Beyond land use: what does it take to evaluate the territorial implications of European policies?

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1 Introduction

As pointed out by the OECD regional outlooks - since 2011, the number of socioeconomic trends requiring a better integration of the subnational spatial dimension into broader strategies or policies has been increasing. Moving away from only looking at Gross Domestic Product (GDP) and productivity growth, the recent focus is increasingly on the level of development and wellbeing (current and potential) associated with regions and cities. Well-being is an intrinsically local concept (OECD, 2014) and multi-faceted in nature: it is determined not only by available income, but also by the quality of the surrounding natural and social environment (measured by, for example, air pollution levels, life expectancy and safety).

The question of “place” and “territory” has thus been newly raised in recent years from a variety of perspectives, in an attempt to understand the source of the differentiation of local development patterns. “Territorial development” is often used to describe the patterns of development of specific portions of territory (EC, 2011). These territorial units are typically comprised of sub-national areas such as urban, metropolitan, regional or rural jurisdictions, but they can also embody spatial contexts that can be differentiated from their surroundings such as islands, coastal or mountainous areas. The concept of territorial capital has been defined to describe the system of territorial assets of economic, cultural, social and environmental nature that determines the development potential of places (OECD, 2001; Perucca, 2013). In this context, the socio-economic performance of a region can be interpreted as an endogenous process based on its specific territorial capital, that can however be influenced by the pervasive characteristics of the national economy and government in which the region is embedded (Camagni and Capello, 2010). Territorial cohesion has been recognised as one of the key aspects in achieving the targets of the Europe 2020 strategy (EC, 2011). Better integration and coordination of policy instruments with a territorial dimension is, therefore, necessary to secure the successful implementation of the Europe 2020 strategy across the various cities and regions of the EU (Böhme et al., 2011).

The function given to land is both influenced by and impacts greatly on a multitude of factors, economic, social, environmental and political alike. Analysing the situation with a territorial approach helps to break down and understand these complex interactions, so capturing both the specific characteristics of a spatial context, and its relations with other contexts of the same geographical level (e.g. regions) or at higher aggregation levels (e.g. countries). In such a way, local policies can be designed which take into account and target the specificities of a territory, whilst keeping in mind the broader context. As support activities to the practices of policy definition and evaluation, "territorial approaches" identify a large family of methods, more or less sophisticated, whose main strength is the ability to analyse a wide range of thematic areas across different spatial scales. These are the basic requirements for a tool to effectively support policies that aim at increasing the well-being of regions and cities. As such, spatially explicit land-use models proved themselves as useful tools to inform policies (Koomen & Borsboom-van Beurden 2011). This is confirmed in the continuous effort of the EC-DG JRC to develop the LUISA territorial modelling platform.

2 LUISA in a nutshell

LUISA is a pan-European dynamic spatial modelling platform specifically designed to assess regional and local impacts of European policies and trends. The platform allocates (in space and time) the demand and supply of resources (biotic and abiotic, including primary energy resources), the settlement of socioeconomic activities (e.g. housing, industry, services, touristic accommodations, etc.) and infrastructures (e.g. for transport, energy, etc.). The allocation of population, economic activities and resources is driven by a combination of factors, including, amongst others, biophysical suitability, policy targets and regulatory constraints and economic criteria. The projected territorial patterns cover all EU member states, EFTA and Western Balkan countries at a detailed geographical resolution (100m), typically from the base year 2012 until 2050.

The LUISA modelling platform relies on inputs from several external models, thus being a truly integrative tool that coherently links specialised macroeconomic, demographic and geospatial models with thematic spatial databases. These features allow LUISA to incorporate complex interactions among human activities that are location-specific and their determinants, translating socio-economic trends and policy scenarios into processes of territorial development. LUISA is typically configured to project a reference (or baseline) scenario (Batista et al., 2016), assuming official socio-economic trends, business as usual preferences and the effect of established European policies with direct and/or indirect territorial impacts (see e.g. Baranzelli et al., 2014; Lavalle et al.,2013). The latest baseline scenario is the Territorial Reference Scenario 2017, which also intrinsically takes into account several policy implications, including the Renewable Energy Directive, the Trans-European Transport Network (TEN-T) policy, the Nitrate Directive, The Common Agricultural Policy, the EU Biodiversity strategy to 2020 and protection of Natura2000 areas. Variations to the reference scenario may then be used to estimate impacts of specific policies, or of alternative macro-assumptions.

