ANALYSIS AND EVALUATION OF NATURE SPACE POTENTIAL IN PERI-URBAN SPACES USING REMOTE SENSING DATA AND GIS

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ABSTRACT

The rapid change of running modifications and processes simultaneously require and enable the execution of a landscape monitoring. With latest methods and geo-information data an important contribution can be made in particular to monitor and evaluate developments being carried out. The landscape monitoring dedicates itself to the check and the prognosis of state and dynamics from natural to technical ecological systems.

In this project an analysis and an evaluation of the nature space potential for the suburban space are to be made by means of remote sensing methods including geographical information systems (GIS). With the results derived a progress control of desired planning goals can be made. Furthermore, planning deficiencies can be discovered, and potentials for an influencing control can be shown to planning authorities of such cultural landscapes.

The project assesses the suitability of IRS-1C&D data for diverse planning requirements, e.g. updating land use plans, municipal survey maps, maps of urban structure types and biotopes, surface-sealing surveys, and working maps for landscape planning. It also examines the potential of IRS-1C&D data to provide the basis for updated general data drawn to a scale of 1:25,000. This paper focuses on the use of IRS-1C data for automatic classification in urbanised areas and on the application of a space reference model to analyse regional structures of certain classes with a stress on gradients between an urban centre and its suburban surroundings. Later on, the project will test the application of very high resolution data such as IKONOS data for certain test sites that are of special interest. First very high resolution data are to be acquired and further research will then be undertaken.

1. INTRODUCTION

Since the reunification in 1990 the redevelopment process in east German urban regions has become a process which has brought forward structurally modified and often disperse settlement structures in an extraordinarily short period of time. This highly dynamic impact has led to a clear re-evaluation of the surrounding countryside and to an absolute deconcentration of population and of work-places. Simultaneously, population density and employment figures show far-reaching social, economic, and ecological consequences for the urban and peri-urban spaces.

The degree of an anthropogenic influence has reached its peak in urban landscapes. It increases in the suburban region compared to almost natural and agricultural landscapes with the growth of overdevelopment. With respect to the immensely expanding suburbanisation and settlement dispersion in German (and other European) urban-suburban regions the importance moves from the centre to the suburbs of towns. This process is closely connected with an enhancement of the suburban status and with an increasing deconcentration of population and working-places.

Suburbanisation processes should currently be observed by scientific investigations which have been lacking so far. Such a monitoring could serve to analyse and evaluate the complex and widespread development processes in the suburban area, and could characterize deriving models and recommendations for planning authorities. Such a recording and description of spatial and dynamic processes needs the application of new quantitative methods and evaluation approaches.

If remote sensing data are only used for landscape monitoring and land-use classification, the experiences of the methodological tools of satellite data will only partially be exploited. Due to the improved geometric resolution of new sensors the analysis of settlement areas is faced with new challenges. Depending on higher monitoring scales the analysis could even then involve the identification of single objects if only whole settlement areas of towns and villages need to be derived. Because of such extended possibilities, several current research efforts try to develop new strategies for very heterogeneous and rapidly changing urban and suburban areas from different points of view. With an increasingly better precision predication about e.g. abiotic and biotic components in landscapes and the sealing degree in urban agglomerations are possible.

2. REMOTE SENSING DATA AND ITS ROLE FOR URBAN AND REGIONAL MONITORING

The vast political changes in east Germany also caused rapid natural and anthropogenic changes that are hardly being recognizable by means of conventional investigation methods. Basic pieces of information on potential natural structures in landscapes and in biotopes can no longer be delivered by spot checks. Information density is low because of lacking regional mapping. Furthermore, the reduced ability to realize and control environmental changes in time is another hint showing us the necessity to establish a system observing, controlling, and evaluating the state in which our environment is in and making its changes recordable, able to be quantified and assessed.

Latest satellite-based remote sensing data (e.g. IRS-1C&D, IKONOS) can make a crucial contribution concerning the presented problems for drawing up the inventory and beyond that for current observation of regions. Geometrically and spectrally they are suitable to enter most diverse structures and features of a cultural landscape. Moreover, they offer two advantages essential for monitoring: for rather small cost expenditures they supply topical and surface covering information, and the data can be repeatedly gained in short periods. Additionally, aerial photographs (e.g. CIR-photographs, taken to produce a country-wide biotope mapping) are available in many urban regions, which are from special use as further sources of information. The use of fuzzy logic classifications and the application of textural parameters allow special classification methods that enable better exploitation of different data. Furthermore, the combination of remote sensing data and spatial models allow predictions that can be essential for urban and regional planning (see chapter 5).

