DIFFERENT APPROACHES FOR URBAN HABITAT TYPE MAPPING – THE CASE STUDY OF BERLIN AND SEOUL

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ABSTRACT: (221Wörter)

Satellite remote-sensing data for urban land-cover and land-use mapping has been investigated over a long time using increasingly more powerful data and more sophisticated techniques. Well-established methods for surveying urban habitats such as aerial photography have to be replaced now for updating previous results. At present additional benefits result from high resolution airborne scanner and satellite data. In this study primarily HRSC-AX and satellite data (QuickBird, IKONOS) are compared. Both visual and automatic interpretation using ERDAS Imagine and eCognition were tested. Study areas offering particular challenges concerning urban green and classification of sealing have been selected in Berlin and Seoul, representing different starting positions according to existing data, mapping methods and urban structures. For the purpose of updating the urban habitats in the study area Berlin the HRSC-AX imagery were classified by a combined approach of visual and automatic pixel-based classification. In Seoul, QuickBird and IKONOS images were classified by a stepwise pixel and segment-based method. As a result of these two case studies potentials of new remote sensing techniques and sensors for mapping urban habitats could be shown. Advantages and disadvantages e.g. colour shift, shadows or inclined recording of the available new data sets are discussed. Over all the visual interpretation of both aerial scanner and satellite data was best suited for habitat type mapping in the two study areas.

KURZFASSUNG: (180 Wörter)

Seit langem wird die Nutzung der Satellitenfernerkundung für Landnutzungskarten in Stadtgebieten erforscht, wobei immer bessere Daten und leistungsfähige Auswertungsmethoden zum Einsatz kommen. Bewährte Methoden der Neukartierung von Stadtbiotopen, meist auf der Basis von CIR-Luftbildern, müssen durch Fortschreibungsmethoden ersetzt werden. Gegenwärtig gelten höchstauflösende Daten, vom Flugzeug oder von Satelliten aufgenommen, als viel versprechend. In der hier vorgestellten Untersuchung werden HRSC-AX-, QuickBird- und IKONOS-Daten verglichen, wobei ERDAS Imagine und eCognition in Verbindung mit visueller und automatischer Auswertung zum Einsatz kommen. Die Untersuchungsgebiete in Berlin und Seoul bieten besondere Herausforderungen bezüglich der Kartierung von Stadtgrün und Versiegelung sowie Stadtstrukturen und Auswertungsmethodik. Zur Aktualisierung der Biotoptypen wurden in Berlin die HRSC-AX Daten mit Hilfe einer Kombination aus visueller Interpretation und pixel-basiertem Verfahren klassifiziert. In dem Untersuchungsgebiet Seoul kamen zur Klassifikation der IKONOS- und QuickBird-Daten ein mehrstufiges pixel- und segment-basiertes Verfahren zum Einsatz. Als Ergebnis der Studien werden die Potentiale der angewandten Methoden und eingesetzten Sensoren gezeigt. Neben den Vorteilen werden die Probleme wie Farbversätze, Schrägaufnahme und Schlagschatten diskutiert. Insgesamt zeigt die Studie, dass z.Z. die visuelle Interpretation der automatischen Klassifikation noch überlegen ist.

1. INTRODUCTION

The need for up-to-date information about land-use changes for different planning purposes is increasing. Especially urban areas are both some of the most rapid changing places in the world as well as complex systems with a lot of user conflicts especially with regard to green areas. A rising number of legal and informal guidelines on the conservation and ecological development of urban areas are drawing particular attention on urban green areas. One essential requirement for urban planning is a good data basis on urban land cover and land use, preferably wide-range areas, up-to-date, precise information while colliding with growing budget holes.

Remote-sensing data has been used for that for a long time. Especially the visual interpretation of Colour Infrared (CIR) aerial photos has a long tradition (Bierhals, 1988; Kenneweg, 1996). They offer an area-wide data basis for a lot of planning purposes such as landscape and urban planning, environmental impact assessment and continuous monitoring.

