MONITORING AND MODELLING INDICATORS FOR URBAN SHRINKAGE
- THE CITY OF LEIPZIG, GERMANY -

Ellen Banzhaf[1], Annegret Kindler[1] and Dagmar Haase[2]

1. UFZ Centre for Environmental Research Leipzig-Halle, Department of Urban Ecology, Environmental Planning and Transport, Leipzig, Germany; e-mail ellen.banzhaf@ufz.de, annegret.kindler@ufz.de, dagmar.haase@ufz.de
2. UFZ Centre for Environmental Research Leipzig-Halle, Department of Applied Landscape Ecology, Leipzig, Germany; e-mail dagmar.haase@ufz.de

ABSTRACT

Urban remote sensing research and model approaches predominantly focus on positive growth patterns. In this paper, the phenomenon of a negative urban growth, in the following named shrinkage, is under investigation. Selected pattern of the spatial process are initially calculated by means of Landsat data for the City of Leipzig, Germany. Satellite imagery taken from Landsat may provide reliable information assessing the different states of urban growth when detecting its spatial expansion into the peri-urban surroundings. For the City of Leipzig two satellite imageries were taken for the years 1994 and 2005 to find out the spatial development within the last decade. As spatial shrinkage is a phenomena that rather occurs in the central parts of the city and on a larger scale a very high resolution colour-infrared data set is integrated for a more detailed inner urban differentiation of urban structure and analysis of buildings. Supplementary, to seek for drivers of the detected pattern, statistical data is investigated as urban growth and shrinkage and decline of population run and interact simultaneously. Using respective predictor variables such as fertility and life expectancy, migration and residential preferences, a prototype model approach is presented to explain urban shrinkage related to the housing sector simulating residential mobility, vacancy and demolition.

INTRODUCTION

The scientific background of urban shrinkage and demographic change in former industrial regions

Tremendously high dynamics of urban development where growth and shrinkage processes occur at the same time can recently be observed in cities of many Northern American and European countries. In this particular situation suburbanization 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. In the last 50 years, about 370 cities with more than 100,000 residents have temporarily or lastingly undergone population losses of more than 10%. In extreme cases, the rate of loss reached peaks of up to 90% (Âbâdân, Iran). (i)

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 derelict land. 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 are helpful in this situation. This counter development can be the opportunity to minimize the amount of further land consumption, to develop a different inner structure of a shrinking city, and to redevelop urban areas of residential vacancy and urban brownfields creating new open spaces or planning densification projects. (ii)

In the annals of history, the decline of cities is usually depicted as a catastrophic, exceptional event (Atlantis, Troy, Pompeii, etc.), but an examination of the past 50 years shows a contrary development. Shrinking cities are increasingly a lasting phenomenon. The increase in the population of growing cities is significantly higher than the losses of the shrinking cities, but the number of shrinking cities has largely increased. Between 1950 and 2000, the number of shrinking cities has expanded by 330%, while the increase in the number of cities with more than 100,000 residents has amounted to only 240%. Thus, despite all the expectations created by the scenarios of constant growth, the number of shrinking cities has increased faster than the number of boomtowns.

Most shrinking cities in the last 50 years have been in Western industrial countries, especially in the USA (59), Britain (27), Germany (26), and Italy (23) (iii). Since 1990, shrinking cities have increasingly been found in former Warsaw Pact countries, like Russia (13), Ukraine (22), and Kazakhstan (13). Between 1950 and 2000, there have also been an above-average number of shrinking cities in South Africa (17) and Japan (12). But the centers of gravity of this development have been in Europe and the USA. And this trend will increase, because in the future Europe will hardly participate in worldwide population growth. In 35 years, only 10% of the world's population will live in the Western world, and some countries must prepare for a general decrease in population. (i)

Research objectives

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 develop an integrated monitoring system in which land use information and demographic data correspond on a certain scale (e.g. neighbourhood, statistical district, local district). When spatially linking the data we calculate if and how they correlate to comprehend problems and interactions and to build scenarios for future urban development.

Set against this background, this paper analyses the chances and limits of urban monitoring with remote sensing methods and modeling approaches to develop a concept explaining and assessing urban shrinkage processes in their quantitative and qualitative dimension. First, predictor variables for the new process quality of shrinkage in the areas of population, housing, urban land use pattern, are identified. Then response from urban planning will be integrated. It will then be discussed to what extend social science knowledge can be brought together with quantitatively based remote sensing methods and urban model concepts.

