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Jean-Luk De Kok
Lien Poelmans
Guy Engelen
Inge Uljee
Leen Van Esch

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Spatial-dynamic visualization of long-term scenarios for demographic, social-economic and environmental change in Flanders

Jean-Luc de Kok¹, Lien Poelmans¹, Guy Engelen¹, Inge Uljee¹, Leen van Esch¹
¹Flemish Institute for Technological Research (VITO)
Boeretang 200 – 2400 Mol – Belgium
¹jeanluc.dekok@vito.be

Abstract: Land-use change in Flanders is characterized by a rapidly growing proportion of the hard surfaced area with on-going ribbon development and an increasing pressure on the remaining open space. The Spatially-Dynamic Land-Use Model for Flanders or RuimteModel Vlaanderen has been developed for the Flemish Ministry of the Environment and the Flemish Ministry of Spatial Planning and Housing to examine the underlying causes of spatial transformations at different scale levels. The model uses a constrained cellular automata approach, incorporating 35 residential, economic and natural land uses to describe annual land-use change in Flanders for the period 2010-2050. In a scenario exercise developed to support the formulation of the Spatial Policy Plan Flanders, the four scenarios developed as part of the Dutch WLO study for the Netherlands (www.welvaartenleefomgeving.nl) are applied to Flanders in an exercise involving stakeholders consultation, qualification and quantification. The integral consequences of four worldviews representing different demographic, social-economic and environmental developments in the world, Europe and Flanders are simulated with respect to the detailed spatial implications during the period 2010-2050. The presentation will focus on the steps taken to implement the scenarios into the RuimteModel and the qualitative evaluation of the model outcomes for the different scenarios.

Keywords: land-use change, scenarios, cellular automata

1 INTRODUCTION

During the last decades the geosciences and domain of spatial planning benefitted considerably from the development of Earth Observation and Geographical Information Systems using a high resolution. Different modelling approaches have been used to examine the social-economic and geophysical mechanisms underlying land-use change. Cellular Automata (CA) models have the advantage of being spatially explicit and process-based [Couclelis, 1988; White and Engelen, 1997] allowing for the high spatial resolution required for planning purposes and efficient computation of land use. The new state of the cells is calculated from the previous cell states in a restricted neighbourhood by means of local transition rules. The RuimteModel is a more advanced application of the MOLAND modelling framework [Engelen et al., 2007], an example of a hybrid CA model, and has been developed to support spatial planning in Flanders. The spatial dynamics are
restricted by the physical, social-economic, infrastructural and policy conditions imposed at the regional and global scale level [Engelen et al., 2007; Poelmans and Van Rompaey, 2010].

The RuimteModel is based on three hierarchically embedded levels: the macroscopic, global level, consisting of the combined Flemish and Brussels Regions, the regional level of 23 arrondissements (EU-NUTS3 entities), and the local, cellular level consisting of a matrix of individually modelled cells. The cell states represent the dominant land use at a 1 ha resolution and can be dynamic function states, non-dynamic feature states such as parks or vacant states such as unregistered agricultural land affected indirectly by the local dynamics. Based on the local interactions with neighbour cells, the physical suitability, administrative zoning and accessibility a transition potential is calculated for each of the cells in a function or vacant state. The land use class with the highest transition potential is assigned as new cell state. The latest version of the RuimteModel [Van Esch et al., 2011] uses a single-year time step and 35 different land-use classes, including residential land use and 12 economic activities. A typical model simulation (2010-2050) requires 30 minutes on a standard desktop PC. In addition to the land use, a simulation results in a large number of environmental and economic spatial indicators which are all available as maps, and can be custom-defined. The Business-As-Usual (BAU) scenario of the RuimteModel [Engelen et al., 2011] describes the land-use change in Flanders between 2010 and 2050 and has been applied to support a cost-effectiveness study of flood risk mitigation measures [De Kok et al., 2011]. The population growth in this scenario is based on the long-term forecasts of the population size by age, gender at the EU-NUTS3 or arrondissement level [FPB/ADSEI, 2008]. The employment forecasts for each of the economic sectors in the period are based on an extrapolation of the development of the sector structure of the PLANET economic model [Desmet et al., 2008] as well as the expected changes of the population age structure [FPB/ADSEI, 2008; Maene, 2011] and the labour participation rates by gender and EU-NUTS1 region [Pelfrene, 2005]. Commuting to and from the Brussels Capital region is taken into account as well.

