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Simulation of land use changes in Warsaw Metropolitan Area (Poland)

Application of Cellular Automata with Neighborhood Coefficients

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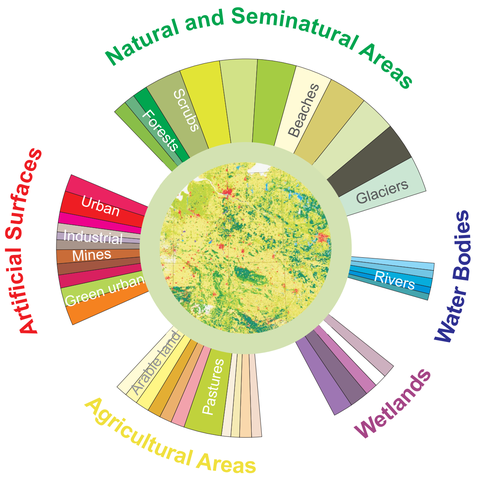
Introduction

Land use is defined as spatial distribution of forms of land cover patches, utilized or not by man within framework of the spatial and mutual relationships. The term refers to the functional character of given terrain and is identified also with the socio-economic description of the surface. Analyses and cartographical visualizations of the changes of land use have their roots in comparison of consecutive time-series of maps. Their overlays and cross-tabulations allow spatial analyses and statistical procedures.

The aim of the research is to verify the hypothesis stating that existing spatial pattern with different classes of land use allow to define tendencies for further spatial development.

Corine Land Cover

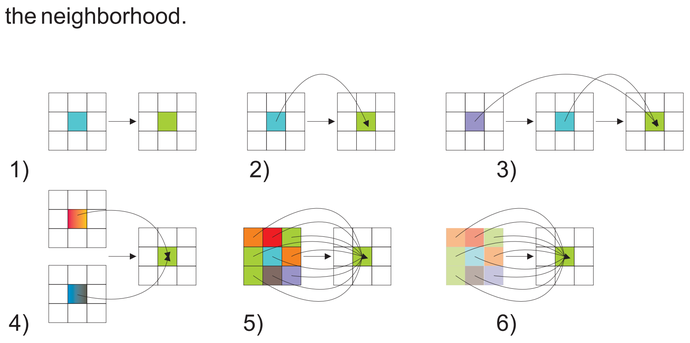
The Corine Land Cover is a computerised inventory on land use of the European countries, at an original scale of 1: 100 000, using 44 classes. The first database was based on the satellite images interpretation in 1990. Next two measurements were made in 2000 and 2006.



Models of land use changes

The main changes of land use has been recognized and the set of models has been distinguished:

1. **Independent model** of changes: each of the following land use form is not related with the previous one in the same place; this is a random variation;
2. **Dependent model** of changes: each of the following land use form is strictly related with the previous one in the same place; the future land use depends on the present situation in the same place;
3. **Historical model** of changes: the newly appearing land use forms depend directly on at least two chronological previous ones in the same place;
4. **Multivariate model** of changes: when the future land use depends on many different features, recognized at present on this area;
5. **Geographical model** (spatial model) of changes - the future land use in the place depends on its neighborhood (at present);
6. **Future geographical model** (conditional spatial model) - the future land use in the place depends on the planned land use forms in the neighborhood.



Neighborhood Coefficient (NBC)

The application of the neighborhood coefficient in analysis of land use changes is the idea of combination the method of map algebra and two-dimensional cellular automata. The neighborhood coefficient is reversible and calculated as the result of the ordered, numbered, nominal classes in the surrounding. The algorithm of calculating NBC is following:

1. Numbering the land use classes:

1	2	3	4	5	6

2. Placing classes into geographical space:

NW	N	NE
W	C	E
SW	S	SE

3. Transfering localizations and values into decimal notation:

$2x6^0$	$2x6^1$	$6x6^2$
$6x6^3$	$6x6^4$	$4x6^5$
$6x6^6$	$1x6^7$	$3x6^8$

4. Calculating NBC as the sum:
:
2+12+216+1296+7776+31104+279936+279936+5038848=5639126

$$NBC = \sum_{i=0}^{8} k_i * n^i, \text{ where } k \in \{0,1,...,n\}$$

i - the consecutive number of the cell in Moore neighborhood
k -the consecutive number, describing in ordered, nominal scale the class of land use
n - the total number of land use classes

5. Obtaining the rules of transition in a conditional form:

if the starting center cell is defined and the starting neighborhood is defined and (some other conditions…) then the destination center cell takes the defined value otherwise it remains intact.

6. Conducting simulation according to NBC and the rules of transition.

Applications of NBCs

1. Detecting the rules of transition
2. Setting priorities in classes
3. Switching from nominal values to ordinal values
4. Comparing classes of different range of values
5. Overlaying von Neumann and Moore neighborhoods
6. Reversing NBC to the initial neighborhood
7. Creating the maps

Simulations in WMA (Poland)

For the purpose of this simulation the land use classes were generalized to 8 classes. The data in 1990 and 2000 were used to create the rules of transition, wherease date in 2006 were used to verify the model. Warsaw Metropolitan Area (WMA) was the area of study. The simulation revealed a high degree of similarity between the maps, which indicates the high efectiveness of the model (histo Kappa Coefficient and loc Kappa Coefficient were used for calculations).

map based on measurements in 2006 (CLC)

map simulation generated for 2006 (NBC)

differences between simulation and CLC
(similarities - green; differences - red)

Conclusions

It seems that NBCs proved their value for simulation of land use changes. The transitional rules, in fact, are the subset of the all changes in the calibration years. They were not supposed to cover all transitions of the geographic model. Some new technical and essential ideas concerning the method would have been applied: using the hexadecimal or any other modular arithmetic, which would limit the very large (decimal notation of) NBCs numbers and lets to extend the neighborhoods. On the other hand, it seems that the described approach summarizes the complexity of factors and lets indirect inferring about spatial patterns of land use changes.
The whole research project has been overworked using the assembled open source and commercial GIS software: IIWIS, Map Comparison Kit and NetLOGO.

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