

# INVESTIGATING URBAN RAILWAY CORRIDORS WITH GEOMETRIC HIGH RESOLUTION SATELLITE DATA

A. Damm <sup>a</sup>, P. Hostert <sup>a</sup>, S. Schiefer <sup>a,b</sup>

<sup>a</sup> Dept. of Geoinformatics / Cartography, Institute of Geography, Humboldt-University Berlin, Unter den Linden 6, 10099 Berlin, Germany – (Damm, Hostert, Schiefer)@hurs.de

<sup>b</sup> Center for Remote Sensing of Land Surfaces, Walter-Flex-Str. 3, 53113 Bonn, Germany

**KEY WORDS:** urban railway, QuickBird, object oriented classification, vegetation succession, imperviousness

## ABSTRACT:

Accurate analyses concerning the ecological value of urban railway sites are required to ensure a sustainable development of inner urban open space. One problem in this context is the great heterogeneity of such areas. New opportunities to investigate heterogeneous urban areas arose with the advent of geometric very high resolution (VHR) satellite data. A bundle of panchromatic and multispectral QuickBird data was employed to explore the potential of such sensors for urban ecological monitoring and assessment exemplified for a railway area in the Southeast of Berlin.

An object-oriented, hierarchical classification approach was employed to integrate shape and texture parameters into the analysis. Seven land use classes based on three hierarchical object levels were distinguished. A validation based on field mapping and aerial photography revealed an overall accuracy of about 85%. The classification result allows to answer various ecologically determined questions and to describe the site's inherent ecological value. Imperviousness was calculated based on the material specific degree of sealing and different vegetation succession states were differentiated. Moreover, the separation of vegetation on tracks from other vegetation allowed deriving information about the recent utilization of railway tracks, which is not available otherwise. It is concluded that the geometric resolution of QuickBird VHR data is suited to separate relevant surface components of derelict urban railway sites at a local scale.

## 1. INTRODUCTION

Today, the availability of derelict urban space is increasing in many cities worldwide. Driven by economical reasons, the presence of derelict railway areas on the real estate market has increased recently. The re-utilization of such areas becomes an important issue within the framework of a sustainable use of natural resources. Detailed analyses are essential, to assess the value of these areas and to develop sustainable concepts for their re-use. From an urban planning point of view, such areas appear very complex. On one hand, they have a great potential to realize major development projects near city centres. On the other hand, there are various specific aspects to be considered when focusing on the potential re-use of such areas: the immediate vicinity to active railway tracks or highly contaminated soils are often negative accompanying factors. In addition, the ecological value of such sites improves after a few decades of being in a derelict state, mainly determined by the spontaneous development of biotopes, leading to great biodiversity in flora and fauna (Kowarik, 1995; Tikka et al., 2001; Zerbe et al., 2002). The development of high quality biotopes is supported by the seclusion of such areas, the presumably low degree of imperviousness, and the existence of anthropogenic soils.

However, a detailed inventory of railroad areas, particularly in formerly eastern Berlin, does not exist. In addition, complicated property rights limited the accession to spatial information of such sites. With the advent of geometric high resolution satellite data, it is now possible to get an inventory of the urban environment at appropriate scales (Hoffman et al., 2001; Meinel et al., 2001; Small, 2003); in the following we will focus on derelict railroad areas. The analysis is centred on the extraction of railroad tracks, the separation of different states of plant succession, or the differentiation between surface types with varying degrees of imperviousness.

## 2. STUDY SITE AND DATA

The study site is located between the center of Germany's capital, Berlin, and its south-eastern periphery. The entire railroad area of Berlin sums up to 25.22 km<sup>2</sup>, the study site makes up about 0.51 km<sup>2</sup> (SSUDB, 2004). The study site is characterized by the centered marshalling yard. In its direct surroundings, diverse technical and administrative buildings are located, which are partially unused. Furthermore, numerous unused tracks and areas developing different states of plant succession are found. The study site is framed by used railway tracks.

