Initial landscape microconditions of areas converted to urban land-use in Bratislava functional urban area

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Abstract: Research is focused on connection between modeling tools and planning practice within the topic of landscape change in urban and suburban areas. Research was concentrated only on changes from natural or agricultural use land to urban type of the land use. Together, 170 areas, where the land use has shifted from agricultural or natural to urban, were identified. We mapped land use in spatial buffers around these areas and calculated coverage of each land use type (in %). The mapping of the spatial buffers in GIS environment was based on data from the ortophotomaps in the scale of 1:2000. Areas were divided into two main groups. First group is represented by the areas that changed to housing land-use type and second group contains areas that shifted to industrial and commerce land-use type. Results indicate correlations and inner relations within the groups. We believe that further complex statistical data analysis might provide sufficient information about similarities between transition areas. This might enable to utilize statistical forecasting tools in planning process practise.

Key words: land-use change; GIS; suburban areas; landscape pattern; Bratislava

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1. Introduction

Conversion of land use types in urban and suburban areas is a permanent process. Landscape must fulfil the needs of society and demands for space growth. Due to this fact, development of urban elements is a natural process. Looking on huge scale urban systems we have started to think about it as a complex system (Batty, 2005). There is a huge amount of different approaches in understanding and describing these systems. When we consider urban models we could find various concepts from the agent-based models (ABM) (Manson et al., 2012, Batty et al., 2012), cellular automata (CA) (Batty et al., 1999; Iltanen, 2012), land use transportation interaction (LUTI) (Dearden a Wilson, 2012) and many others. All these approaches operate with system complexity, self-organization and emergence (Batty et al., 2012). They are useful in describing of the system behaviour and help us to explore interconnections and relations within the system. However, the basic principles of CA or ABM are one of the reasons that make them less useful in practical application in urban or landscape planning. Basic principle in this type of modelling is simplification. Using this approach we can examine the elementary system behaviour based on individual behaviour and actions of system elements. But in the urban or landscape planning we are not interested in the transition process and behaviour itself, but rather on the final state. The deterministic models are better for the simulation of most probable final state of the system (Berry, 1995). These models produce exact result based on provided data inputs. Second basic characteristic of CA and ABM is their focus on emergence and self-organization. Contrary to this fact, urban systems are influenced by law, planning interventions and irrational individual decisions. These are the reasons why we consider concept of microsimulation models (MSM) (Birkin and Wu, 2012) more useful for planning purposes and application. MSM might be rule-based and have a strong applied policy focus. Spatial microsimulation models allow data gained from various sources to be linked and patterns to be explored at different spatial scales with re-aggregation or disaggregation of the data. Furthermore they allow updating and projecting, which is of particular importance in forecasting future patterns (Ballas and Clarke, 2001). Undoubtedly, there are more existing concepts of describing change in urban systems except of physical structure effect. Both public and private economic resources are responsible for functional change in urban systems (Jamečný, 2006). Likewise, real-estate models were firstly researched by Healey (1991) and Ball (1998).

Aim of the research was to provide primary insight into landscape change patterns and investigate the employment of obtained data for the future forecasting. The paper describes how proximate surrounding of transition areas affects their shifting process and how these formulas could be used in development of dynamic forecasting microsimulation model (dfMSM). We operated with hypothesis that proximate surrounding of particular area in the landscape affects (or indicates) probability of its change.

2. Methods and material

Within the research we employed classical landscape-ecological method of land-use mapping in combination with several spatial analytical tools provided by GIS environment. After the creation of two GIS layers (using ArcGIS 9.3 software) of land-use (for years 2002 and 2011) we focused on functional urban area (Finka a Kluvánková, 2010) of Bratislava city. Studied area was selected according to the administrative division (cadastres) and consisted of 36 cadastres of Bratislava city.

We concentrated on the areas in the process of their functions conversion. In intensive urban areas, the identification of these changes is difficult because of polycentrism and multifunctionalism in current cities. Due to these facts we have studied changes of areas from natural or agricultural land to urban type of land-use. Landscape represents complex system formed by components of the environment. Environment is characterized by landscape and its physical expression in the space. The advantage is in possibility of simple identification of landscape based on ortophotomaps. We used them to create maps of land-use in two time horizons of years 2002 and 2011. We identified three basic land-use types: natural, agricultural and urban.

