ANALYSING A REVERSE DEVELOPMENT OF OPEN SPACES AND DENSIFICATION IN THE (SUB)URBAN GRADIENT

- A GIS TOOL WITH REMOTE SENSING AND VECTOR DATA -

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ABSTRACT

Tremendously high dynamics of urban development where growth and shrinkage processes occur at the same time and can recently be observed in cities of many Central and Eastern European countries. Suburbanisation is going along with an expansion of residential and commercial areas at the urban fringe. In this particular case it is simultaneously observed and interacts with an overall declining population and a stagnating economy as a consequence of de-industrialisation (i). As a diverging development inner cities with their compact urban form suffer from this decline in population density and are affected by an increase of residential vacancy as well as commercial brownfields (ii). In this context the gradient from the central urban area to the suburban region is focused to find specific indicators characterising this phenomenon. Such indicators comprise land use changes as well as changes in population, commerce and employment even on the smallest administrative unit (iii). In the developed methodology statistical information from all administrative districts, classification and spatial change detection for pervious and impervious surfaces derived from remote sensing data between 1994 and 2005 are analysed. Goal is an instrument to support evaluation procedures for collaborative authorities to judge where and how fast open spaces come into existence and which densification tasks or open green management should be undertaken (iv). The analysis aims at highlighting the development potentials of the whole regional gradient without the limitation of single administrative boundaries. Therefore neighbouring local authority areas can make use of the instrument.

INTRODUCTION

Landscape fragmentation is regarded as one of the most urgent problems of urban development (v). Urbanisation is related to multiple issues of global change like changes in economic, social, and also spatial structures going along with environmental conditions. Facing the structural change from industrialised to service-oriented and information-based society, current urban functions are a continuous process of decline and reorganisation or revitalisation. Driven by an increasing demand for living space, an augmenting number of single-person households, a higher mobility and recreational requirements the urban population has an expanding need for settlement and transport spaces. This development parallels to the rising land use claim for commercial and industrial sites.

With regard to the national sustainability strategy 2002 (vi) a goal was formulated to reduce land use demand from presently 105 ha to 30 ha per day in the year 2020. The strategy of urban planning is to pursue a so-called double interior development in order to provide a rather compact city with revitalisation through re-use of demolished sites plus open spaces for recreational facilities. The redevelopment of inner urban derelict land for temporal and even long-term renaturalisation of

parcels can be taken as an ecologically valuable chance. So the release to build-up open spaces in the suburbian belt should be minimised and inner urban spaces should become more valuable. The project aims at checking urban planning concepts of shrinking and growing cities in Germany and defining effective management concepts for the one and the other. Expert interviews and qualitative studies of the design of open spaces will be the core of the planning concept. Remote sensing analysis helps to provide quantitative information to differentiate the expansion and vacancy problem in time and space.

As this investigation is part of the whole project it aims at providing land use change information through change detection and linking land use information to demographic features to take selected indicators to implement a well adapted urban and regional planning concept. This study examines a gradient that is not restricted to administrative boundaries but includes local districts and communes into the test site to give a statement for the urban to peri-urban region without the standard municipality limitations.

The area for which the methodology is tested is the City of Leipzig. Leipzig has a long standing history as an important metropolis in Central Europe. More than a century ago the city experienced a period of vibrant growth from the 1870s to the 1930s followed by a gradual decline for many decades. Right after the German reunification in 1990 an artificial economic push was launched. According to rising unemployment and out-migration these financial incentives led to high misinvestments and negative spatial consequences with a slowing-down suburbanisation process at the turn of the millenium (vii). As an area that stands for the process of suburbanisation and inner urban deconcentration having taken place during the 1990s the region of Leipzig East towards the town Wurzen was selected. The eastern part of Leipzig is a highly dynamic shrinking part of the city. Its adjacent suburbs belong to the growing region with newly built-up single family houses and developed land for commercial sites with direct access to the motorway. Historically, it has been agriculturally used and possesses fertile land. The chosen gradient also reaches the outskirts with the small town Wurzen as a rural centre which is the most eastern part of the test site.

The overall goal is an instrument to support evaluation procedures for collaborative authorities to judge where and how fast open spaces come into existence and which densification tasks should be undertaken (viii). The analysis aims at highlighting the development potentials of the whole regional gradient without the limitation of single administrative boundaries. Therefore neighbouring local authority areas can make use of the instrument. As statements beyond administrative affiliation (urban districts, villages, suburban towns) are supported, a common land management pool can be created for several adjacent municipality districts and villages. What is presented in this paper is work in progress.

