simulations for three scenarios (2006-2030).

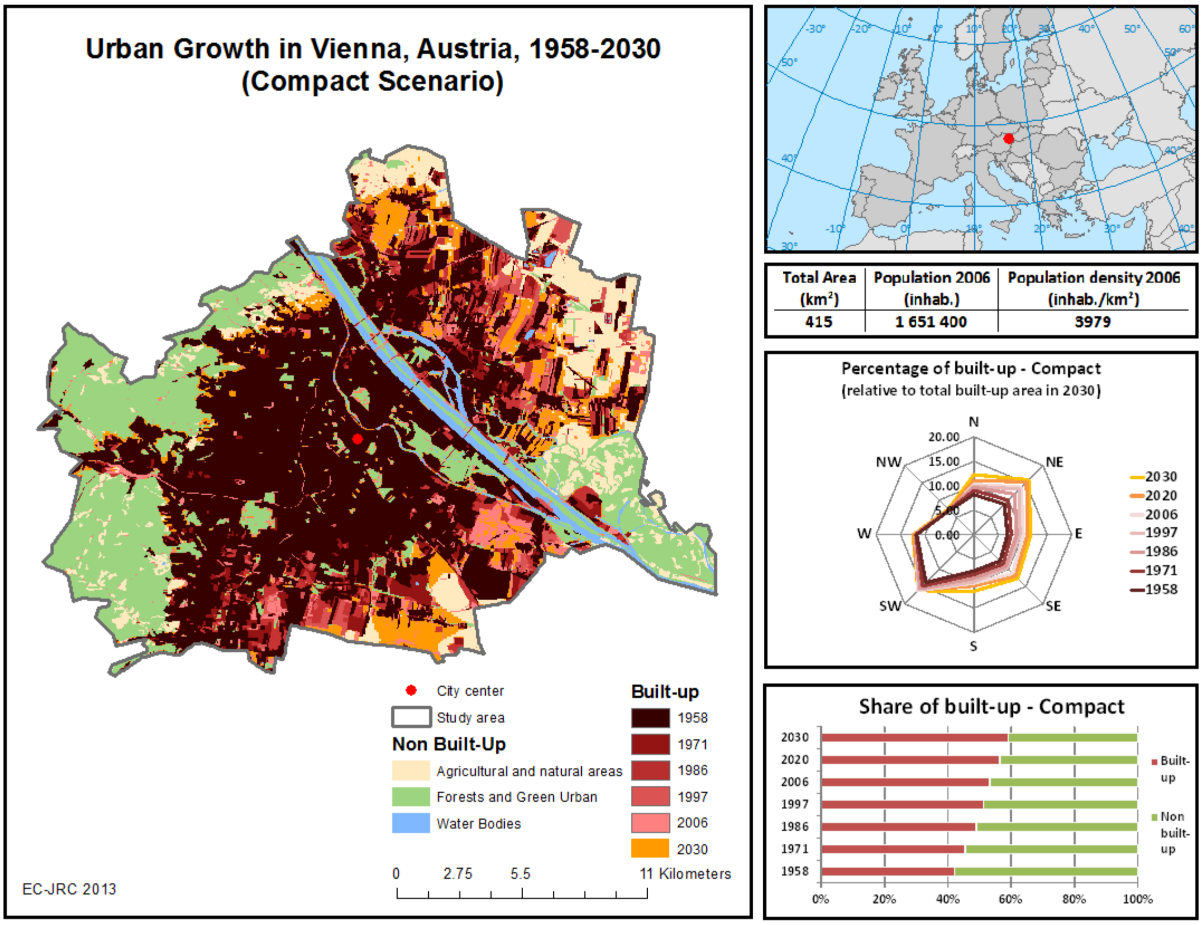


Figure 15. Insight of past and future urbanization trends in Vienna, Austria.

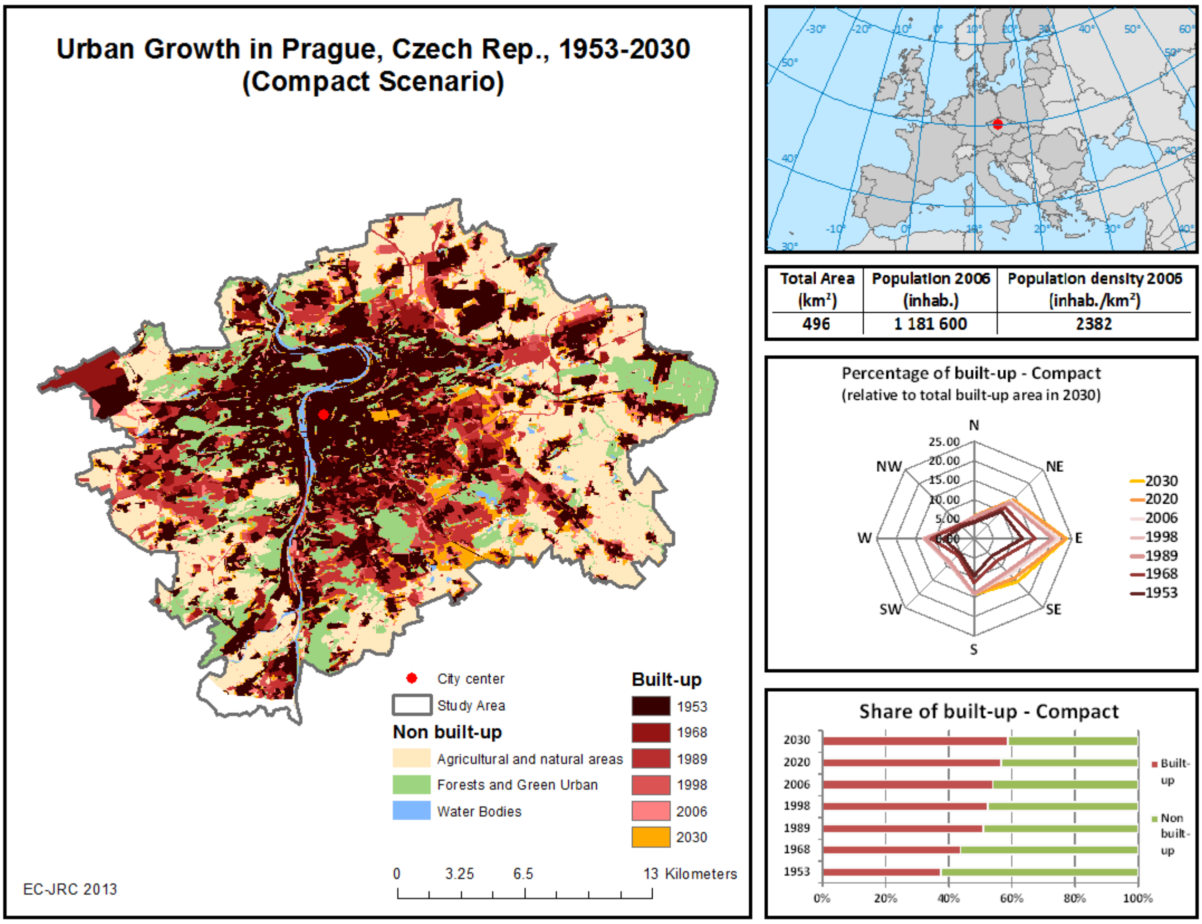


Figure 16. Insight of past and future urbanization trends in Prague, Czech Republic.

- *Accessibility and urbanization*

The accessibility changes may have profound impacts on population distributions and, consequently, on urbanization patterns. In figure 17, for all scenarios the changes in percentage of land covered by urban land-use are given for a number of categories that indicate travel-times to nearby city centres. The travel-times are based on the network used for accessibility computations, including presumed network upgrades. The included city-centres are from the 173 largest cities of the four countries under analysis[11]. When comparing the results of the BAU and Compact scenarios with the Reference scenario it is immediately clear that accessibility improvements cause a shift of urbanization closer to cities, where accessibility levels are the highest. In both scenarios this comes at the cost of more rapid de-urbanization in remote areas. The shift of urbanization towards cities is the strongest in the Compact scenario, where urban development is in fact only allowed in the proximity of existing population centres. The results

[11] The smallest city that is accounted for is Frankfurt an der Oder in Germany (population approx. 58,000).

of the BAU scenario exhibit more spread out effects of accessibility improvements on urbanization, with urban development further away from city centres.