The final output of LUISA is in the form of a set of spatially explicit indicators that can be grouped according to specific themes and be represented at various geographical levels (national, regional or others). Given its highly flexible and customisable structure, LUISA has the ability to integrate within a unique modelling framework the territorial capital factors that influence the spatial patterns of socio-economic activities and population distribution at different scales. LUISA is therefore a well-suited tool for impact assessment of a wide range of policies with territorial dimension, including their potential synergies, conflicts and trade-offs.

The LUISA platform goes beyond the traditional modelling of land cover/use change in that, using a territorial approach, it looks at the functionality of land and the differing intensity levels of use, as well as identifying mixed uses and discerning quality of land in the allocation process. For example, natural habitats under pressure can be identified, or the suitability of certain urban environments for human settlement. As such, the platform integrates a multitude of different spatial scales to simultaneously capture a number of dynamics which move at different spatial scales and along different spatial horizons.

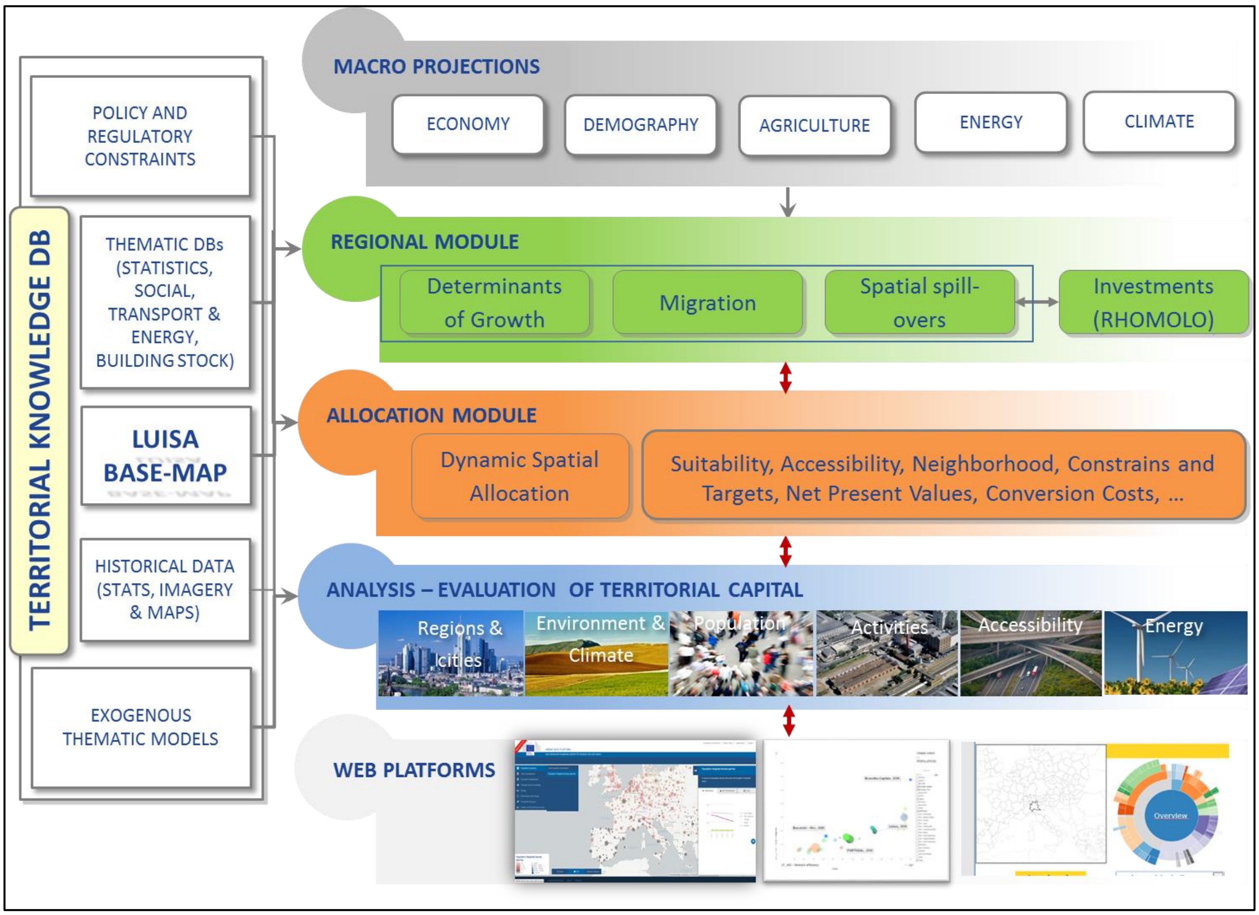

Figure 1. Schematic overview of the various components involved in the working of the LUISA platform.

LUISA has been used in many different applications over the years, such as assessing the efficiency of infrastructural investments on the energy system (Baranzelli et al., 2016a; Baranzelli et al., 2016b) and transportation hubs (Jacobs-Crisioni et al., 2016), and the impact of Resource Efficiency Roadmap targets on the uptake of land (Barbosa et al., 2016).

3 Applications of LUISA

LUISA has been employed in a number of different policy assessments projects. As can be seen in the following sections the scope and goals of those projects varies substantially, thus emphasizing the breadth of topics where territorial impacts are relevant as well as the flexibility of the LUISA platform.

More detailed descriptions of methods and applications are given in Lavalle e al, 2016.

3.1 Impacts of policy alternatives for coastal zone management