METHODS

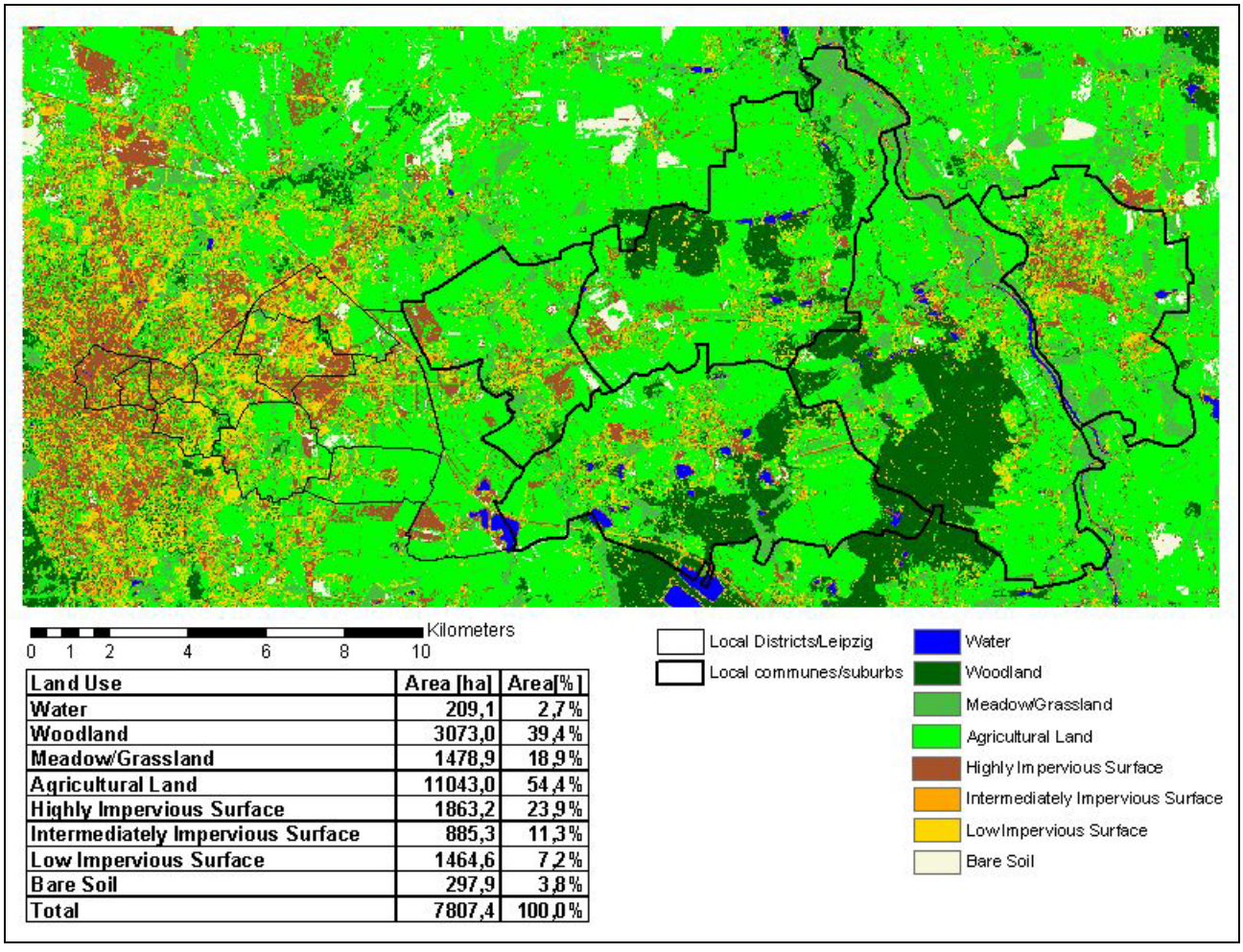
The developed methodology consists of several data packages being analysed: statistical information from all administrative districts, classification and spatial change detection for pervious and impervious surfaces derived from remote sensing data, mainly Spot multispectral, but also IRS-LISS and pan and CIR imageries for the time series between 1994 and 2005, and cadastral data sets for registered derelict land and land use planning from the Authority of Environmental Protection, City of Leipzig. GIS tasks comprise linking the data sets, analysing the spatial dynamics, and evaluating the data with respect to re-activating open spaces and densification potentials for a more sustainable land management.

