HIGH RESOLUTION SATELLITE IMAGERY FOR THE ANALYSIS OF SEALING IN THE METROPOLITAN AREA SEOUL

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ABSTRACT

In Seoul, the sealing of surfaces was surveyed in the field by biotope type mapping, which was accomplished in 1999 and used as an important criterion for the definition of urban biotope types. Due to the subjective interpretations by surveyors as well as the fast changes of urban areas, continuous updating is a matter of great importance. For this purpose the new generation of satellite remote sensing offers a large potential with its very high geometrical resolution. In this context, the availability of this technology for the analysis of the sealing degree in the metropolitan area of Seoul was studied using IKONOS and QuickBird image data; a new method for classification of high resolution satellite data was suggested. The result shows firstly the applicability of high resolution satellite data for the analysis of urban sealing degree. Secondly, the classification method used in this study is transferable to other satellite image data. However, the inclined recording (off-nadir-mode), particularly in high developed urban areas, is still causing problems. The negative effects can be specified by big and dark shadows and visible facades instead of concealed areas by sloping high-rise buildings leading to the loss of information and poor geometric accuracy.

Keywords: high resolution satellite image, IKONOS, QuickBird, sealing degree, green proportion, segment-based classification

1. INTRODUCTION

Seoul is one of the largest metropolitan areas in the world with over 10 million inhabitants and an area of 600 km^2. The high population density caused a high proportion of sealed surfaces, and the green spaces have been threatened by more and more buildings and roads. The sealing of surfaces in urban areas plays an important role as an ecological indicator for e.g. ground water formation and urban climate condition. In the biotope type mapping of Seoul, which was first carried out in 1999, the sealing degree was a standard criterion for the definition of urban biotope types. As aerial photography is classified in South Korea because of military restrictions, sealing was investigated by field surveying (Seoul, 2000). This procedure is affected by subjective influences of surveyors because it was difficult to gain an overview of the field's surface. Some areas such as private estates and military areas were not allowed to enter. In this case, it had to be estimated by surveyors and thus leaded to uncertain and irreproducible results. In addition, park areas are always assigned as a 100% vegetation-covered area in spite of the sealed surfaces in forms of ways, parking lots or squares.

Nowadays the new satellite systems IKONOS and QuickBird open up new perspectives, particularly in urbanized areas. The complex housing structures, small green spaces as well as single trees can be identified with their very high geometrical, radiometrical and temporal resolution. In this context this study aims to verify the applicability of IKONOS and QuickBird satellite data for the analysis of sealed urban surfaces in order to improve as well as update the terrestrial biotope type mapping in Seoul. At the same time, it is expected to find out some interesting references about the suitability and transferability of the analysis methods by the comparison of IKONOS and QuickBird, which have a different geometric resolution and recording date.

2. MATERIALS AND METHOD

2.1 STUDY AREA

The study area is a very densely developed area with heterogeneous land use in forms of residence, commerce, administration, education, traffic, park and forest. This area is extremely sealed by compact and dense housing, which is representative of the urban situation of Seoul. In case of accessibility the field survey is reliable and can be used as reference data to compare the classification of satellite image data. The main land use is residential in forms of low story houses with and without garden. Within these

residential areas some schools can be identified by their own feature with playground. In an apartment housing complex in the south one can also recognise a group of high-rise buildings. In the north-east part, public institutions are located with their own green facilities and on the east part of this area there are high-rise buildings along the roads representing business and commercial uses. The central railway station is situated in the south-east and above that there is a public park.

Figure 1. Study area: Seodaemun-Gu, Seoul (QuickBird, 2002)

2.2 PRE-PROCESSING OF THE SATELLITE IMAGES

For this study IKONOS (CATERRA GEO, recorded on 27. Nov. 2000) and QuickBird (Standard, recorded on 22. Feb. 2002) satellite data were available. Due to the more inclined recording, the problems of the representation of facades of high-rise buildings and resulting shadows by concealed areas are more serious on IKONOS than on QuickBird.