LUISA has been employed to evaluate the impacts of two policy alternatives specially developed for European Coastal Zones, one of which was directly targeted to implementing recommendations related to Integrated Coastal Zone Management (EC 1999a). The two policy scenarios were assessed through a range of indicators to give support in the definition of future strategies that were currently evaluated in the framework of the follow-up proposal of the EU ICZM Recommendation (EC 2002).

The study was based on the use of an early version of the LUISA model at 1 km resolution. Considering the European scope of the study and the fact that the modelling framework chosen only focused on land, it was necessary to define a European coastal zone that could not only embrace terrain heterogeneity, but also be wide enough to encompass the land use dynamics of these areas. In light of this and in compliance with the coastal zones definition as given in the EC Demonstration Programme on ICZM, the following criteria were adopted to define the geographical delimitation of coastal zones:

- A 10 km buffer from the coastline (derived from the GISCO administrative boundaries);
- A 2 km buffer from the aggregation of five CLC classes:
    - Coastal wetlands (salt marshes, salines and intertidal flats);
    - Marine waters (coastal lagoons and estuaries).

Even though the coastal zones are the focus of these policies, the simulations were carried out for the entire territory of all EU countries.

The simulated policy alternatives represent two theoretical and rather extreme policy alternatives: they both refer to the simulation period of 2000-2050 and represent alternatives to the global B1 scenario (IPCC 2000), with which they share the main socio-economic assumptions. The two policy alternatives are characterised as follows:

- Uncontrolled development: urban growth will continue, and is only restricted by the pre-existent framework of environmental protection (e.g. Natura 2000). The scenario reflects a lack of restrictions in urban planning and an increase in the potential of urban sprawl.
- Sustainable Environmental Friendly Planning: a more balanced development is promoted, i.e. urban growth is constrained by increasing measures to protect vulnerable areas (e.g. erosion/flood sensitive areas) and the presence of natural areas is fostered (forest or semi-natural). Specific LU conversions are not allowed (i.e. change of semi-natural and forest into built-up areas). Regarding built-up targeted policies, built-up areas are constrained within the immediate shore-line to control risks and provide access to coast, as well as to provide landscape protection in a broader band of 3 km from the shoreline. In addition, urban sprawl is discouraged.

