PLUREL

Driving forces and global trends

Module 1

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PERI-URBAN LAND USE RELATIONSHIPS – STRATEGIES AND SUSTAINABILITY ASSESSMENT TOOLS FOR URBAN-RURAL LINKAGES, INTEGRATED PROJECT, CONTRACT NO. 036921

D1.4.3

Maps of land-use change scenario projections for Europe

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SIXTH FRAMEWORK PROGRAMME

Contents

Abstract

Objectives/aims

Changing land-use relationships within emerging rural-urban regions, and their manifestation in phenomena such as urban sprawl and development of large transport corridors, have lasting consequences for regional sustainability. Better understanding of the drivers of land-use changes and their interactions with regional, national and European policies is necessary to minimise the negative consequences of urbanisation and enhance the adaptive capacity of rural-urban regions. Quantities of artificial surfaces (defined here as CORINE level 2 land-cover classes 1-11) and their location are one of the strongest influences of mankind on the environment. This part of the project explores the response of artificial surfaces to the four PLUREL scenarios in 2015 and 2025.

Methodology

The study area includes all EU-27 countries except Bulgaria and Cyprus. We derive future proportions of artificial surfaces per NUTS 2 region from projections of population and gross domestic product (GDP), using a regression model similar to the one described by Reginster & Rounsevell (2006). The population and GDP projections come from the NEMESIS model (Brécard *et al.* 2006; Chevallier *et al.* 2006). The new artificial surfaces are then allocated within each region by using the RUG (Regional Urban Growth) model (Fontaine unpublished-a). The locations depend on planning preferences (e.g. housing concentration, avoidance of flood zones) and household preferences (e.g. accessibility of cities, distance to the coast.) The accessibility of cities (medium or large/capital) takes the form of a new index, which takes into account both the probability of commuting to a city of that size (a function of Euclidian distance to the centre) and the travel time-cost along the transport (road, rail & sea) network. We ran simulations for the four PLUREL project scenarios by varying the parameters determining the preferences' respective weights.

Results / findings / conclusion

The future patterns of artificial surfaces shown by the RUG model simulations are in keeping with the scenario storylines, for instance concentrated growth around the city centres for the "peak oil" (B1) scenario. The projected values for artificial surfaces in 2015 and 2025 may exceed 1 (100%), which is interpreted as increased pressure to build in the third dimension, particularly in already densely-urbanised areas. Because of this, these results could be used as a proxy for the population in each grid cell.

Popular science description of main results

Across Europe in general, the results show patterns of urban growth consistent with the scenario storylines (e.g. public vs. private transport), such as concentration of artificial surfaces in or near urban centres for the "peak oil" (B1) scenario and urban/peri-urban sprawl for the "hyper-tech" (A1) scenario. In some areas, very large proportions of artificial surfaces (above 100%) show an increased pressure to build upwards (e.g. blocks of flats) or downwards (e.g. multi-storey car parks). Because the RUG model runs on a regional (NUTS 2) level, the results can be used to show differences between regions, for instance in terms of concentration/sprawl of artificial surfaces or pressure on city centres.

Classification of results/outputs

For the purpose of integrating the results of this deliverable into the PLUREL Explorer dissemination platform as fact sheets and associated documentation please classify the results in relation to spatial scale; DPSIR framework; land use issues; output indicators and knowledge type.

Spatial scale for results: Regional, national, European	European
DPSIR framework: Driver, Pressure, State, Impact, Response	Response
Land use issues covered: Housing, Traffic, Agriculture, Natural area, Water, Tourism/recreation	Housing
Scenario sensitivity: Are the products/outputs sensitive to Module 1 scenarios?	Yes
Output indicators: Socio-economic & environmental external constraints; Land Use structure; RUR Metabolism; ECO-system integrity; Ecosystem Services; Socio-economic assessment Criteria; Decisions	Land use structure
Knowledge type: Narrative storylines; Response functions; GIS-based maps; Tables or charts; Handbooks	GIS-based maps

How many fact sheets will be derived from this deliverable:	**5**

Introduction

PLUREL WP1.4

The objective of this workpackage is to model changes in land use for the European territory based on the economic, demographic, environmental and technology change projections developed in M1. It draws on the scenarios and data generated in WP1.1-3 and also WP2.3. The results feed into work by other workpackages, WP2.3 in particular. It is expected to contribute to the book, training/teaching material, the PLUREL Xplorer and land use change maps.