Spatial planning requires information on the state of land use in short time intervals, and in high spatial and spectral resolution. This demand can only be met by using the latest satellite data that offer an optimum spectral analysis at a high scale. The Indian satellite IRS-1C&D currently delivers multispectral data on 23 metres and a 5-metre panchromatic image at the same time. Landsat TM – 7 possesses a 30 metres multispectral image and a 15 metres panchromatic plus a 60 metres thermal band. Such satellites and sensors offer basic data information for regional planning and, with their simultaneous records, are a challenge for the analysis of image fused data. Other sensors such as IKONOS-2, launched in September 1999, or Orbview 3 are capable of collecting both panchromatic images at a resolution of one meter, and multispectral images with a resolution of four meters. As they image an 11-kilometer-wide strip or, respectively, an 8-kilometer-wide strip their data will mainly be applied on small test sites at a high scale. These data will offer diverse possibilities to work on urban structures, linear structures in landscapes, or to develop new parameters for landscape metrics.

Satellite data and further geo-information data are used for landscape ecological evaluations, e.g. to predict structural diversity in landscape, to derive quantitative data on open space fragmentation and on interlink of biotope structures. Satellite images are just as much used to identify compensational areas for planning of building land in conurbations or to quantify landscape metrics by means of derived IRS-1C parameters in order to calculate neighbourhood relations of objects.

3. LANDSCAPE STRUCTURE ANALYSIS AS A NEW TOOL FOR NATURE SPACE POTENTIAL ANALYSIS

After Plachter (1991) and Fiedler et al. (1996) the dimensions of human influence on spatial structures are so fundamental that land use is entitled to an indicator function for the detection and valuation of a social influence (Schönfelder 1984). The appearance of a landscape is characterised by its natural equipment including its complex effects on the one hand and the social demand expressed by intensive land use and multipurpose land demands on the other hand. Therefore landscape monitoring is understood as a system of observations showing modifications in the state of landscape under the effect of human concern, and referring to landscape components such as vegetation and soil cover, land use as well as landscape structure.

Landscape monitoring includes

- the observation and evaluation of factors which have an influence on landscape, its state and dynamics,
- the estimation and evaluation of such influencing factors, as well as
- the prognosis and estimation showing the development of the state a landscape is in (Bastian & Schreiber 1999, Zierdt 1997).

An integrative, spatially oriented landscape monitoring requires the entry of landscape´s variety grown historically, landscape structure, substantial landscape functions, and also their consequences as for example land use modification, cutting, disperse settlement, modification in the spatial structure of a landscape as well as the loss of habitats. Such structural features of the terrestrial land cover are linked with a multiplicity of functions in direct or indirect manner. Landscape metrics can be taken as indicators to analyse, describe, and quantify patterns, compositions and configurations of a landscape type and its compartments (Turner 1990).

In particular in the peri-urban cultural landscape nature is described by indicators such as structure (line or planar expansion, cutting, island areas, etc.), dynamics (entry of the modification processes) and texture (neighbourhood relations to other land use forms) (Netzband et al. 1999). This is based on the identification and computation of static and dynamic indicators that help providing a synthetic assessment of peri-urban landscapes. The indicators will also allow the comparison of the environment's condition in different conurbations. The static indicator includes proportion of urban land uses at different points in time, of road network cutting land uses, but also of fragmenting recreational sites within metropolitan areas, and of built-up areas within green spaces in peri-urban areas. Dynamic urban area indicators refer to typology of changes and the transition from one land-use class to another.

The landscape between the agglomerations of Leipzig and Halle (east Germany) is in a process of rapid transformation by anthropogene interventions often uncontrolled. Thus new landscape structures are established which enable new development and process cycles in the region. So far structural investigations referred to flora and fauna. With the available research concept criteria are to be compiled for the need of local recreation and for nature-referred prerequisites concerning the quality of life.

Initially a detailed inventory of different examined areas should be executed dependent upon data availability and entry of the natural-space configuration as current as possible (e.g. nature protected areas, watercourses, wood, forest - / field proportion, cycle track configuration, etc.). On the basis of these empirical investigations indicators can be derived to evaluate landscape features, attractions and deficits regarding the following characteristics:

- nature space potential
- suitability for recreation
- aspect of nature protection
- aspect of culture protection

The rapid change of running modifications and processes simultaneously require and enable the execution of a landscape monitoring. With latest methods and geo-information data an important contribution can be made in particular to monitor and evaluate developments being carried out. The landscape monitoring dedicates itself to the check and the prognosis of state and dynamics from natural to technical ecological systems (Banzhaf 1999). It refers to landscape components such as vegetation and soil cover, land use and spatial landscape structure (Bastian & Schreiber 1999).

