RESEARCH ON NEGATIVE URBAN GROWTH BY MEANS OF REMOTE SENSING AND GIS METHODS

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ABSTRACT:

Urban remote sensing research and model approaches predominantly focus on positive growth patterns. In this paper the phenomenon of a negative urban growth is investigated upon. Such a negative development is mainly named as urban shrinkage. Selected driving forces indicating the spatial process are initially calculated by means of Landsat data for the City of Leipzig, Germany. For a more detailed inner urban differentiation and structure analysis VHR and hyperspectral data will be integrated in future investigations. Supplementary statistical information is analysed as land consumption and decline of population run and interact simultaneously. Apart from relevant predictor variables the concept of a rule-based model approach related to urban shrinkage and demolition is presented.

1. INTRODUCTION

1.1 Motivation

Urban growth with its complex phenomenon of urbanization belongs to the predominant characteristics of spatial development in most European countries. At present, the countries of the European Union are delineated by an average urbanization level of about 75 % (Committee on Spatial development, ESDP).
Interdisciplinary decision making requires integrative tools to analyse quantitatively and melt spatial statistics with vital statistics and qualitative information on living standards and population demands in order to avoid unilateral planning decisions. Tremendously high dynamics of urban development where growth and shrinkage processes occur at the same time can recently be observed in cities of many Central and Eastern European countries. In this particular situation suburbanisation going along with an expansion of residential and commercial areas at the urban fringe is simultaneously observed and interacts with a declining population and a stagnating economy as a consequence of de-industrialization. As a diverging development inner cities with their compact urban form suffer from declining population density and are affected by an increase of residential vacancy as well as industrial and commercial brownfields. As a result, such shrinking cities with expanding spatial land consumption have developed an urban form that is far from being sustainable. Neither the paradigm of growth-driven development nor the well-established planning instruments (e.g. general concepts, land utilisation planning) are helpful in this situation. This counter development can be the opportunity to minimize the amount of land consumption (built-up and not built-up), to develop a different inner structure of the shrinking city, and to redevelop urban areas of residential vacancy and urban brownfields for various demanding neighbourhood purposes.
These processes need to be followed-up upon in terms of their spatial fingerprint, and a more detailed inner urban differentiation to support sustainable management decisions. The methodological approach is to integrate a monitoring system into a sophisticated urban shrinkage model. Such an integrated modelling should be able to comprehend problems and interactions and to permit building scenarios of future urban development.

1.2 References to related work

In many cities where former boomtowns now decline research has been done on urban shrinkage. In most cases research focuses on population decrease and a loss of population density in the central part of the city. The studies correspond to vital and economic statistics that are based on overall, individual, and household statistics, and refer to boroughs or urban structures such as single family houses, prefabricated houses, historical districts, commercial as well as industrial sites. Couch et al. (2005) compare Liverpool, Britain, and Leipzig, Germany, as two cities undergoing the profound functional transformation from a former industrial metropolitan agglomeration to a service economy based city. The study on Ivanovo, Russia, shows a city in post-socialist economic transformation in the aftermath of perestroika (Sitar & Sverdlov, 2004). Booza et al. (2004) investigate on Detroit, USA, as an American metropolis now being a shrinking city. Dura-Guimera (2003) investigates the process of urban de-concentration and urban sprawl dynamics including social processes in the Barcelona metropolitan area, Catalonia, Spain. Using statistics for population development, in and out-migration with respect to a specific urban development of Mediterranean cities in Europe he analyses the decrease of population in the central area, the increase in peripheral area, and the expansion of a dispersed city.
Again, economic, social, and population figures are analysed but not put into an integrative spatial model. On the one hand, land use change models are an important and innovative tool to support spatial planning and development of desired sustainable urban areas.
On the other hand, there are quite a few models that are concerned with urban development: All of them seem to be aimed at urban growth. Due to the complexity of each model and their individual objectives the data requirements for parametrization, calibration, and validation are intense. Models such as CUF 2 for California's Urban Future 2 by Landis & Zhang, LUCAS – Land Use Change Analysis System by Berry et al.,

UPLAN – Urban Growth Model by Shabazian & Johnston, and the SLEUTH Urban Growth Model by Clarke et al. are raster based stochastic models that simulate urban growth or examine the impact of human activities on land use keeping spatial density and expansion in mind. All of them underlie the assumption of a growth-driven paradigm disregarding negative growth as a possible urban development. Some other, vector-based models such as What If by Klosterman or the URBAN SIM by Waddell are modelling systems that support traditional planning activities but do not pay any respect to the phenomenon of shrinkage either.
To describe and to explain the spatial and environmental effects of urban shrinkage the above mentioned conceptual and computational models are not sufficiently reliable in calculating shrinkage processes (Haase et al. 2004). Moreover, not only numerical model concepts but also existing theoretical approaches explaining urban spatial development suffer from insufficiency. They ignore shrinkage or (population, economic) decline process as one major issue of the worldwide existing current urban development (http://www.shrinkingcities.com/index.php?id=31&L=1).