Objectives of the deliverable

This deliverable aims to provide data, mainly in the form of maps of projected urban land use change, to be used both within and outwith the PLUREL project. This report aims to allow users to understand how the maps were obtained and how the data is structured. Aside from the maps, its contribution to the project end-products also includes PLUREL Xplorer factsheets.

Structure of the deliverable

The report is mainly a description of the maps, consisting of:

- an introduction giving the context and background information;
- a description of the methodology;
- an overview of the output data.

Context

Peri-urban areas can be defined in multiple ways, depending on the perspective, e.g. land-cover or population density. These can also differ according on the country considered, for instance rural areas in India frequently have higher population densities than sub-urban areas in Europe or the US (Kölbl & Haller 2006). Peri-urban areas are by nature transitional and can be described as a complex mosaic of rural, urban and natural subsystems (Allen 2003; Dandy et al. 2009).

As the interface between urban and rural areas, peri-urban are at the leading edge of the urbanisation process. Land-use change in peri-urban areas therefore depends largely on future patterns and distribution of artificial surfaces, which we define here broadly as "urban" land-use (CORINE level 2 land-cover classes 1 to 11). These future patterns will affect the rural/urban/natural mosaic and the balance between the three.

Although urbanisation represents a small change on the global scale, it affects global land-use through the transformation of urban-rural linkages (Lambin et al. 2001). At the regional level, the effects of urbanisation are more directly observable. For instance, urban sprawl into the peri-urban zone in Scotland means increased contact between people and roe deer, for which management plans have to be drawn (Dandy et al. 2009). More generally, increased urbanisation fragments the landscape, which has a large impact on ecosystem services such as energy exchange through evapotranspiration or hydrological regimes (Gill et al. 2008; Lambin et al. 2001).

Urbanisation results mainly from changes in household preferences (e.g. for proximity to green areas or public transport availability) in response to changing socio-economic

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conditions. The effect of these changes is mediated by institutional factors such as planning policies (Lambin et al. 2001; Veldkamp & Lambin 2001).

Modelling urban land-use change needs to be carried out at a reasonably fine resolution, as this land-use type typically covers smaller areas than, for example, forests and can be quite fragmented, especially in peri-urban areas. This results in very large datasets for models on a continental scale, which then become excessively resource-intensive. One way around this is to run the model on a regional basis (e.g. NUTS 2), but using continental-wide input data, which includes cross-border spatial interactions with neighbouring regions or countries.

The work presented here aims to provide projections of urban land-use change under various scenarios. These may be used to inform policy-makers either directly or through further analysis, such as the effects of these changes on ecosystem services. This information could therefore contribute to the development of a more sustainable future.

Methods

We simulated percentages of artificial surfaces (CORINE land-cover class 1) in 2015 and 2025 for 25 European countries (EU-27 minus Bulgaria and Cyprus; figure 1), following the assumptions in the four PLUREL scenarios (D1.3.2 & D1.3.3). This was done using the RUG (Regional Urban Growth) model (Fontaine unpublished-a).

Artificial surface projections per NUTS 2 region

Similarly to the work described by Reginster & Rounsevell (2006), we calculated a linear regression model linking the proportion of artificial surfaces per NUTS 2 region to the population (*POP*) and gross domestic product per capita (*GDP_CAP*), with the country (*COUNTRY*) and urban type (large city vs smaller city/rural region; *URBTYP*) as additional factors:

$$\log(PR\_ARTS) \sim POP + POP^2 + GDP\_CAP + URBTYP + COUNTRY$$

This model was then applied to projected values of population and GDP per capita for 2015 and 2025, obtained using the NEMESIS model (Brécard *et al.* 2006; Chevallier *et al.* 2006). This resulted in a set of projected artificial surfaces per NUTS 2 region for the four PLUREL scenarios.

The RUG (Regional Urban Growth) model

The RUG model runs on one region (NUTS 2, figure 1) at a time, on a grid (raster) of 1-km square cells.

The model has a parsimonious structure. It evaluates the potential for settlement in each cell, based on the cell's characteristics and the scenario storyline (Fontaine unpublished-b). It then returns the new percentage of artificial surfaces for each cell, based on the total amount of artificial surfaces expected in the region (NUTS 2) for the scenario considered.