During the last ten years landscape structure indices have started to be implemented on remote sensing image data at different mapping scales. As original input data topographic maps, aerial photos as well as satellite images have been used. Thus the analysis of historical samples represents the basis for the comparison with current as well as with possible future landscape structures and allows predication about the dynamics of a certain landscape type. A methodological approach is presented, after which monitoring and evaluation of a landscape diversity in peri-urban landscapes are feasible on the basis of high resolution satellite data.

4 AREA TO BE INVESTIGATED AND DATA BASIS

4.1 Test Areas

Two areas are to be investigated with respect to the sustainable development of a culture landscape in the urban-regional field of tension. One example is taken in the new "Bundesländer" of the Federal Republic of Germany, and the other one taken is located in the old “Bundesländer”. The first mentioned region is the one between Halle and Leipzig, and is example-giving to be investigated for the following reasons:

- it underlies high dynamics with respect to land-use development,
- it shows a strong growth of peri-urban settlements,
- it is regarded as a region formerly polluted by industrial plants and mining industries, and presently as a region put pressure on by traffic, commercial sites, new settlements,
- the configuration of its nature space potential presently shows a deficit in comparison to other regions, and it offers relatively little recovery potential,
- with respect to heterogenity it has suffered of a high loss over centuries compared to the former grown culture landscape.

The region between the City of Halle and the City of Leipzig can be described as a suburban area intensively used for business parks, new settlement quarters, and recreational spaces. Apart from its historical meaning as an agricultural region and the ongoing of agricultural land use this area contains a multiple use that underlie competitive economic and ecological constraints. Since the reunification of east and west Germany took place in 1990 this suburban region has been suffering a lot from a lack of regional planning, especially during the first years, and is now about to get restrictions for further landscape fragmentation by planning institutions. A major problem for planning authorities is that Halle belongs to Saxony-Anhalt and Leipzig is part of Saxony, so in-between this multipurposely used region the border of two different „Länder“ (federal states) cuts through the responsibilities of each particular planning authority. Thus regional planning does not work on the whole area but stops at the administrative border. This is where analysed satellite data offer a very useful instrument to show both „Länder“ the necessity of concerted actions in order to recognize the state in which this region is in and to be able to regulate the process. Furthermore, this highly dynamic region with competitive land use types offers a splendid possibility to test the suitability of landscape structure indicators for landscape monitoring.

Based on this region, a method will be developed and will be checked for its transference to other example-giving regions. In particular, structural developments of the peri-urban cultural space between Leipzig and Halle are pointed out. Parallels and deviations of such typical structures will be derived in a similar cultural landscape.

4.2 Remote Sensing Data

In this first project phase the following satellite image data have been analysed.

Tab. 1 List of Utilized Satellite Images

Date of Acquisition	Sensor	Path / Row	Total RMS Error
07.07.1989	Landsat TM - 5	193 / 24	0.3
13.09.1999	Landsat TM - 7	193 / 24	0.3
08.08.1998	IRS - 1C / LISS-III	27 / 32	0.4
21.06.1998	SPOT-XS	058 / 246	0.3

5 FIRST RESULTS

5.1 Change Detection Classification Based on Landsat TM-5 and TM-7

The area between the two conurbations is classified for the years 1989 and 1999 in order to differentiate the development of human interventions right after the political change has taken place. As IRS data have only been available for Germany since 1996 and as the two classifications need to be compared as precisely as possible both dates are classified on the basis of Landsat-TM data. Several preprocessing steps are necessary on the images before the classification could take place. The older image is taken from Landsat-5-TM (7^{th} July 1989) and contains bad lines that need to be eliminated and veils of clouds that are diminished applying the histogram minimum method. The latter image could be gained from Landsat-7-TM, dated on the 4^{th} September 1999, and does not contain any disturbances.