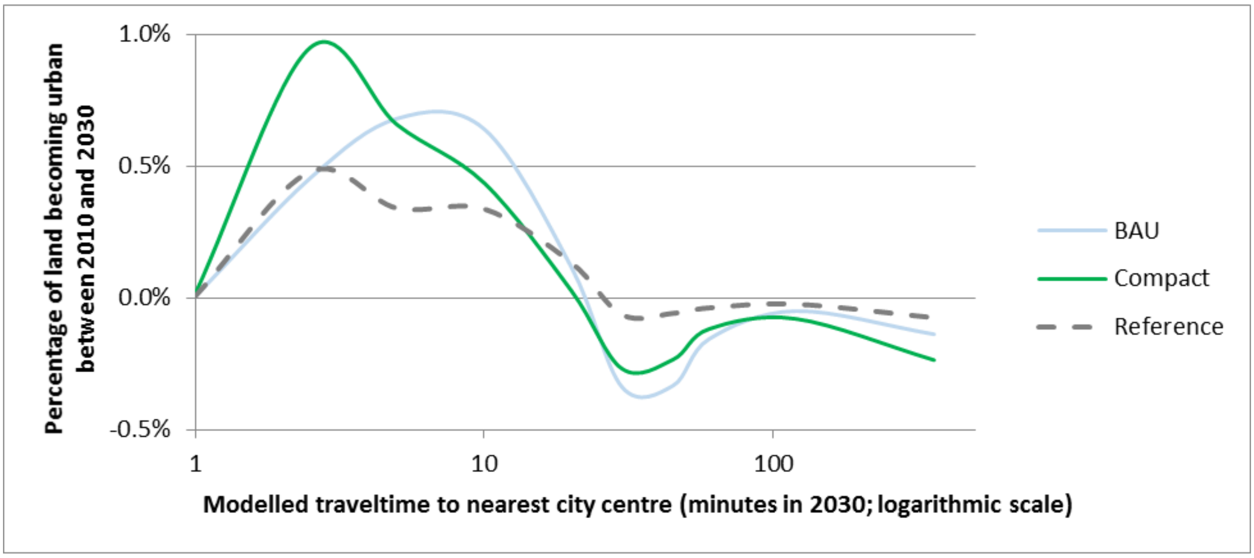


Figure 17. Changes in fractions of urban land use according to the three scenarios versus modelled travel-time to nearest city centres.

4.1.3 Bottom-line

While cities offer extremely important opportunities and benefits for individuals, business and the society as a whole, substantial spatial expansion may pose various problems. From an environmental standpoint, urban growth threatens ecosystem services, and consumes resources (land and materials) indispensable for the long term well-being of humans. Sprawled and dispersed cityscapes further accentuate these problems. More compact urbanization, on the other hand, is seen as a smart way to meet societal needs in terms of new infrastructure while minimizing the consumption of soil.

Analysis of the cities in Europe nowadays shows that there is a great diversity of urban morphologies. In general, bigger cities tend to be denser. And cities in certain European countries tend to be overall denser than in other countries. Historical background, geography, culture, spatial planning policies, and other mechanisms may underpin the observed differences. In addition, in denser cities, the per capita impermeabilization of soil is reduced significantly – that is to say, the scarce soil resource is used more efficiently.

Three scenarios of urban growth were modelled using the Land Use Modelling Platform. The trends and the simulation results indicate that some degree of city sprawling is likely to continue, in particular in regions where population and economic growth are expected.

Moreover, financial incentives from Cohesion policy and other EU programs could induce some additional land take through direct investments in infrastructure and more indirect positive effects on the economic growth (leading to higher demand). The land use simulation exercise conducted for Austria, Czech Republic, Germany and Poland shows that, by 2030, some of these effects can, however, be offset if adequate urbanization policies are put in place. As such, in what regards urbanization, economic growth and Cohesion funds do not necessarily have to be detrimental to the environment as long as recommendations on urban compactness are taken seriously by policy making at different territorial scales.

4.2 Ecosystem services

4.2.1 Introduction

Ecosystems are essential to human life. They provide a diverse range of services, from the clean water we drink to the air we breathe, from the pollination of crops that end on our dinner table to the sense of place we experience from a back-pack trekking adventure in the mountains. These so-called ecosystem services are vital to our well-being. The continued and sustainable provision of ecosystem services and the protection of natural capital are increasingly recognized by EU policies as a strategy to cope with potentially changing conditions in the future.

Biodiversity underpins the delivery of ecosystem services so it is crucial to ensure the long term survival of species and habitats. One way to protect natural capital is the conservation of biodiversity using a network of nature reserves, such as the EU's NATURA 2000 network. Ecosystem functions and their services do not stop at the borders of protected or natural areas and the synergy between them has been demonstrated to be directly correlated with a good biodiversity status (Maes et al., 2012). Besides that it has been estimated that green infrastructure deliver multiple ecosystem services.

A spatially explicit synthesis of the current provision of ecosystem services, an analysis of their trade-off and of their relationship with green infrastructure (GI) can underpin decision about where do investments in GI lead to the largest net benefits.

4.2.2 Current provision levels – the Total Ecosystem Service Index (TESI)

Historically, people used to live in areas with a high flow of ecosystem services. Fertile soils in lowland areas with extended portions of woodland to provide timber and nearby rivers to ensure water supply and transport were to best places to settle. Economic growth based on fossil fuels has decreased our dependency on nature to deliver services and has favoured a shift toward maintaining a few provisioning services such as food and timber production. This shift happened often at the cost of, in particular, the many regulating services. Agricultural intensification, for example, is partially responsible for the loss of pollinator species which, in turn, are essential pollen vectors to maintain production levels (Zulian et al. 2013). As a result, ecosystem services are, in the 21st century, mainly delivered in regions with a high share of natural/rural areas, mountains, wetlands and forests. Also regions with natural coastal zones prove to be key providers of ecosystem services.

Regions where land is intensively used are expected to provide fewer services. This is evident from Figure 18. This figure summarizes available data at the regional scale using a single, composite indicator that measures the aggregated capacity to deliver ecosystem services (Maes et al. 2011; Maes et al. 2012). This indicator is called TESI, which stands for total ecosystem services index.

The TESI index entails 13 single indicators (Table 8, Figures 1-4 in Appendix 2), each approximating the capacity to provide in a single ecosystem service. Four of these reflect provisioning services: the goods or products we obtain from ecosystems. Eight indicators refer to regulating services: the benefits we obtain from an ecosystem's control of natural processes. One indicator refers to a cultural service: recreation, which is a non-material benefit obtained from ecosystems. Each indicator approximates the capacity of ecosystems to supply a single service. Next, these indicators are normalized between 0 and 1. Finally, the TESI index (Maes et al. 2011; Maes et al. 2012) is calculated as the average value.

Figure 19 helps explain why some regions score higher on the TESI scale than others. Regions where a large share of land is taken for crop production and urban development have less land left where ecosystems such as forests and wetlands provide multiple, regulating ecosystem services. In contrast, regions with a medium or high TESI have a wider and more balanced array of ecosystem services relative to regions with low TESI. The difference between medium and high capacity is explained by the different level of productivity among natural and semi-natural ecosystems, which, in turn, is related to climate. Wetlands and forests are the more productive systems and generate higher levels of ecosystem services than for instance grass- or shrub-land.

- *Green infrastructure and ecosystem services*

Green infrastructure (GI) comprises all natural, semi-natural, and artificial networks of multifunctional ecological systems at all spatial scales. The share of GI in each NUTS 2 region of the EU is depicted in figure 20. Across Europe, there is a strong, positive relationship between the area of a region covered by green infrastructure and its capacity to provide multiple ecosystem services. Investing in green infrastructure is thus expected to enhance ecosystem services. The next step is to identify those regions where such investments are cost-effective. This means developing a network of green infrastructure across regions that supports healthy ecosystems able to sustain green economy and provide essential goods and services, while it helps achieving targets with respect to sustainable agriculture and forestry, climate adaptation, resource efficiency and biodiversity.

Figure 19 demonstrates that even in regions where land is predominantly used for growing crops, many other ecosystem services can still be present. This provides a good basis for building a green infrastructure with a view of delivering multiple services. A recent study for the UK demonstrated indeed that converting some comparatively small amount of land from agriculture use into open-access recreation yields a relatively modest loss in farm produce value while at the same time generating a much bigger value from increased recreation (Maes et al. 2012).

Table 8. Ecosystem services which are included in the assessment with the proxy indicator used and reference to the map in the annex.

Ecosystem service type	Ecosystem services	Example of the delivered service	Proxy indicator (unit)	Map*
Provisioning	Food production	Vegetables and fruits from cropland	Percentage agricultural land (%)	Fig. 1, 1-A
	Livestock production	Meat, wool and milk from cattle	Livestock densities of sheep, goat and cattle (number ha^{-1})	Fig. 1, 1-B
	Water production	Water supply from lakes	Percentage land covered with surface water (%)	Fig. 1, 1-C
	Timber production	Timber harvest in forests	Timber standing stock (m^3 ha^{-1})	Fig.1, 1-D
Regulating	Air quality regulation	Urban trees capture fine dust	Deposition of pollutants on trees (cm s^{-1})	Fig. 2, 2-A
	Climate regulation	Forest store carbon	Carbon sequestration in vegetation (ton ha^{-1})	Fig. 2, 2-B
	Water regulation	Soils store water and prevent fast runoff which causes flooding	Water infiltration in soil (mm)	Fig. 2, 2-C
	Water quality regulation	Wetlands capture and process pollutants	Nitrogen removal from surface water (ton km^{-1})	Fig. 2, 2-D
	Pollination	Bees are essential pollen vectors for many plants, thus enabling fruit production	Pollination potential (index between 0 and 1)	Fig. 3, 3-A
	Erosion control	The roots of trees prevent soil erosion	Soil retention (ton ha^{-1})	Fig. 3, 3-B
	Soil quality regulation	Fertile soils increase agricultural production	Soil organic carbon (%)	Fig. 3, 3-C
	Coastal protection	Dunes protect against high water	Protection capacity (index between 0 and 1)	Fig 3, 3-D
Cultural	Recreation	Mountains are beautiful place to hike and camp; green urban areas, peri-urban forest and heterogeneous agricultural landscapes are places for outdoor activities	Recreation potential (index between 0 and 1)	Fig. 4, 4-A

*Individual maps for each ecosystem services in Appendix 2.