By means of map overlay in GIS environment we were able to determine a list of areas converted in the given time frame. In the next step we described the microconditions of each area by area position, perimeter, size, initial land-use type, target land-use type and real land-use composition of the area spatial buffer. Together, we identified 170 areas where land-use has shifted from agricultural or natural to urban use. We operated with hypothesis that areas, which have changed to similar land-use type, are going to have similar spatial patterns. These patterns create initial microcontitions that affect the transition process. We have divided the transition areas into two main groups. First group consisted of areas that have changed to rural or urban housing (137 areas). Second group included areas that have changed to industrial areas, storage houses, agricultural or commerce buildings (29 areas). Average surface size of each transition area was 39120 m2.

Within the analysis process we considered Tobler's first law of geography which indicates that "everything is related to everything else, but near things are more related than distant things" (Tobler, 1970). Following this note we regarded the nearest land-use coverage as the most significant factor that might drive (or at least indicate) the transition process. Spatial buffer of ten meters for each transition area was created. Then we mapped land-use in these buffers and calculated area coverage (in %) of each land-use type. The mapping of the spatial buffers in GIS environment was based on data from ortophotomaps with scale of 1:2000. We recognized 8 land-use types: forests, grasslands, agriculture, water bodies, subsurface, housing, industrial and commerce, transport infrastructure. Consequently, we rounded coverage size of each land-use type and display results in the distribution chart.

3. Results

Results of selected methodological approach are displayed in the table 1 and in figures. As we noted above, the areas were split into two main groups. First group (1.) is represented by areas that changed to housing land-use type and second group (2.) contains areas with change to industrial and commerce land-use type. From the eight surrounding land-use types, four of them - agriculture (A), housing (B), industry and commerce (C), transport infrastructure (D) - were regarded as crucial in affecting (indicating) land-use transition. Spatial distribution of their extents in surrounding of transition areas is displayed in charts below. Figs. 1A–1D represent distribution in first group and figs. 2A–2D represent distribution in second group.

Table 1: The ratio of areas without selected land-use types in the spatial buffers

	Areas changed to housing land-use type [%] (1.)	Areas changed to industrial and commerce land-use type [%] (2.)
Absent agriculture land-use type	2.92	17.24
Absent housing land-use type	24.82	82.76
Absent industry and commerce land-use type	63.50	41.38
Absent transport infrastructure land-use type	11.67	20.69

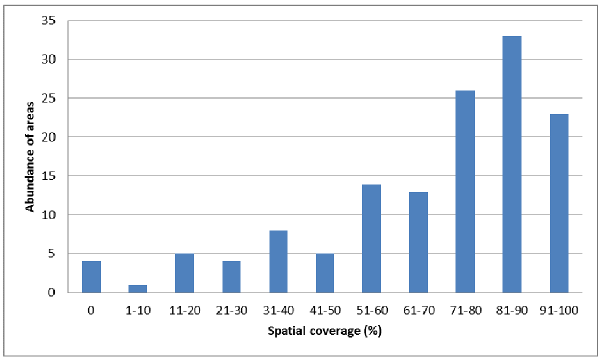

Fig. 1A: Coverage of agriculture land-use type in buffers around areas changed to housing land-use type

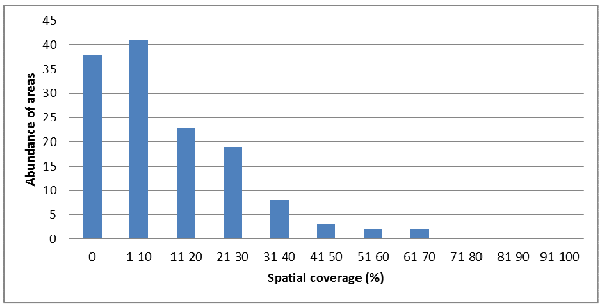

Fig. 1B: Coverage of agriculture land-use type in buffers around areas changed to housing land-use type

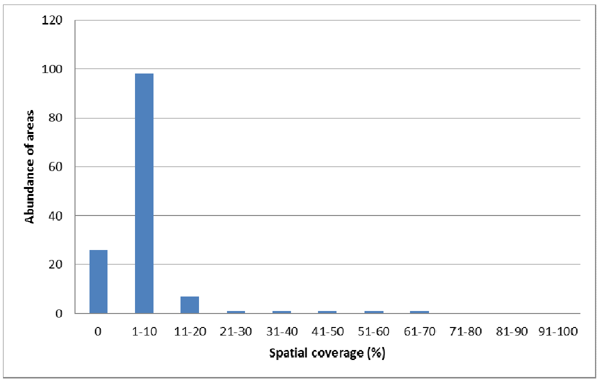

Fig. 1C: Coverage of industry and commerce land-use type in buffers around areas changed to housing land-use type