The WLO study [CPB-MNP-RPB, 2006] is an integrated scenario exercise for the Netherlands which resulted in four world views, differing in terms of the demographic, social-economic, environmental and political developments from 2002 until 2040 with an intermediate state in 2020 (Figure 1).

![Figure 1. The WLO worldviews [CPB-MNP-RPB, 2006].](image)

The world view Strong Europe (SE) is based on effective European unification, strong regulation by the EU and lower administrations, and strong population growth as a result of economic migration. In the world view Global Economy (GE), on the contrary, the private initiative and individual freedom prevail, with limited administrative control and a very strong population growth and prosperity at the cost of social inequality. The world view Regional Communities (RC) is the opposite scenario with low economic growth, a loss of material wealth, and larger
influence of local administrations as well as regional self-sufficiency. The Transatlantic Markets (TA) world view, finally, is comparable to the Global Economy world view but at the regional instead of the global scale, resulting in lower economic growth. Although the WLO study was developed for the Netherlands, the scenarios were considered to be applicable to Flanders as well because of the proximity, the social-economic similarities and confrontation with comparable demographic, economic challenges and developments at the EU and global scale [Kuhk et al., 2011]. Nevertheless, differences could be expected with respect to issues such as housing, water management, safety against flooding, agricultural policy and the residential patterns.

The RuimteModel was recently used to develop four different spatial scenarios for the Flemish Policy Research Center of Spatial Planning and Housing to support the formulation of the new Spatial Masterplan Flanders (www.rsv.vlaanderen.be). The scenarios for Flanders are based on a combination of expert and stakeholder consultations [Kuhk et al., 2011], and qualitative and quantitative interpretation and translation of the trends from the WLO scenario study. The WLO scenarios for the Netherlands are not spatially explicit and little detail is given about the spatial aspects of the envisaged developments. This implies certain adaptations were necessary for a spatial application in the Flemish context [Engelen et al., 2011] which will be discussed here together with the added value of the spatial indicators that can be developed with a spatially-explicit visualization of the scenarios.

2. MATERIAL AND METHODS

The procedure started with the recalibration of the global sub model of the RuimteModel, followed by setting the relevant parameters for the regional and local sub model, taking the initial state for 2010 in the BAU scenario as starting point (Figure 2).

During the sessions with Flemish stakeholders and end users each WLO world view was described in terms of 88 qualitative indicators, followed by qualitative screening and sensitivity analyses to identify the most relevant model parameters at the regional level of the RuimteModel. The authors also updated the suitability maps, zoning maps and accessibility parameters for each scenario, which are needed to represent the heterogeneous character of the Flemish region. This
ensured the spatial patterns generated with the RuimteModel were sufficiently consistent with the differences in the descriptions for the WLO scenarios.

At the global level the parameters describing the population growth, total employment and land demand for nature and agriculture were adjusted for each world view. A semi-qualitative approach was used to allocate the employment figures to the different economic sectors in the RuimteModel, representing the differences in the economic sector structure for each of the world views. This, for example, resulted in a larger importance of services in the GE world view scenario compared to the other world views.

A more detailed distribution of the employment over the 12 economic sectors in the RuimteModel was obtained from the development of the economic sector structure in the BAU scenario for 2010-2050. Next, the land demand for natural land use classes had to be determined for each of the world views. The total land demand for nature was obtained by applying the ratio of the land use for nature in the Netherlands in 2040 and the area in use in 2002 for each world view to the growth rates from the BAU scenario for 2010-2050. Agriculture was considered to be a rest category, occupying the area remaining after allocation to the residential, economic and natural land use classes. Total area in use for residential land use, economic activities, nature and features such as parks, infrastructure etc. was calculated for each world view. The remaining area was distributed over five different agricultural land use types, based on assumptions reflecting the world views.

The regional model settings for the BAU scenario had to be adapted in two respects: (i) the distribution of the population and employment over the 23 NUTS3 regions (arrondissements) and (ii) the translation of these figures to the land demand. Quantitative sensitivity analyses were carried out to identify the model parameters with the largest influence on the regional attractiveness. An iterative approach was used to estimate the appropriate value of the density parameters determining the translation of the population size and economic activities to the land demand for each of the world views. This resulted in a continued decline in the population density for the RC and TA world view, and a decline followed by an increase for the SE and GE world view.