Methodologically it will be focused on the way shrinkage processes challenge existing monitoring and modeling approaches, why this shrinkage phenomenon demands both, updated prognostic and observation instruments as well as procedures, and, last but not least, what kind of methodological implications for the development of an urban monitoring and modeling concept is required that includes shrinkage as an accepted urban development strategy.

To allow for a more detailed picture, the paper draws on empirical evidence from East Germany where dramatic shrinkage processes pre-dominate the urban presence and future alike.

Case Study: Leipzig, East Germany

The City of Leipzig is the focus of our investigation as it is one example for cities with negative demographic figures and a decrease in population going along with numerous economic impacts. This negative demographic development is due to numerous facts: a dramatic decrease in birth rates to place after the reunification of Germany in 1990, an extreme loss of inhabitants because of economic contractions going along with a job-driven out-migration to other parts of the country, and a decline for inner urban population density due to suburbanisation processes. (iv)

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 in 1990 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 suburbanization in terms of new family housing constructions now is about to decline.

» In consequence, apartments and houses fall vacant. Vacancy is no longer restricted to uninhabitable housing but also to completely renovated buildings and building complexes. The supply outweighs the demand even if, at present, household numbers still continue to rise. Some residential districts exhibit vacancy rates higher than 30 %, few even exceed 50 % (own investigation).

» This severely negative und unsustainable development brought up the discussion of demolition. As a new strategy, a federal program of urban restructuring was launched (v). It operates in terms of a guideline to organise and finance the demolition of overhang of housing stock and revaluation of the remaining residential areas. Furthermore, it represents a scientific approach to deal with urban development under the conditions of non-growth or stagnation, and shrinkage.

METHODS

Urban monitoring using remote sensing data

Mapping land use and its changes as well as other information taken from remote sensing data satellite imageries were taken from the Landsat series. For 1994 a Landsat TM imagery was available (21/07/1994) and for the year 2002 a Landsat ETM imagery was used dated 20/08/2002. For the City of Leipzig these two satellite imageries were taken to find out the spatial development and structural changes within a very dynamic time period of spatial expansion and continuous population loss. In order to map land use a Maximum-Likelihood classification was carried out for each imagery. The Maximum-Likelihood classification showed an overall accuracy of about 85 % for the year 1994 and approximately 82 % for 2002 (vi).

When calculating the change detection for the two classifications the post-classification comparison method was taken to detect the highest part of land use changes (vii). Figure 1 shows the spatial distribution of changed land uses and assigning *from* and *to* which class the changes occur. Change detection considerably marks suburbanisation processes with the inherent growth pattern and the expansion of impervious surface for large adjacent areas on this spatial scale. Smaller variations in central urban local districts being characterized with a high building density and some of them now under shrinkage conditions are harder to be distinguished with this methodology. So the most significant changes are portrayed in a kind of belt around the central part of the urban area where the city is growing and a functional and structural change takes place with decreasing farmland in favour of newly sealed surface for commercial and industrial sites followed by single family settlements.

In order to monitor and analyse the land use information of the city on the scale of the urban structure types a much larger scale is needed. Therefore a ColorInfraRed (CIR) imagery from the 29/07/2002 is used to calculate the built-up and natural environment within the city by means of an object-based classification approach. The classification shows that single buildings could be extracted and the type of the building could be assigned. The object