Geometrically corrected panchromatic and multispectral QuickBird data from March 28<sup>th</sup> 2002 was employed in this study. Ground sampling distances for panchromatic and multispectral bands is 0.7 m and 2.8 m, respectively. A pan sharpening based on principal component analysis was performed to enhance the geometric resolution of the multispectral bands. Information from the Digital Environmental Atlas of Berlin was used to extract the railway corridors from the full dataset (SDUDB, 2004). An orthorectified color aerial photography with a spatial resolution of 0.5 m was used to validate results.

## 3. METHODS

Urban railway areas are characterized by small objects with a heterogeneous topology. It is hence essential to use adequate data that can resolve relevant objects in railway sites. At the same time, urban areas are characterized by materials with extremely low spectral contrast. Because of the aggregation of pixels to objects, object oriented approaches enable an efficient data processing and analysis (Baatz and Schäpe, 2000). In addition, the option to include object specific shape and texture

parameters generates a surplus of information for subsequent analyses (Herold et al., 2002; Meinel et al., 2001; Zahn et al., 2001). An object based classification is usually performed in two steps: the segmentation followed by a knowledge based classification of image objects defined by these segments.

### 3.1 Image segmentation

The process of image segmentation merges adjacent pixels to image objects according to specific homogeneity criteria. These criteria are based on the spectral behavior of the merged objects, as well as on their spatial compactness and smoothness. A sequential repetition of the image segmentation using different boundary criteria results in a hierarchical network of image primitives (Baatz and Schäpe, 2000).

level	spectral bands	scale	spectral weight	smoothness weight	compactness weight
1	red, nIR, pan	30	0.9	0.05	0.05
2	red, nIR, pan	30	0.1	0.85	0.05
3	red, nIR, pan	80	0.2	0.65	0.15

Table 1. Parameterisation of final segmentation levels.

The individual strategy for a segmentation depends on the scale of the analyzed phenomenon as well as the spatial heterogeneity of the study site in general. In lack of previous studies on urban railway areas, an exploratory strategy for image segmentation had to be developed. Because of their high contrast, the original panchromatic band and the pan sharpened red and near infrared bands were chosen as segmentation base. Different variations of the homogeneity criteria were tested and a hierarchical network of image objects in three segmentation levels as shown in table 1 turned out to be useful for the applied classification scheme.

The parameters in table 1 show that a lot of weight had to be given to the smoothness criterion in order to generate image objects appropriately describing the shape of railroad tracks.

### 3.2 Classification

The advantage of a knowledge based classification of image objects compared to a pixel based classification results from the integration of shape and textural information. In addition, statistical parameters from sub objects as well as contextual information from super objects can be included (Meinel et al., 2001).

At first, tracks and vegetation on tracks were separated from remaining areas at a small scale. This rough pre-classification turned out to be crucial for the quality of the following detailed classification and was based on the information from two segmentation levels: Railroad tracks, vegetation on tracks, and other areas were classified based on level 2 segments. The actual separation into two areas as mentioned above was performed on level 3 utilizing statistical information from the sub objects of the classified level 2.

The classification of the seven final classes was performed on level 1. Segmentation parameters of this level were chosen in a way that object outlines in the image data met the actual boundaries of the objects of interest. As a first step of the main classification, vegetated areas were separated from the rest based on spectral information. Vegetated areas and non-vegetated areas were further classified based on spectral information, form parameters and the pre-classification of level 3. Figure 1 shows details of the classification scheme.