A policy targeted at clustering natural land-use types towards large robust natural areas, and against landscape fragmentation (semi-natural and forest), is implemented.

In order to evaluate the pressure on coastal zones, the policy alternatives were assessed by computing LU change indicators and a selection of thematic indicators: built-up pressure, soil sealing, vulnerability to coastal erosion (EC 2004), vulnerability to coastal floods , mean species abundance index (Alkemade et al. 2009) and Green Infrastructures connectivity (Saura and Rubio 2010).

The two policy alternatives show greatly contrasting environmental impacts. The results show that the built-up pressure in coastal zones, if not managed with particular attention, could increase significantly. According to the simulations, expansion of built-up areas in the 'uncontrolled' scenario between 2000 and 2050 is circa 8 percent more than under the 'sustainable' policy alternative. The simulation results showed, in addition, that urbanization patterns within coastal areas are significantly more sprawled under the 'uncontrolled' scenario, leading to additional landscape fragmentation, increased habitat loss, reduced biodiversity and further imbalances of the water cycle. The analysis indicates as well that Europe has much to benefit from further protection measures of coastal zones, for example to limit the exposure of people and economic assets to coastal erosion and coastal flooding.

3.2 Impact of the green measures of CAP

In November 2010, the European Commission launched the revision of the CAP with the Communication "The CAP towards 2020" (EC 2010), based on the outcome of a wide public debate that was initiated in April 2010.

In this context, and in the framework of the impact assessment procedure, the JRC was requested by DG Environment (DG ENV) to assess a range of environmental impacts that may be caused by the implementation of different policy settings foreseen under the CAP reform; and focus on the greening component of direct payments, as defined in the integration policy option.

A baseline scenario and a policy alternative were defined and implemented in LUISA, resulting in two different simulated land use maps for the year 2020:

- 'Status Quo' scenario: represents the current socio-economic and environmental trends with existing policy provision maintained (business-as-usual);
- 'Integration' policy option: builds on the present policy provisions but encompasses a specific set of greening measures.

The 'status quo' was considered to be the benchmark scenario, with which the impacts of the Integration policy option were then compared. For the 'integration' policy option, the following specific greening measures were considered:

- ecological focus area;
- maintenance of permanent pastures;
- separate payment for Natura 2000 areas.

The implementation of the 'integration' policy option settings in the LU model required both the introduction of new measures and the strengthening of measures already existent in the 'Status Quo'. For example, the green measure 'ecological focus area' was implemented by encouraging the occurrence of natural vegetation in a 50 metre strip width along water courses within currently mapped Nitrate Vulnerable Zones (CEC 1991). In addition, in both scenarios, LU change to arable land and permanent crops was encouraged in Less Favoured Areas (see art. 18 and 20 of EC 1999b) and discouraged in environmentally sensitive areas. In this particular context, sensitive areas included the following components: a) 50 metre width strips along water courses in currently designated Nitrate Vulnerable Zones; and b) areas sensitive to erosion processes (greater than 20 ton/ha/year). Under the 'integration' policy alternative, however, the latter measures were more strongly enforced.

To assess the impact of the projected changes in land use by 2020, a set of indicators were computed: LU shares and conversions, conservation of natural areas, conservation and connectivity of green infrastructure, and soil organic carbon stocks (IPCC 2003, 2006). Overall, the modelled greening options were found to reduce the pressure on naturally vegetated areas and on environmentally sensitive sites. Summarily for all EU countries, the 'integration' policy option resulted in a lower level of environmental impact as compared to the 'status quo' scenario. However, several indicators also showed pronounced regional differences in impact.

3.3 Contribution to the Blueprint to Safeguard Europe's Waters

The Blueprint to Safeguard Europe's Waters (EC 2012) was a commission communication looking into the current state of Europe's water management, and into options to improve it with emphasis on quantity management and efficiency. Within this framework, a request was made to evaluate the effectiveness of Natural Water Retention Measures (NWRMs) in terms of reducing river discharges in flood-prone areas, and maintaining environmental flows in drought-prone areas. NWRMs are all landscape management methodologies which can be applied without artificial construction. The results of the analysis were synthesized in the report by (Burek et al. 2012).