Urban land-cover and land-use mapping by means of satellite remote sensing has been investigated since the early seventies. Increasingly more powerful data and more sophisticated evaluation methods have been introduced. As soon as reliable results on vegetation cover or sealing degrees could be obtained for small reporting units like city blocks remote-sensing techniques became interesting for operational use in the framework of city planning. In 1997 the European Union tested Russian high-resolution photographic satellite data (KVR 1000) for land-use purposes. Land-use classes at a certain (but not on the highest) level could be obtained for statistical blocks both in Athens and in Berlin (ATLAS Berlin, 1997). It is not always necessary to apply data of the highest ground resolution in order to obtain reliable results for sealing degrees of statistical city blocks. Good radiometric resolution in combination with good ancillary data and a well-designed evaluation procedure enabled Kenneweg et al. (2000) in Berlin to produce a map of sealing degrees for the total Metropolitan area of Berlin using subpixel classification and a combination of Landsat TM-7 and SPOT-4 data. Hence more ambitious goals such as habitat type mapping for urban areas with the aim to acquire more specific information on ecological structures and processes within cities were started after 2000. In this study the term "habitat type mapping" is used. In Europe the term "biotope type mapping" is preferred instead, because most mapping methods are closely related to well-known vegetation types, whereas the term "habitat" is primarily understood as connected with animal populations.

With the fast development of remote sensing sensors technique such as the high-resolution airborne scanner (HRSC-AX) or high resolution satellite images (QuickBird, IKONOS) and also new image-processing methods in the last few years new possibilities have been offered to apply effective and automated methods for habitat type mapping. The challenge is now to refine existing and to develop new digital and, as far as possible, automated and operational methods for an effective mapping of urban areas.

2. PRESENT STATE OF URBAN HABITAT TYPE MAPPING

2.1 In Berlin

In Germany, first initiatives for urban habitat type mapping can be traced back to the late 1970's, when a specific method for urban habitat type mapping was developed in Berlin (AG Methodik der Biotopkartierung im besiedelten Bereich, 1986; Sukopp et al., 1979). At that time, formal landscape planning instruments were introduced in the planning system by the Berlin Nature Conservation Law (NatSchGBln 1979). Data on habitat types were collected according to this method, which was revised later on. The systematic presentation of this environmental information, including the habitat type mapping, has been focused since the 1980's. As one of the first environmental information systems, the Berlin "Umweltatlas" has been used for web-based visualization and access to data.

However, a reliable and up-to-date Berlin-wide information on habitats does not exist. There is an urgent need to detect the enormous changes of land use and land cover in Berlin in the last years, which are partly due to the reunification of Eastern and Western Berlin. This information is required for a diverse number of planning instruments, both already existing as well as new ones. One example is the proposed establishment of a habitat network system (Biotopverbundsystem) on 10% of each Federal land by the amendment of the German Federal Nature Conservation Act in 2002. Therefore, the existing habitat type mapping has to be updated; it is scheduled for 2005 by the Senate department. For that reason, a new habitat type list and mapping manual were recently released. The habitat type method is based both on terrestrial and remote-sensing data acquisition, the latter one focusing on aerial photography. The possibilities of new high resolution remote-sensing data for updating the existing habitat type maps have to be assessed.

2.2 In Seoul

As a main problem for planning tasks in Korea, the lack of available data and information has been indicated. Mostly the data have been produced with different objectives, mapping scales as well as recording dates and in addition, the topicality of these data cannot be guaranteed because of the extremely fast changes and constant developments in the metropolitan area Seoul. Above all, most data contain mainly the urban structure based on buildings and traffic systems. In contrast, green spaces are generalized and schematized strongly. To be able to ascertain urban environmental situations and to support the sustainable development, which is the objective of the ongoing urban planning in Seoul, an efficient data base is necessary. That was the motive for urban habitat type mapping, which was first carried out in 1999. With the reason of the limited availability of aerial photography in South Korea because of military restrictions, the data contents were gained mainly by field surveying (Seoul, 2000a), namely land use, land cover, vegetation. These terrestrial data were digitized for a GIS and then habitat types were defined based on these three theme layers. So the procedure was affected by subjective results during the data acquisition because of varying interpretation among surveyors. The most serious errors were found in sealing degrees, which is a standard criterion for the definition of urban habitat types, because it was difficult to gain an overview of the field's surface. In case the areas such as private estates were not allowed to enter, it had to be estimated by surveyors and thus led to uncertain and irreproducible results. In addition, park areas are frequently assigned as a 100% vegetation-covered area in spite of the contained sealed surfaces in forms of ways, parking lots or squares. Another problem of terrestrial mapping is the deficient delimitation of habitat boundaries. So there is a need for error-detection and correction as well as updating of the terrestrial habitat type mapping in Seoul.

