Land-use modelling in a transnational context

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1. Introduction

Management of the world's coastal and marine resources was set on the international agenda by the conference in Rio in 1992. Since then, several bodies have called for a more integrated management of the coastal zone as a fundamental prerequisite for sustainable development, and one of the most recent efforts is the EU Recommendation for a European Strategy for Integrated Coastal Zone Management (COM, 2000). The challenge for planning is to ensure the efficient use of limited land resources and to contribute to balanced regional business development and balanced use of resources, including natural and landscape resources, soil, water and air. Using modelling and simulation, we can reduce uncertainty and increase our understanding of the land-use system. Spatial planning is a future-oriented activity, and with the help of land-use models, it can facilitate scenario building and provide an important aid in the decision making process.

Forum Skagerrak is a EU financed project aiming at a sustainable development for the Skagerrak region, covering parts of Denmark, Norway and Sweden. The current paper describes the effort to develop a land-use simulation model facilitating the decision process including the public participation phase concerning regional development plans, particularly in the coastal zone.

The paper is divided into 5 parts. After the introduction follows a discussion of land-use modelling and a conceptual description of the model. Then in the next sections follows a description of the implementation and data issues related to the model. The paper ends with some conclusions and an outline for subsequent work.

2. Land-use dynamics and modelling

Models of land-use change can address two separate questions: a) where are land-use changes likely to take place – the location of change); b) and at what rates are changes likely to progress – the quantity of change (Veldkamp & Lambin, 2001). A prerequisite to the development of realistic land-use simulation models is the identification of the most important drivers of change, and how to represent these drivers in a model.

1.1 Model formulation

Basically the current model simulates future land-use patterns based on socio-economic drivers at two distinct levels, and the land-use types are divided into three categories similar to the MOLAND model (Barredo et al., 2003). The most important category is the active land-use types, which are forced by the demands generated externally. The passive land-use types are not driven by an external demand, but disappear by being transformed into one of the active land-uses. The static land-uses cannot be transformed into one of the active land-uses, but will affect the land-use simulation by attracting or repelling land-use transformation within their vicinity. The underlying driving forces are basically population growth and economic growth. These drivers represent what we call macro-level drivers, and they are modelled externally to our model in various sector models, and basically define the demand for land from each active land-use type.

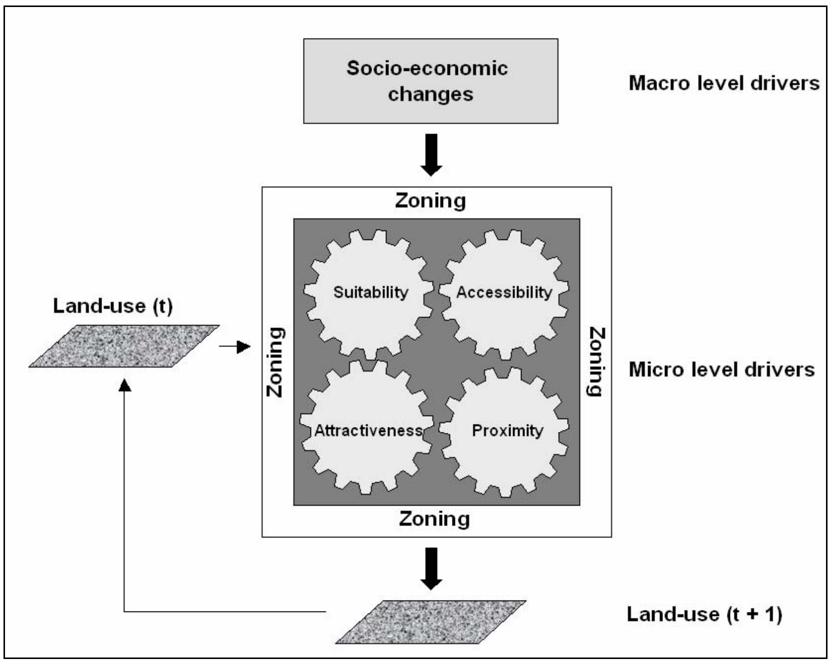

Figure 1. The principles of the land-use model.