1. Mapping Land Use

Mapping land use and its changes as well as other information taken from remote sensing data satellite imageries were taken from the Spot 4 and 5 series for 1994, 1998, and 2005. 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 these satellite imageries were taken to find out the spatial development and structural changes within a very dy-

namic time period of spatial expansion and continuous population loss. The question rises if spatial changes in the urban development can be detected for the urban fringe and for the central parts of the city in the same detailed manner. In the latter, the structural patterns have been developed slowly over centuries, and it is exciting to find out how fast the changes may become visual and be detected on this spatial and temporal scale.

In order to map land use a Maximum-Likelihood classification was carried. The ground truth data were either taken from Colour Infrared Aerial Photographs or from topographic maps. Test sites were chosen based on the idea to distinguish a range from highly impervious surface, to impervious surface interspersed with greenery, marking low impervious surface in the classification procedure. This method was only applied for built-up structure types, i.e. single family and row-to-row family houses, old built-up housing estates with built-up or open courtyard, free standing blocks of flats in rows, or large housing estates built during socialist times in the city. Other land use, such as woodland, or agricultural land, and larger parks did not fall under this proportioning assignment as these land use types are a matter of larger contiguous areas. These areas of interest were used to define best fitting test sites for the classification scheme. The Maximum-Likelihood classification showed an overall accuracy of about 80 % for the year 1997 (see Figure 1). As a work in progress is presented the latest Spot data for the year 2005 are not analysed yet. The test site shows the City of Leipzig in the west with the agriculturally used rural area in the centre and the sub-centre Wurzen in the east. The special interest lies on certain transport axes and clustered settlements in-between the urban cores.



Land Use	Area [ha]	Area [%]
Water	209,1	2,7 %
Woodland	3073,0	39,4 %
Meadow/Grassland	1478,9	18,9 %
Agricultural Land	11043,0	54,4 %
Highly Impervious Surface	1863,2	23,9 %
Intermediately Impervious Surface	885,3	11,3 %
Low Impervious Surface	1464,6	7,2 %
Bare Soil	297,9	3,8 %
Total	7807,4	100,0 %

Figure 1: Land Use for the Urban Gradient Test Site (Leipzig East to Wurzen) in 1997

2. Mapping Vegetation Patterns for the Selected Local Districts of Leipzig

The vegetation pattern is looked at under the aspect of developing derelict land in the urban agglomeration over the time slot of more than a decade (1994 to 2005). In this part of the study the rural outskirts were not taken into consideration. As the amount and structure of vital vegetation cannot be assigned exactly in the above described classification scheme the NDVI was exploited in addition. The Spot images from 1994 and 1998 were processed to enhance grey level patterns related to vegetation using the Normalised Difference Vegetation Index (NDVI). The grey level scale reaching from -1 to 1 indicates the amount of greenness as a result of chlorophyll in plants and gives information on the quantity and distribution of vegetation. The NDVI features of the two dates were calculated and compared pixel by pixel. A binary data set was produced on the basis of similar thresholds established for each date, changes in vegetation from the earlier to the later date were labeled with the two classes “1 = vegetation” and “0 = no vegetation”. It is of interest if and how much the similarity between the pattern of vegetation change and vacant property can be found for this period. With reference to the study by Ryznar & Wagner who found a close correlation between the patterns of vegetation change and the urban structure we wanted to compare this phenomenon of the shrinking Detroit City with the one of Leipzig. In this context, information on derelict land taken from the Department of Environmental Protection, City of Leipzig will be overlayed with the classified images to check when and how fast assigned brownfields developed. The question rises if the depopulation of some parts of the inner city going along with an increase of empty houses and an economic decline shows a similar occurrence where natural succession is spreading and so portrays a rising vegetation pattern as it did for Detroit City. Therefore the mean difference NDVI was calculated subtracting the two data sets and the difference in the amount of absolute green space was derived to see the differentiation in absolute figures (see Table 1).