1.3 Study area

The City of Leipzig is located in the northwestern part of the Federal State of Saxony Germany, and historically it was part of the former German Democratic Republic. Leipzig has a long standing history as an important urban centre in Central Europe. More than a century ago the city experienced a period of vibrant growth from the 1870s to the 1930s, making it the country's fourth city when it reached its population peak with more than 700000 inhabitants. An artificial economic push was launched right after the German reunification had taken place by institutional subsidies aiming at an attraction of capital and investments into East German regions and cities. According to unemployment and out-migration these financial incentives led to high misinvestments and negative spatial consequences. As a concomitant of expired promotions of investments further suburbanisation in terms of new family housing constructions now is about to decline.
Regarding the present statistical figures, Leipzig is the second largest city in Saxony with a total urban area of about 298 km^2 behind the capital of Saxony, Dresden covering 328 km^2. With respect to the population it is the largest city in Saxony wit about 481000 inhabitants followed by Dresden with approximately 475000 inhabitants (primary residents in 31/12/2002).
Based on a reform of the municipalities in Saxony during the 1990s the area of Leipzig doubled its size from 153,2 km^2 to 298,1 km^2 between 1994 and 2002. This was due to the fact that between 1995 and 2001 14 adjacent communities were integrated into the City of Leipzig (total area since 2002 see satellite imagery Figure 1).

2. METHODOLOGICAL APPROACH

As satellite imagery as well as statistical data were available for the years 1994 and 2002 these two years became the focus of our investigation.

2.1 Remote Sensing Analysis

Satellite imageries were taken from the Landsat series: for the acquisition date 21/07/1994 a Landsat TM imagery was available and for the 20/08/2002 a Landsat ETM imagery was used. Satellite imagery may provide reliable information assessing the different states of urban growth when detecting its spatial spreading into the peri-urban surroundings. For the City of Leipzig two satellite imageries were taken to find out the spatial development and structural changes within eight years. The question rises if urban development can be shown for the urban fringe or also for spatial changes in the central parts of the city (also see Weber, 2003).

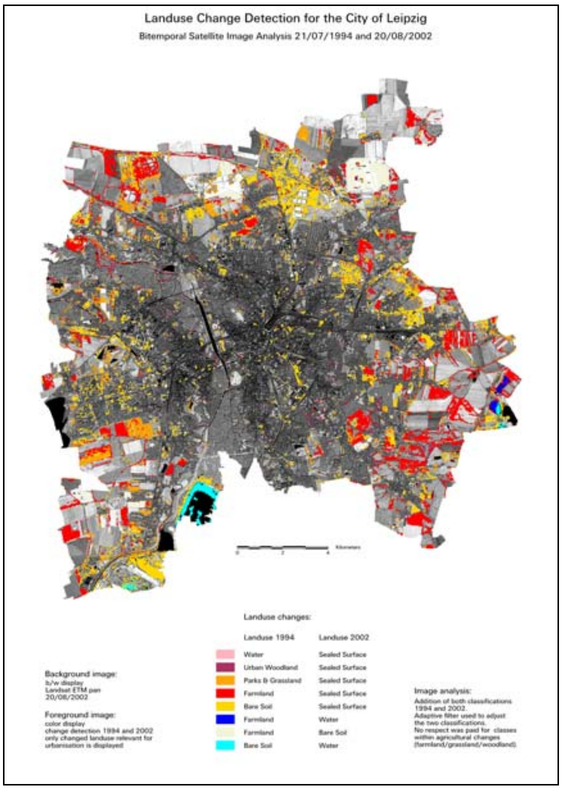

Figure 1: Change detection based on two classifications from Landsat data 21/07/1994 and 20/08/2002