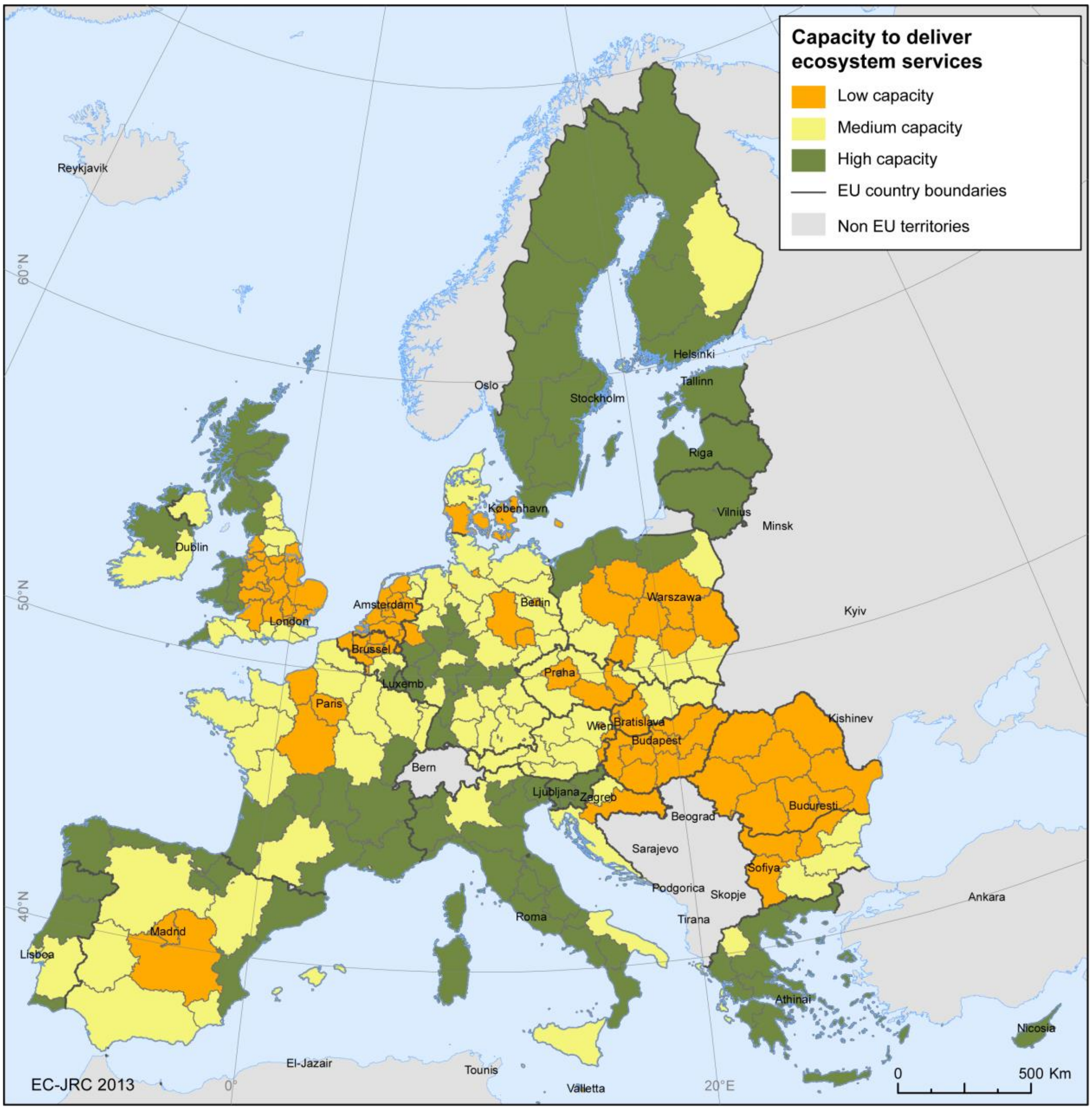


Figure 18. Differences in the regional capacity of ecosystems to deliver services. Low capacity is assigned to regions where the TESI index is lower than the 25th percentile; high capacity is assigned to regions where TESI is higher than the 75th percentile.

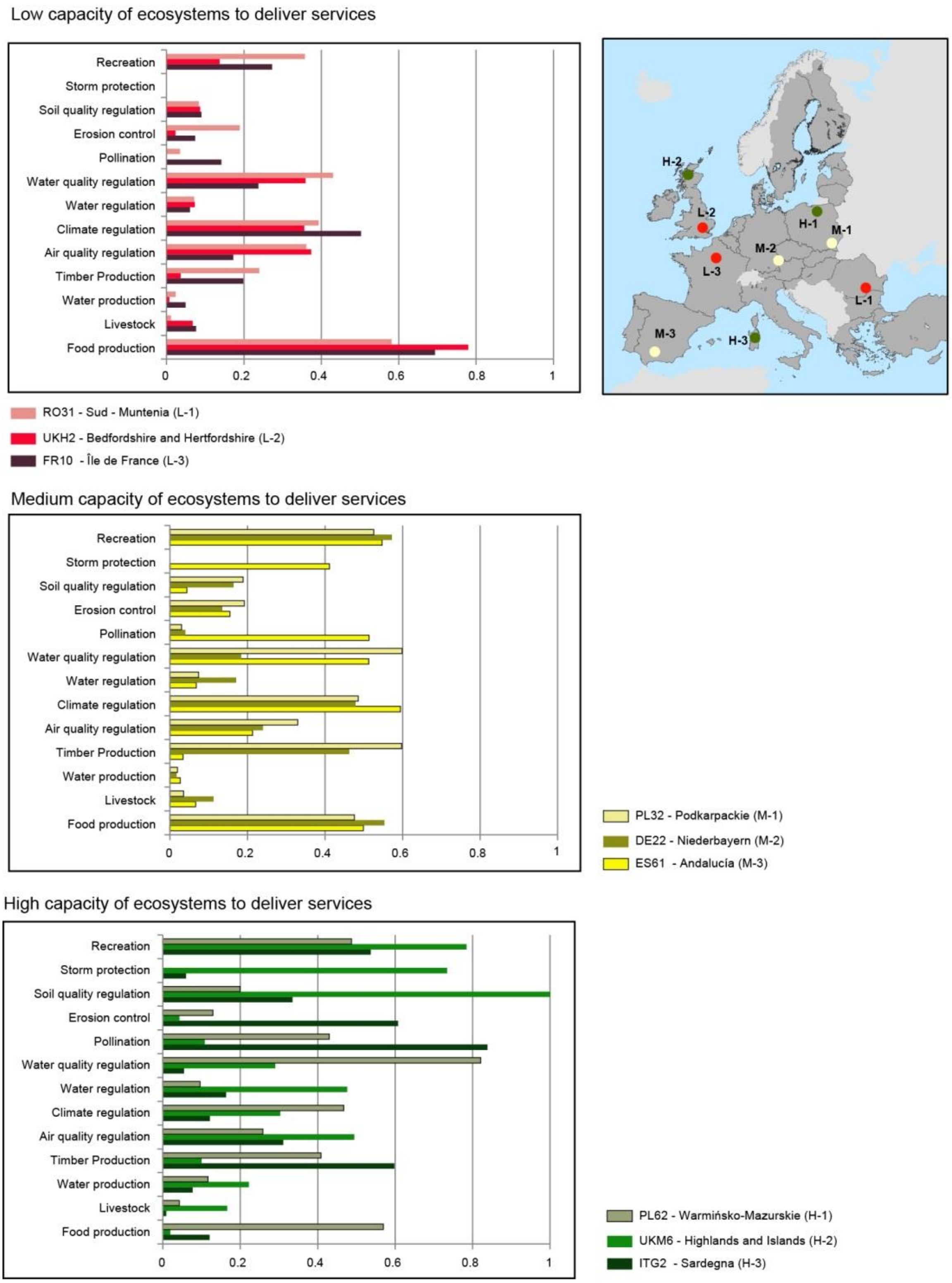
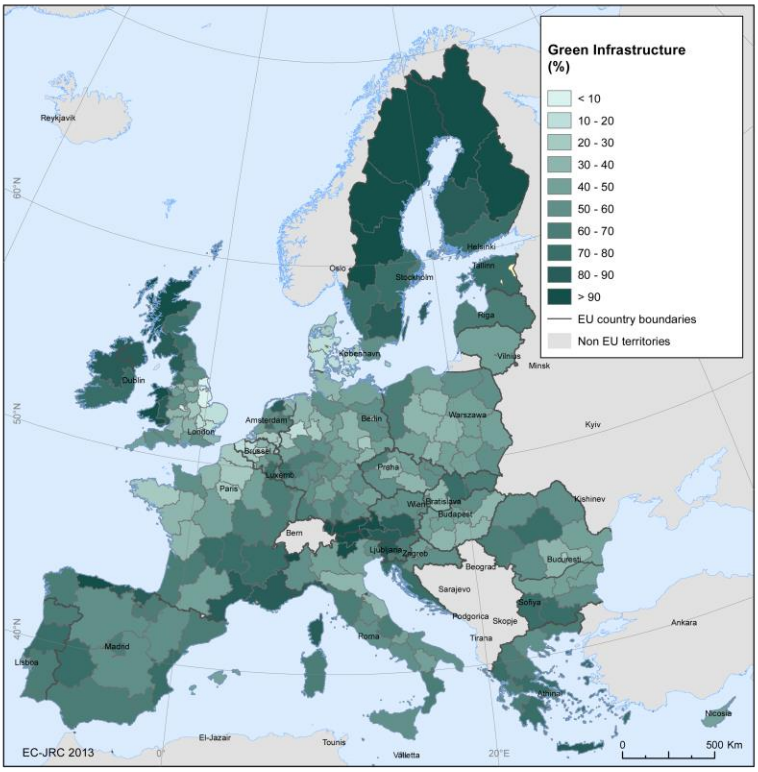


Figure 19. Ecosystem services delivery in selected regions with low, medium or high capacity to deliver ecosystem services.