As the study area was expected to show only minor changes, the classification results of these two satellite images could be comparable with terrestrial biotope type mapping. IKONOS and QuickBird satellite image data were processed separately by the software ERDAS Imagine© (version 8.6). Firstly, multi-spectral channels were fused with a panchromatic channel so that pan-sharpened multi-spectral images were gained (1 m resolution by IKONOS and 0.6 m by 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 area is topographically plain. The projection was also transferred from WGS84 into Transverse Mercator. The Root Mean Square errors are about 3 m on both satellite images.

2.3 ANALYSIS METHOD

The sealing degree was an important criterion for the definition of urban biotope types in Seoul. Each of the residential, commercial, industrial as well as public biotope type groups are subdivided 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, 2002), which corresponds to 30% green or denuded land. But since in urbanized areas one hardly does find denuded waste land another kind of intensive use will take place very fast.

So far many studies have ascertained that vegetation-covered areas can be well extracted automatically from non-vegetation areas by means of their clear spectral characteristics in satellite image data. In addition, the high resolution of IKONOS and QuickBird permits to distinguish very small urban green spaces, up to single trees. So in this work, the sealing degree was calculated indirectly by green proportion through classifying vegetation-covered areas from non-vegetation areas. A further reason for calculating green proportion is that green spaces are less affected by negative influences of distortion and sloping

resulted from off-nadir-recording mode. But this green proportion means "minimum green proportion" because vegetation can hardly be recognised if situated under the shadows or behind inclined recorded high-rise buildings.

With regard to the classification of vegetation-covered areas, the very high resolution of new satellite data requires a new kind of classification method. Due to the strongly increased variations and noises within a thematic class or object, the traditional pixel-based classification, which considers just individual pixel values, leads to the so-called "salt and pepper effect". In order to overcome this problem, the segment-based classification method uses more parameters in addition to spectral characteristics, e.g. object form, size, texture, neighbourhood and hierarchy relationship as well as other vector data. By the segment-based classification with the software eCogniton© (version 3.0), the classification accuracy depends on the successful segmentation, which creates homogeneous patches and functions as fundamental units for classification. However, problems are arising if the segment boundaries are not created thematically meaningful because of varying reflection values within a thematic class (Leser, 2002). Particularly in very heterogeneous urban areas like Seoul, incorrect segmentation occurs more often and, in general, can neither be reproduced nor is it reliable (Kleinschmit & Kim, 2004). So a combination of pixel-based and segment-based classification was suggested (Fig. 2).

In order to prevent incorrect segmentation, a pixel-based pre-classification was accomplished. IKONOS and QuickBird data were separately classified into three classes of vegetation, non-vegetation and shadow by Maximum Likelihood Method. In order to minimize the affection on classification results by different training areas, these areas were selected in both satellite data on the same location as far as possible. However, a little shift was necessary because of a different recording angle and direction. The problem of 'salt and pepper effects' was reduced by majority filtering (Fig.2, step 1a) 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.

By segment-based classification, the segmentation was accomplished at first on the finest level with a very small scale factor in order to create segments as homogeneous as possible. So the pre-classified patches were further sub-segmented within their classes regarding multispectral characteristics, NDVI values and object form (Fig.2, step 2). Then the pre-classification result of these sub-segments were analyzed and improved by segment related characteristics, e.g. mean NDVI value, neighbourhood and hierarchy relationship (Fig.2, step 3). On the rougher level, the segmentation was accomplished just by vector data of biotope type mapping in order to derive biotope boundaries (Fig.2 step 4). Then the green proportion was calculated in every biotope feature (Fig.2, step 5). The errors of biotope boundaries were corrected manually by overlaying satellite image and digital biotope type map (Fig.2, step 1b).