Cells are characterised by their proportion of artificial surfaces, Euclidian distance to the coast (sea or large lake), flood risk classification and "remoteness" relative to the nearest medium (≥100'000 inhabitants) and large (≥500'000 inhabitants or country capital) city, which combines travel time costs and the proportion of commuters. The "remoteness" variable is described in more detail in the sub-chapter following the one describing the model parameters. The scenario characteristics define the location preferences of residents relative to the various

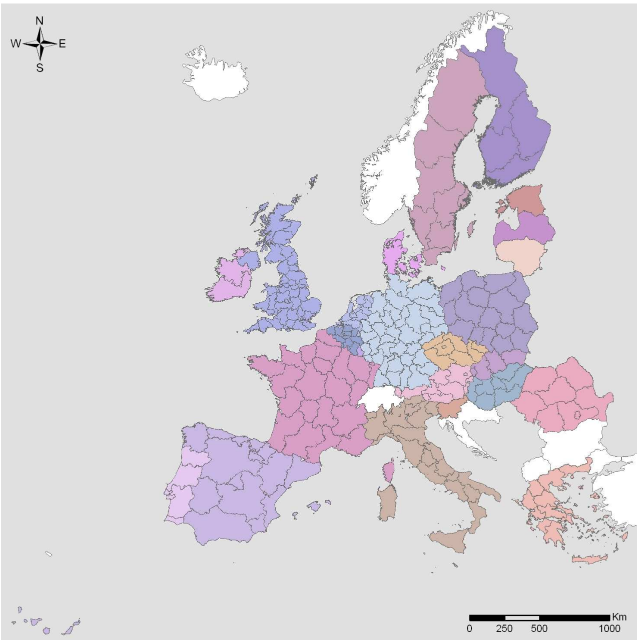

Figure 1. Map of the RUG simulation area showing the countries and NUTS 2 regions within them.

cell characteristics and the type of planning policy. The cell characteristics define the variables used in the model, whereas the scenario characteristics define the parameter values associated with these variables (Fontaine unpublished-b).

The RUG model currently runs on a "growth-only" assumption, so it cannot simulate shrinkage. If the projected proportion of artificial surfaces is lower than the current value, it returns the latter. Future proportions of artificial surfaces may exceed 1 (100 %). This is to be interpreted as building in the third dimension (either above or below ground).

Scenario parameters

The baseline parameters (Table 1) are the ones tried and tested in the original RUG model developed for East Anglia (UKH1). Of these, the one most likely to differ is *compaction*, which depends on each country's planning policy (strict *versus* liberal). We compared results using various values of *compaction* and concluded that the original value of 0.2 still gave the best results when compared to the real data (from CORINE land-cover 2000).

We derived qualitative parameters (Table 1, 1st column for each scenario) from the PLUREL scenario story-lines (D1.3.3, p. 17, 31 & 60). These parameters were then translated into quantitative values (2nd column).

Table 1. Input parameters for the RUG model. Externalities: β = "green", γ = "red". Cities & coast: w = weight, s = slope. Constant parameters: θ = 1.0, φ = 0.5. The qualitative parameters (1st column for each scenario) reflect the scenario story-lines in D1.3.3 (p. 17, 31 & 60).

		baseline	hyper-tech (A1)		extreme water (A2)		peak oil (B1)		social fragments (B2)	
externalities	β	2	+	4	-	1	--	0.5	++	6
	γ	0.5	0	0.5	0	0.5	0	0.5	0	0.5
nearest city	w	5	0	5	+	6	++	7	+	6
	s	2	--	0.5	-	1	+	3	0	2
primary city	w	0.5	+	1	+	1	++	2	-	0.3
	s	1	--	0.5	0	1	+	3	+	3
coast	w	0.1	0	0.1	--	0.02	-	0.05	+	0.5
	s	1	0	1	0	1	-	0.5	-	0.5
compaction		0.2	--	0	-	0.1	++	1	+	0.5
flood zones		N	N		N		Y		Y	
protected areas		N	N		N		Y		Y	

Index of "remoteness" from nearest/primary city

This index combines two different types of information relating to the proximity of a location to a city: travel time costs and the proportion of commuters. The former accounts for the accessibility of the city, in units of time, through the transport network. The latter accounts for the radius of influence of different types of cities, by showing the proportion of commuters as a decay function of the Euclidian distance from the city centre.

The current maps of travel time costs to the nearest medium (100'000-500'000 inh.) and primary (country capital or large, >500'000 inh.) cities come from the work of Verburg *et al.* (2008). For 2025, we used projections of travel times according to the four PLUREL scenarios (see D1.4.2), but we kept the current values for 2015. This is due to the fact that changes in travel times do not occur gradually, but in leaps and bounds and any transport project resulting from the policies developed in the scenario storylines will take years to first gain approval and then be implemented.

