Modelling land use dynamics in Luxembourg cross border region.

The use of Cellular Automata and decision Tree Learning Model.

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1. Introduction

Human activities (urbanisation, industry) and natural hazard effects (floods, drought, etc.) shape land use and land cover features over space and time. Stakeholders need planning tools to develop land policy strategies (e.g. zoning regulations) and to improve various aspects in urban planning. Therefore in the last decades, they relied on scientist to provide them with efficient decision support tools. In this paper, a decision support system is presented that aims at helping stakeholders in forecasting future changes in land use, which will result in better planning. This system consists of an integrated model combining Cellular Automata (CA) and decision tree learning. The later is used to define the transition rules of the former. The results from applying this model on Luxembourg and its cross-border regions show that the integrated model performed very well in predicting the change in land use and in detecting its patterns. This model also proved to be a useful for finding out why and where changes in land use occur?

Keywords: Cellular Automata, Decision Tree, Land Use, Cross Border Region.

2. Context and problem

There is a debate in Luxembourg around the future of this country in term of land use changes due to the expected future urban growth. Like many country in Europe, Luxembourg has to face the fact that the increase in land demand in the last decades resulted in creating serious challenges in term of sustainable development and territorial management to the stakeholders. The IVL (Integratives Verkehrs-und Landesentwicklungskonzept), the Luxembourg zoning status (strategic document for urban planning) is a strategical instrument and conceptual plan. In this document several scenarios to 2020 are presented including: spatial scenarios (densification of the habitat zones; polycentrism, etc.), socio-economic and socio-demographic scenarios (economic development resulting in increasing employment, population of the country, and number of commuters from cross border region). Proposing such a futuristic plan will contribute in promoting a sustainable urban development in Luxembourg.

3. General motivation and objectives

The goal of this paper is to take an active part in the debate initiated by stakeholders about how to better anticipate the change in land use for the future of Luxembourg and its cross border regions. To do that, this contribution aims at proposing concrete answers and provides the stakeholders with a decision support system capable of detecting and extracting indicators that are relevant for land use change. Furthermore, the contribution will also be discussing around the potential of integrating cellular automata and decision tree learning model for modelling the land use change.

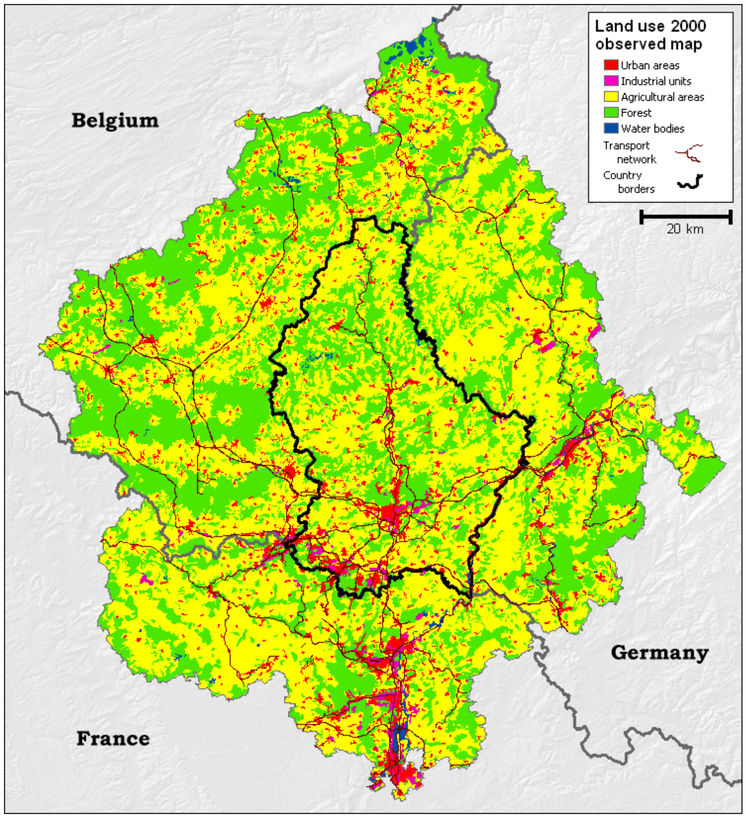

Figure 1: The study area
(Source: Corine Land Cover. EEA, 2000)

The research questions behind this paper, which are presented in section 4, show the way that we are going to contribute into the debate of land use change forecast.

4. Methodology

Land use and land cover are very complex structure due to the dependency and spatial correlation between land use classes and the multiple relationships that govern their evolution. Urban land (e.g. residential, transport networks, commercial and industry) is one of the most complex land use class to analyse due the presence of the human activities and planning. In fact, urban land has different shapes including dense/compact, disperse or both. The urban shape/morphology depends on the available land and on decisions concerning urbanisation (densification or dispersion) that stakeholders take. In the case of Luxembourg and its cross border region, the following fundamental questions come up: which kind of urban growth is suitable for Luxembourg? where to encourage the growth? and where to make strong restriction? And why? where are the suitable area for growth? What are the trajectories of the land use/cover changes? where to stimulate territorial restructuration/reorganisation and why? what are the main risks associated with the establishment of such an urban growth in terms of the sustainable development? To answer these questions, we model the land use changes in Luxembourg using cellular automata based model.