At the micro level, we deal with drivers often used in various land-use modelling efforts. The first element to consider is the S*uitability* of each grid cell – i.e. how the specific characteristics of each cell can support a given land-use. The next element to consider is A*ccessibility* – i.e. access to the transportation network. Some activities like shopping require better accessibility than for example recreational activities. The third element to involve in the model is the neighbouring effect, which represents the attractive or repulsive effects of various land-uses within the neighbourhood. Within the model we refer to this effect by the term P*roximity*. The fourth micro level driver for urban development can be summarised in the term A*ttractivity*. Generally, bigger cities are considered more attractive due the wide supply of services and jobs, but even within cities some neighbourhoods are considered more attractive than others, and this kind of attractiveness can even change over time. These four headline factors define the basic preconditions for the cells ability to support a given land-use. Policy making at national and local level have a strong influence on land-use – particularly policies that have a spatial manifestation like creation of conservation areas or designation of areas for subsidised development. However, the current version of the model does only involve policies and legislation with an explicit spatial aim under the headline *Zoning*. Based on these principles we can set up a conceptual model for our land-use simulation model.

The current model applies a cell-based modelling technique, relying on the general principles for multi-criteria evaluation, whereas the native CA approach is disregarded. The transition potential is calculated in two steps. First by combining the factors in the form of a weighted linear combination, and next the constraints multiplied with the factor expression.

$$P^L(t+1) = C^L{}_1(t) * C^L{}_2 * \dots C^L{}_n * \sum (w^L{}_i * F^L{}_i)$$

where
P = Transition potential
C = Constraints (0 or 1)
F = Factors (values between 0.0 and 1.0)
w = individual weight factor between 0 and 1
L = land-use type

By combining the factors and constraints for each active land-use type (L), we can estimate for each cell the transition potential (P) for changing the land-use from one type to another. The number of cell values to be changed during the iterations is determined by the external socio-economic drivers, which spatial distribution are taken into account

3. Implementation

An earlier version of the model was implemented in ArcGIS Spatial Analyst using Map Algebra and Python (Hansen, 2007). Although this model was appealing due to the adaptability and transparency of the model, one serious bottleneck was the really slow simulation performance. Using land-use simulations in an operational context with decision makers and stakeholders requires high-speed simulations. Therefore the simulation environment is redeveloped and separated from the ArcGIS. This new so-called LUCIA (Land Use Change Impact Analysis) modelling framework is developed using the Delphi development suite. The simulation speed is strongly improved. The execution time is reduced with 98 – 99% compared with the ArcGIS solution! LUCIA is a complete user-friendly framework for doing land-use change impact analysis. Besides the application have facilities for model validation using various Kappa statistics as well as several analysis operations like cross tabulation, zone analysis, cross-classification map, distance analysis, and fragmentation index.

4. Data

The LUCIA modelling framework requires a lot of data on socio-economic drivers, land-use, road network, soil type, terrain etc. Obtaining and adapting the data at the national level can be a time-consuming task, but developing a land-use model to be used in a transnational context is a much bigger challenge. Although the Skagerrak region is at the forefront concerning the implementation of SDI it is a huge task to combine these data in practice. One of the basic inputs to the LUCIA model is the CORINE land cover for 1990 and 2000, but these data are only available for Denmark. CORINE is available in Sweden for year 2000, whereas no CORINE data is available for Norway. Therefore we had to rely on other sources for land-use data, with different semantics and with risks for misinterpretation. Similar problems were found for the socio-economic drivers. Thus it has been a huge task to build a common set of input data covering the three countries.

5. Concluding remarks

The coastal zone goes through a critical period with high pressure on nature and environment. In order to mitigate the negative consequences of this development the European Union has defined a set of recommendations for integrated coastal zone management. The use of spatial models and scenarios are repeated from several of the projects. Therefore we have developed the LUCIA land-use modelling framework aiming at supporting the decision making process in the Skagerrak region. The model calculates ex-ante indicators for the assessment of various planning and policy scenarios. However, due to the lack of interoperability it has been a huge challenge to obtain and adapt the necessary data for the model. The subsequent research will focus on methods to carry out most of the harmonisation work automatically.

6. Acknowledgements

I would like to acknowledge the financial support from the Forum Skagerrak project financed by the INTERREG-IIIB program under the EU. Additionally, I will thank my partners in the Counties of Northern Jutland, Østfold, Vestfold and Väster Götaland for helpful suggestions during the course of this research.

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