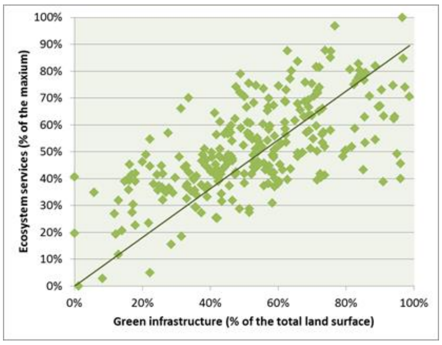


Figure 20. The share of green infrastructure at NUTS 2 level (as a percentage of the surface area) and the relation between the percentage green infrastructure and the total delivery of ecosystem services (as a percentage of the maximum delivery).

4.2.3 Air quality: A modelling exercise for future provision

Air pollution is an important environmental concern across cities in the EU. Much progress has been made as a result of EU legislation which targets the reduction of emissions of air pollutants such as nitrogen and sulphur oxides or heavy metals. Importantly, also the maintenance and development of green urban areas can be part of an integrative strategy to help increase air quality in European cities. Trees reduce temperatures in cities by evaporating water and they remove air pollutants and particulate matter via their leaves through dry deposition. Urban trees, green areas and forests surrounding cities have the capacity to remove significant amounts of pollutants hereby increasing environmental quality and human health.

The removal of air pollutants and dust is a so called ecosystem service, which is provided by urban parks and forests for free. Computer models which overlay observed data of air quality with green urban and peri-urban areas can be used to quantify the amount of pollutants that is removed from the atmosphere. The economic value of air pollutant removal could then be calculated by estimating the reduced costs of pollution to society that are not accounted for in the market price of polluting goods and services like electricity and transportation.

Three types of data are used to assess air quality regulation in Europe. Firstly, a map of pollutant concentration is calculated based on air quality measurements across Europe. The mapping considers spatial data which reflect sources or sinks for air pollution such as the road network, traffic volumes, different types of land use, population density. Furthermore, factors such as elevation, distance to sea, temperature and wind speed also influence the spatial concentration of pollutants. Next, a model determines how much of the pollutants is removed by urban vegetation using mapped removal rates. Population data is finally used again to assess exposure to air pollution.

NO_2, or nitrogen dioxide, is a prominent air pollutant which is released during the combustion of fossil fuels. Figure 21 presents a map of downscaled average concentration of NO_2, which is also a precursor of ozone, in Europe in 2010. Moreover it illustrates how urban green areas contribute to NO_2 removal and to which extent urban population is exposed to air pollution. Pollutant concentration is normally higher where human activity is more intense, such as intensively urbanized areas and transport corridors. We also show zooms for three European capital regions. The unit of analysis was the Large Urban Zone, which includes peri-urban forests and natural vegetation. The estimated removal of NO_2 differs from city to city, and depends chiefly on the amount of land covers such as forest of green urban.

The total pollutant removal by trees in Wien, München and Warszawa was estimated at 3456, 2293 and 5045 ton/year, respectively (figure 21). The pollutant removal represents avoided costs of social, environmental and economic damages caused by NO_2. The urban areas considered in this example are densely populated areas which result in a high share of exposure to high pollutant concentration, especially in Wien and Warszawa. Differences in absolute removal per year reflect the size of the area under analysis and the proportion of tree coverage. If the estimated total removal of NO_2 in each city is normalized by the respective area, then, on average, NO_2 removal would be greater in Warszawa, with 0.00585 ton/year/ha, whereas in Wien and München removal rates would be situated at lower levels, 0.00376 and 0.00425 ton/year/ha, respectively.

For an assessment of scenarios of air quality regulation in Europe in 2030 we focused on three land use change simulations: a Reference scenario and two policy scenarios (Policy-BAU and Policy-Compact). The Reference scenario does not consider the investment in regions by the European Cohesion Policy. Moreover, the urbanization follows a 'Business As Usual' (BAU) trend, with no particular restrictions to urbanization and potentially sprawling processes. The Policy-BAU scenario does include the Cohesion Policy investment in regions up to 2020, and their expected land use impacts. Like the Reference scenario, the urbanization is assumed to follow a BAU trend. Finally, the Policy-Compact scenario includes the investment in regions, plus certain urban planning measures are simulated in order to promote city densification and more compact urban morphology. It is further assumed that certain amount of investment is channelled to promote the conservation and expansion of forested and green urban areas in metropolitan areas. The simulations were carried out for four countries, namely Germany, Poland, Czech Republic and Austria.

Figure 22 shows the results of the impact of the three land use simulations on air quality regulation. For all countries, the removal rate of NO_2 is estimated to decrease, sometimes down to -5%, in the period 2010-2030. According to the simulations, the Policy-BAU scenario can accentuate this trend (Poland and Czech Republic). However, for all countries, the Policy-Compact simulation off-sets considerably and consistently the potentially negative impact of land use changes in the period 2010-2030. In fact, the measures considered in the Policy-Compact scenario, such as controlling urbanization processes (thus reducing the need for transportation and fuel consumption), while preserving and/or expanding the extent of forested and green areas, had a positive effect in the estimated removal rate of NO_2. It should finally be mentioned that the capture of air pollutants depends as well on species selection, design and management. These more detailed aspects were not taken into account in the simulations, but they should be considered at mores operational scales.

Population exposure to high concentration of pollutants remains a problem in European cities since increasing population density and economic activities act as an important driver of atmospheric pollution. Increasing the canopy cover of trees within and around cities will improve pollutant removal but these measures should go hand in hand with the continued implementation and monitoring of air quality legislation and associated environmental policies.

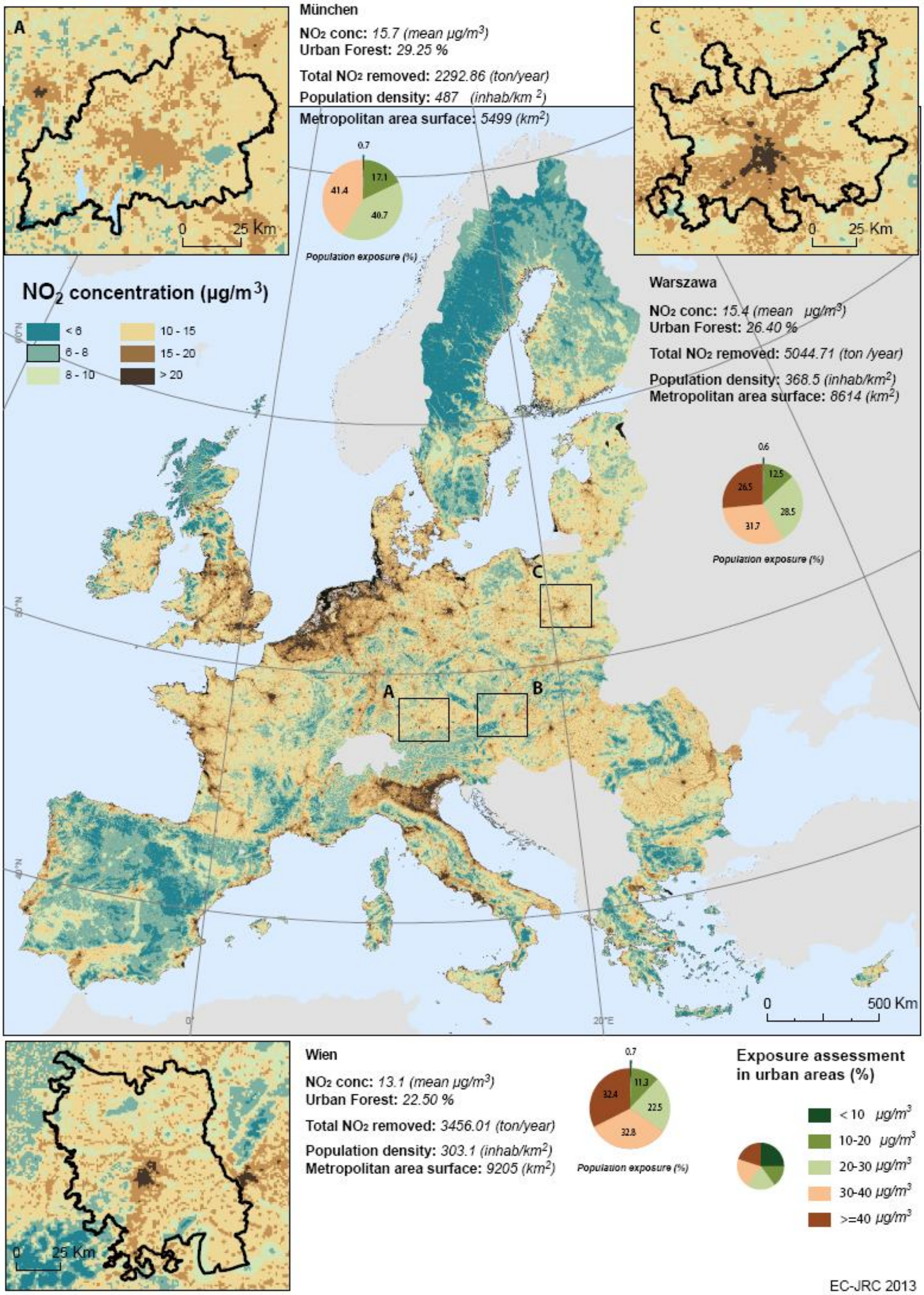


Figure 21. Downscaled concentrations of NO2 and related removal rates and population exposure in 2010.