As a first step before classification took place the Normalised Difference Vegetation Index (NDVI) was calculated and stacked to the spectral image layers as an additional synthetic band. In order to compare the two classification results a Maximum-Likelihood classification was carried out for each imagery. The ground truth data were either taken from Colour Infrared Aerial Photographs or from topographic maps. The overall accuracy was about 85 % for the year 1994 and approximately 82 % for 2002 (see Banzhaf & Kindler, 2005).
When calculating a change detection it needs to be considered that variations in classification, e.g. between highly, intermediate, and low sealed surface, or between different types of agricultural land can be due to phenological differences, different atmospheric conditions, classification deficiencies, etc. The post-classification comparison method was taken to detect the highest part of land use changes (Singh, 1989). As classification errors would also indicate changed land use an adaptive filter was used to adjust wrongly detected changes. A change detection of each single pixel can become meaningless because only contingent areas belonging to the same class in a classification and being differently assigned in the comparison of the two classifications allow a reliable conclusion for a changed

landuse. Using the neighbourhood relation focal diversity the compared data sets are modified.
Figure 1 shows the spatial distribution of changed land uses and from which class to which other class the changes mainly occur. It becomes obvious that suburbanisation processes taking place on larger adjacent areas are likely to be detected properly whereas small variations in central urban neighbourhood can hardly be distinguished. Major changes take place in a kind of belt around the built-up part of the urban area where farmland decreases in favour of newly sealed surface. As many areas where assigned to become built-up in 1994 large plots were demolished in the central urban area and farmland was started to be levelled so that the class bare soil occurred all over Leipzig in that very year. In the south and east of the City open pit mining had stopped, slope fixing had started and man-made recreational lakes have been created along the urban fringe.

Landuse	1994		2002		Change	
	[ha]	[%]	[ha]	[%]	[ha]	[%]
Water	74,4	0,7	165,3	1,6	**90,9**	**0,9**
Urban Woodland	539,0	5,2	828,4	8,0	**289,4**	**2,8**
Parks & Grassland	1810,4	17,6	2811,0	27,3	**1000,5**	**9,7**
Farmland	3688,5	35,8	1754,8	17,0	**-1933,7**	**-18,8**
Sealed Surface	1019,7	9,9	4407,4	42,8	**3387,7**	**32,9**
Bare Soil	3172,5	30,8	337,7	3,3	**-2834,8**	**-27,5**
Total	10304,6	100,0	10304,6	100,0		

Table 1: Share and changes of the main land use classes

Table 1 shows the total amount of increase and decrease for the main classes without local assignment. The most dominant development is shown in the increase of sealed surface mainly in the southeast and in the north of Leipzig. This corresponds to the demographic change (see Figure 2). Little stress should be dedicated to the increase in parks and grassland, as the single classifications show a shift from farmland to grassland in the agricultural surroundings. As mentioned before the decrease in bare soil is due to the fact that this class was a transitional stage within the built-up area now being re-built again. One witness of this in-between stage is the large area of bare soil in the northeast of Leipzig (see Figure 1) having been farmland before and now being a huge site of the newly built BMW plant.
As a consequence of the overall result derived from Landsat data there will be further demand for very high resolution imagery and additional hyperspectral data to characterize inner city differentiation and to produce a more detailed input data into the shrinkage model (see Figure 4). In this context there will be airborne hyperspectral data acquisition this summer. In the focus of this analysis will be neighbourhoods under demolition, de-constructed row-to-row houses and urban brownfields.

2.2 Supplementary GIS Analysis

In addition to the spatial configuration the demographic development between 1994 and 2002 was in the focus of investigation.

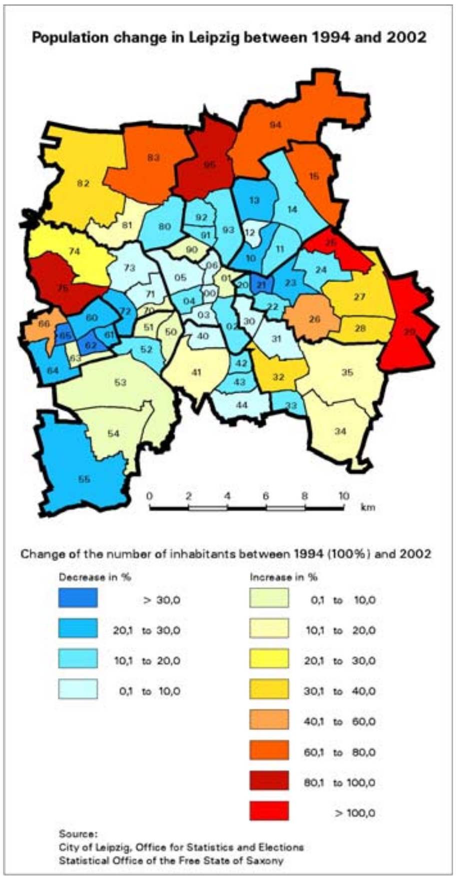

Figure 2: Population change in Leipzig between 1994 and 2002 based on official statistical data