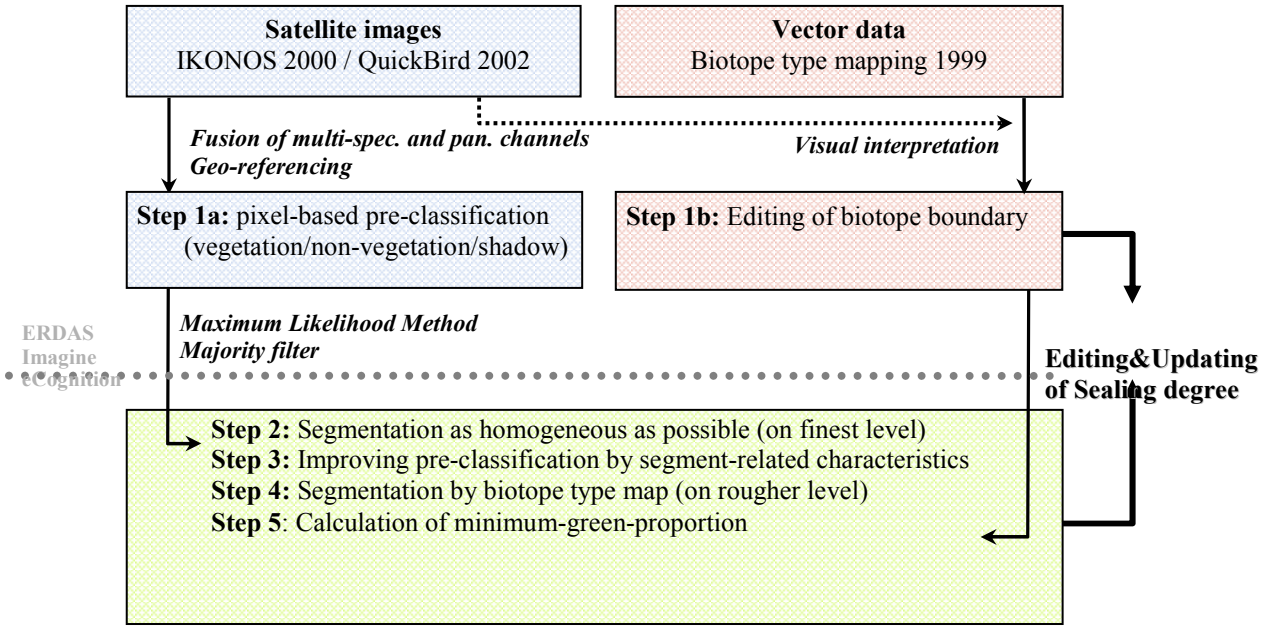

Figure 2. The combined method of pixel and segment-based classification for the analysis of sealing degree

3. RESULTS

3.1 CLASSIFICATION OF VEGETATION-COVERED AREA

By the pixel-based pre-classification of IKONOS and QuickBird satellite data, vegetation-covered small and fragmental green spaces were extracted very successfully from urbanized sealed surfaces, and shadows were also well classified by the obvious spectral characteristics. However, some errors still exist. Some roof tops were classified as vegetation on both data (Fig. 3) but this kind of errors happened a little more often by QuickBird. These areas were analyzed by eCognition with their sub-segments, but they have very similar vegetation characteristics. So it could be supposed at first, that they are constructed by roof planting. But they don't appear as vegetation by the real colour combination of multispectral bands of both satellite images. On the other hand, it could be supposed that there are very various building materials in urban areas and that some of them have really similar vegetation characteristics. In this case, other parameters are need for the classification of urban vegetation-covered areas. In order to verify the reason, the visit on the site was necessary but in this study it was not possible. Some other errors were found in the class of non-vegetation, e.g. some grass areas were classified as non-vegetation (Fig. 3). The reason could be the recording date of these two satellite images. As the vegetation cannot be calibrated by the full mass of green volume at the end of November (IKONOS) and February (QuickBird), the separation between vegetation and non-vegetation only by spectral characteristics could not be always successful.