3. MATERIALS AND METHODS

Two types of the new high-resolution remote-sensing data have been investigated in this study; aerial scanner data (HRSC-AX) and satellite data (IKONOS and QuickBird).

	IKONOS	QuickBird	HRSC-AX*

Geometric Res.(m) Spectral Res. (nm)	Pan: 0.82 MS: 3.20 R:450-520 G:520-600 B:630-690 IR:760-900	Pan: 0.61 MS: 2.44 R:450-520 G:520-600 B:630-690 IR:760-890	Pan/MS: 0.20 DSM: 1.00 R: 642-682 G:530-576 B:450-510 IR:770-814
Radiometric Res. (bit)	11	11	8
Swath Width (km)	11	16.5	0.8
(Orbit) Height	681km	450km	varying
Repetition Rate (days)	3 – 5 (off-nadir)	1 – 3 (off-nadir)	Varying
Suited for Map Scales	1:25 000 – 1:5 000		Up to 1:500
Available since	2000	2001	2000
Starting from (€/km²)	= 28	= 24	
Provider	Digital Globe	SpaceImaging	DLR

* Flying Height of 4120 m

Table 1. Characteristics of used remote-sensing data

3.1 HRSC-AX aerial scanner data in the study area Berlin

The HRSC-AX imagery used in this study was acquired by the German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt e.V. - DLR) in Berlin-Adlershof and consists of multispectral and panchromatic bands and a Digital Surface Model (DSM). Two subsets were selected including a variety of urban habitat types in Berlin. The data was acquired on June, 7th 2003 and each band is stored with 8-bit, the additional DSM used, however, was acquired on May, 3rd 2001 and is stored with 16-bit. In addition, digitized CIR-photos and vector data, such as the Automated Real Estate Map (Automatisierte Liegenschaftskarte - ALK) and data on vegetation and land use from the "Umweltatlas" have been applied. The HRSC-AX imagery is usually completely pre-processed by a fully automatic system at the DLR before data delivery. In this study, the single bands were fused to multispectral composites and the PAN data was fused with the DSM to produce a pan-sharpened DSM image with 1-m resolution. Then the data needed to be georeferenced due to missing and incorrect georeferencing. This pre-processed data was classified with a supervised maximum-likelihood approach with the Software ERDAS Imagine. The urban land-cover classes used were road, building, grass, tree, bare soil, water, and shadow. These classes correspond to the main categories of habitat types in the Berlin habitat type list. The additional shadow class was required to minimize the problem of shaded urban environments, e.g. building shadows being classified as water. An accuracy assessment was performed by making use of reference pixels that were independent of the pixels used to train the classifier. The reference pixel data sets were generated via visual interpretation of the multispectral imagery. The derived land use classes, which are too general for the purpose of updating the Berlin urban habitat type mapping, and literature review (Gähler et al., 2003; Leser, 2003; Möller, 2003) as well, suggested to focus on visual interpretation. Based on the Berlin habitat type list, an urban habitat type mapping was carried out in the study areas. The HRSC-AX imagery used for that was a multispectral composite, similar to the traditional CIR-images, the PAN, and the DSM. Additional information for the habitat type mapping was derived by terrestrial mapping and available data sets. Finally, these visual and automatic interpretation of HRSC-AX were compared to visual interpretation of CIR-photos.

3.2 IKONOS and QuickBird satellite data in the study area Seoul

Urban habitat types in Seoul are defined according to the proportion of sealed surfaces, e.g. "residential area in the form of single family houses with over/under 70 % sealed surface" (Seoul, 2000b), which corresponds to 30 % green or denuded land. But there is hardly denuded land in urbanized areas because of high land-use intensity, i.e. another kind of use takes place very fast. So urban sealing degree can be calculated indirectly by its green proportion, which can be gathered by the automatic classification of vegetation-covered areas from non-vegetation areas by means of their clear spectral characteristics. In addition, the high resolution of IKONOS and QuickBird permits to distinguish very small urban structures, up to single buildings and trees. In this context, for the purpose of detection and correction of terrestrial habitat type mapping in Seoul, an analysis method with satellite image data was suggested (Fig.1).