The study required a strong linkage with the hydrological model LISFLOOD. The model is driven in part by land sensitive parameters derived from LUISA, including the Leaf Area Index, Rooting Depth and Manning's coefficient. The fraction of land covered by forest, sealed area, water, or other LU is also a derived input – each of these LU has their own adapted algorithm (e.g. for infiltration rates and surface runoff) within the hydrological model.

The NWRMs were individually translated into necessary model adaptations, either in the LU or hydrological modelling, or in both. The main scenarios assessed were afforestation in CAP areas and within riparian zones; increases in green urban areas; the implementation of grassed waterways and buffer strips; conversion to grassland, and improvement of crop practices. Most measures were modelled by altering the settings of LUISA to allow or encourage certain LUs to be allocated over others, usually following a GIS procedure to outline the area in which the conversion was encouraged. Some additional scenarios (e.g. re-meandering of rivers, polders, buffer ponds) were assessed using only the LISFLOOD model, and are not further described here.

Each NWRM was modelled as a separate LU scenario, which was run from the base year 2006 up to 2030. For each resulting LU map, the necessary input parameters were derived, and LISFLOOD was run to simulate the expected river discharge. The scenario results were then compared to the discharge results obtained from the baseline 2030 run (no NWRMs taken into account) for the whole of Europe, divided into 21 hydrological regions.

The scenarios were compared in terms of their effectiveness in:

- Reducing flood peaks – Re-meandering was the most effective measure in reducing flood peaks in Scandinavia, green urban in the UK, polders in central Europe, afforestation in Germany, and crop practices for the rest of the continent.
- Increasing low flow – The most effective measures were grassland in Scandinavia and the UK; buffer ponds in southern Spain; green urban in Italy, and re-meandering for the rest of Europe.
- Increasing groundwater recharge - for most of Europe, the 50% urban green scenario was the most effective in improving recharge - in Scandinavia the grassland scenario was most effective.
- Reducing water stress – where crop practices were applied all over Europe there was a significant reduction in the number of water stressed days per year.

LISFLOOD is indeed sensitive to changes in LU, and there was a wide variety of discharge response depending on the scenario evaluated. Natural Water Retention Measures can indeed contribute to increased low flows, reduced flood peaks, improve ground water recharge and decrease water stress. In each of the 21 macro-regions, however, the most effective set of measures will differ depending on the climate, flow regime, land use and socio-economic situation, and the application of measures should therefore be tailored to the specific site location. Using a combination of measures may also be beneficial.

3.4 Impacts of shale gas development in Europe

The extraction of shale gas by hydraulic fracturing (fracking) in Europe remains controversial. There are several environmental concerns involved with this extraction procedure, including impacts on water and air quality; noise and visual pollution; potential impacts on biodiversity and nature conservation objectives; and even seismic triggering (Rutqvist et al. 2013; Gény 2010). Competition for surface area with other LU is also of concern, as the actual take of land for shale gas exploitation may have serious and lasting impacts on the landscape, especially in densely populated areas (Wood et al. 2011). On request of the EC's Directorate-General of Environment (DG ENV), a modelling exercise was carried out to assess the possible land and water use implications.

An extensive literature study was carried out (Kavalov and Pelletier 2012), and Germany and Poland were selected as case sites. This was due to the availability of necessary data and the fact that commercialization of shale gas extraction was proceeding in both countries.

The modelling exercise addressed the following questions:

- What are the discrete and potential aggregate land-use requirements associated with individual shale gas sites, fields, and potential development scenarios?
- Are there potential LU conflicts associated with shale gas development in Member States, including competition with alternative land uses?
- To what degree does shale gas extraction have to compete for water with other water-intensive sectors?