The local sub model had to be readjusted for each of the world views. The 88 distinguishing characteristics were aggregated into 13 thematic, qualitative descriptions for each world view. The themes, ranging from demography, energy, and mobility to the use of open space, were screened for aspects which were relevant for the spatial patterns that could be used to support the calibration of the local sub model. The maps for the policy zoning, geographic suitability and accessibility were adjusted to reflect the assumptions of the four world views as well as possible. Finally, the influence rules for the local interactions between the cell states were adjusted for each world view, starting from the rules for the BAU scenario. This was done in an iterative approach in order to generate realistic spatial patterns for each of the four world views.

3. RESULTS

The outcomes of the exercise consist of land use maps for the 2010-2050 time span, and a large number of custom-defined indicators. Figure 3 shows the differences between the four world views for the land use in the region to the South-East of Antwerp by 2050.
On close examination the results show differences in terms of the residential-urban pressure exerted on the surrounding rural-agricultural area (mainly arable land) for the two world views, with a clear clustering of smaller residential centres in the RC world view, for example. In addition to land use the outcomes of the scenario study for Flanders include a variety of time series and spatial indicators in GIS format which can be custom-defined and derived easily from the model results directly. These are extremely useful for detailed analysis of the spatial consequences of the different world views and spatial planning purposes.

We will discuss a few examples here. Figure 4 shows the changes in residential land use in the Antwerp region. The urban expansion is most noticeable for the GE scenario, contrary to the RE scenario which shows the formation of a large number of small residential clusters. Both observations are in line with the qualitative descriptions in the two scenarios.

Figure 5 shows the percentage change in the population pressure on “green space” at the EU-NUTS3 level for Flanders as a whole, expressed in the number of persons in a 5 km radius of managed and unmanaged nature, and parks. As expected, the increase is highest for the GE scenario, although the other scenario show regional differences as well. For example, the TA scenario shows an increase in the population pressure on green space for the Brussels region with a decline in the coastal areas. However, even for the moderate RC scenario we notice an increasing pressure on nature in East Flanders.
Figure 4. Changes in the residential land use (red = residential in 2010, blue = residential in 2050, green = residential in 2010 and 2050) in the region of Antwerp for the four world views [Engelen et al., 2011].

Figure 5. Regional differences in the percentage change of the population pressure on green space in the four world views between 2010 and 2050 [Engelen et al., 2011].

Figure 6 shows an example of a probabilistic indicator: the probability of urbanized land use (residential land use and economic activities), which was obtained from a Monte Carlo analysis based on 25 model simulations with one stochasticity parameter used for the local interactions. Clearly, spatial planners will be faced with the expansion of large cities such as Antwerp at the cost of other, surrounding functions such as agriculture and unprotected nature. Although the exact location and timing cannot be predicted the general pattern is clear, and should be taken into consideration when discussing long-term strategies with respect to infrastructure, services or utilities.
4. DISCUSSION

Uncertainties are inherent to the formulation of scenarios, the assumptions underlying the application to Flanders as well as the procedure followed for the spatially explicit translation to the RuimteModel, which had to be based on a combination of different qualitative and quantitative sources. The main objective of the procedure was to obtain parameter settings resulting in model behaviour matching the qualitative descriptions of the world views in the best possible way. A general conclusion is that the land use maps and in spatial indicators derived with the RuimteModel are sufficiently distinct for the world views and consistent with the qualitative descriptions given.

The ability of the RuimteModel to enable spatially explicit interpretation of the long-term scenarios has considerable added value for for regional and local planning. All in all the spatial information generated is substantial given the limited time and budget available for the exercise. Nevertheless, the real value of the outcomes of the exercise for planning purposes should be verified in a practical application. Furthermore, it should be emphasized that the exercise is based on a qualitative interpretation of the WLO study and application to Flanders by domain experts and key stakeholders, based on an afternoon workshop. A more systematic follow-up of the approach should be based on a qualitative systems analysis of the social, institutional, physical and economic feedback mechanisms governing land use in Flanders prior to a quantitative modelling exercise of land use change. Future scenario studies for Flanders or elsewhere could benefit considerably from the inherent consistency resulting from such an approach.
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REFERENCES