This study combine decision tree machine learning algorithm and cellular automata to forecast the land use dynamics in Luxembourg, and provide a model that can be used as a decision support system. The integration of these two modelling techniques has not yet been much elaborated in the land use change literature.

The decision tree model is used to define the transition rules. The driving factors are joint and structured into one data set, which is then cleaned, filtered and sampled into training and test data set. The sampling strategy used in the paper is proportional stratified random sampling where observations (cells) are proportionally sampled according to their land use class. 60% of the data set is devoted for training the decision tree whereas the remaining 40% are used for testing the developed model. The training data set is used to calibrate the model, extract land use change patterns, and define the rules controlling cells dynamism. The model resulted from the calibration process is then validated using the test data set, and its performance is assessed with various predictive modelling performance metrics such as mean square error and accuracy. The spatial data were processed, filtered and structured using ArcGis 10.1 and the development of the model was done using Matlab.

In the current version of the model, only business as usual scenario is implemented. In business as usual scenario, we assume that future land use will follow the land use change trend learned from historical of 1990 and 2000. In this model, we assume that only the driving factors presented in table 1 affect the land use change. Thus, we did not consider the impact of socio-economic and demographic factors on the dynamic of the land use.

The model performed very well in extracting and capturing the land use change patterns and mimicking the land use evolution processes. The model has over 95% of overall accuracy in predicting the land use for the year 2000. In particular, 82.44% and 99% of changed and unchanged cells, respectively, were correctly predicted. The changes to urban land use forecasted by the model are located on a suitable slope and within an adequate distance from major and transportation facilities. The majority of predicted change to urban are located in the south and the center of the study area, which is totally in line with the reality (see figure 1).

4.3. Data versus. Model variables

Table 1: Model inputs vs. details of datasets

Variables	Description of the variables
Land use states	1: Urban, 2: Industry, 3: Agriculture 4: Forest, 5: Water. 6. transport
Moore-neighbours	- Urban–neighbours in the 3×3 Moore neighbourhood - Industrial–neighbours in the 3×3 Moore neighbourhood - Agriculture–neighbours in the 3×3 Moore neighbourhood - Agriculture–neighbours in the 3×3 Moore neighbourhood - Forest–neighbours in the 3×3 Moore neighbourhood - Water–neighbours in the 3×3 Moore neighbourhood - Transport–neighbours in the 3×3 Moore neighbourhood
Border/Frontier	Distance to border/Frontier in Km
Slope terrain	Slope value of cell (%)
Distance	Distance to main cities
	- Distance to Luxembourg city in Km - Distance to Differdange city in Km - Distance to Esch-sur-Alzette city in Km
Transport–networks	Distance to transport networks
	- Distance to the closest bus station (meters) -Distance to the closest train station (meters) - Distance from cell to the nearest highway access point (meters) - Number of bus stations located 2km away from cell - Number of train stations located 2km away from cell

5. Expected results

In this section, we will present:

- The spatial and temporal analysis of urban and industrial land using accessibility variables.
- The time access in minutes from highway to industrial and urban land use classes

- The distribution of urban and industrial land uses considering the distance from border.
- The land use dynamics (e.g. Business As Usual scenario/ the identification of the trajectories of the land use/cover changes).
- The spatial and temporal discontinuity of land use changes.
- CA-based decision learning tree model as the new contribution in CA based land use/cover change model.
- Developing a realistic decision support tool allowing the stakeholders to be able to anticipate changes and face sustainable development and territorial cohesion challenges for the upcoming decades.

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7. References

Adams D, 1994, Urban Planning and the development process. *UCL press, London*.

Batty M, Xie Y, 1994, *From cells to cities*. Environment and Planning B: Planning and Design 21(7) 31-48.

Breiman L, 1993, Classification and regression trees. *CRC press*.

Clarke K C, Gaydos L J, 1998, *Loose-coupling a cellular automata model and GIS: long-term urban growth prediction for San Francisco and Washington/Baltimore*. International Journal of Geographic Information Science 12: 699-714.

Couclelis H, 1985, *Cellular Worlds: A framework for modeling micro-macro dynamics*. Environment and Planning A (20): 99-109.

EEA, 2000. CORINE land cover technical guide—Addendum 2000. *Technical report No 40, European Environment Agency, Copenhagen, pp. 105.*

Phipps M, 1989, Dynamical *Behavior of Cellular Automata under the constraint of Neighborhood Coherence*. Geographical Analysis 21: 197-204.

Tobler W. R, 1979, Cellular geography *in Philosophy in Geography, S.Gale, G.Ollson (Eds), Reidel, Dordrecht: 279-386.*

Torrens P. M, O'Sullivan D, 2001, Cellular automata and urban simulation: where do we go from here. *Environment and Planning B: Planning and Design 28(2): 163-168.*

White R, Engelen G, 1993, Cellular automata and fractal urban form: a cellular modelling approach to the evolution of urban land-use patterns. *Environment and Planning A: 25: 1175-1199.*