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# External geo-information in the segmentation of VHR imagery improves the detection of imperviousness in urban neighborhoods

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A B S T R A C T

Object-based image analysis (OBIA) has become an established way to detect imperviousness and other land cover classes from very high resolution (VHR) multispectral imagery. Data fusion with LiDAR derived digital surface models (DSM) and large scale vectorial datasets containing building footprints and road boundaries have the potential to significantly improve this method. However, the individual contribution of the large scale vectorial dataset remains unclear. In this paper, we studied the improvement of segmentation and classification results when including a vectorial dataset in the OBIA. Two slightly different segmentation methods making use of the vectorial dataset (boundary suggestion method and absolute boundary method) are compared with each other, with a per-pixel classification of the image and an OBIA segmentation without the input of a vectorial dataset. The performance of all four segmentation methods was assessed both for per-pixel image classification and for segmentation accuracy. The classification accuracy was highest for the segmentation method where the vectorial boundaries were absolute (overall accuracy 82%). However, the boundary suggestion method, where segments were smaller than the reference polygons, had the highest segmentation quality. Although differences between the two methods were clear, the differences with the results of the object-based analysis which did not use the vectorial dataset, were even larger. This indicates that the explicit inclusion of a large scale vectorial dataset is beneficial for the segmentation and classification of imperviousness in an urban environment.

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## 1. Introduction

Knowledge of the location, extent and physical properties of impervious surfaces is important for hydrological studies due to their impact on stream water quality and runoff volumes (Arnold and Gibbons, 1996; Booth and Jackson, 1997; Jennings and Jarnagin, 2002). The focus of early research was mainly on the impact of imperviousness on watershed scale, while more recently attention shifted to large scale assessments of smaller areas, especially within built-up environments (Xiao et al., 2007; Mitchell et al., 2008; Perry and Nawaz, 2008). Although individually small and seemingly without effects, the cumulative area of imperviousness in residential gardens can have a large impact on the local water balance (Perry and Nawaz, 2008). Therefore, we are interested in all impervious entities on the parcel both large and small, from large houses to narrow pathways.

Object-based image analysis (OBIA) has shown its potential to detect and classify imperviousness in urban environments using very high resolution imagery (e.g. Mathieu et al., 2007a; Zhou and Troy, 2008; Wurm et al., 2010; Myint et al., 2011). In the object-based approach of image classification, the image is first segmented into spatial objects that are internally relatively homogeneous. These objects are richer in spectral (mean values, minimum and maximum values per band, etc.) and spatial information (shape, distances, context, etc.) compared to the single pixels they consist of. The segmentation step is the first and foremost important step in OBIA, as the accuracy of the classification of the objects is highly dependent on the quality of the segmentation (Neubert et al., 2008). Within the numerous algorithms that exist for image segmentation (Blaschke et al., 2004; Meinel and Neubert, 2004; Blaschke, 2010), the multi-resolution segmentation based on the fractal net evolution approach, implemented in the eCognition software (Definiens, 2010), is a widely accepted segmentation algorithm used for land cover detection in urban environments (e.g. Herold et al., 2002; Van de Voorde et al., 2004; Mathieu et al., 2007a,b; Im et al., 2008; Platt and Rapoza, 2008; Zhou et al., 2008). This segmentation technique has the advantage of being able to produce segments of various sizes within one step as it is based on equal within-object homogeneity rather than size. However, there is no standardized or widely accepted guideline to optimize the homogeneity setting (scale parameter) of the segmentation (Carleer et al., 2005; Jacquin et al., 2008; Kim et al., 2008; Myint et al., 2011). As such

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guideline is lacking, the scale parameters for the segmentation are often chosen based on trial-and-error and a visual appreciation of the segmentation results (Im et al., 2008; Platt and Rapoza, 2008; Zhou et al., 2008). Myint et al. (2011) even state that successful object-based image analysis cannot but be iterative: "repeatedly modifying training objects, performing the classification, observing the output, and/or testing different combinations of functions in a trial-and-error process".

The fusion of external geodata with VHR satellite imagery has shown to improve classification accuracies (Santos et al., 2010). Especially the fusion with LiDAR-derived digital surface models have been reported to substantially improve impervious detection in an urban environment (Van de Voorde et al., 2004; Mathieu et al., 2007a; Zhou et al., 2009; Dinis et al., 2010; Wurm et al., 2010). Vectorial geodata containing parcel boundaries and/or building footprints are also successfully used for fusion with both VHR imagery and LiDAR data for detection of impervious surfaces at the parcel level (Zhou and Troy, 2008; Zhou et al., 2008; Freire et al., 2010). In an OBIA review article, Blaschke et al. (2004) specifically pointed to the possibility of using these types of high resolution digital topographic databases, which are becoming available in many countries. The advantage of using such databases is that they offer a geometric as well as a semantic prediction for part of the impervious objects in the satellite image. A disadvantage is that they are often limited in their degree of detail, causing small impervious elements of interest (such as pathways) to be absent.