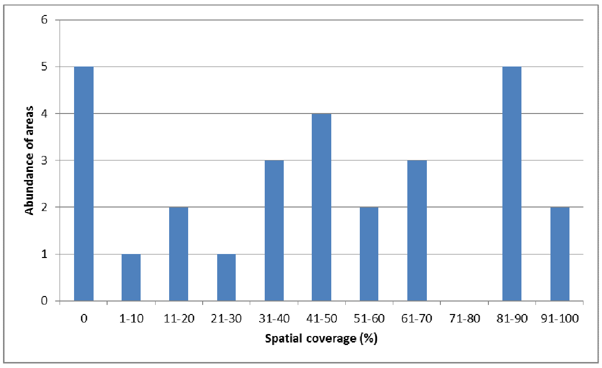

Fig. 1D: Coverage of transport infrastructure land-use type in buffers around areas changed to housing land-use type

It is obvious that agricultural land is one of the key factors in conversion process (Fig. 1A). There are only 4 areas in first group and only 5 areas in second group that have no spatial contact with agricultural land. In fact, most of all transition areas were originally types of agricultural land, mostly large-scale ones. Fig. 1A and partly also Fig. 2A show that most of the transition areas are surrounded by agricultural land (the ratio of agricultural land is more than 40 %). The highest number of areas is surrounded by agricultural land in the range of 70-98 %. Coverage of housing land-use type in the surrounding buffers (Fig. 1B and Fig. 2B) is crucial only in the first group. In general, coverage of housing land-use type is lower than coverage of agriculture land-use type.

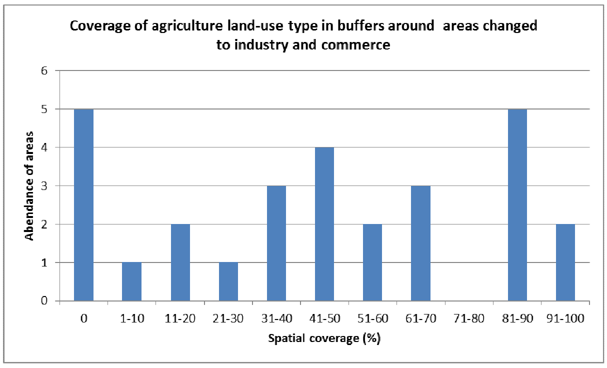

Fig. 2A: Coverage of agriculture land-use type in buffers around areas changed to industry or commerce land-use type

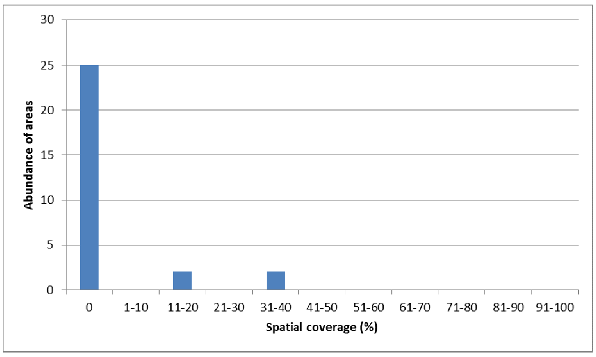

Fig. 2B: Coverage of housing land-use type in buffers around areas changed to industry or commerce land-use type

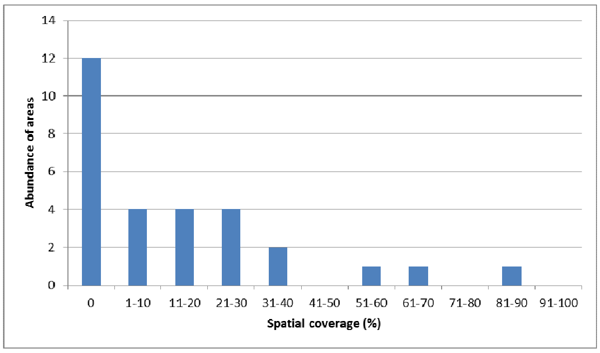

Fig. 2C: Coverage of industry and commerce land-use type in buffers around areas changed to industry or commerce land-use type

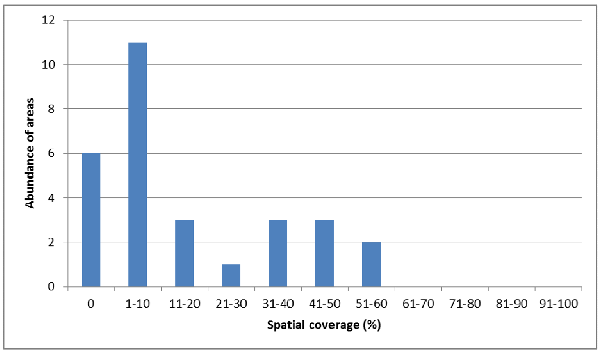

Fig. 2D: Coverage of transport infrastructure land-use type in buffers around areas changed to industry or commerce land-use type