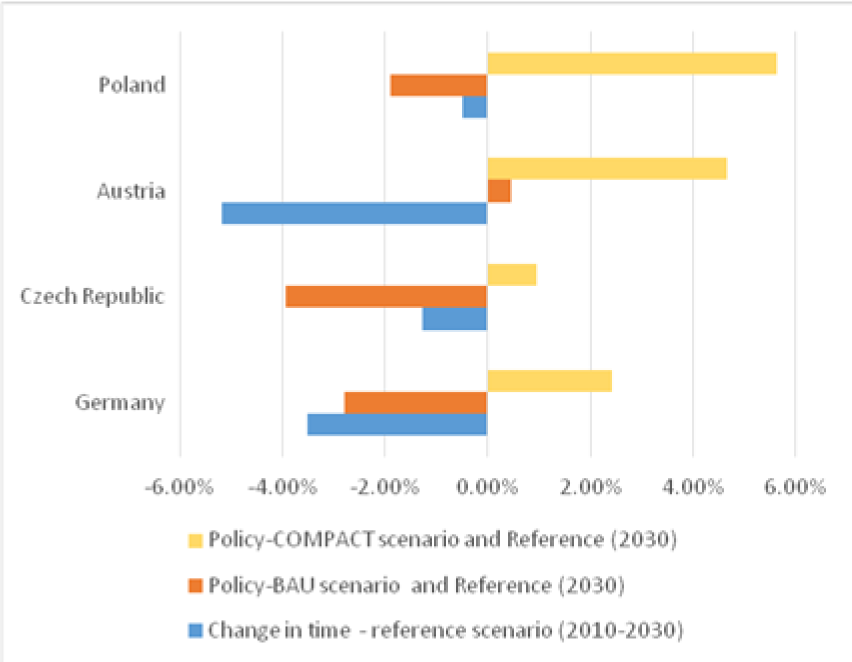


Figure 22. Relative differences in the estimated removal rate of nitrogen dioxide by urban green areas and trees in metropolitan areas of Austria, Germany, Czech Republic and Poland, in relation to a base year 2010 (blue bar), between Policy-BAU and Reference in 2030 (orange bar) and between Policy-Compact and Policy-BAU in 2030 (yellow bar).

5. Discussion and way forward

5.1 Overall remarks

With an approaching new Cohesion policy programmed for the period 2014-2020, the JRC was asked to produce a pilot ex-ante assessment of the potential land use and environmental impacts of the expected investments in regions. We started off by looking at the expenditure categories (thematic priorities) of the previous programming period (2007-2013) and identifying specific interventions that were funded. This allowed us to map specific expenditure categories against their potential land use impacts. The Land Use Modelling Platform (LUMP) was then used to simulate future land use changes taking into consideration the implementation of the Cohesion policy, and other macro land use drivers such as the economy and demography. We have created two branches of the Policy scenario. One in which future urbanization is not restricted by any specific spatial planning instruments, and another in which the urbanization is constrained by policies that encourage more efficient land consumption and compact urban development. The results of these two simulations were compared to the results of a scenario in which the main macro drivers are similar, but the Cohesion is not implemented.

The tentative results of this exercise provide some first insights of the trade-offs between physical capital investment, development, land use changes and their environmental impacts. The comparison of the different scenarios and options allowed us to retain that the Cohesion policy, as any other investment policy, can induce additional land take through a) direct investments in infrastructure and b) indirect positive effects of economic growth (leading to higher demand for land). Some of these effects can, however, be offset if adequate urbanization policies are put in place. As such, economic growth and Cohesion funds can but do not necessarily have to be detrimental to the environment as long as smart spatial planning policies and recommendations are considered at different territorial scales, and more efficient land use and investment in green infrastructure is encouraged.

The work developed to assess land use and environmental impacts of the Cohesion policy encompassed a number of conceptual, methodological and technical challenges that were overcome during the past year. In order to make this assessment possible, we could mention technical improvements to the LUMP (e.g. dynamic population allocation module), linkages with external models (e.g. Rhomolo), and the establishment of a framework to assess the response of ecosystem services to scenario-driven land use changes. All these developments help pave the way for even further modelling improvements, and more complete and better assessments of EU policies. In the subsections below, we will look with more detail into the concrete aspects that we find important and necessary to develop in the short to long term.

5.2 Proposed improvements to the LUMP model

In the coming years, work will be initiated to further improve LUMP as a comprehensive tool to evaluate the effects of various policies on land-use and associated indicators that are relevant for society, the environment and the economy. Summarily, LUMP uses economic rationale and particular optimization methods to incorporate various sectoral expectations on future land demand into land-use projections on a very fine spatial resolution. The end goal of LUMP development should be a model that closely approximates true economic land-conversions, explicitly modelling all costs and benefits that are internalized in the land-use change process, while broadly taking into account both the internal and external costs and benefits of land-use changes when evaluating model results. Different aspects of planned LUMP development are geared towards that end goal; other aspects deal with more immediate technical challenges and policy questions. Lastly, a number of efforts need to be undertaken in order to better underpin the validity of the model approach, variable selection and model reliability. In the following sections we discern short-term plans, for which necessary data is available, and long-term plans, which will require data sources that are currently unavailable in the LUMP team.

- *Short to medium term*

One of the most important changes that is planned for LUMP on the short term concerns updated CAPRI claims. This work eventually aims to include CAPRI claims on the smallest spatial scale to which those claims are being disaggregated, and creating feedback mechanisms concerning available land from LUMP back to CAPRI. On the one hand, using smaller regions in which CAPRI demands are imposed will make LUMP more consistent with CAPRI outputs; on the other hand, using feedback from LUMP may increase the accuracy of CAPRI projections. Another important planned improvement is to start integrating air quality indicators in the LUMP model. To do so, assumptions on activity levels have to be extended further from the population allocation model already in place. By integrating air quality levels in the model, the modelling platform gains a useful indicator necessary to understand the full range of external costs of land-use change and also opens up possibilities to evaluate air-quality improvement policies that aim at behavioural changes and structural measures. Another important improvement extends the modelling work made during 2013. During that work, regionally important trends such as decreasing household sizes and increasing consumption of land per capita have been incorporated in the population allocation model. In addition, regional land-use claims and discrete urban land-use allocation methods have been merged. The link between regional land-use claims, the population allocation module and the discrete allocation methods needs, however, to be redesigned; preferably with additional emphasis on potential endogeneity between land consumption per capita and regionally varying levels of urbanization.

Other works that are considered to be done on the short term:

- *a study is under way that aims to underpin the conversion cost matrices currently used in the model with either empirically obtained probabilities or costs derived from an economic rationale; this serves to more closely link the model to real processes; furthermore;*
- *green urban areas are incorporated in the model as a distinct static class, which is useful to more accurately assess the quality of ecosystem services in urban areas;*
- *ecosystem service indicators will be integrated in the modelling framework, which is useful to generate results faster and with more flexibility;*
- *water scarcity levels are included as a suitability factor for particular land uses, which is useful to better assess direct and indirect effects of water policies;*
- *border effects on cross-border accessibility levels are considered to be included in the model. Including such border effects is useful to be able to evaluate the potential effects of international economic integration policies on future urban land-use patterns.*

Lastly, a number of technical improvements will be implemented in the model as well. Changes to improve the user-friendliness of the model are under way. These should ultimately aid the speed of the modelling process. Furthermore, the relatively small regions enclosing major cities are found to be too limiting for the land-use allocation process, and therefore the geography of regions into which individual urban, industrial and forest claims are imposed will be reconsidered.

- *Long term*

One of the most substantial improvements planned on the long term is no doubt the proposed coupling between resources used in product life cycles and the LUMP model, which should serve to better understand for example land-use implications of product interventions and supply-side constraints of product consumption. Although the potential products of such a coupling are very promising for understanding the environmental impacts of behaviour-changing and end-of-pipe policy measures, data availability is critical here and the production of data concerning life-cycle resource dependencies is still under way. Another substantial improvement planned on the long term is to fully adapt an economic rationale in the land-use model – based on true utilities, true costs and true willingness to pay data. This would better underpin the rationale of the model, and would allow inductive approaches in the model to evaluate the effect of policies on land-use behaviour (i.e., not starting from an assumed overall effect, but from a clearly defined added cost or financial incentive in the utilities of particular land-use conversions). In this improvement, data availability on financial aspects of land-use conversions is also critical, and the necessary data is currently unavailable on a European level.