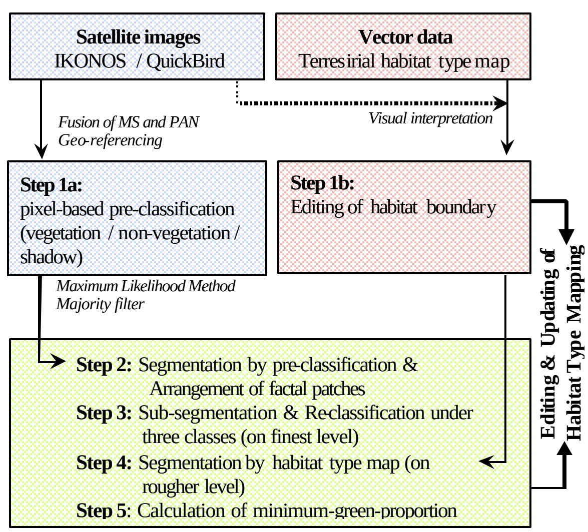

Figure 1. Analysis procedure.

For this study IKONOS (CATERRA GEO, recorded on Nov., 27th 2000) and QuickBird (Standard, recorded on Feb., 22nd 2002) satellite data were available. For the first, pan-sharpened multi-spectral images were gained by means of "Resolution Merge" between multi-spectral and panchromatic channels (1 m resolution of IKONOS and 0.6 m of QuickBird). Then the data were geometrically corrected with over 30 Ground Control

Points derived from digital topographic maps on a scale of 1:1000. Hereby the digital terrain model was not necessary because this study area is topographically plain. The projection was also transferred from WGS84 into Transverse Mercator. The RMS errors are about 3 m on both satellite images.
These pre-processed satellite images were classified pixel-based into three classes of vegetation, non-vegetation and shadow by the Maximum Likelihood Method. The problem of 'salt and pepper effects' was reduced by majority filtering (Fig.1, step 1a; pixel-based procedure) and these improved classification results were considered as a thematic layer during the segmentation in order to prevent mixed segments among vegetation, non-vegetation and shadow. In parallel, incorrect habitat types and boundaries were corrected manually by visual interpretation through overlaying satellite image and digital habitat type map (Fig.1, step 1b; visual procedure). In the segment-based procedure, the segmentation was accomplished at first by pixel-based classification results and fractal patches were arranged by minimum size and neighbourhood relationship (Fig.1, step 2). Then, the sub-segmentation was achieved with a very small-scale factor regarding multi-spectral and NDVI values as well as object form. In this way, the improved pre-classified patches were further sub-segmented within their three classes. These sub-segments were analysed and reclassified by spectral differences under their super-segments, eg. some light shadow segments could be further classified into vegetation or non-vegetation (Fig.1, step 3). In this way, vegetation-covered areas were extracted and the green proportion was finally calculated in every habitat feature through the overlaying of two levels of corrected habitat type map and classification result (Fig.1, step 5). However, in this study the green proportion means "minimum green proportion" because of the dark shadows, which could not be further identified as vegetation or non-vegetation, and the building façades, caused by inclined recording of IKONOS and QuickBird satellite image data.

4. RESULTS AND DISCUSSION

4.1 Evaluation of high resolution remote-sensing data

The modern remote-sensing data have extended their applicability on urbanized areas as an alternative to aerial photos. In contrast to colour films of analogeous photography, which are restricted to three emulsion layers resulting in either red-green-blue or colour-infrared images, aerial scanner data (HRSC-AX) and satellite data (Quickbird and IKONOS) offer additional spectral information with different channels (red, green, blue, near infrared), which can be fused and analysed with different indices leading to an improved cognition and identification of habitat types. In combination with the high geometrical accuracy of the scanner data, complex urban structures and shadow areas can be analysed (Fig. 2).

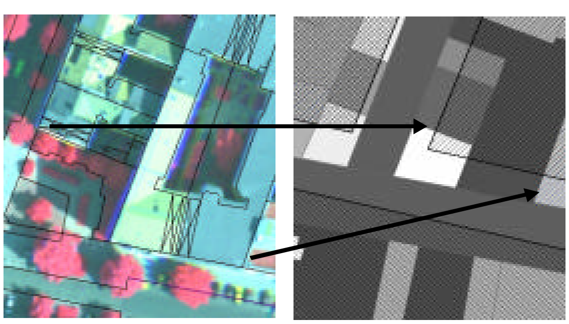

Figure 2. HRSC-AX: Multispectral information with a high geometric accuracy used for visual interpretation to update the old habitat type data (left: multispectral view with automated real estate map; right: new habitat type mapping compared to old data (in hatchings).