As sources of statistical data came from the Office for Statistics and Elections of the City of Leipzig and the Statistical Office of the Free State of Saxony various analyses can be derived.
The substantial land use change which many East German cities have undergone since 1990 corresponds highly to an extreme demographic change.. On the basis of population change and migration data the overall demographic development is shown. The City of Leipzig is an example for a shrinking city accompanied by an image and role change. In 1994 521539 inhabitants (with primary residence) lived in the present 63 local districts. In 2002 Leipzig only had 481025 inhabitants. This is a decrease of 40514 inhabitants which corresponds to a population decline of 7,8 %.
There are two main reasons for this fact: On the one hand, the population has been decreasing dramatically mainly through an out-migration of the younger population to the western part of Germany because of the lack of job offers and a high unemployment rate that has constantly been between 10 and 20 %. Therefore Saxony has suffered from a population decrease of 9,5 % during the last decade. In the same period the City of Leipzig has lost 11,7 % of its population, even a higher figure than the average of the whole state. On the other hand an urban out-migration into the adjacent communities took place in the period between 1994 and 2002 caused by an

enormously rapid suburbanisation process. The declining population is located in 37 of the inner city local districts and the increasing population has moved to the other 26 rather peripheral local districts (see Figure 2).

There are three local districts with a population decrease of more than 30 %. Eight local districts have a population decline between 20 % and 30 % which are concentrated in the western and in the northeastern part of the city where prefabricated housing constructions from the 1970s and 1980s are dominant. All other districts either show a decline between 10 % and 20 % or below.

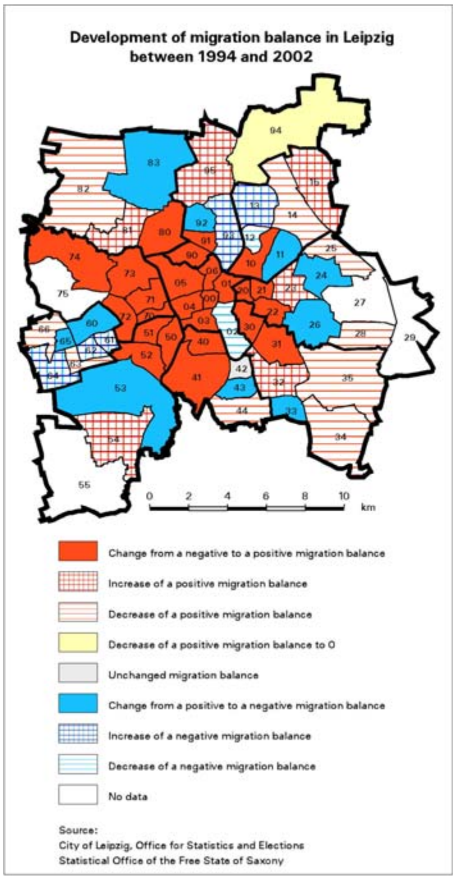

Figure 3: Migration balance in Leipzig between 1994 and 2002 based on official statistical data

On the other hand, 26 local districts are characterized by an increasing population. There is a tremendous population increase in single local districts with e.g. 200,9 % and 166,5 %, both located on the eastern periphery of the city. Other fringe districts with newly built single family houses in the north and in the west have a growth rate 60 % to 90 %. Some traditional inner city parts also have an increase between 0.1 and 10 % which is due to urban redevelopment and a revitalization of the central districts.

The building stock of the more historic houses was in poor condition during the socialist German Democratic Republic. So people had a high demand for better living conditions and started to build family houses along the urban fringe during the 1990s when governmental subsidies were rather easy to get. At the same time redevelopment of the older houses happened with a time shift and the residential environment remained neglected for an even longer period of time. These facts result in an oversupply of urban flats with about 65000 unoccupied dwellings (21% of all dwellings in 2002), and the above mentioned out-migration of families from rather central rented flats to the suburban single family houses.

Therefore it was until 1998 that the out-migration exceeded the in-migration. For the first time this tendency was stopped in 1999. Since then Leipzig has started to get a positive migration balance.

The in-migration doubled from 42902 to 84229 inhabitants showing an increase of 96 % between 1994 and 2002. At the same time the out-migration grew by 72 %. As a consequence the city gained again with a migration balance of minus 3521 persons in 1994, and plus 4539 inhabitants in 2002.