Other planned improvements to the model are:

- *feedback mechanisms with the Rhomolo economic model, in order to have more accurate industrial land demand forecasts;*
- *modelling a wider range of urban activity levels in order to compute more accurate air quality levels, better assess land suitabilities for urbanization, and potentially to compute various social indicators that deal with urban activity levels and urban activity diversity;*
- *including public transport accessibility as an explanatory factor for urbanization, which is useful to more accurately model effects of EU initiated public transport development;*
- *estimating transport use within the model to more accurately compute air quality levels, and to assess transport consumption and potential congestion levels as a societally relevant effect of land-use changes.*

5.3 Research agenda for the ecosystem services mapping and modelling

In the ecosystem services framework, the spatial interaction and synergies between ecosystems, their services and benefits to the society are assessed (Maes et al. 2012; Maes et al. 2013). To improve the capacity of the JRC to study and evaluate the impact of EU policies on the ecosystem services, we plan to extend Land Use Modelling Platform in order to dynamically map and assess the future provision of an increasing number of ES. We also plan to further develop indicators for certain ecosystem services whose evaluation can be improved with currently available data and knowledge, as well as start moving towards a more robust analysis of trade-offs using ecosystem service valuation methodologies. In addition, we will focus on urban areas and their ecosystem services.

The Total Ecosystem Service Index (TESI) is a composite indicator that measures the aggregated capacity of regions to deliver ecosystem services. In the current version of the index, only four indicators are dynamically linked to the LUMP. Table 9 shows the state of the indicators that participate in the TESI. As mentioned, part of our research agenda will be dedicated to develop four new indicator and build dynamic linkages with the LUMP. This is a mandatory effort to estimate spatial trade-offs between ecosystem services according to different policy options at the European level.

There is also a great need to focus on large settlements and agglomerations because they are the greatest 'basins' of potential beneficiaries of ecosystem services. Cities and their inhabitants are dependent on the ecosystem services generated primarily beyond their boundaries, but it has been also demonstrated that inner-city areas can also be providers of certain ecosystem services, depending on their geographical characteristics and on how the territory is managed (Bolund and Hunhammar 1999; McFrederick and LeBuhn 2006; Dobbs et al. 2011; Larondelle and Haase 2013). To cover aspects such as these, we will focus on the ecosystem services provided by urban territories, and further develop indicators of air quality regulation (by taking into consideration a larger list of pollutants), recreation and cultural ecosystem services which are typically associated with urban areas. On top of this, we will consider other services not directly related with nature but with human well-being (education, health care, etc.).

Benefits and values related to human well-being and their economic valuation are as well an important component of the ES framework (Smith et al. 2011; Confalonieri and Effen 2011). "Healthy ecosystems have the full potential to deliver their functions and hence, where access and demand by humans exist, they might also deliver services to humans" (Maes et al. 2013: 20). Key policy questions are: How do ecosystem services affect human well-being? Who and where are the beneficiaries? Are socio-economic inequalities related to ecosystem service benefits provision? As such, the ambition is to investigate the spatial relationship between socio-economic deprivation and the provision of ecosystem services using a composite measure of human well-being (Tell et al. 2005). In the short to the medium term, we will also focus on ways to carry monetary evaluation of services delivered by forest, semi-natural vegetation and urban green infrastructures.

Table 9. Input data for the TESI and current state of development

Inputs	Example of the delivered service	Indicator (unit)	State
Air quality regulation	Urban trees capture fine dust	Deposition of pollutants on trees (m s^{-1})	Dynamically linked with the LUMP
Pollination	Bees are essential pollen vectors for many plants, thus enabling fruit production	Pollination potential (index between 0 and 1)	
Coastal protection	Dunes protect against high water	Protection capacity (index between 0 and 1)	
Recreation	Mountains are beautiful places to hike and camp; green urban areas, peri-urban forests and heterogeneous agricultural landscapes are places for out-door recreational activities	Recreation potential (index between 0 and 1)	
Water supply	Water supply from lakes	Percentage land covered with surface water (%)	To be linked with the LUMP
Water quality regulation	Wetlands capture and process pollutants	Nitrogen removal from surface water (ton km^{-1})	
Green Infrastructure	Green infrastructure connectivity index	%	
Conservation status			
Food production	Vegetables and fruits from cropland	Percentage agricultural land (%)	
Livestock production	Meat, wool and milk from cattle	Livestock densities of sheep, goat and cattle (number ha^{-1})	
Timber production	Timber harvest in forests	Timber standing stock (m^3 ha^{-1})	Indicators under development
Climate regulation	Forest stored carbon	Carbon sequestration in vegetation (ton ha^{-1})	
Erosion control	The roots of trees prevent soil erosion	Soil retention (ton ha^{-1})	
Maintenance of habitat quality	Maintaining habitats for plants and animals life and reproduction	Habitat degradation (index between 0 and 1)	

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Appendix 1: Non-technical description of the LUMP model

1. Non-technical summary

The changes in the cover and use of the surface of the earth depend on natural processes and are, at the same time, shaped by demographic, economic, cultural, political, and technological drivers. A land-use/cover model can help to understand and interpret the complex interactions between the bio-physical and human factors that influence land use/cover dynamics. In addition, it can be used as a tool to assess environmental consequences of policies with direct or indirect spatial impacts.

The Land Use Modelling Platform (LUMP) has been developed by the Institute for Environment and Sustainability (IES) of the Joint Research Centre (JRC) to support the policy design of different services of the European Commission. It aims to provide a comprehensive, consistent and harmonized analysis of the impacts of policies and/or specific proposals in the context of environmental and socio-economic changes in Europe. LUMP is based upon the combination of a spatially explicit land use model and its linkages with other modelling activities in thematic fields such as hydrology, agriculture, economy, forestry, etc.

The Land Use Modelling Platform has a modular structure and is organized in three main components: 1) the land demand module; 2) the land allocation module; 3) the indicator module. The first module is where demand for different land uses is defined. Different drivers and algorithms are used to compute demands for each land use. A range of maximum and minimum demand for each land use, for each year and for each NUTS2, is passed onto the second module, the land allocation module, which is the core of LUMP. This second module is responsible for allocating the yearly projected quantities of land in space (at pixel level). This module is also called EUClueScanner (EUCS) and was developed in collaboration with DG Environment. It is based on the dynamic simulation of competitions between land uses. Its spatial allocation rules stem from a combination of land demand, overall suitability, temporally-dynamic neighbourhood characteristics and scenario/policy-specific decision rules.

Finally, the indicator module takes the main output of the land allocation module – a simulated land use map for a given year in the future – and computes various indicators to better interpret the results. There are two main families of indicators: land use change related and thematic. The land use change indicators put into evidence the most prevalent changes from and changes to land-use/cover classes and shows, for instance, the land change hotspots for agricultural land abandonment or expansion and urban expansion. The thematic indicators are land cover connectivity potential, soil sealing, river flood risk, urban sprawl and content of organic carbon in soils. All indicators are calculated per cell and can be aggregated at various resolutions.

LUMP undergoes a continuous metamorphosis, its development is mainly dependent on the requirements of each project.

2. Impact assessment

The purpose for which LUMP is most suited for is ex-ante impact assessment of European policies that influence, directly or indirectly land use/cover change. The forecasted land use/cover changes are not only analyzed per se. Land use/cover is an important factor for many ecosystem services such as provision of food; fibre and timber; biodiversity; water flows and climate regulation; carbon sequestration; provision of recreational opportunities; etc. Therefore, LUMP aims at providing relevant input to analyse a growing number of environmental domains that are influenced by land use/cover change.

LUMP's modelling framework allows the translation of policy questions into alternative scenarios that could be compared through a set of indicators that capture economic, environmental and social issues. To date, LUMP has been applied in the following ex-ante impact assessments:

- *Integrated Coastal Zone Management ;*
- *Green measures of the Common Agricultural Policy post-2013 ;*
- *2012 Blueprint to Safeguard Europe's Waters;*

Further applications are being prepared in the fields of energy, resource efficiency, bio-economy and the adaptation strategy to climate change.

3. Spatial resolution

The first version of the land allocation module operated with a spatial resolution of 1 x 1 km. The contribution to the Impact Assessment for the Integrated Coastal Zone Management was made using the model at this resolution. During 2010 and 2011 the model was significantly improved in order to operate with a much finer resolution of 100 x 100 m . This is also the resolution of the most important input map, the CORINE Land Cover 2006, which defines the original state of the land use/cover in Europe. This resolution is more appropriate because it captures more details of the geographical patterns, which is of particular relevance in urban contexts. This improved version of the allocation module was used in the assessment of the green measures of the Common Agricultural Policy post-2013. The model's outputs and indicators can be aggregated to a coarser resolution.

4. Input and output variables

LUMP links specialized models and data within a coherent workflow. The land demand module uses outputs from demographic (EUROPOP 2008, 2010) and economic models (CAPRI, GEM-E3, RHOMOLO) to drive aggregated land use changes at NUTS2 level. The land allocation module uses a number of spatially explicit parameters at different resolutions (1 x 1 km, 100 x 100 m) in order to define an overall suitability for every modelled land use/cover type. These individual input are called “factor maps”. LUMP integrates factor maps related to accessibility measures (computed using the TRANSTOOLS network), soil characteristics and topography. In addition, the neighbourhood interactions between land use types are taken into account dynamically, as the land use patterns evolve and change through time. The definition of policy options requires the development of a range of parameters which take into account both location specific policies (e.g.: demand for each land use class, zoning maps, region-specific support measures, etc.) and the characteristics of land-use dynamics (e.g.: transition rules, neighbourhood effects, attractiveness etc.). The actual “conversion” from the land-use state in tn to a land use state in tn+1 for each location is based on the most suitable land use type for that specific location at that specific time. The land use state in t0 is given by a refined version of the CORINE Land Cover map of 2006.