The proportion π of commuters (Ristimäki *et al.* 2008) is calculated using Equation 1:

$$\pi(d) = \left[1 + \frac{1-\pi_S}{\pi_S}\left(1 - \frac{B}{100}\right)^{S-d}\right]^{-1} \quad [1]$$

where S is the radius of the city's central circle, d the Euclidian distance to the city centre (centre of circle), π_S the proportion of commuting trips to the central circle among all commuting trips starting at the distance S from the city centre (i.e. from the edge of the circle) and B the decaying effect of distance from the place of residence of the commuter to the centre point of the city on the proportion of commuting trips directing inside the central circle. The values of π_S, B and S depend on the type of city, according to the RUR typology (D2.1.3).

The "remoteness" r for a given location l is then calculated by combining the travel time cost and proportion of commuters using Equation 2:

$$r = \frac{(1-\pi)\cdot t}{tmax_{reg}} \quad [2]$$

where π is the proportion of commuters (equation 1), t the travel time to the centre of the nearest city and $tmax$ the maximum value of t within the region reg (NUTS 2) in which l is situated. These steps are repeated for the nearest medium and primary cities. Figure 2 shows an example for primary cities in Belgium.

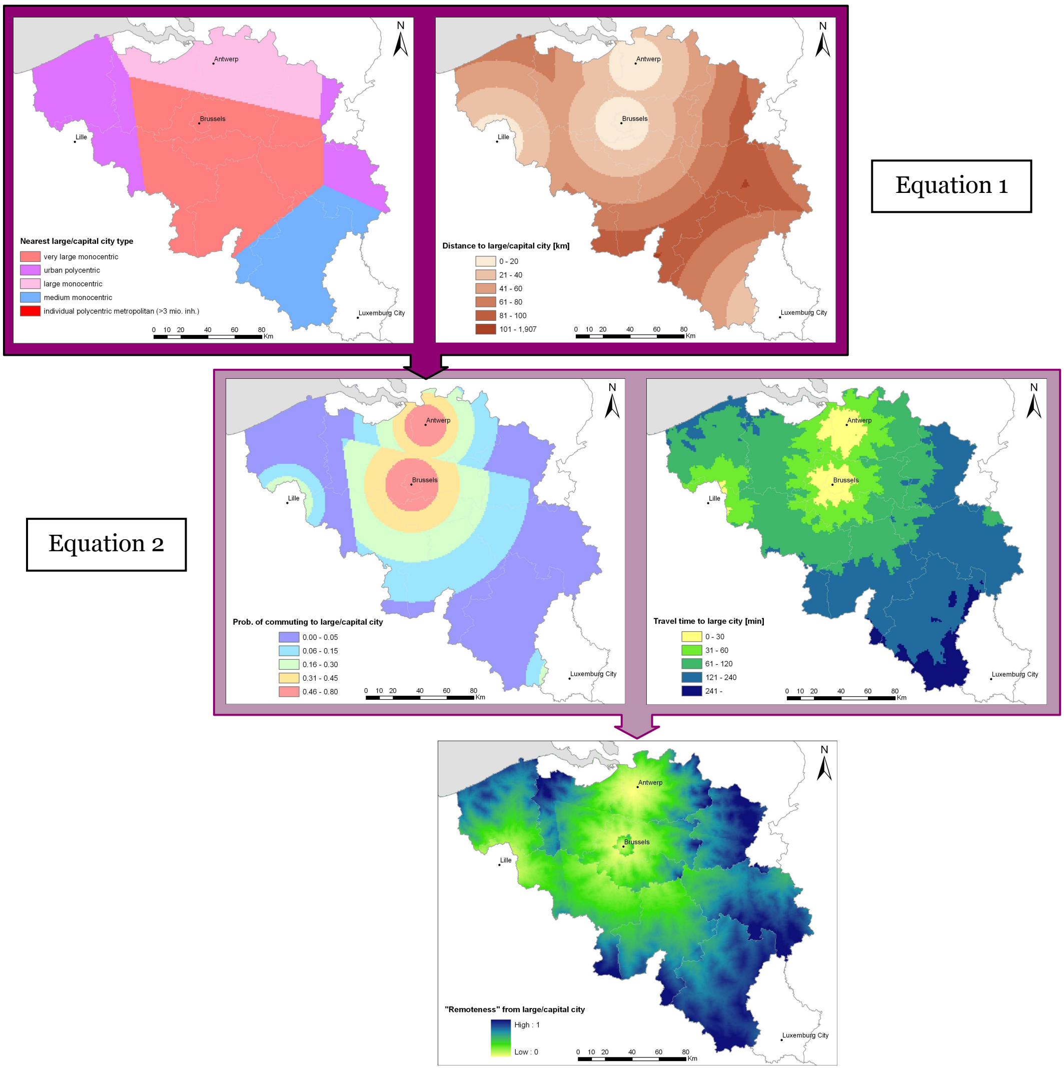

Figure 2. Illustration of the calculation of the "remoteness" index with the example of primary (capital or >500'000 inh.) cities for Belgium.