In this research, we aimed to quantify the potential of the geometries included in such a digital topographic database in an object-based classification of a VHR multispectral image focusing impervious land cover types at a parcel scale. Hence no use was made of semantic information included in the database or of other external data sources. We evaluated the results by pixel-based accuracy and segmentation quality.

## 2. Data and software used

### 2.1. Study area

The study area is a social housing neighborhood in the north of the municipality of Leuven in Belgium. The neighborhood was built in 1952 and covers a total area of 6 ha, with an average parcel size of 845 $m^2$. Out of the 63 single family houses 62 are semi-detached, designed and built as each other's mirror. However, due to renovations and extra housing spaces added over time, this is no longer fully the case. This type of neighborhood was chosen as it has a regular layout pattern and very similar parcel and building characteristics, which is a common feature of social housing projects and was expected to facilitate the OBIA.

### 2.2. Very high resolution imagery

The segmentation and classification were performed on a QuickBird-2 image (acquired on 7 March 2009) with a very high spatial resolution of 2.44 m in multispectral and 0.61 m in panchromatic mode. Four spectral bands were available: red, green, blue and near-infrared. To correct for topographic distortions and to ensure an acceptable positional accuracy, the image was first pan-sharpened and then orthorectified based on the rational polynomial coefficients provided with the image.

### 2.3. Ground reference data

Ground reference data were acquired for the training of the classification and for the validation of segmentation and validation. The data were partly collected by a field survey in March 2011 in which all land cover patches with a minimum size of 1 $m^2$ were registered. But as not the whole neighborhood was accessible for the survey, data from a visual interpretation of the area using Microsoft Bing maps (spectrometric oblique images in 4 directions, acquired in September 2006 by Blom spectrometry) was added to reference dataset. The field data were digitized with the VHR QuickBird images serving as a backdrop. When anomalies were noticed as a result of recent construction works, the corresponding objects (13.6% of the neighborhood) were left out of the dataset.

The ground reference dataset was divided into equal subsets for calibration and one for validation by stratified random sampling (Fig. 1). The neighborhood was stratified into 32 building zones which were defined as the union of parcels and their adjacent road parts that belong to one building structure or, in other words, the two parts of two semi-detached housing.

### 2.4. External dataset

The dataset used in two of the four segmentation methods was extracted from the "Grootschalige Basiskaart Leuven (GBK)", a high resolution topographic reference database, which is developed and maintained by the municipality of Leuven. The GBK contains object classes as 'buildings', 'parcels', 'road border', 'street lanterns', 'sewer systems' and other objects relevant for use within cartographic scale limits of 1:250 and 1:1250.

We selected the object classes of the GBK related to impervious land cover: roads, buildings, pathways and driveways, to create the

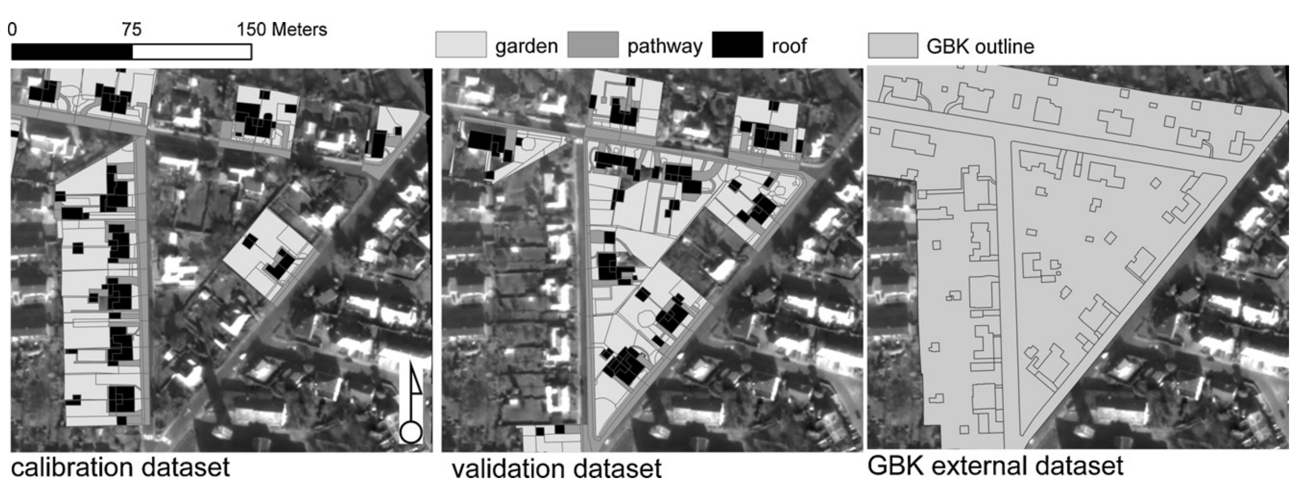


**Fig. 1.** Extract of the calibration dataset, the validation dataset and the GKB outlines used in approach C and D, with the VHR QuickBird image as backdrop.

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