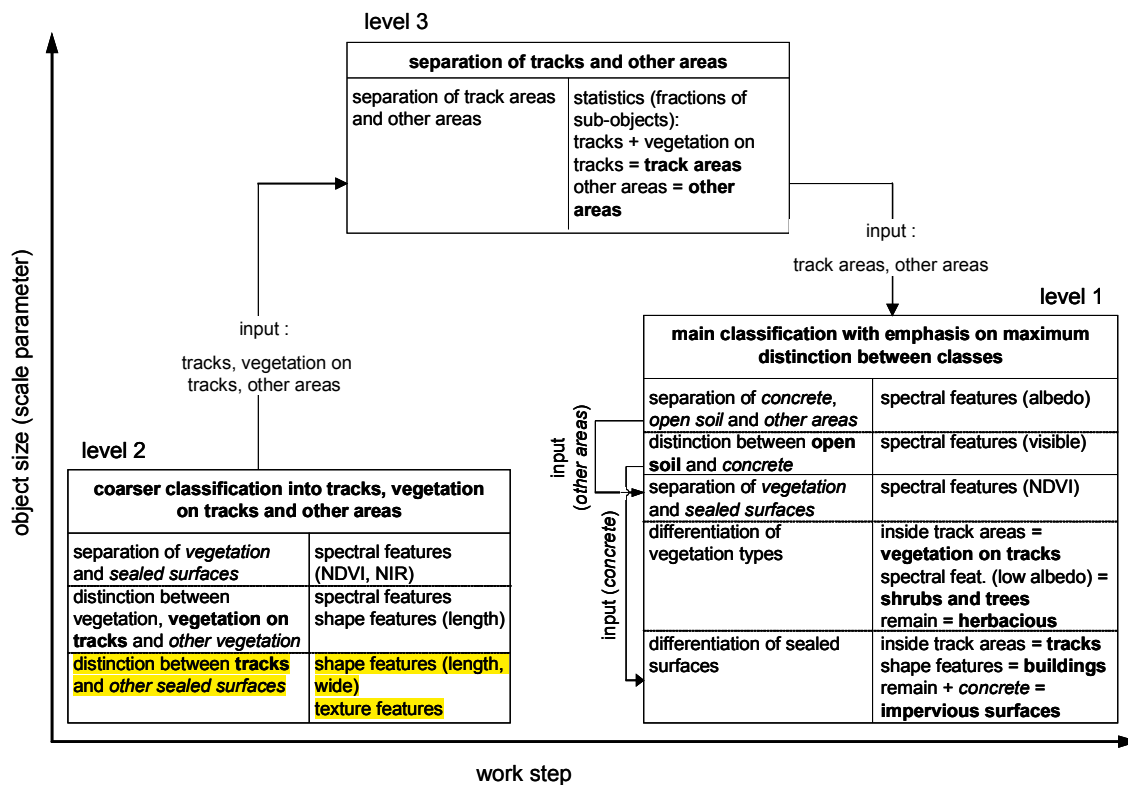


Figure 1. Illustration of the used classification scheme.

#### 4. RESULTS AND DISCUSSION

Based on well distributed test areas derived from field based mapping and aerial photography, quantitative measures were calculated to validate the accuracy of classification results. The test areas sum up to 1.9% of the study site. The validation shows an overall accuracy of 85.04% and a kappa statistics of 81.08 % (table 3).

Seven classes were extracted that were used for a differentiated inventory of the study site (compare figure 2). The degree of imperviousness is a good indicator for the ecological value of derelict sites (soil exchange function, local climate, biotope functions). Collapsing all classes standing for impervious surfaces led to an overall degree of imperviousness of 35.01 %, given the assumption that railway tracks have a degree of imperviousness of 40 % (SDUDB, 2004).

The spatial distribution of different states of succession is also important. Advanced states of succession, for instance bushes or trees, suggest to survey in detail, in how far such areas exhibit an increased ecological value (Zerbe et al., 2002). We could identify three successional stages: 8.79 % of the whole study site is covered by shrubs and trees, 16.97 % by herbaceous vegetation and 28.46 % are vegetation on railway tracks, which was not further differentiated in the context of this study.

With regard to impervious areas, a possible differentiation between buildings and not built-on surfaces (streets, pathways) is interesting: planning for the re-development of derelict areas is often based on information about the inventory of buildings in order to assess the actual cost for clearance of such areas. The analysis of the data showed that 11.5 % of all impervious areas are buildings and 9.4 % can be assigned to streets and paved pathways.