Atmospheric conditions of the two images are corrected by means of the histogram minimum method. In this preprocessing step histograms of all TM bands are computed for the full image, which generally contains some areas of low reflectance (e.g. clear water, deep shadows or exposures of dark basalt). These pixels will have values very close to zero in the short wave infrared band (TM band 4). If the histograms of TM bands 1 to 3 are plotted they will generally be seen to be offset progressively towards the higher grey levels. The lowest pixel values in the histograms of these three bands ia a first approximation to the atmospheric path radiance, and these minimum values are subtracted from the respective images (Mather 1987). In both images band 6 is eliminated; a synthetic NDVI band calculated and attached. Both classifications are calculated using the maximum likelihood classifyer with the non-parametric rule of the parallelepiped optimization put first. A hierarchical classification needs to be generated as different settlement densities and open pit mining are spectrally very similar, as well as fields without crops and unsealed ground (e.g. airport) are difficult to be separated.

Tab. 2 Classified Land Use for the Region between Halle and Leipzig

Image Date and Sensor / Land use classes	07.07.1989 TM - 5 [%]	13.09.1999 TM – 7 [%]	Change Detection [%]
Disperse settlement	6.4	12.9	+ 6.5
Dense settlement	3.5	4.2	+ 0.7
Sealed area (e.g. roads)	2.9	7.2	+ 4.3
Area without green vegetation	12.5	6.5	- 6.0
Fields with crop	34.4	29.8	- 4.6
Green top and bush vegetation	10.1	16.7	+ 6.6
Pasture and meadow land	20.6	9.9	- 10.7
Forest	7.7	10.2	+ 2.5
Water	1.9	2.6	+ 0.7

The change detection for this region is shown in the table above. It is obvious that especially disperse settlements and sealed areas have increased at agricultural land´s expense. As rather natural wetlands have remained under conservation their share could augment. The quantified analysis is a first step to investigate land use changes but it does not show structural modifications at this scale. Therefore a detailed classification is made for green spaces using IRS-1C data.

5.2 Binary Classification Concentrating on Green Spaces by Means of IRS-1C LISS Data

In this first classification phase a conventional, multispectral classification is applied to the IRS data. The produced intermediate result provides a set of spectrally rather homogeneous landcover classes, and thus it is reliable to identify landcover classes, like water or forest. A multi-step, hierarchical procedure is then undertaken, which was developed in earlier projects, to classify both, satellite-based and airborne, multispectral scanner data (Netzband, 1998). In a first step, an unsupervised classification (i.e. without signature analysis by the analyst) is executed which supplies 15 classes. These classes have to be assigned to land-use types by interactive, visual check and postprocessing or, if necessary, aggregated. Furthermore, it is important to separate individual classes that are spectrally unique. The class separation is performed by a multispectral, supervised classification in which each identified class is "extracted" by masking it in the intermediate result, in order to exclude it from the following classification steps. For the classification, a parallelepiped classifier is used. In this procedure pixels are not classified which do not belong to clusters of the spectral signatures, and pixels in the overlap area of two clusters are classified according to the Maximum Likelihood method. The resulting classes can be overlaid as masks on the finally resulting image and can be stored as independent layers.

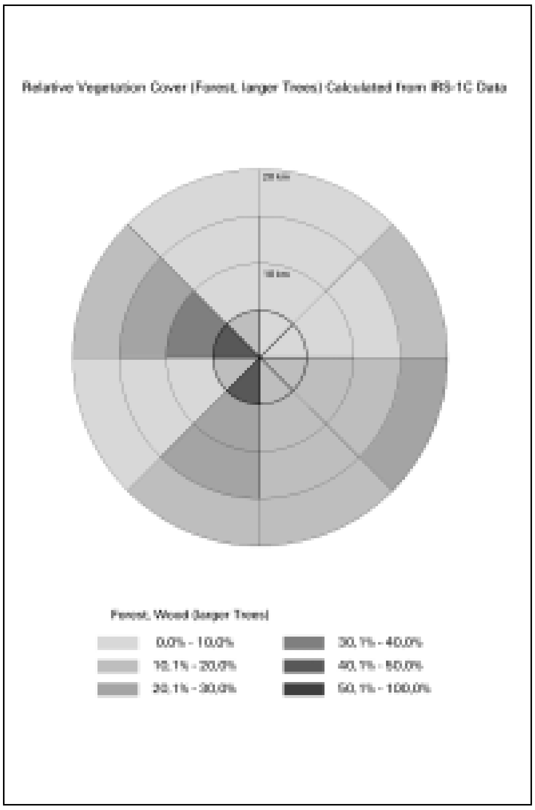
For the following calculation process especially two classes could be separated:

- Forest, stand of woods (larger trees),
- Allotments as well as grassland and meadow surfaces in the inner and peri-urban areas.