The main output of LUMP is a simulated map of the land use/cover for a given year in the future. The allocation module is currently able to simulate land use/cover classes such as urban, industry and commerce, agriculture, forest and semi-natural areas, thus allowing the competition between land uses to be accounted for dynamically in time and space. However, due to its components, functionalities and linkages with other models, the platform goes beyond the simple allocation of land uses and can be considered an integrative platform capable of translating scenarios into physical impacts in a range of environmental domains. LUMP is currently prepared to provide relevant output to the LISFLOOD model, which models river discharge at European level.

5. Timeframe

The land allocation module of LUMP requires a calibration which is based on the observed/historical land use/cover changes, as reported by the CORINE Land Cover set of maps (1990, 2000, and 2006). As currently configured, the allocation module runs from 2006, producing yearly results up to 2030. However, the runs can be extended 10 or 20 more years as long as demand is provided for the land use/cover types of interest.

6. Country coverage

LUMP is prepared to make simulations for all EU27 Member States. It can be set to run individual NUTS1 or individual countries alone. In addition, the model can run all EU27 by batching all countries-runs. Each NUTS1 is dealt as a single “allocation problem”, and results for all Europe are the aggregation of the individual results obtained for each NUTS1. Consequently, it is actually possible to work with irregular regions of interest, composed of any configuration of NUTS1.

The model can be extended to cover new Member States of the European Union or to other neighbour countries of interest for which CORINE Land Cover 2006 (or comparable map) is available.

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Appendix 2: Maps of proxy indicators included in the TESI index

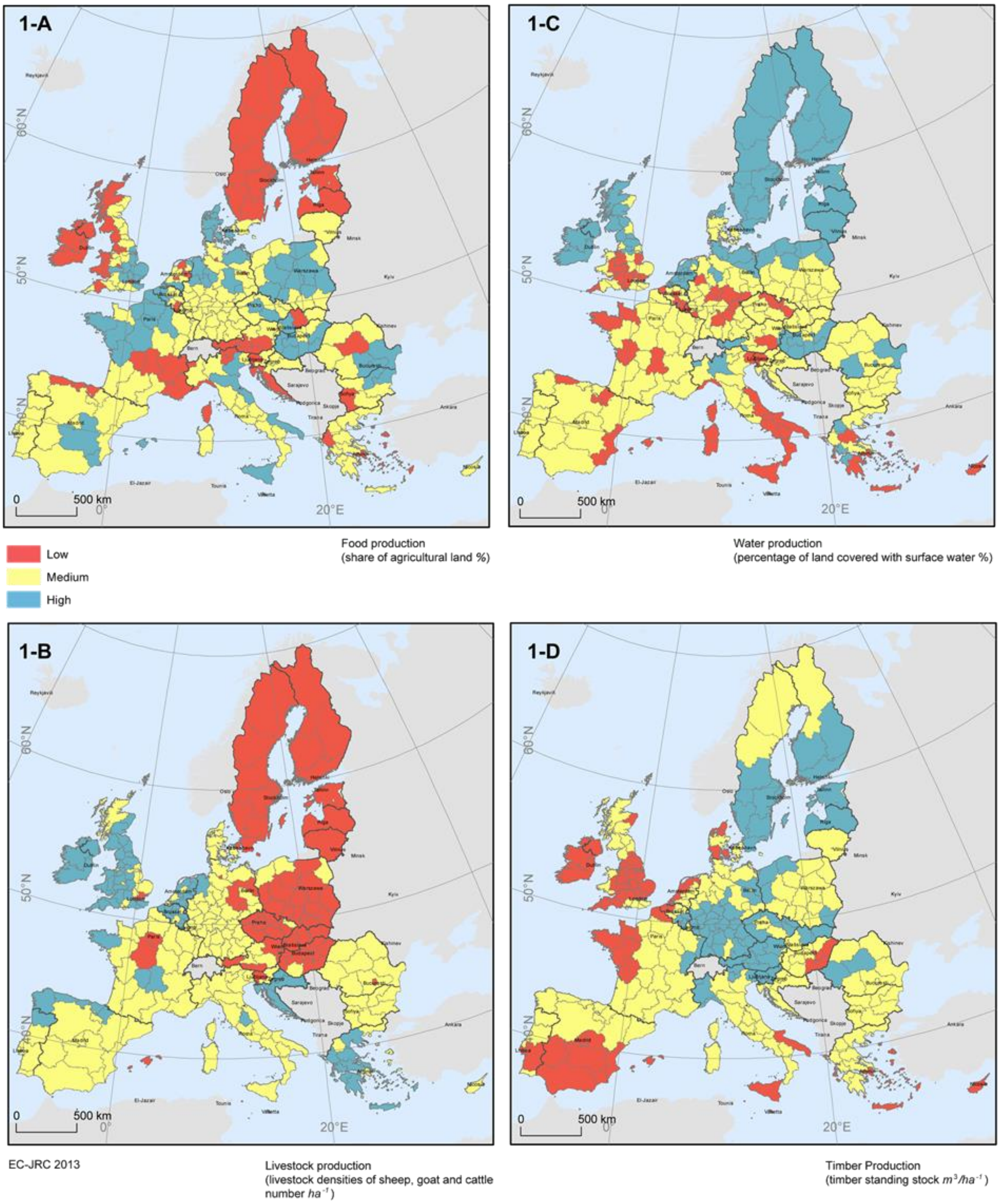


Figure 1. Provisioning services.

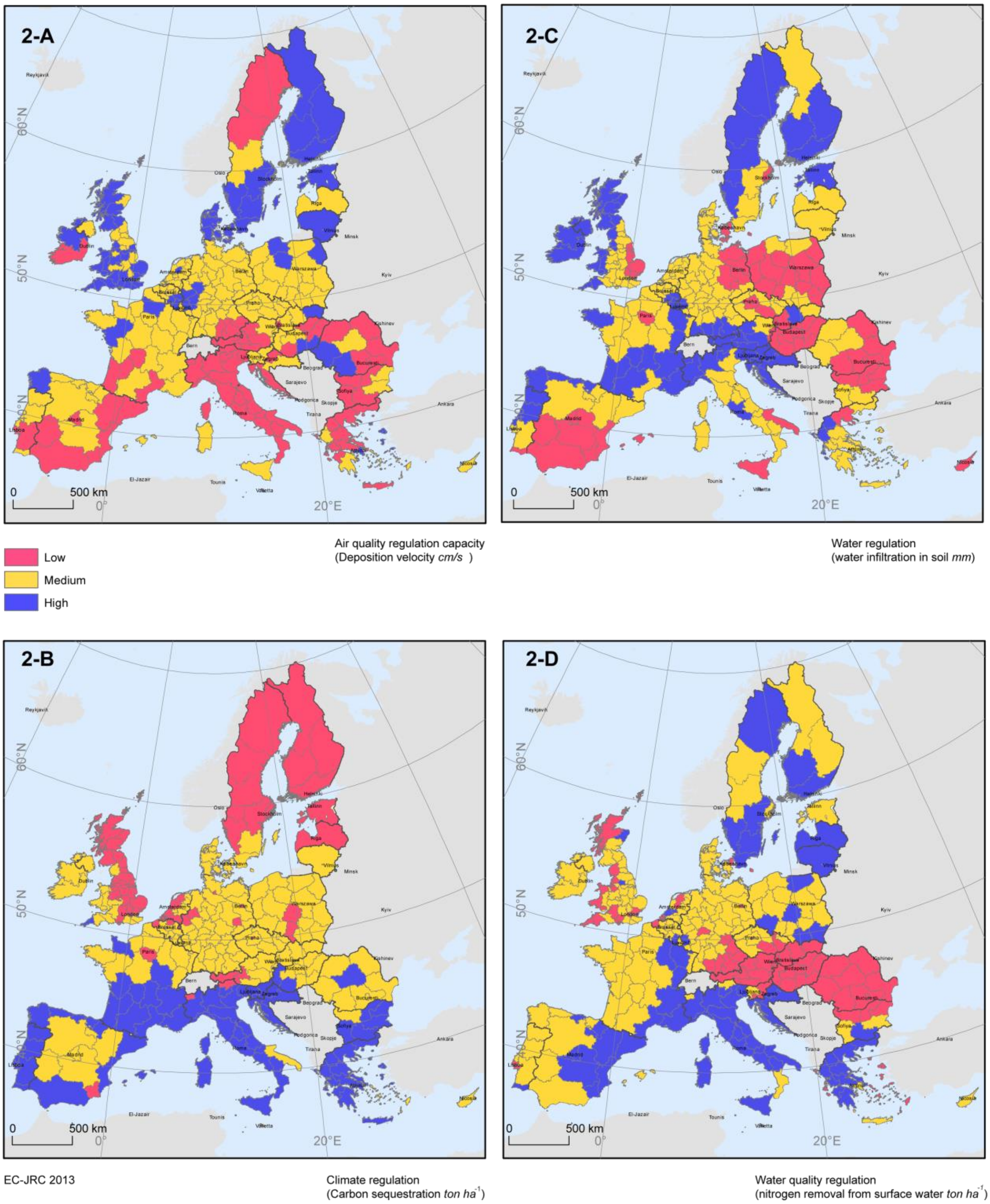


Figure 2. Regulating services (1 of 2).