To answer these questions, variables were identified that may influence the land and water requirements associated with shale gas development (e.g. the range of actual land area and freshwater required, spacing of well-pads, rate of development of the resource, recycling ratio of water etc.). A range of representative values spanning worst- and best-case scenarios for each variable were derived, and thus two specific development scenarios were defined with maximal and minimal expected environmental impact. Those scenarios were then compared to the baseline land and water use scenarios that assume no shale gas extraction.

In order to assess the related land and water use of well-pads (drilling sites), they were modelled as a new LU class, based initially on the settings used for the allocation of industrial land. A Water Exploitation Index (WEI), indicating the ratio of water consumption to water availability per sub-catchment area (EEA 2010) has been added to the model. Furthermore a new suitability layer was created specifically for the allocation of well-pads. Areas with favourable conditions for well-pads (having low WEI values or beneficial geological characteristics, resource availability and connectivity) were given higher suitability scores. Areas where the allocation of exploitation sites was strictly forbidden were excluded (e.g. protected areas, floodplains, minimal distance from urban zones), and the allocation was assumed more likely to take place with increasing distance from sensitive areas.

The land-use simulation was carried out for the time period 2013 to 2028, with well-pads allocated every 5 years. For each allocation year, four main steps were carried out:

- Land Use change simulation (taking into account locations of previously placed well-pads);
- Update of the WEI and suitability layer (as the LU based parameters are dynamic in time);
- Allocation of well-pads based on the suitability score and a neighbourhood effect (which takes into account the location advantage of placing extraction sites in areas where the necessary infrastructure has already been developed)

The modelled high- and low-impact scenarios vary substantially in terms of both projected land and water consumption and allocation patterns of the well-pads. Highly complex, multi-use landscapes imply the presence of numerous barriers to drilling activities. The land taken up for shale gas extraction as a percentage of the total land converted to industrial purposes within the shale play area considered in the period 2006-2028 ranges from 19.0–38.2% for the low versus high impact scenarios respectively. Water consumed by the extraction of shale gas as compared to the total consumption of water per shale play reaches a maximum of 1%. Although these values may not seem significant at the country-level, they may have large impacts locally. The full results are given in Baranzelli et al., 2015 and Vandecasteele et al., 2015.

3.5 An analysis of potential future water consumption in Europe's energy production sector

This study was carried out to assess the potential impact of the EU Energy Reference Scenario 2013 in terms of future water requirements for energy production, both in terms of cooling water and irrigation water for the cultivation of energy crops. This scenario was configured in LUISA in compliance with the "EU Energy, Transport and GHG emissions trends until 2050.

A new methodology has been implemented to estimate and map water requirements for energy production in Europe. In this study, the category of dedicated energy crops (ENCR) played an important role. These crops are expected to emerge as additional fuel sources within the EU28 by 2020. Water requirements in the remaining energy sectors have also been estimated in order to assess whether the introduction of these ENCR may, in any way, compete with the existing water requirements for energy production. More specifically, the study tackles the following questions:

- Where and to what extent will there be potential competition with cooling water required for electricity generation related to the introduction of these crops?
- How will these trends evolve over time?
- How will the introduction of energy crops affect the overall water consumption trends in Europe?

Example of the results are given in figure 3, which shows both the projected water consumption in Europe for cooling water in energy production, and the estimated future water requirements for energy crops as a share of the total irrigation per NUTS2 region. The analysis indicates that high irrigation requirements for ENCR are foreseen in France, Poland, Spain, eastern Germany, and regions of Italy and the UK. Water consumption for cooling in electricity production has been quantified for the years 2020 and 2030 for 2 scenarios with a minimum and a maximum value (according to potential type of cooling system used). There is notable variation in overall water consumption, both over time and between the scenarios, but most regions show an increase in cooling water consumption in both scenarios over the period 2020 to 2030.