There are almost 25 % of all areas that have no contact with other housing land-use type in the first group (Table 1). Most of them have less than 30 % coverage of surrounding housing land-use type (Fig. 1B). It is worth noting that presence of surrounding housing land-use type in proximate or short distance is a key factor in transition process of area to housing land-use type. On the other hand, almost 83 % of areas changed to industry or commerce (second group) land-use type, had lack of surrounding housing land-use type. Following the noted, it might be assumed that approximation to housing land-use type acts like negative factor of attractiveness mostly for industrial land-use type. Presence of industrial and commerce land-use types do not represent an explicit factor (Fig. 1C and 2C). More than 63 % (in the first group) and more than 41 % (in the second group) of all areas have no contact with this land-use type (Table 1). For finding a further spatial pattern there is a need to consider the related data. We don't believe that a significant correlation between proximity of industrial and commerce land-use type in the areas, that changed to housing land-use type (first group), exist. The term of industrial and commerce land-use covers various buildings and services. Some of them might act as attractors, some of them (like heavy industry, storage houses) act as inhibitors of housing development. We are convinced that 'the proximity of industrial and commerce areas affect the future evolvement of housing land-use types'. However, it is necessary to examine data more deeply and use more complex cross checking (probably statistical) analysis in order to reveal the pattern. Contrary to the case of second group we believe in strong correlation, which is not obvious. We think that in the process of industrial and commerce land-use development two main types of development might occur - expansion type and creation type. The first one reflects the development of new, mostly industrial, buildings in the highly industrial areas. To reduce the costs, this land-use evolves in the area of former industrial zones with present infrastructure. Second (creation) type is interconnected with the harmful process of urban sprawl. These areas (mostly storage and commerce) develop on the greenfields in the suburban areas. It could be said that there are only two main factors attracting such development. The first is sufficiency of free spaces (mostly agricultural land) and the second represents good connectivity and proximity to roads. Availability of traffic infrastructure is crucial in all kinds of development (Fig. 1D and 2D). Of course, it is possible to build new roads and infrastructure but, following the efficiency principle, this is less probable. Just 12 % (first group) and 21 % (second group) of all areas had no direct connection to traffic infrastructure. The real number is even lower as several roads in areas with high density of industrial or housing land-use types could not be observed from aerial photos. Thus, we believe that the connectivity to transport infrastructure in the transition areas is higher that the results demonstrate, although the spatial patterns in both groups are different. In the first group (areas with housing land-use type) the majority of areas have around 1-10 % of the transport land-use type in the proximate distance. Other variables are more an exception than a rule. It is complicated to observe a spatial pattern in the second group due to lack of data. But generally, according to the fig. 2D the maximum extent of the transport infrastructure land-use type within the selected areas is 55 %.

4. Discussion

We admit that forecasting of urban sprawl and modelling its impact on the environment is of great significance and represents a powerful tool in the planning process. Complex view on the system is necessary in order to understand the process of transition of landscape. Additionally, it permits the emergence of complexity from these assemblies across complicated mechanism such as non-linearity, path-dependence, self-organization, feedback, scaling, bifurcation, fractality, etc. (O'Sullivan, 2004). We confirmed our hypothesis that precise data, gained from small area, can be used to predict the possibility of the future development. Main problems in data collection were caused by ambiguity of object in ortophotomaps and their difficult recognition and classification. The map from year 2002 was used as a base for creating a map layer for the year 2011. In several cases we needed to apply the cartographical generalization in order to maintain the structural connectivity between land-use elements. We think that not only ortophotomaps but also cadastre maps could be used to obtain relevant data due to their detail.

5. Conclusions

This research represents first steps in the more complex methodology we would like to accomplish in the future. After the exploration of proximate surrounding of transition areas we want to focus on larger buffer areas which might provide more information about wider context of each area spatial pattern. Findings obtained by this research shown that visual interpretation of results is not enough to explore deeper connections and patterns in the complex system of urban landscape and its development. We are convinced that this goal might be achieved by utilization of advanced statistical tools which analyze deeper interconnections between the data.

This paper revealed some of the spatial patterns and rules that are describing behaviour of the urban system. It also provided relevant insight in the research field which will be irreplaceable in the subsequent statistical analysis. According to our opinion, the complex statistical analysis will provide enough information about similarities between transition areas. This will enable to utilize statistical forecasting tools which might be implemented directly to GIS environment as a plug-in. Using this we will be able to predict possible future transition of the land-use based just on an accurate land-use map.

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