5.3 Calculating the Green Spaces according to the Ring-Sector-Model

To evaluate the green area distribution by classified satellite image data in the peri-urban area the so-called 'ring-sector-model' is suggested. This space reference model was developed by Simon (1990) to analyse intra-regional occupation commuter relations in Switzerland. It is based on the dimensional grid (same distances) of conurbations, by superposing any number of concentric sets and sectors over a region.

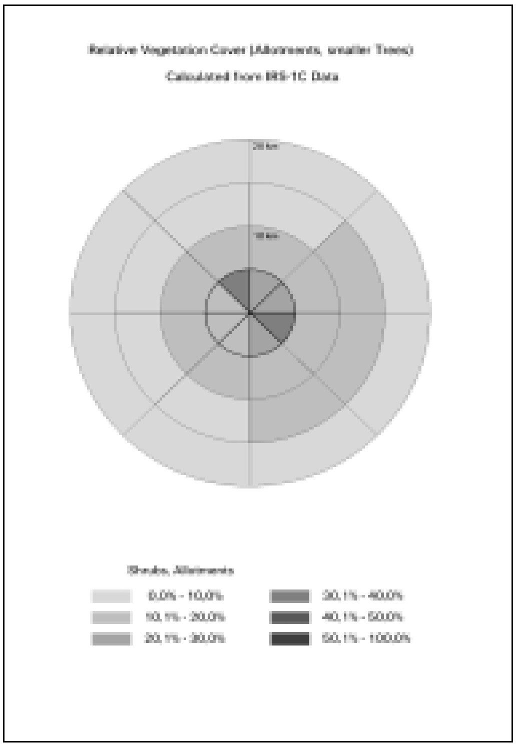
The model guarantees that a uniform external limitation of different test areas is given. Additionally, it serves to describe intra-regional characterisations of features. Gradients between the town centre and outskirts can be analysed and quantified with the ring-sector-model in a differentiated manner.



In this case the greenery distribution is investigated in the region of Leipzig using four radii (5km, 10km, 15km, 20km) with eight selected sectors respectively to arrange in parts. The following figure shows the calculated green proportions, on the one hand concerning wood (forest, larger trees), on the other hand with respect to allotments and shrub vegetation. In each case it is calculated for all radii and sectors for the classified IRS-1C LISS image data.

Distinct differences are recognizable in the distribution:

- emphasis on the forest and large tree vegetation is in the northwest and south/southwest of the City of Leipzig (area of wetlands)
- the internal ring (5 km) is equipped the best with large vegetation
- large deficits exist in the northern peri-urban area
- the eastern to southern environment has a higher stand of large vegetation
- the supply of the suburban landscape with small trees and bushes is very poor in total
- these small trees and bushes are distributed relatively regular around the city
- an emphasis on small trees and bushes is detectable in the eastern surroundings
- towards the city centre the highest values appear



6 CONCLUSION AND OUTLOOK

With the aid of geo-information efficient spatially and temporally recording methods and classifications of the urban nature supply are discussed. Multi-criteria evaluations of urban nature are compiled for the suburban area regarding the quality of life, biotope protection, biodiversity, nature aesthetics and recovery. A balance and a modelling of the dynamics in nature and a conflict analysis will follow.

Nature, in particular, in the suburban cultural landscape is to be described and analysed with respect to indicators such as structure (line or planar propagation, cuttings, etc.), dynamics (entry of the modification processes) and neighbourhood relations with other land-use forms, as for example with settlements or business parks.

First results for drawing up the inventory of the nature space supply clarify the possibilities modern monitoring methods offer using geo-information to evaluate the nature space potential in the peri-urban landscape. It is of special importance to develop applicable indicators for planning processes.

Further investigations and analyses are in particular intended for the following main topics:

- Overlay of the classification with the map of the historical settlement development
- Classification of the green areas compared to open spaces in topographic maps
- Calculation of different parameters to separate different landscape units with the aid of
  - Texture parameters,
  - Vegetation indices,
  - Landscapemetrics,
  - Morphological filter and segmentation procedures.
- Developing an evaluation scheme for the state and change of the culture landscape, and its positive and negative influencing factors
- Detection of particularly strongly changed areas as well as of especially little changed areas
- Detection of endangering and of positively influencing neighbourhood relationships (examples:new districts versus historical, local centres; business parks versus landscapes close to nature)
- Detection of intense settlement growth axes in the recent past and their evaluation regarding cultural landscape structures having been developed over a long time
- Detection of local recreation correlations (potential, meaningful relations regarding accessibility, perceptibility, etc.).

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