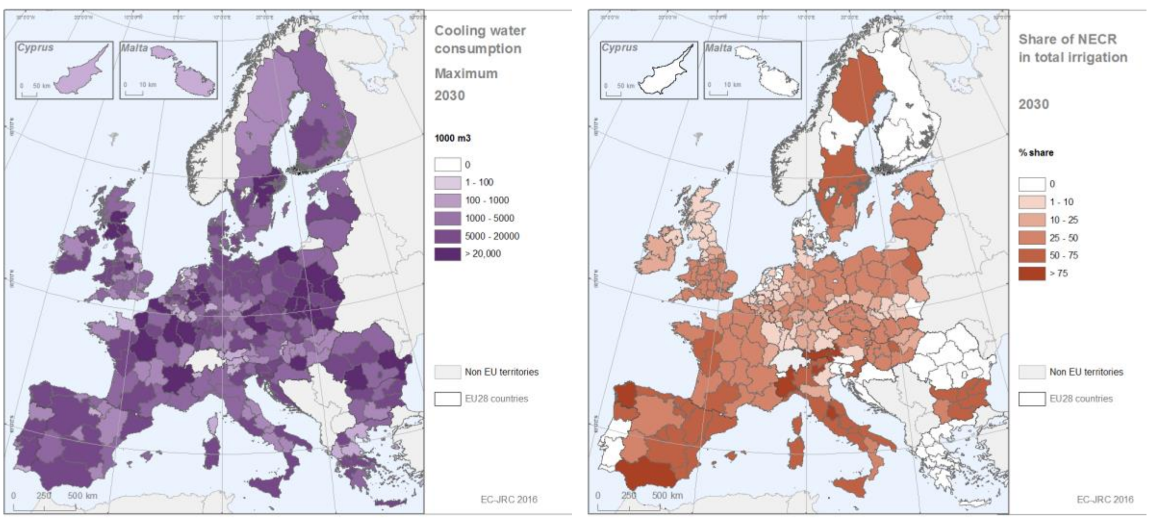

Figure 2. LEFT: Total cooling water consumption in 1000 m3 per NUTS2 region, 2030, maximum scenario. RIGHT: Water consumption by ENCR as a share of the total consumption in irrigation per NUTS2 region, 2030.

Overall, the share of ENCR water consumption in total foreseen irrigation is estimated at 25.7% by 2020, and 26.2% by 2030. Irrigation of ENCR is projected to account for between 0.27 and 0.50% of total water consumption in all sectors by 2030.

As for any modelling exercise, the study presents a level of uncertainty due to the number of external models giving input and to the assumptions made. In the case of the cooling water mapping, a possible range of minimum/maximum values has been used to reflect the large variation due to the type of cooling system used by each power plant. For the energy crop water requirements we relied on estimates found in the literature. Nevertheless, the study presents an overall continental scale analysis of the potential impacts of the 2013 Energy Reference scenario, covering many of the involved sectors and provides the framework for further refinements and improvements.

More details are given in Vandecasteele et al., 2016

3.6 Assessing the direct and indirect land-use impacts of the Cohesion Policy

Social and economic disparities between European regions have long been a preoccupation of the European Commission. In the late 1980s the EC initiated a series of multi-annual investment programmes – known as Regional or Cohesion policies – to promote overall growth and convergence of the less developed countries and regions in the Union. Currently the Cohesion policy is one of the most important policy instruments of the EU. The 2014-2020 program allocates circa 322 billion EUR (2011 prices), roughly one third of the total EU budget, to promote competitiveness, economic growth and job creation, while reducing economic, social and territorial disparities between regions. The actual investment is broken down into the following broad categories: research and development (12%), aid to the private sector (12%), environment (17%), infrastructure (32%), human resources (22%), and technical assistance (5%).

In support to the EC's Directorate-General for Regional and Urban Policy (DG REGIO), the JRC was asked to investigate the potential future territorial and environmental impacts of the Cohesion Policy 2014-2020. The main goal of the study was to identify regional trade-offs between investments and LU, and provide insights on how potentially detrimental LU impacts could be minimised. Such a large scale and wide-scope assessment of the overall Cohesion policy has never been performed before. All details can be found in (Batista e Silva et al. 2013).