Both updating of existing data sets and initial data acquisition are possible. Furthermore, the DSM information helps to distinguish objects by their height, built objects and vegetation (Fig. 3). It is very useful in shadow areas, however, the information is limited by smooth edges of high objects and the geometrically lower resolution of 1m.

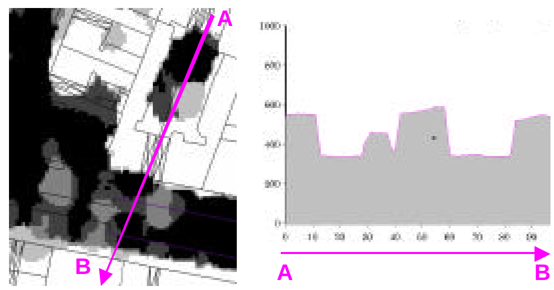

Figure 3. The DSM of the HRSC-AX: useful for detecting complex urban structures.(left: DSM and ALK, right: urban surface profile).

Another advantage of HRSC-AX is the user-friendliness of the digital and pre-processed format because there is no need for the user for film developing, digitizing, aerotriangulation, mosaicking, and georeferencing.
Compared to the aerial scanner data (HRSC-AX), IKONOS and QuickBird satellite image data show a limited opportunity to interpret urban structures and individual objects because of their lower spatial resolution, e.g. different kinds of vegetation species can hardly be identified. However, their resolution is appropriate for the cognition of urban structures and habitat type mapping on a scale of up to 1:5000, which is useful for urban planning. In this study, incorrectly assigned habitat types and boundaries of terrestrial surveying could be corrected by visual interpretation. It was also possible to classify vegetation-covered areas from sealed urbanized surfaces, which makes it possible to calculate the sealing degree indirectly. Furthermore, the short revisit frequency (about 1-3 days) of these satellite systems shows the opportunity for constant updating and monitoring.
However, challenges of this new type of data have to be met to enable urban habitat mapping. One significant problem of the scanner data is colour shift, e.g. the colour mismatches at high and moving objects. The reason is the position of the sensor rows in the focal level and the recording from different angles (Leser, 2003). Although these colour mismatches have been significantly reduced with the further technical development of the HRSC (A ? AX) it still limits the automatic classification. Furthermore, the data amount is very high compared to digital aerial photos and requires specific hardware to deal with it. Another confinement might be the limited availability of this

new kind of data for multitemporal analysis. While aerial photos are available for a long time series, the product lifetime of scanner data is, up to now, unsure.

The most urgent problem of the satellite data is caused by the inclined recording method (off-nadir-mode). The negative effect of inclination, e.g. off-nadir recording allows up to ca. 30° by IKONOS and QuickBird, can be specified by large and dark shadows and representation of façades, particularly in urban areas developed compactly with high-rise buildings (Fig. 4). With this reason, the automatic calculation of green proportion in satellite images can be affected by areas that cannot be interpreted. It means that the recording angle of satellite image data is an important criterion for the data analysis and evaluation. In order to avoid the effect of shadows and inclination of buildings, true-nadir recording is needed. But the repetition rate of e.g. IKONOS in the case of true-nadir-recording is 144 days. Additional problems such as improper weather situation when recording can make it even more difficult to get well suited data. Therefore, the application of high resolution satellite image data recorded off-nadir should be limited to specific circumstance, e.g. the areas with certain height of buildings for the purpose of automatic calculation of urban sealing degrees. However, the radiometrical resolution of 11-bit of IKONOS and QuickBird improved the possibility to identify shadowy areas because the spectral range of dark shadows can be widened. Some shadowy areas could be further identified and furthermore classified into vegetation or non-vegetation areas in this study.

Figure 4. Problem of shadow and inclination of buildings. (left: IKONOS. right: QuickBird).

	Aerial photo	HRSC-AX	IKONOS/ QuickBird
Data characteristics			
Advantages	• Widely applied data • Regular recordings for a long time series • Reasonable price	• Digital data • Separate bands • High geometric accuracy • Additional DSM	• Digital data • Different bands • High repetition rate • relative low costs
Problems	• Analogue data • Restricted to RGB or CIR or B/W	• Large data amount • Colour shifts, processing errors • Limited availability • High costs	• Off-Nadir-Mode: representation of façades, large shadows
Applicability of classification methods			
Visual	Very good, well established	Very good	Good
Pixel-based	Not favorable	Problematic (“Salt and Pepper Effect”)	Problematic (“Salt and Pepper Effect”)
Segment-based	Dependent of conditions	Mostly favorable	Better than pixel-based, Ambiguous segmentation process

Table 2: A comparison of different high resolution remote-sensing data for habitat type mapping in urban areas.