Two positive and negative trends determine the overall development: most of the inner city's local districts having shown a negative value in 1994 could turn the tables and reach a positive value in 2002 (see Figure 3). This is due to the fact that urban planning succeeded in making the city centre vibrant and attractive for inhabitants and tourists. Another positive trend is that boroughs with renovated historic houses and a well-running infrastructure have got a positive balance as well. The negative development either takes place in boroughs with prefabricated houses, or in boroughs with older houses either having a poor residential environment or a badly equipped infrastructure. This is where demolition and de-construction proceeds in a rapid pace.

The development of migration balance also reflects another tendency. In some of the more peripheral local districts in the south east and north east of the city the positive migration balance slowed down between 1994 and 2002 underlining the decline of further suburban demands.

2.3 Concept of Urban Shrinkage Model

The model, based on the theoretical framework given in Figure 4, is supposed to describe the spatial phenomenon of urban shrinkage and related demolition measures based on different spatial configurations, overall concepts and there from derived weighted indices.

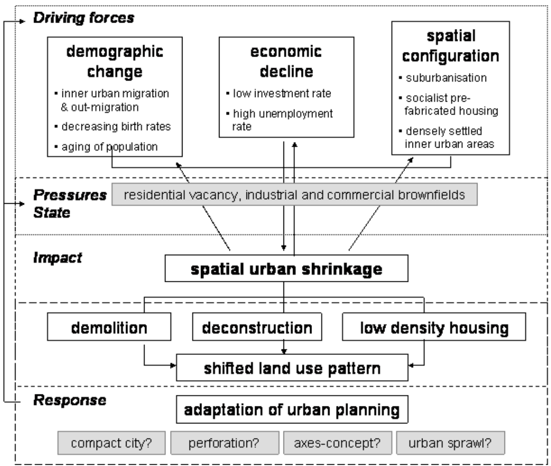

Figure 4: Concept of the Spatial Urban Shrinkage Model

Major objectives of the modelling are to calculate related demolition processes in a socialist prefabricated building area of Leipzig, to know how to weight the predictor variables for given settings (scenarios of the compact city, perforation, and the axes concept). Finally, the applicability of the spatially explicit model utilizing the SELES modelling environment shall be tested (Spatial

Explicit Landscape Event Simulator, http://www.cs.sfu.ca/research/SEED/seles.htm, see Figure 5).

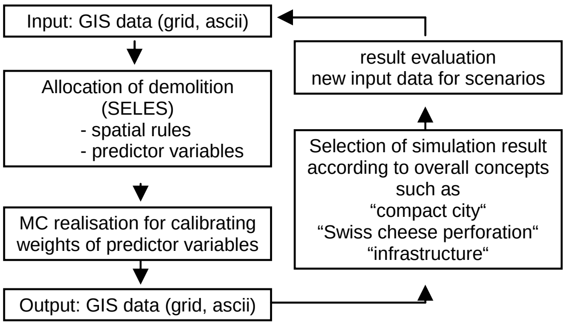

Figure 5: Model flow chart and structure

In a static expert-based and rule-based model, priorities of residential demolition are given to each model unit with residential land use. Demolition priorities depend on specific site characteristics (urban structure type, distance to city (sub-)centre, share of bordering main roads, of bordering brownfields, restrictions and sustainability of preservation. The model includes the variables out-migration, share of residential vacancy, share of population above 65 years. Weights given to these site characteristics make expert knowledge observable and enhance model comprehension.
The model is realised in the SELES modelling environment and bases on the GIS and remote sensing raster database discussed in chapter 2.1 and 2.2. As base units serves a raster model at block level (5x5m) taken from the basic city map 1:500, generated in 1996.

3. CONCLUSIONS

The phenomenon of urban shrinkage can be characterised by spatial changes that will further influence population behaviour. Urban growth models have mainly been concerned with scenarios of a positive growth whereas negative growth is being investigated but not yet linked to an integrative model. Standard remote sensing data such as Landsat can help to investigate suburbanisation processes but come to a limit in the inner urban differentiation especially when focusing on local districts under demolition or de-construction. Further remote sensing data, such as Very High Resolution (VHR) and hyperspectral data, will be taken to tackle this inner urban development. In this paper only some parameters of the driving forces are investigated but others, such as data on economic decline available for the whole city are incorporated into the model (see Figure 4).
The described model approach is designed to build overall concept scenarios for future urban land use pattern using a multi-criteria evaluation with respect to ecological effects of shrinkage. The results will meet in an optimization approach for re-allocation of urban land use pattern. Scenarios will be derived including a shifted land use pattern and trying to follow-up on different adaptations for urban planning instruments.

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