Technology of suitability maps designing for land use and land cover change modelling

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INTRODUCTION

As a result of increasing anthropogenic impact, which causes irreversible local and global change of nature ecosystems, the tasks of land use/cover change modelling is becoming more urgent. Now the most effective tools for that analysis are the program facilities for land use/cover change modeling such as Conversion of Land Use and Its Effects – CLUE (Veldkamp A., et al., 2002), Land Use Change Analysis System – LUCAS (Berry M., et al., 1994), Urban Growth Model – UGM (Clarke K.C. et al., 1997) and others. There is an important part for the effective application mentioned GIS tools, impacts significantly to land change processes. It is a revealing the driving factors for each land cover types of the investigated area. Driving factors in urban growth model, for instance, influence on urbanization in a specific location. The examples of such driving factors are the influence of distance to roads, distance to markets, distance to water facilities, slope information etc. that could change urbanization probability in each location.

The practical implementation of driving factors information on a degree of impact to expansion (depression) of land use/cover types is convenient to represent with use of so called suitability maps (Clarke K.C. et al., 1997, Zamyatin A., Markov N. 2005). These maps are raster images, where each element (pixel) contains a probability of replacement to specific land use/cover type in accordance with the driving factors influencing on this type. The example of these maps are biophysical suitability map for cereals, shows the probability of

cereals vegetation in each specific location, humidity map, slope map, map with distance to roads, to reservoirs, to trade centers and industrial objects etc.

Now the designing of suitability maps is based on functions for spatial analysis, implemented in up-to-date geoinformation systems (GIS). While suitability maps designing researchers face problems, which complicate the designing itself, disturb taking into account the features of a land use/cover types expansion (depression) and its mutual impact. The difficulties of a limited set of existing spatial analysis functions, the combination impossibility for the raster and vector operations, lack of transparent algorithms for typical cases of suitability maps designing are among of these problems.

The paper proposes a technology of suitability maps designing with expert supporting and significant simplification of the designing procedure for an ordinary researcher. Besides, the program module for GIS ArcView, which has been developing in Tomsk Polytechnic University and realizing the proposed technology, is discussed.

TECHNOLOGY OVERVIEW

Majority of existed GIS has few facilities for designing some suitability maps. It, in their turn, allows taking into consideration few driving factors. However, as practice shows, researchers need more comprehensive facilities for analysis and research driving factors and suitability maps designing. Moreover these facilities should be flexible enough and allow to perform the suitability maps designing transparently.

The proposed technology directs to solving the mentioned problems. It has been creating as a special program module on the basement of GIS ArcView, with a special wizard for suitability maps designing. The wizard offers two different trajectories – for beginners and for advance users (researchers). At the "beginners" trajectory a user designs suitability maps with a minimum intervention to the process, and at "advanced" trajectory a user is allowed to put

parameters and make modification. Let's consider the features of the proposed technology for suitability designing tasks.

The general functional scheme of suitability maps designing, where grey color blocks are the intermediate data and white color blocks – the data processing, is represented on Fig. 1. Let's consider the core of each stage.

Stage 1. As possible to reveal the majority of the driving factors set $F = \{f_1, f_2, \ldots, f_N\}$, which influences to expansion (depression) of the land use/cover types at the investigated area. Next, to match each driving factor $f_h \in F$ with a subset of land use/cover types T_{Fh} ($h = 1, \ldots, N$), so that $T_{Fh} \subset T = \{tp_1, tp_2, \ldots, tp_K\}$, where K – the common number of land use/cover types on the investigated area.

Stage 2. This stage is devoted to the set of additional features for $\forall tp_s$ ($S = 1, \ldots, K$), with the information about driving factor Fh: does it promote the expansion or depression for type tp_s? Taking into consideration, that type tp_s could be represented by objects of vector types (point, line or area objects), researcher set this additional property very easy (expansion or depression) by choosing an object on a map. Next, all vector objects, corresponding their driving factors, should be rasterized, to transfer all data to the same raster format.

Stage 3. Here the pairs "driving factor–land use/cover type" is ranking by priority. It is needed for cases when, for instance, either one driving factor impacts on expansion (depression) of two or more land use/cover types, or one type of land use/cover types is expanding (depressing) in dependence on two or more driving factors. As rule, the problem of the priority is not being discussed and considered during the process of suitability maps designing. Practically, a lot of driving factors could impact on the process of urban growth modelling (Clarke K.C. et al., 1997) and all these factors, obviously, have not the same priority. Therefore, the facility to set such priority in prior could increase the adequacy of modelling process and modelling result significantly.
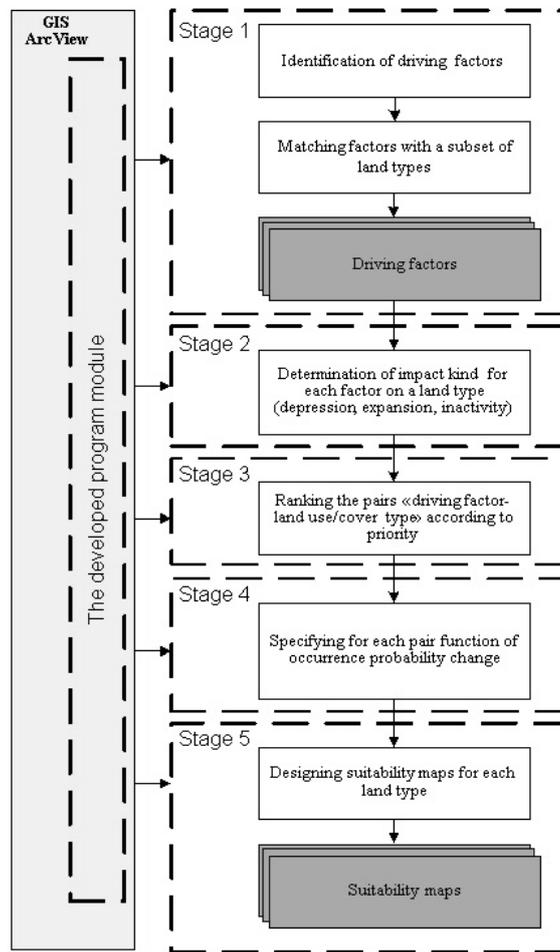
GIS ArcView