Knowledge about the use or disuse of tracks is also necessary to develop scenarios for re-using derelict railway areas. In the present case, the track system is partially abandoned, leading to problematic impacts for re-use strategies: residential areas, to name one important example, can not be established when neighboring railroad tracks are still in use. **Active railroad tracks are kept free of vegetation by mechanical clearing or herbicide treatment** (Schweinsberger et al., 1999). It is hence easy to separate between used an unused track system, if the geometric resolution of a sensor allows for distinguishing pixels with or without vegetation devoid of spectral mixing. Against

this background, emphasis was placed on the separation of vegetation on tracks: this class indicates the degree by which tracks are used. 64.13 % of the study site are made up of tracks, whereof 44.38 % are out of use, leaving 55.61 % as being in use or only recently abandoned. In addition, the spatial distribution of the tracks that are still in use is important: being surrounded by active track systems, many strategies for a potential re-use of the study site will have to be discarded.

Validation statistics, results, and deducible conclusions should be critically examined. The early acquisition date of the QuickBird data in late March results in little photosynthetic activity in vegetation, especially concerning tree and shrub species. Thus, the amount of vegetated areas was underestimated during the analysis. Similarly, a differentiation of succession states was affected by the early acquisition date: a distinction of trees could only be achieved by including information on tree shadows. **Low trees or bushes could not be separated from herbaceous vegetation and were hence also underestimated.** There is almost no open soil at all, indicating on one hand that early succession species will occupy suitable habitats immediately. On the other hand, almost no building or demolishing activity that could create new open soil surfaces was taking place at time of image acquisition.

The relatively low spectral resolution resulted in some problems separating buildings from other impervious surfaces: objects of these two classes often consist of materials that have similar reflective characteristics. A distinction between these objects requires shape and textural properties to be included in the analysis scheme. However, buildings are characterized by heterogeneous shapes and a general solution to this problem was found.

The classification accuracy for tracks was satisfying, **but a description of the frequency by which tracks are used is limited:** in many cases the use of herbicides induces a time lag for the invasion of pioneer species on unused and contaminated tracks (Schweinsberger et al., 1999). An overestimation of used tracks has therefore to be expected. In addition, different image segments belonging to the same single track are sometimes assigned to the two different classes, 'tracks' and 'vegetation on tracks'. This alternating classification is probably due to variable herbicide accumulations in soils. However, it causes only minor errors in terms of statistics, but has a considerable impact on topology.

class	ground truth [%]						
	1	2	3	4	5	6	7
open soil (1)	81.62	0.00	0.00	1.36	0.00	0.00	0.00
shrubs and trees (2)	1.62	64.21	0.00	2.76	0.13	0.53	0.04
vegetation on railroad tracks (3)	0.00	17.61	84.45	21.22	0.24	0.15	0.68
herbaceous vegetation (4)	9.73	10.37	0.08	73.96	0.01	0.00	0.20
railroad tracks (5)	0.00	6.31	15.36	0.00	99.60	0.00	4.48
buildings (6)	0.00	1.50	0.00	0.69	0.02	85.33	8.19
impervious surfaces (7)	7.03	0.00	0.11	0.01	0.00	13.99	85.61
sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table 2. Class-wise accuracy in % of ground truth pixels.