Output data

Coverage:	EU-27 minus Bulgaria & Cyprus
Resolution:	1 km
Coordinate system:	ETRS 1989 LAEA
Years:	2015 & 2025

The data consists of 16 ARC GIS grids, i.e. 2 variables x 4 scenarios x 2 time steps, which are named as follows:

variable_scenario_year

with:

variable	*pr*	proportion of artificial surfaces (CORINE land-cover classes 1-11)
	rdi	relative difference, i.e. the difference in proportion of artificial surfaces between time step and 2000, as a percentage of the current (2000) proportion
scenario	*a1*	hyper-tech
	a2	extreme water
	b1	peak oil
	b2	social fragments
year	*15*	2015
	25	2025

As the data is based on a 1 km grid, the proportion is equivalent to the actual area of artificial surfaces, in km-squared. The proportions may be greater than 1 (sometimes quite considerably.) This is to be interpreted as building in the third dimension (above or below ground) and means that the artificial surfaces can be used as a proxy for population. It is always possible to recalculate the maps, giving a value of 1 to all cells with values greater or equal to 1, for purposes where only the two-dimensional information is required.

The RUG model as it currently stands is "increase-only", i.e. it does not allow a loss of artificial surface.

Figure 3 gives an example of results for 2025, for the second output variable (*rdi*) around the Montpellier case study area.

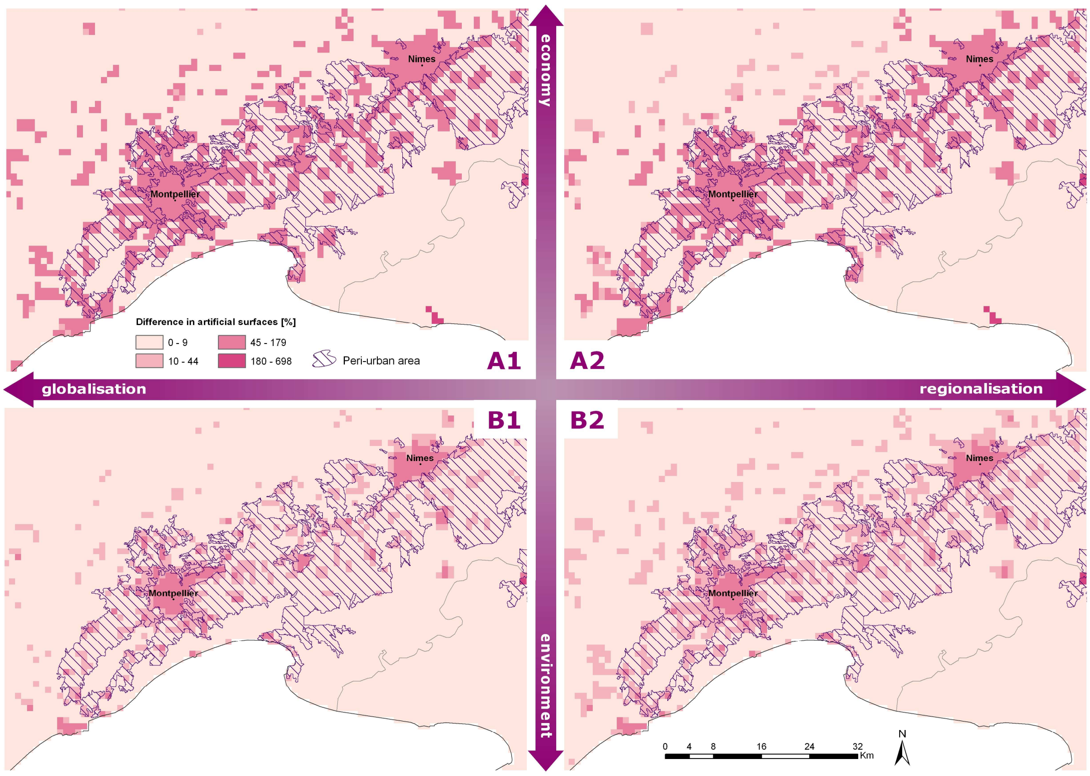

Figure 3. Example of results for the variable *rdi* (relative difference) in year 2025.

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