Automatic Land Use Classification
and SEA-compliant Indicator Assessment in Urban Areas

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Abstract

The Strategic Environmental Assessment (SEA) directive 2001/42/EC of the European Commission prescribes inter alia that significant effects of the implementation of certain plans and programs on the environment will be monitored. To support SEA in urban areas, a (semi-)automatic method based on the object oriented classification software eCognition was developed and applied to extract land use categories and selected ecological indicators from remote sensing data of an allotment area in the city of Berlin. The hitherto available results show that compared to a fully manual classification, the object oriented classification with eCognition provides promising results for sealed areas, but a less accurate classification of trees and low vegetation.

1. Introduction

Rapid progress in the fields of Geographical Information Systems (GIS) and Remote Sensing has made new, innovative approaches for land use monitoring and change detection possible, which are relevant for city planners and environmental departments. In the 'e-Land Use Information Management' work package of the EU FP6 project IntelCities, methods for the GIS-based assessment of land use changes in urban areas were developed and tested in three showcases. The showcase presented in this paper involved a city partner (Berlin), an industrial partner (Definiens Imaging GmbH) and a research institution (Swiss Federal Laboratories for Materials Testing and Research - Empa).

The City of Berlin is committed to apply the Strategic Environmental Assessment (SEA) directive 2001/42/EC of the European Commission (European Commission 2004) for all land use plans set up after July 21st, 2004 and not adopted by July 20th, 2007. The SEA directive prescribes that the significant effects of the implementation of certain plans and programs on the environment have to be monitored.

Recent developments in satellite-based remote sensing and classification methods suggest the application of (semi-)automatic evaluation methods to monitor environmental effects of land use changes in urban areas. Within the showcase 'Berlin' of the IntelCities project, the potential of high-resolution remote sensing images classified with the object oriented software eCognition was assessed in view of an application within SEA. For a study site in the city of Berlin, the calculation of selected structural ecological indicators for urban areas was exemplarily performed and assessed with regard to its possibilities and limitations.

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2. Remote sensing for urban planning

Until recently, civilian satellite sensors delivered a minimum footprint of 30m and were not able to provide data of sufficiently high spatial resolution (i.e., large mapping scale) to identify the features of interest in urban areas, such as individual buildings, roads and areas of open space. Hence satellite-based remote sensing has mainly been used in forestry or agriculture, where the spatial structures are larger. This situation, however, changed over recent years with the advent of a number of commercial satellites (QuickBird and IKONOS) providing image data with a spatial resolution as fine as 0.8 m. Today, satellite-based remote sensing has the potential to be used for urban areas.

For the purpose of land use planning, relevant spatial features have to be extracted from satellite images. This is either done with supervised classification, where reference areas for each class are manually identified, or with unsupervised classification, where the computer uses absolute values (e.g., average reflectance characteristics) to classify the image. Generally, the results of supervised classification are more accurate, but unsupervised classification leads to user-independent and reproducible results and is therefore more suitable for standardized classification services. However, for high resolution images, the uncertainty of unsupervised pixel-based classification is especially high because of image complexity (shadows, small objects, structures within the objects) and non obvious relations between the reflection characteristics of a single pixel and the corresponding land use class. In contrast to pixel-based classification, some recently developed classification tools such as eCognition from Definiens Imaging GmbH (Definiens Imaging 2004) are object oriented. eCognition uses image object primitives created by aggregation of pixels to classify the provided earth observation data. With the generation of these image object primitives on different scales in a hierarchical network, it is possible to make new object attributes available, which support the classification of the data. Besides information about the color of an object, these attributes can be, inter alia, size and shape of the object or the relation to neighboring objects.

Starting from classified remote sensing images, structural indicators can be calculated. Structural indicators based on biotope classification and their temporal variations are, in turn, a measure for changes in species and ecosystems biodiversity (Hansson et al. 1995). Thus far, the calculation of structural ecological indicators from remote sensing data has been restricted to non urban landscapes. Peterseil et al. (2004) evaluated the ecological sustainability of Austrian agricultural landscapes on the basis of structural indicators generated from Landsat TM5 data and a region-growing, pixel based segmentation and classification method. Bock (2004) analyzed the conservation status of protected habitats using habitat maps and spatial indicators to assess fragmentation, spatial distribution and neighborhood relations of key habitats. Zebisch et al. (2004) evaluated land-use maps based on color infrared (CIR) aerial photographs with respect to biodiversity by means of six indicators representing the three aspects of biodiversity: composition, structure and function.