The developed program module

Stage 1
- Identification of driving factors
- Matching factors with a subset of land types
- Driving factors

Stage 2
- Determination of impact kind for each factor on a land type (depression, expansion, inactivity)

Stage 3
- Ranking the pairs «driving factor-land use/cover type» according to priority

Stage 4
- Specifying for each pair function of occurrence probability change

Stage 5
- Designing suitability maps for each land type
- Suitability maps

Figure 1: General scheme of suitability maps designing.

Stage 4. To each pair "driving factor–land use/cover type" specifies a function by which (according to linear distance up to an impact factor's object) the change process of expansion (depression) probability for a land use/cover type is implemented. In case of linear dependence, the function will be $y = ax + b$, in case of exponential dependence — $y = ae^x + b$, at that parameters a and b set by the analyst. In addition to mentioned features the developing program module is allowed to specify user's functions.

Stage 5. At this stage on the basis of all collected information the probabilistic suitability maps designing is performing. For this purpose for each land use/cover type tp_s according to the driving factors and using formulas below, corresponding probabilistic maps are calculating. In case of linear and exponential dependence, value of probabilities in each point can be defined as follows. For the linear function in expansion case – $P_{ij} = ((-1/a_j) \cdot x_j + 1) \cdot koef_j$; for the linear function in depression case – $P_{ij} = (1/a_j) \cdot x_j \cdot koef_j$; for the exponential function in expansion case – $P_{ij} = ((-1/\exp(a_j)) \cdot x_j + 1) \cdot koef_j$; for the exponential function in depression case – $P_{ij} = (1/\exp(a_j)) \cdot x_j \cdot koef_j$, where i — number of surface type, j — number of influence factor, a_j — linear distance from j-th object (factor j) to the edge point of thematic map, x_j — linear distance from j-th object (factor j) to the examined point (pixel), P_{ij} — probability of replacement to i-th surface type in the examined point (pixel) depending on j-th factor, $koef_j$ — the coefficient depending on the priority of j-th factor.

After distance maps calculation for each land use/cover types, all corresponding elements (pixels) of these maps with probabilities are multiplied. The result is an aggregating probability of replacement for type tp_s in the given specific location of the analyzed area. These resulting probabilities, matched in accordance with types tp_s, it is offered to use in the land use/cover change modelling.

APPLICATION EXAMPLE

The proposed technology has been realizing as a GIS program module which can be presented in two components – interface and

computing. For the program interface designing the integrated development environment Borland Delphi 7.0 is applying. For module's computing part realization the Microsoft Visual C ++ 6.0 environment with effective compiler and flexible operative memory manipulation capabilities, is implementing.
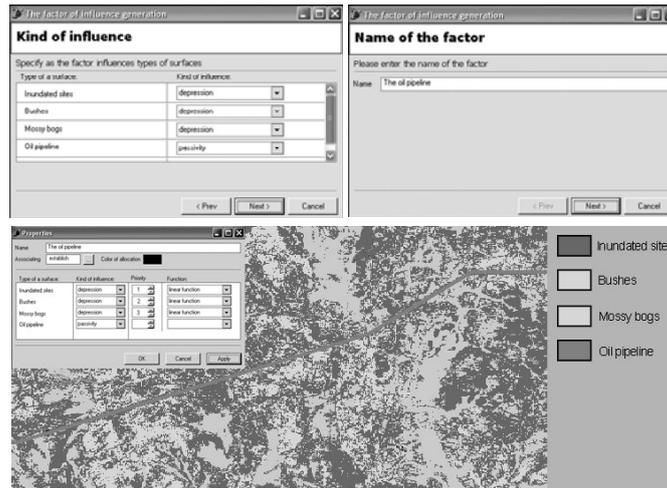

Figure 2: Wizard application for suitability maps designing.

On Fig. 2 an example of the wizard application is depicted during the construction of some suitability maps. The example shows, that the type «Oil Pipeline» depresses vegetation along the pipe, therefore the probability of vegetation class's occurrence near the pipeline is minimal and it is increasing during the process of moving away from the oil pipeline.

CONCLUSIONS

The analysis tasks of land use/cover change dynamics become more and more important year by year. Today the decision of land

use/cover change dynamic analysis tasks, including research problems of the urban areas growth, is becoming especially urgent at deficiency of non-occupied areas in Europe. At that all stages of these tasks require to take into account a lot of various components, including probabilistic suitability maps. Unfortunately, today designing of these maps is not enough transparent and researchers should pay much more attention to that sphere.

The research represented in the paper is directed to solving some of the mentioned problems. The technology and the software implements it, should be directed to regulating, increasing usability the analyst's everyday work. Moreover, the general technology of suitability maps designing, realized as GIS ArcView module, could make the modelling process more effective.

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