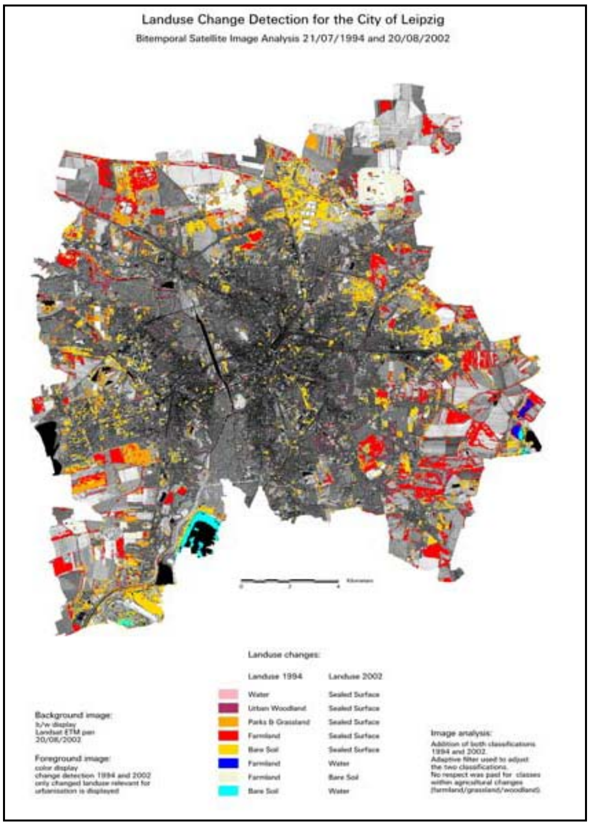


Figure 1: Change detection based on two classifications from Landsat data 21/07/1994 and 20/08/2002

identification could also be applied for water bodies, vegetation, and paved surfaces that do not belong to buildings as the imagery has a ground resolution of 40 cm. Depending on the districts that were classified the overall accuracy was between 82% and 89 %. This classification symbolised the period in time before most of the demolition started in 2003 and mainly continued in 2004. (viii)

So this classification is overlaid with ATKIS (Authorised Topographic-Cartographic Information System) data updated in 2006 and a ground-truth mapping that was undertaken in 2005 to check the building inventory and quantify and localise the demolition of buildings for the period 2002 to 2005.

Mapping demographic processes of deconcentration

Satellite imagery as well as statistical data were available for 1994 and 2002. Assuming, that besides economic variables demography is the main driver of urban land sue change, in addition to the spatial configuration, the demographic development between 1994 and 2002 was under investigation. Statistical analysis show the rapid demographic changes mainly occurred after 1990. Respectively, the substantial land use change which many East German cities have undergone since this time highly corresponds to this extreme demographic change. Based on population change and migration data the overall demographic development is given in Figures 3 and 4. It comes clear, that the City of Leipzig is an example for a shrinking city accompanied by a smart growth at its periphery and an additional change in role and image. Whereas in 1994 521,539 inhabitants (with primary residence) lived in the 63 local districts, in 2002 the total population of Leipzig decreased to 481,025 inhabitants. This is a decrease of 40514 inhabitants in a period of 8 years which corresponds to a population decline of 7.8%. To the most declining belong the 37 inner-city local districts due to a movement to the more peripheral other 26 rather local districts (see Figure 2). This reflects the spatial change of suburbanization shown in the change detection analysis. Until 1998, out-migration clearly exceeded in-migration. In 1999, this tendency stopped. Since then, Leipzig turned to

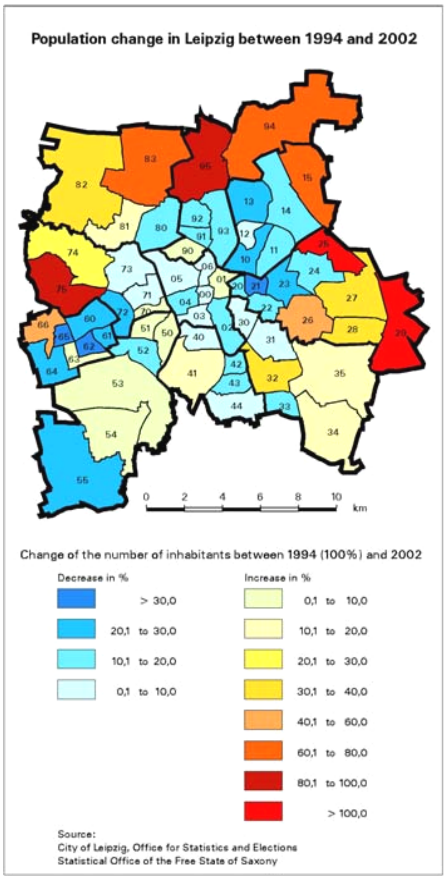


Figure 2: Population change in Leipzig between 1994 and 2002 based on official statistical data