3. Showcase Berlin

3.1 Methods

The former allotment area called "Neu-Venedig" in the Southeast of the Berlin was chosen as the study site. "Neu-Venedig" is a green area crossed by watercourses and surrounded by forests and lakes. Over the last 15 years, "Neu-Venedig" has steadily changed into a residential area. To stop this undesirable development, the land use change plan was changed in the late 1990s. With its highly complex, garden-like structure, "Neu-Venedig" is an ideal test bed for unveiling the limitations of unsupervised, object-oriented image classification.

Initially, it was planned to use high-resolution satellite images. However, it was not possible to find suitable satellite images from IKONOS or Quickbird that were taken during the vegetation period, fully
covered our study area and exhibited a cloud coverage < 5%. Finally we took airborne false-color infrared images of the study site for two points in time (July 1995 and August 2000), which we then digitized into images with a resolution of 0.25 m.

As a pre-condition for classification, a land use classification hierarchy was established on the basis of the biotope list of Berlin (Zimmermann et al. 2003). The original and the digitized airborne images were classified using three different approaches:

1. a manual classification with an individual, manual identification of all patterns using a GIS (Geographical Information System). This approach is very time-consuming and subjective, but it leads to a high quality classification. We used this approach to define a reference state.
2. a supervised, pixel-based classification using a maximum-likelihood algorithm from ERDAS Imagine (Pouncy et al. 1999).
3. a (semi-)automatic, object oriented classification using eCognition (Definiens 2004). To support classification, additional GIS data on watercourses and streets, as they are available in most European cities, were provided by the City of Berlin.

Based on the manually and (semi-)automatically classified images, structural ecological indicators of different metric types were calculated for selected urban landscape categories (vegetation high, vegetation low, sealed area, buildings). The following indicators were chosen: Share of urban landscape categories (area metrics), urban landscape category edge density (edge metrics), number of urban landscape category patches (patch density & size metrics), mean shape index (shape metrics) and mean proximity index (diversity and inter-dispersion metrics).

3.2 Results and discussion

For a subset of 26,000 m² in the study site, the indicators calculated from the fully manual classification and the (semi-)automatic classification with eCognition were compared to each other (Fig. 1).

During the classification process it appeared that the land use classification hierarchy on the basis of the biotope list of Berlin could not be fully adopted for the manual and the object oriented classification with eCognition. This was especially true for categories with no obvious correlation between function and object attributes like size or relations to neighboring objects, e.g. the different sub-categories of the built area.

Fig. 1 shows the original airborne image from 1995 (A) and the resulting classifications using the manual approach (B) and the object-oriented approach (C). The differences are rather small for the sealed classes, but very high for the vegetation classes. The differences for the water class are irrelevant, because both classifications use the same GIS layer from City of Berlin. Fig. 2 illustrates the quantitative differences between the two classification approaches. For both points in time, the differences are less than 10% for the classes of total vegetation, buildings, and sealed area. The discrimination between low vegetation and high vegetation is obviously not accurate when working at this very high resolution. Fig. 2C shows the relative change in land use from 1995 to 2000. Both methods are able to detect the same trends for the classes of total vegetation, buildings, and sealed area, while the results for low vegetation and high vegetation are very different for the two methods.

Our findings stand in contrast to the results of Walker & Briggs (2005), who were able to classify urban trees with high accuracy, but had more difficulties with classifying the sealed area. These contradicting findings can be explained by the different vegetation zones of the two study sites. The color contrast between trees and the dry vegetation is very high in the desert city of Phoenix, Arizona (Walker & Briggs 2005). In Berlin, similar reflectance characteristics for trees and low vegetation and a lot of shadows made the differentiation among vegetation types difficult.
The quality of the results allows the calculation of structural indicators that are based on the sealed area and the water area like proportion of sealed area or riparian length. Indicators basing on different vegetation patches, like proportion of forest, length of forest border, connectivity of forest patches or diversity of vegetation patches could not be assessed with reasonable precision.

Fig. 1: A) Subset of the study site in Neu-Venedig, Berlin, False color airborne infrared image from 1995, 0.25 m resolution. B) Manual classification of the subset into five classes. C) (semi-)automatic classification of the subset into five classes using definiens eCognition.
4. Conclusions and outlook

The extraction of ecological indicators of remote sensing images from urban areas in Berlin with the object oriented classification software eCognition has so far shown promising results for indicators that are mainly based on sealed areas. Due to the high vegetation complexity and the large tree shadows on the test images, the method was less suited for the discrimination among vegetation classes. In view of a reliable, (semi-)automatic quantification of ecological indicators from remote sensing images, future research will have to focus on the development and refinement of algorithms, which allow a context-independent classification of the relevant landscape classes.

Bibliography


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