To determine the potential territorial impacts of the Cohesion policy, LUISA was configured to simulate three scenarios - one ignoring the Cohesion policy (baseline scenario), the others accounting for it (Cohesion policy scenarios). All scenarios were configured assuming the accomplishment of the 'Europe 2020' targets regarding Energy and Climate, and compliance with major approved environmental legislation. Agriculture, forestry and demographics projections were the same in both scenarios. Urbanization was assumed to continue according to a 'business-as-usual' approach in the baseline scenario. The Cohesion policy scenario assumed the following additional elements:

- Expected economic implications of the Cohesion policy (Rhomolo model);
- Expected investments in infrastructure (transport, R&D, social infrastructure);
- Specific urban planning policies:
    - Branch of the Cohesion policy scenario which assumes 'Business-as-usual' future urbanization patterns ('Cohesion policy-BAU');
    - Branch of the Cohesion policy scenario which assumes more restrictive urbanization policies to limit urban sprawl/dispersal and to encourage urban densification ('Cohesion policy-Compact').

The definition of the Cohesion policy scenario and its configuration within LUISA required a preliminary analysis and selection of investment categories (from a total of 86) which could lead to direct or indirect LU impacts. A key assumption was that the LU impacts of future investments would be similar to those observed in the past. Accessibility changes due to cohesion policy investments in road transport infrastructure were explicitly taken into account in the model by reducing impedances in the underlying road network data. Lastly, new ways of estimating demand for industrial and commercial LUs were adopted (Batista e Silva et al. 2014). Given these scenario settings, the baseline and policy scenarios were computed for a sample of four European countries, namely Austria, the Czech Republic, Germany and Poland.

The results showed that implementation of the Cohesion policy may result in increased land take due to direct investments in infrastructure and a higher demand for land as a result of economic growth. In addition, it was found that expected improvements to the European road network will impact the location of economic activities and residents, thus influencing LU change patterns. These effects can, however, be offset by putting adequate spatial planning policies in place that encourage more efficient urban LU; and by investing in green infrastructure (natural areas and environmental features) to preserve the provision of goods and services by ecosystems. It was also highlighted that compact urban development and investment in urban green infrastructure have positive effects on the environment and air quality, notably regarding the estimated removal rate of nitrogen dioxide.

4 Next steps

With the launch of the New Urban Agenda (NUA, UN-Habitat, 2016) and the Commission's Urban Agenda (http://ec.europa.eu/regional_policy/sources/policy/themes/urban-development/agenda/pact-ofamsterdam.pdf), there has been an increasing focus on the importance of cities within the European context. The LUISA platform is planned to be further used as a powerful tool in helping to make sense of the dynamics occurring at the urban scale, and in doing so, assist city administrators in working towards sustainable urban development policies. LUISA provides several outputs which can provide important insights into city strengths and weaknesses, and where potential improvements can be made to achieve a high level of well-being for citizens. Themes specifically looked at include demography, urbanisation and housing, education, economic development, transport and accessibility, the natural environment, and energy efficiency. The capacity of the LUISA platform to identify urban and regional profiles, would allow capturing all the nuances of their territory well beyond the stylised opposition between urban areas and remote rural regions.

Specific research on the attractiveness on European cities, is also being frame around the framework herein described, focusing, amongst others, buildings' and households characteristics.

Further enhancements of LUISA concerns the integration of endogenous macro-economic capabilities and the gradual inclusion of agent-based elements.

Lastly, the frequent use of the LUISA framework in policy consultation presses the need to validate the model's output in terms of accuracy and reliability. Since years, the JRC began a cross-validation exercise with European and international institutes involved in similar modelling exercise (Alexander et al., 2017). Furthermore, data to do an empirical validation of the model using historical trends is finally becoming available, in the form of a historical time series of municipal population counts and historical time series LU data (EC 2014; Barranco et al. 2014). These historical data will be instrumental in empirical validation projects that are planned on the short to medium term.

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Chapter 24 Land Use and Scenario Modeling for Integrated Sustainability Assessment

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