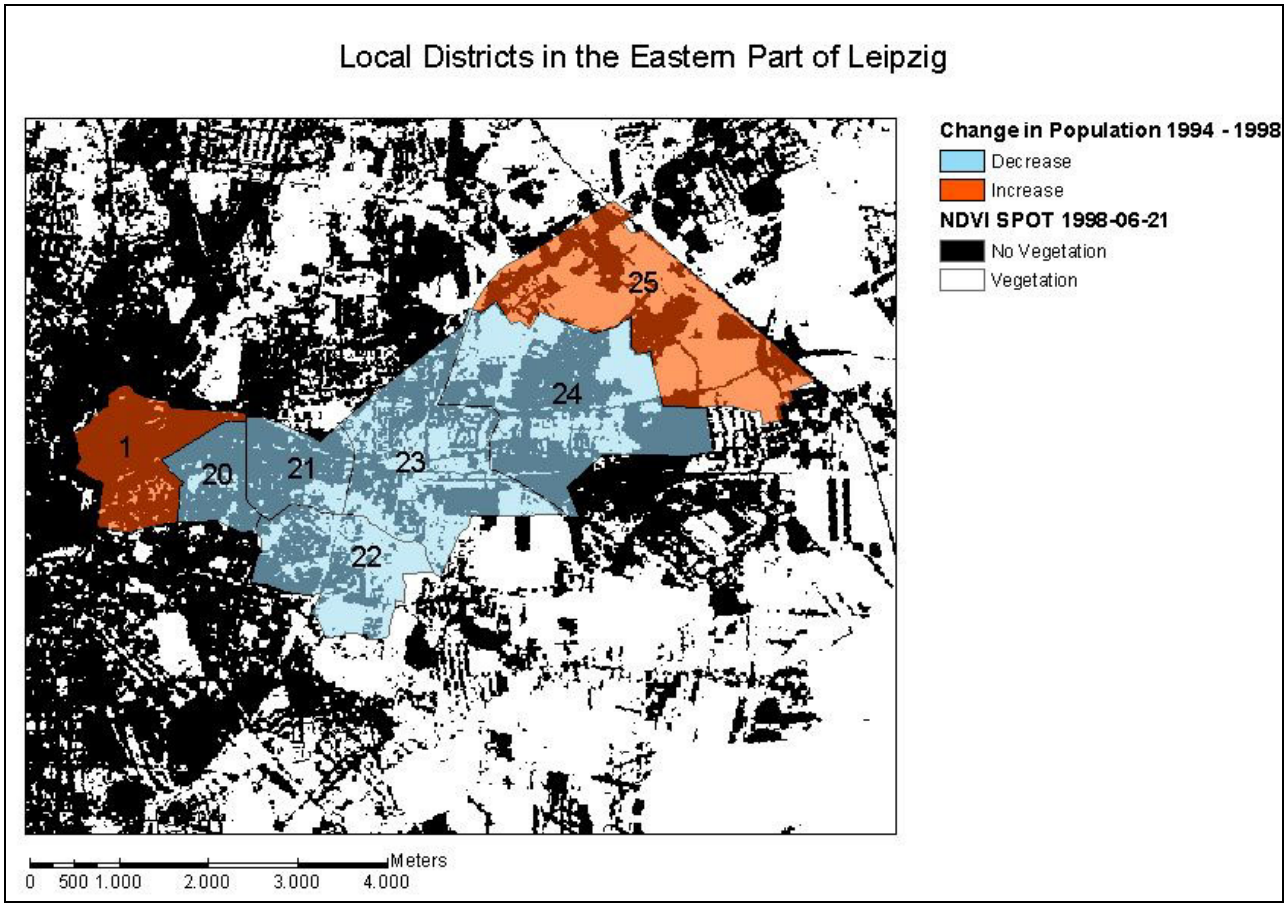


Figure 2: Binary NDVI Data Set Overlayed with Population Changes for the Local Districts of Leipzig

The choice of indicators is dependent on the demographic measures published by the Statistical Office of the City of Leipzig (ix and x). The major demographic indicator being compared with the vegetation provided is the number of inhabitants for which the change in population and the population density in each local district can be derived. Not available on the level of local districts is the median income for each district. So the economic vitality cannot be specified. The data were stacked in such a way that each local district contained data for each acquisition date and could be associated both spatially and temporally with the vegetation change data. It was investigated if, how much, and in which local district differences could be depicted.