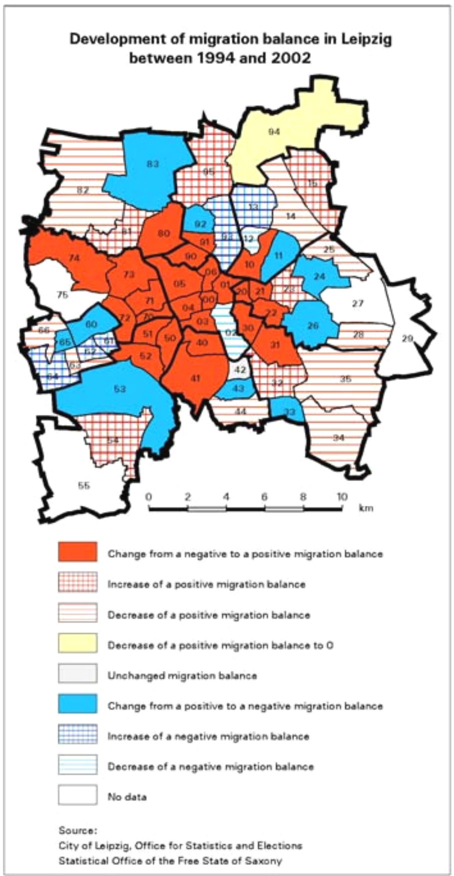


Figure 3: Migration balance in Leipzig between 1994 and 2002 based on official statistical data

have a positive migration balance. In addition to the general in-migration and out-migration pattern an internal migration at district level occurs. This internal mobility is of great interest for the research question on residential pattern and vacancy and will be followed-up by asking why certain districts are the most preferred when rental costs are generally at a low level everywhere. As an overall observation suburbs do not grow as much as in the mid 1990ies. Extreme contrasts are to be observed in the central inner districts where demolition of houses and residential vacancy opposes vital districts with considerable regeneration activities.

Urban land use change modeling under conditions of shrinkage using spatial and socio-demographic predictor variables

In order to analyse land conversion and decline of the urban fabric in cities caused by the socio-demographic shrinkage processes described above, models can be used as innovative tools to support spatial urban planning with scenarios. Urban models that deal with interactions between urban land-use change and its socioeconomic driving forces. Frequently used approaches in urban modeling are agent-based models (ix; x), logit models of discrete choice (xi) and complex cellular automata (CA) models (xii; xiii). Most CA and ABM model-applications however deal with urban growth as the predominant form of urban development whereas the process of urban shrinkage remains still out of focus (xiv).

Shrinkage as an urban phenomenon seeks for additional experience-based and agent-, i.e. household-related, knowledge to explain the process. A model approach has to focus on the development of predicator variables and indicators for shrinkage and therefore needs to use evidence provided by quantitative social surveys and statistics: Due to empirical findings of sociological research (xv) as determining socio-demographic factors of shrinkage and residential vacancy related to the housing sector and the agents of this change new age group and household compositions as well as their residential mobility and migration behavior had been identified. Following this socio-demographic path to explain urban shrinkage is driven by demographic changes including new household types and decreasing birth rates as well as out-migration as the Eastern German example explicitly shows. Changes related to the concept of the Second Demographic Transition (SDT; xvi) imply a coincidence of sharp decrease in birth rates, ageing, smaller and less stable households and societal changes in terms of a diversification of lifestyles. Recent research brought up that households act as nexus between changing demographics and residents' housing preferences and thus households are the 'subjects' and 'agents' of housing markets (xvii).

Further, urban policy delivers contextual constraints for the model approach which could be spatially implicit such as verbal arguments and guidelines as well as spatially explicit in form of planning maps. As one pathway of urban shrinkage the following 'compact city concept' is preferred by regional policy makers: The centre of the city is foreseen to be preserved as functional core to maintain urban quality of life in compact structures and to avoid perforation. Demolition activities should be concentrated at the periphery. In fact, not in all cases, the concepts of the policy makers are in line with those of the housing enterprises who take the final decision regarding demolition of their housing stock. Shrinkage and demolition of vacant housing estates provide new place for other uses such as spacious living, less density and more greenery in the neighbourhoods which is equal to typical suburban advantages of housing.

In order to gain knowledge on the creation and progress of residential vacancy and to draw a first sketch of the complex housing sector under conditions of shrinkage an innovative object-oriented framework for modeling firstly the residential mobility of "new household types" (micro simulation) and secondly, decision making in the housing sector is formulated (Figure 4).