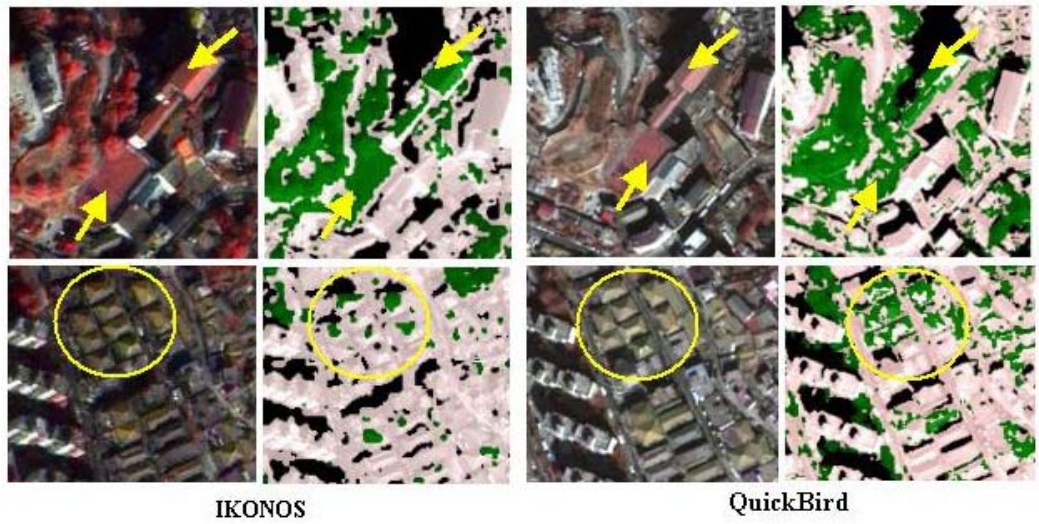

Figure 3. Example of errors on roof tops (Green: vegetation, Pink: non-vegetation, Black: shadow)

3.2 COMPARISON OF CLASSIFICATION RESULTS AND FIELD SURVEYING

The proportion of vegetation-covered area (minimum green proportion), which was derived from classification of IKNOS and QuickBird satellite data, was compared with terrestrial biotope type mapping (Fig.4). The green proportion resulting from classification of satellite data shows the close correspondence to that of field surveying, and generally the green proportion was assigned a little higher by the classification of QuickBird than IKONOS. The reason is that very small green spaces and single trees could be better classified by QuickBird with the help of its higher geometric resolution. Another reason is the lesser influence of the inclined high-rise buildings and shadows by the QuickBird data. Hereby some areas appear remarkable. Firstly, the green proportion of a residential area (Fig. 4A) was assigned to 10-15% by field surveying, 20-25% by IKONOS and 30-50% by QuickBird. This residential area is a family house complex with relative big gardens (Fig. 5A), so it verifies that the green proportion was underestimated by field surveying. The potentials of satellite data for verification and improvement of field surveying were thus proven. One other point is that the green proportion was a little underestimated by IKONOS because of more inclined recording. It shows that the recording angle is an important criterion for the applicability of high resolution satellite image data, particularly in high developed urban areas. Secondly, another housing complex was assigned with 25-30% green proportion by field surveying, 20-25% by IKONOS and 10-15% by QuickBird (Fig.4B). The reason was a real change of sealing degree resulting from a new construction (Fig. 5B) during the time between 2000 (IKONOS) and 2002 (QuickBird). It shows the possibility of updating of sealing data by means of automatic classification, since in this case the changes of sealing degree were observed. Thirdly, the green proportion in a road area is

assigned with less than 10% by field surveying and QuickBird but 10-15% by IKONOS (Fig. 6). Here trees were not recorded vertically because of the more inclined recording of IKONOS image, so the green volume was overestimated depending on the size of the trees.