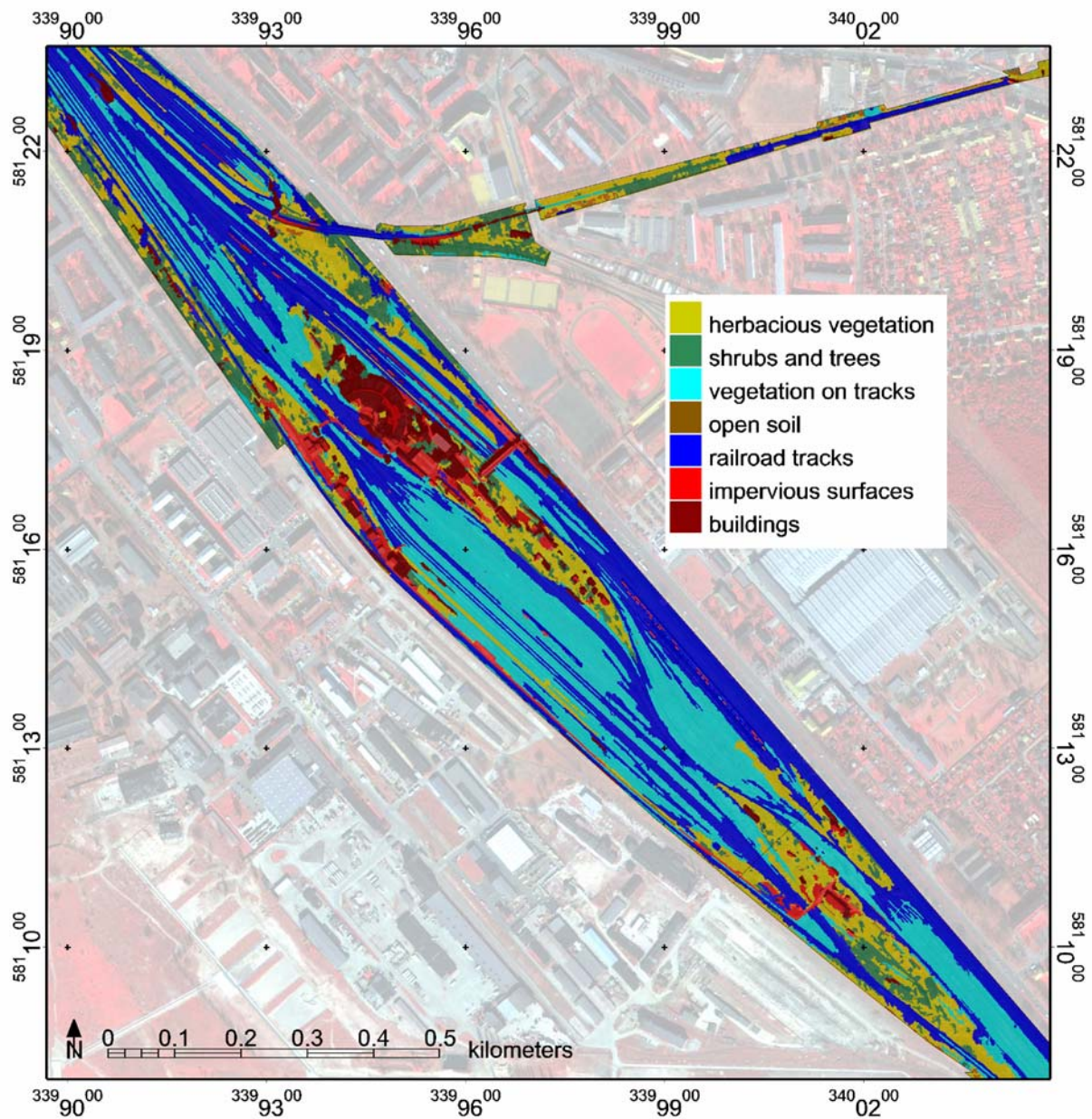


Figure 2. Classification aggregated to 7 main classes over QuickBird backdrop.

## 5. CONCLUSIONS

We have analyzed merged panchromatic and multispectral QuickBird data for a remotely sensed inventory of a partially derelict railroad site in Berlin. In this context an object oriented, knowledge based classification was applied. Some limiting factors need to be kept in mind, e.g. the low spectral resolution or the early acquisition date of the dataset. Despite the fact, that the early acquisition date hindered a detailed differentiation of vegetation, the small size of tree crowns at this point was advantageous for the analysis of other surfaces. Classification accuracy and the spectrum of extractable classes might be increased by including data with a higher spectral resolution. Data of higher spatial resolution will be very useful for a more accurate description of small or narrow objects. In principle, the chosen approach can be applied to other sites, but the parameters of the respective class description might have to be adjusted. The strength of the approach is that results can be

used to analyze various thematic aspects. Several were mentioned: the different states of plant succession, the distinction between different types of impervious surfaces, as well as the recent utilization of railway tracks.