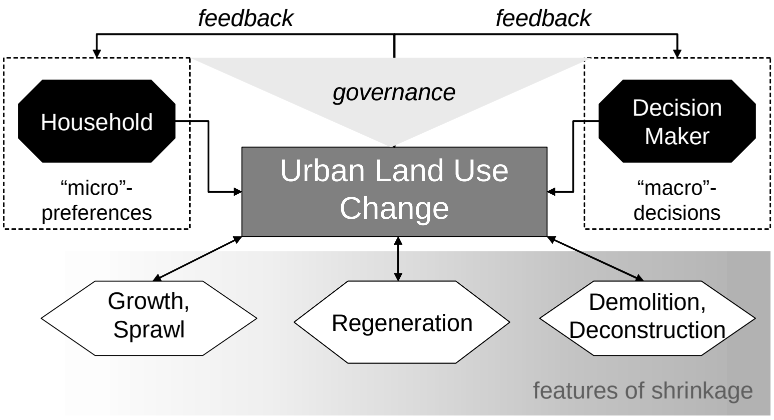


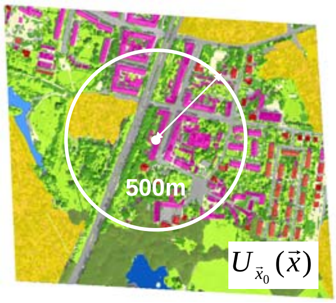
Figure 4: Model concept to operationalise urban shrinkage

In a first procedure, a demographic model translates cohort-based population development into SDT-typical household types (a.o. singles, cohabitation "dinks", patchwork families, single-parent families, elderly cohabitation households, apartment-sharers) drives the model dynamics. Here, we achieved a very good accordance with population statistical data of Leipzig from 1994-2005. An attractiveness vector matrix on spatial environment properties of each household (social neighborhood, housing form, prices, security, transportation, greenery, social infrastructure, shopping facilities etc.) at local district and building level used to formulate a preference-restriction profile for each household to simulate the household mobility represents the "heart" of the simulation (Figure 5). Here, social science survey data and results of the object-based image classification are utilized. In consequence of this model procedure, we achieve a household and cohort distribution for each time step for the whole city. Further, a calculation procedure for the created residential vacancy and new construction sites form the final output of the micro simulation.

Attractiveness (A_h) of a residential unit $\vec{x}$ for a household h:

$$A_h(\vec{x}_0) = \sum_{k=1,2,..} w_{h,k} I_k \left(U_{\vec{x}_0}(\vec{x})\right)$$

$$\sum_{k=1,2,3,...} w_{h,k} = 1$$



I_1 : social milieu SM_h
I_2 : urban structure type St_u
I_3 : social infrastructure (educational, shopping facilities,…)
I_4 : accessibility to urban green (distance to next park,…)
I_5 : security (% of crimes per land parcel)
I_6 : noise, air pollution (mg/kg; dB)
I_7 : travel distance to work (location of working place)
I_8 : travel costs (integrated transport means, infrastructure, …)

Figure 5: Example taken from the classification scheme showing the building structure and building classes "apartment blocks", "detached and semi-detached houses", and "discontinuous Wilhelmeanian style row houses" as well as the vegetation structure ("parks" and "community gardens") - Spatial units of the housing sector serve as base to which a social science data based preference matrix is applied.

RESULTS & DISCUSSION

After having identified spatial suburbanisation processes, a new focus in urban land use monitoring activities was set on deriving urban structure types (land use and buildings) from remote sensing data. This data set is compared with ATKIS (authorized topographic-cartographic information system of Germany) to produce a change detection for the process of the demolition of houses and, what is more, to assign demolished houses to specific urban structure types. Besides economic variables, urban land use changes are mainly related to the demographic development of a city. In the presented integrated model approach we assume that there is a causal relation between the built-up environment (housing and infrastructure), the configuration of green spaces and demographic processes (first of all migration). First results of the model gave evidence that different household types prefer different housing environments and structures, and thus typical pattern of residential behaviour and, what is most, residential vacancies are created. To validate the model results and to set a relationship between residential vacancy and demolition processes there is the need to create valid data of urban land use change at building level. This brings us back to the remote sensing data based object-oriented classification where next steps in research have to prove that data sets on urban structure types could be reproduced reliably, so that demolition and, respectively, new built-up areas can be monitored regularly on a local scale.

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