4.2 Evaluation of different approaches

The high resolution leads to the increased variation of spectral values within one object or thematic class. It causes some disadvantages like “salt and pepper effects” by traditional pixel-based classification and inaccurate segmentation by segment-based classification. Particularly, the spectral variety and complexity of the urban land cover materials lead to a large number of misclassifications (Kim & Kleinschmit, 2005). Additional information besides the one on spectral characteristics is needed.

One possibility is to derive this information by visual interpretation including the knowledge of the people interpreting the imagery. The results of the analysis of HRSC suggest that habitat type mapping on a larger scale will remain to be done by visual interpretation. Additional data derived from the pixel-based approach, the DSM and existing data sets were used. The challenges of colour shift can be met by visual interpretation far more easily, the high geometric accuracy can be exploited.

There is another possibility to support the evaluation procedure: the combination of both pixel-based and segment-based classification; visual interpretation can contribute of the segmentation process, too. The problems resulting from purely pixel-based classification with very high -resolution data can thus be reduced. At the same time, it prevents inaccurate segmentation by adopting pre-classified thematic layer. In general, other vector data can be taken into account during the segmentation process. However, the exact overlay between satellite images and other vector data is hardly possible because of their geometrical differences. In this case, very small and fractal segments can result causing similar problems as the “salt and pepper effect”. Furthermore, the inclined façades of high-rise buildings are divided and classified according to the attribute of vector data, which makes no sense. This is why the same satellite image data were used in this study in order to shape robust boundaries of classes: vegetation, non-vegetation and shadow. In this way, mixed segments among the classes could be prevented.

The advantage of automatic classification can be seen in a higher credibility than field surveying because the whole area can be handled without subjective interpretation. In addition, the extraction of green spaces shows the spatial dispersion pattern, which can contribute to model and simulate e.g. habitat network and urban micro climate situation.

This classification method can be transferred to other high resolution satellite data. But some changes of parameters, e.g. scale factors or threshold values, are needed because of the different geometric resolution as well as the different atmospheric and phenological factors. Nevertheless, the decision of the best scale factor and form index by a segment-based classification with eCognition is still an experimental approach which needs further testing.

5. CONCLUSIONS

The new remote-sensing data with the very high geometrical resolution prove potentials for urban habitat type mapping as this study showed. The main advantages of this kind of remote-sensing data are topicality, simultaneous recording of wide-range area, digital format and direct integration into GIS. However, in how far it is worthwhile to apply these new data has to be answered by considering the specific local situation and the already existing data and methods. Additionally available data sets need to be implicated to support the evaluation and outweigh the disadvantages of shadowy areas and colour mismatches. The requirements on the identification of different urban land-use or habitat types and the depth of information lead to the decision of whether to apply automatic or visual interpretation. The greater the size of the area to be mapped the greater the advantages of wide-ranging satellite data. The requirements on geometric accuracy will determine the decision of whether scanner data can be used for acquiring geometrical precise data including multispectral information. The required temporal resolution is decisive because airborne data, compared to satellite data, may be up-to-date, but cannot be ordered on a defined repetition rate. Furthermore, the structure of an urban area, especially the heterogeneity and the number of high-rise buildings resulting in shadow areas are important for choosing specific data and methods. Due to the formation of shadows, façades of high-rise building by inclined recording (satellite data) and colour mistakes at high and moving objects (aerial scanner data), the automatic interpretation cannot fulfil the expectations for the mapping of whole urban areas. The high diversity of artificial and also natural surfaces in urban areas limits the automatic classification as well. This kind of high resolution data can be of great value for the pre-mapping before the terrestrial work in order to gain an overview with correct geometric information. On the other hand, they can be used to testify and control errors caused by terrestrial mapping.

Although the technical characteristics seem to suggest the application of these new types of data, due to reasons of costs and usability rights the shift towards the operational application of digital scanner and satellite data in planning might take some time. The possibilities of automatic classification seem to be promising but a closer look at the task of urban habitat type mapping points out severe challenges. Mapping urban areas needs to provide data on a large scale, which is generalized and is heavily based on context information. Therefore, visual interpretation will not be substituted by a fully automatic classification on a larger scale in the near future.

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