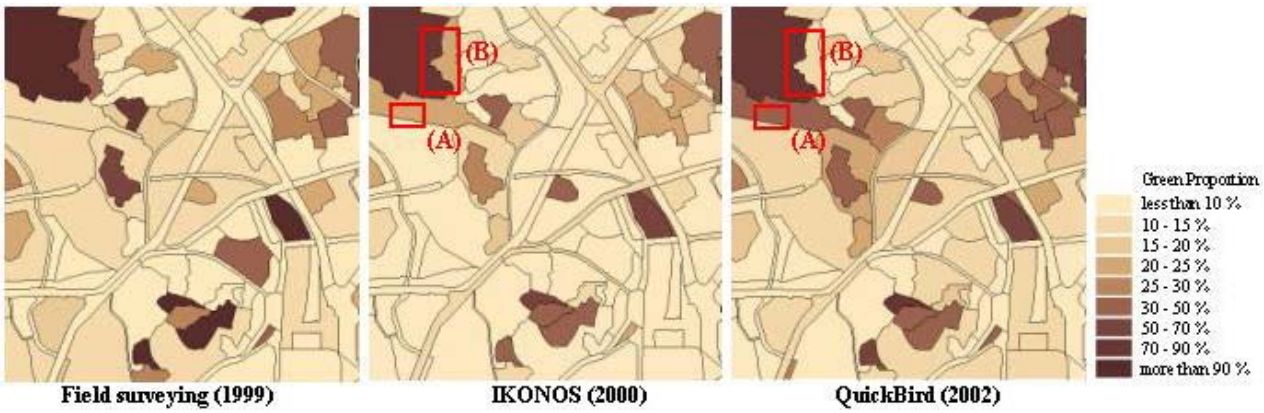

Figure 4. Comparison of green proportion of satellite images with field surveying (A, B is related with Fig. 5 for the verifying of classification by visual interpretation)

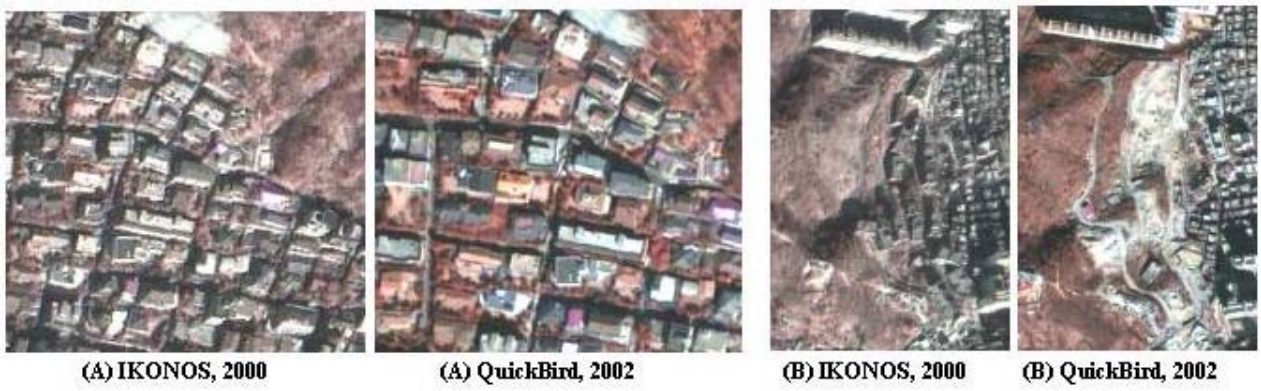

Figure 5. Verifying the green proportion by visual interpretation of IKONOS and QuickBird