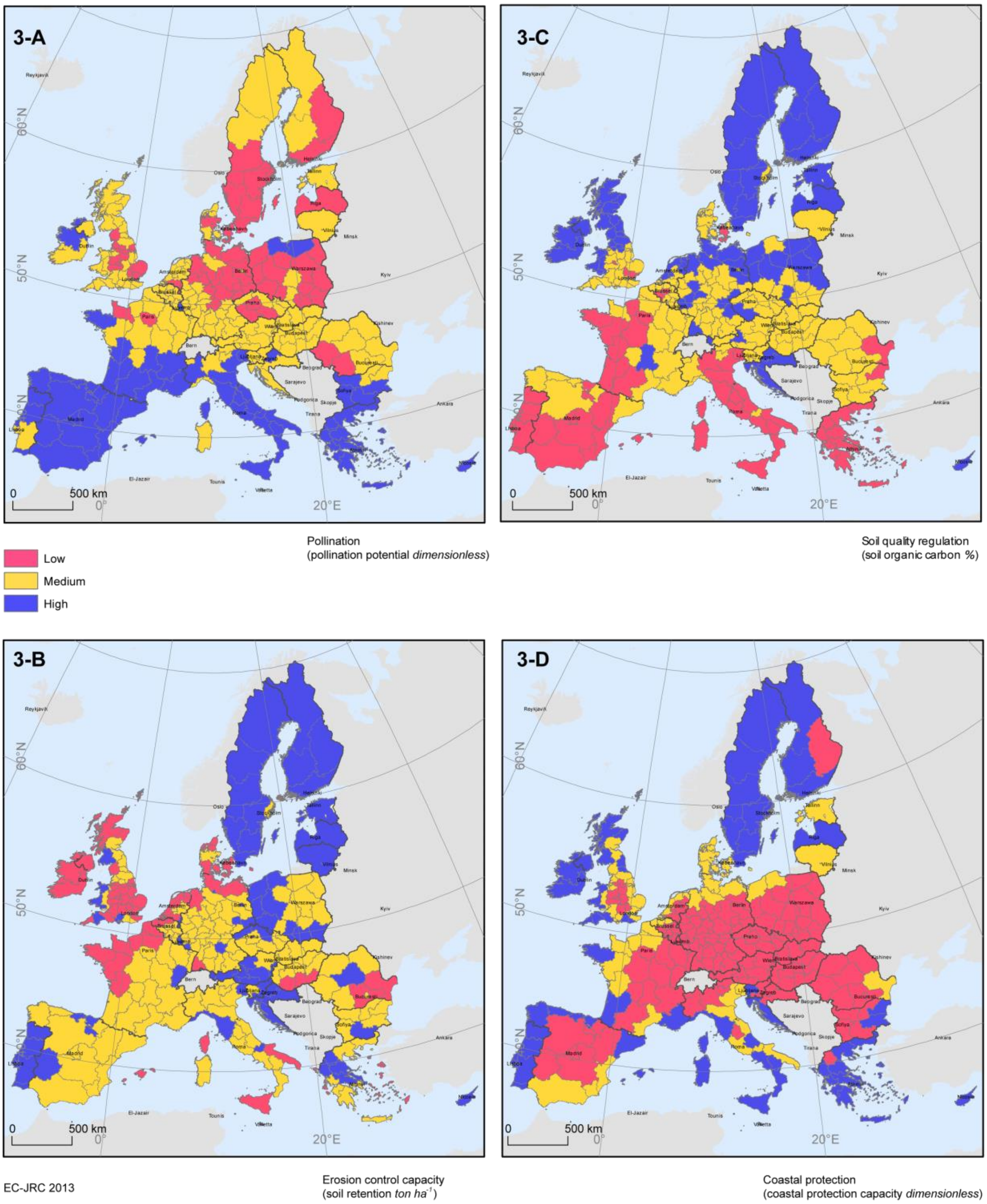
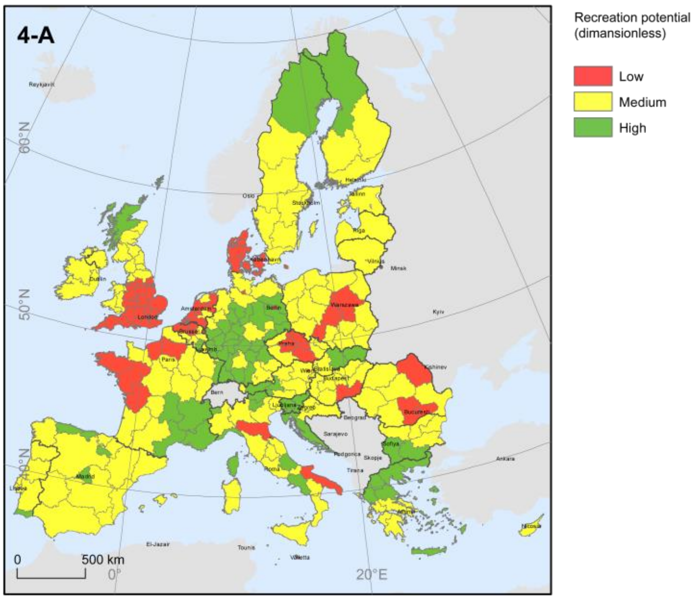


Figure 3. Regulating services (2 of 2).



EC-JRC 2013

Figure 4. Cultural services.

Appendix 3: List of thematic priorities considered in the programming period 2007-2013

Research and technological development (R&TD)

1 R&TD activities in research centres

2 R&TD infrastructure and centres of competence

3 Technology transfer and improvement of cooperation networks

4 Assistance to R&TD, particularly in SMEs

5 Advanced support services for firms and groups of firms

6 Assistance to SMEs for the promotion of environmentally-friendly products

7 Investment in firms directly linked to research and innovation

8 Other investment in firms

9 Other measures to stimulate research and innovation

Information society

10 Telephone infrastructures (including broadband networks)

11 Information and communication technologies

12 Information and communication technologies (TEN-ICT)

13 Services and applications for citizens

14 Services and applications for SMEs

15 Other measures

Transport

16 Railways

17 Railways (TEN-T)

18 Mobile rail assets

19 Mobile rail assets (TEN-T)

20 Motorways

21 Motorways (TEN-T)

22 National roads

23 Regional/local roads

24 Cycle tracks

25 Urban transport

26 Multimodal transport

27 Multimodal transport (TEN-T)

28 Intelligent transport systems

29 Airports

30 Ports

31 Inland waterways (regional and local)

32 Inland waterways (TEN-T)

Energy

33 Electricity

34 Electricity (TEN-E)

35 Natural gas

36 Natural gas (TEN-E)

37 Petroleum products

38 Petroleum products (TEN-E)

39 Renewable energy: wind

40 Renewable energy: solar

41 Renewable energy: biomass

42 Renewable energy: hydroelectric, geothermal and other

43 Energy efficiency, co-generation, energy management

Environment protection and risk prevention

44 Management of household and industrial waste

45 Management and distribution of water (drink water)

46 Water treatment (waste water)

47 Air quality

48 Integrated prevention and pollution control

49 Mitigation and adaption to climate change

50 Rehabilitation of industrial sites and contaminated land

51 Promotion of biodiversity and nature protection

52 Promotion of clean urban transport

53 Risk prevention

54 Other measures to preserve the environment and prevent risks

Tourism

55 Promotion of natural assets

56 Protection and development of natural heritage

57 Other assistance to improve tourist services

Culture

58 Protection and preservation of the cultural heritage

59 Development of cultural infrastructure

60 Other assistance to improve cultural services

Urban and rural regeneration

61 Integrated projects for urban and rural regeneration

Increasing the adaptability of workers and firms

62 Development of life-long learning systems and strategies

63 Design of innovative and more productive ways of organising work

64 Development of special services for employment and training

Improving access to employment and sustainability

65 Modernisation and strengthening labour market institutions

66 Implementing active and preventive measures on the labour market

67 Measures encouraging active ageing and prolonging working live

68 Support for self-employment and business start-up

69 Measures to improve access to employment

70 Specific action to increase migrants' participation in employment

Improving the social inclusion of less-favoured persons

71 Integration and re-entry into employment for disadvantaged people

Improving human capital

72 Design, introduction and implementing of reforms in education

73 Measures to increase participation in education and training

74 Developing human potential in research & innovation

Investment in social infrastructure

75 Education infrastructure

76 Health infrastructure

77 Childcare infrastructure

78 Housing infrastructure

79 Other social infrastructure

Mobilisation for reforms in the fields of employment and inclusion

80 Promoting partnerships, pacts and initiatives

Strengthening institutional capacity at national, regional and local level

81 Mechanisms for improving good policy and programme design

Reduction of costs in development of outermost regions

82 Compensation of any additional costs due to accessibility

83 Compensation of additional costs due to market forces

84 Compensation of additional costs due to climate conditions

Technical assistance

85 Preparation, implementation, monitoring and inspection

86 Evaluation and studies; information and communication

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Title: Direct and Indirect Land Use Impacts of the EU Cohesion Policy: Assessment with the Land Use Modelling Platform

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Abstract
The Cohesion policy for the programming period 2014-2020 is analyzed in terms of its likely land use and environmental impacts using the Land Use Modelling Platform (LUMP). This report describes in detail the process and the methodology by which the ex-ante impact assessment was made, and presents the results for Austria, Czech Republic, Germany, and Poland. The modelling approach can provide insights on the trade-offs between economic growth, investment policies (such as the Cohesion policy), and land use and the environment. In addition, ways to mitigate potentially negative land use and environmental impacts were explored. The future development of the LUMP is discussed in view of the work plan.

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