Table 1: Demographic Changes and Changes in Vegetation for the selected local districts of Leipzig

Local District	1	20	21	22	23	24	25
Urban Structure Type	I	II	II	II	III	III	IV
Area [km²]	1,61	0,86	1,09	1,9	3,04	3,85	3,89
Mean binary NDVI in 1994	0,064	0,095	0,133	0,509	0,504	0,384	0,66
Mean binary NDVI in 1998	0,059	0,111	0,199	0,552	0,462	0,387	0,599
Mean Diff. NDVI 1994-1998	-0,005	0,016	0,066	0,043	-0,042	0,003	-0,061
Inhabitants in 1994	2622	9779	12173	10722	10380	17328	1420
Inhabitants in 1998	3027	8174	8505	8239	8325	16780	3462
Population Change 1994-1998 [%]	13,4	-16,4	-30,1	-23,2	-19,8	-3,2	59
Population Density 1994	1629	11370	11168	5643	3414	4501	365
Population Density 1998	1892	9082	8505	4336	2775	4303	911
Foreigners in 1994 [%]	9,3	2,4	2,8	1,4	1,5	3,9	1,7
Foreigners in 1998 [%]	12,7	13,5	14,6	10,4	11,1	11,3	5,9
Age Group 6 <18 in 1994 [%]	8,4	16,8	18,2	13,4	11,7	17,8	15
Age Group 6 <18 in 1998 [%]	6,2	14,1	16	12,3	9,9	15,9	14,6
Unemployment rate in 1994 [%]	-*	-*	-*	-*	-*	-*	-*
Unemployment rate in 1998 [%]	12,7	13,5	14,6	10,4	11,1	11,3	5,9

* no reliable data available
I: Wilhelminian Style: old built-up housing estates, built between 1871 and 1918, mixed with old high density industrial and commercial sites and infrastructural facilities
II: Wilhelminian Style buildings dominate
III: Wilhelminian Style buildings mixed with prefabricated houses, detached and semi-detached houses and old, high density industrial and commercial sites
IV: Prefabricated houses, built between 1970 and 1990, mixed with detached and semi-detached houses and old, high density industrial and commercial sites

RESULTS

Table 1 shows selected local districts of Leipzig with high depopulation figures typically found in the most problematic urban structure types of either old built-up housing estates, having been in bad condition or the large concrete housing estates, represented by prefabricated houses, only rarely mixed with other structure types. No such striking result can be interpreted in this figure as in the Detroit study. On one side, it needs to be mentioned that the single family houses in central Detroit City are easier to demolish because they are mostly wooden fabric, in contrast to the European multi-storey brick houses, on the other side it must be reflected that demolishing houses started earlier than it did in Central European cities. The land use structure has still remained more constant throughout the time frame given. The massive depopulation does not mirror the change in the landuse structure significantly yet. What comes last in the changing the green space values are the local districts with the Wilhelminian Style structure type. The land use structure is compensated by empty houses before demolition which only started in 2003. As the two structure types *Wilhelminian Style* and *Prefabricated Housing* are block of flats with renters it is not up to the residents living in the buildings to maintain the properties. So the deterioration of local districts is part of a planned governmental attitude in the German Democratic Republic (Wilhelminian Style) and lack of economic prosperity (Prefabricated Housing Estates and Wilhelminian Style). Interestingly, a number of land use and demographic variables chosen from the land use classification scheme and from the statistical data for this study appeared to have little environmental change and relationship to some change. To find out if over time vegetation increased in the most on vacant land the 2005 data need to be analysed.

CONCLUSIONS

The presented time-slot 1994 and 1998 does not show spatial changes in land use and in the vegetation pattern as it does in demographic figures. The vegetation changes are of minor significance.

The question needs to be discussed if there is no or hardly any net vegetation increase associated with European shrinking cities, or, if methodology, data set and scale are not appropriate to distinguish the process spatially. Research is ongoing to determine if the processes and natural environmental effects of open spaces with and without urban brownfields, and population shifts, will continue, and if so, at what pace. Spot data for 2005 should help to find out inner urban and peri-urban changes on a large scale, change detection of net vegetation growth and gaining open spaces as a lack of urban densification. Only with the integration of most recent data sets statements beyond administrative affiliation (urban districts, villages, suburban towns) can be supported, and a common land management pool created for several adjacent municipality districts and villages.

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