## ACKNOWLEDGMENTS

This study was financed by the German Research Foundation (DFG) in the frame of the project "Urban Environmental Monitoring with hyperspectral and geometric high resolution remote sensing data" (HO 2568/2-1). We would also like to thank the Berlin Department of Urban Development for supporting this study with data from the Urban and Environmental Information System (UEIS). Alexander Damm is sponsored by a scholarship under the Berlin Graduate Support Law (NaFöG). Sebastian Schiefer is sponsored by the German Federal Environmental Foundation (DBU).

## REFERENCES

Baatz, M. & Schäpe, A., 2000. Multiresolution segmentation: an optimization approach for high quality multiscale image segmentation. In Strobl, J. & Blaschke, T. (Eds.), *Angewandte Geographische Informationsverarbeitung, vol. XII* (pp. 12–23). Heidelberg: Wichmann.

Herold, M., Scepan, J., Müller, A. & Günther, S., 2002. Object-oriented Mapping and Analysis of Urban Land Use / Cover Using IKONOS Data. *Proc. 22nd EARSEL Symp. "Geoinformation for European-wide integration", 4<sup>th</sup>-6<sup>th</sup> June 2002*, Prague, 531-538.

Hoffman, C., Steinnocher, K., Kasanko, M., Toutin, Th. & Cheng, P., 2001. Urban Mapping with High Resolution Satellite Imagery: IKONOS and IRS Data Put to the Test. *GeoInformatics*, 4(10), 34-37.

Kowarik, I., 1995. On the role of alien species in urban flora and vegetation. In: Pyšek, P., Prach, K., Rejmanek, M. & Wade, M. (Ed.), *Plant invasions. General aspects and special problems* (pp. 85-103) Amsterdam: SPB Academic Publ.

Meinel, G., Neubert, M. & Reder, J., 2001. The potential use of very high resolution satellite data for urban areas – first experiences with Ikonos data, their classification and application in urban planning and environmental monitoring. *Proc. 3<sup>rd</sup> Int. Symp. Rem. Sensing of Urban Areas, 22<sup>nd</sup>-23<sup>rd</sup> June 2001*, Regensburg, 196-205.

Schweinsberg, F., Abke, W., Rieth, K., Rohmann, U. & Zullei-Seibert, N., 1999. Herbicide use on railway tracks for safety reasons in Germany? *Toxicology Letters*, 107, 201-205.

SDUDB: Senate Department of Urban Development in Berlin, 2004. Urban Environmental Information System. [http://www.stadtentwicklung.berlin.de/umwelt/umweltatlas/edu\\_a\\_index.shtml](http://www.stadtentwicklung.berlin.de/umwelt/umweltatlas/edu_a_index.shtml), (access: 29<sup>th</sup> November 2004).

Small, C., 2003. High spatial resolution spectral mixture analysis of urban reflectance. *Remote Sensing of Environment*, 88, 170-186.

Tikka, P.M., Hogmander, H. & Koski, P.S., 2001. Road and railway verges serve as dispersal corridors for grassland plants. *Landscape Ecology*, 16 (7), 659-666.

Zerbe, S., Maurer, U., Schmitz, S. & Sukopp, H., 2002. Biodiversity in Berlin and its potential for nature conservation. *Landscape and Urban Planning*, 62, 139-148.

Zahn, Q., Molenaar, M. & Xiao, Y., 2001. Hierarchical object-based image analysis of high-resolution imagery for urban land use classification. *Proc. IEEE/ISPRS Workshop Rem. Sensing and Data Fusion over Urban Areas, 8<sup>th</sup>-9<sup>th</sup> Nov, 2001*, Rome, 35-39.