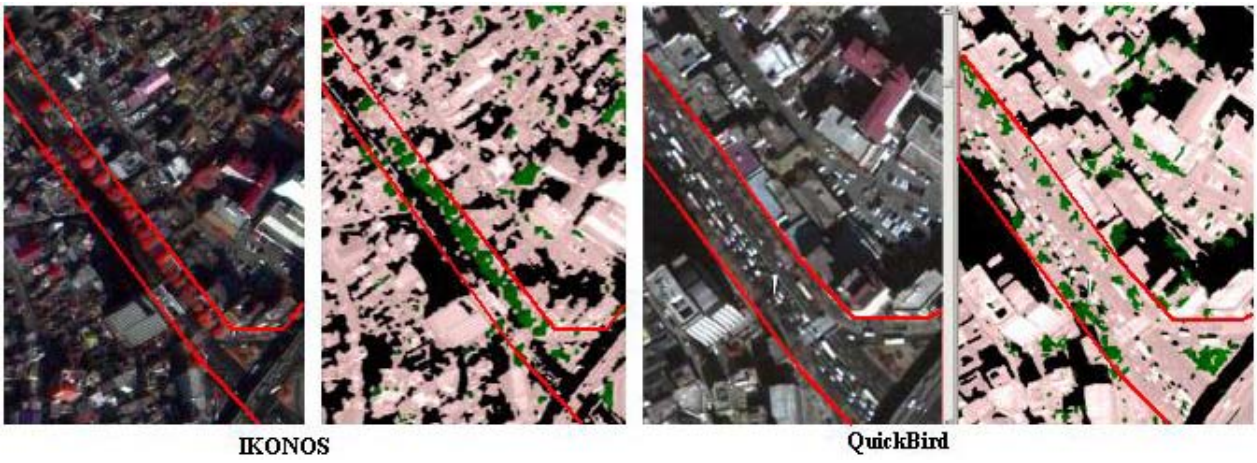

Figure 6. Example of overestimating green proportion in a road area by IKONS comparing with QuickBird

4. DISCUSSION

With very high geometrical resolution, the new satellite image data make it possible to interpret complex urban structures, up to single buildings as well as trees. As the study area (Fig.1) shows, normally green spaces are in Seoul very small, so they cannot be identified by previous satellite image data such as Landsat because of their inefficient spatial resolution. The high spatial resolution of IKONOS and QuickBird can be regarded as the most important advantage of this type of data. They can be used as an alternative to aerial photos for the purpose of mapping the sealing degree, at least for the pre-mapping before the field survey, by visual interpretation. It is also possible to classify vegetation-covered areas from

sealed surfaces by buildings and roads, which makes it possible to calculate the sealing degree indirectly, as this study showed. The advantage of automatic classification can be seen in more creditability than field surveying because the whole areas can be handled without subjective interpretation. In addition, the extraction of green spaces shows the spatial dispersion pattern, which can contribute to some kinds of planning, e.g. biotope network or urban micro climate. The most urgent problem is caused by the inclined recording, particularly in urban areas developed compactly with high-rise buildings. The negative effect of inclined high-rise buildings can be specified by big and dark shadows and representation of facades, which means a loss of information. The shadows are normally so dark that the further identification appears hardly possible. In this study, it was tried to improve the shadows with artificial transforming of spectral values, e.g. vegetation index, but it did not work.

On the other hand, the high resolution leads to the increased variation of spectral values within a thematic class. It causes some disadvantages like "salt and pepper effects" by traditional pixel-based classification and inaccurate segmentation by segment-based classification. All this calls for a new classification method. The combined method of pixel and segment-based classification, which was suggested in this study, reduces the problems of pixel-based classification by further segmenting and improving with segment-related characteristics. At the same time it prevents inaccurate segmentation by adopting pre-classified theme 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 in practice 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 facades of high-rise buildings are divided and classified according to the attribute of vector data, which makes no sense. This is why in this study the same satellite image data were used in order to shape robust boundaries of theme classes, which were vegetation, non-vegetation and shadow in this study. In this way, the mixed segments among their theme classes could be prevented. In addition, this classification method can be transferred to other high resolution satellite data. But some changes of parameters, e.g. scale factors or threshold values of NDVI, are needed because of the different geometric resolution as well as the different atmospheric and phenological factors. Nevertheless, the decision of best scale factor and form index by segment-based classification with eCognition© is still an experimental approach which needs further testing.

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