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Sustainable Urban Planning: A Spatial-Explicit Mapping and Evaluation Approach for Monitoring Urban Green

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Abstract: This paper presents a monitoring concept based upon the utilization of very high spatial resolution remote sensing data by means of object-based image processing and spatial analysis techniques for the purpose of: (1) automated spatial-explicit delineation of urban green structures, (2) their characterization and quantification of urban green structures, and (3) their relative importance in the eyes of the citizens. Meeting the demand from the planning commission of the city of Salzburg, a transferable method has been elaborated for monitoring and evaluation of urban green. Using QuickBird imagery from June 21, 2005, several indices have been elaborated, which both integrate object-based fine-scaled classification of relevant green structure types and the results of an interview-based survey revealing the relative importance of these types. The method discussed has been designed for monitoring urban green in a repeatable and transferable manner by comprising (1) automated feature extraction from remotely sensed data, (2) spatial explicit measures for distribution and spatial characterization, and (3) subjective, social science data reflecting the perception of green structure types and by this, the quality of some aspects of urban life and residential satisfaction.

Keywords: urban planning, urban green, monitoring, remote sensing, high spatial resolution.

1. Motivation

Sustainable city planning in ever growing urbanised agglomerations relies on preserving and consolidating urban green space. In our highly transformed technosphere both natural and managed green areas are vital for retaining and improving city climate, urban ecology and the comfort of the citizens (Pauleit, 2004). To this end, prospective planning must ensure the maintenance of urban green structure. Measures for management and monitoring rely on relevant information, obtained from objective sources, transformed and conditioned by transferable means. Spatial indices and indicators are considered potential bridges between the often ambitious planning aims on the one hand and the availability of adequate data and methods on the other hand. Possible indicators for residential attractiveness address infrastructure facilities, local recreation, shopping facilities and educational establishments, and the quality and distribution of urban green. Quantifiable, spatially explicit information on green structures, their distribution and dynamics is an onset for monitoring needs in the light of sustainability. The poster presents an integrated monitoring concept (Amerigo & Aragones, 1997) which utilizes very high spatial resolution remote sensing data through object-based image processing and spatial analysis techniques. The objectives of the underlying project, funded by the municipality of Salzburg, Austria, were three-fold: (1) automated delineation of a given set of urban green structures; (2) quantification and assessment of their spatial distribution; and (3) evaluation of their relative importance in the eyes of the citizens.

2. Data sets and methods

The study site comprises an area of 65.7 sqkm and coincides with the outer limits of the city of Salzburg, Austria. The city of Salzburg is dominated by the Altstadt and the surrounding, densely built-up inner city, in which three wood-covered hills are embedded. QuickBird imagery from June 21, 2005 has been used for this study. This type of satellite data was chosen to fully utilize both high spatial detail and the infrared information for analyzing different green structure types effectively. QuickBird collects four multispectral (MS) bands (VIS and VNIR) at 2.44 m spatial resolution and a 0.61 m panchromatic (PAN) band, each band coded in 11-bit radiometric resolution. The scene was co-registered to a digital cadastral map (BMN-31). Pan-sharpening was done using an image fusion model after Liu (2000) implemented Erdas Imagine 8.7. The implemented low-pass filter is realised by a 5 by 5 matrix. Nearest neighbour interpolation was used for resampling. In absence of an appropriate DEM, rubber sheeting was used instead of rationale polynomial orthorectification for geometric correction. For providing the spatial units for class modelling, we used a strictly hierarchical, multi-resolution segmentation approach, as implemented in the software Definiens Professional.

An interview-based survey, conducted among 128 respondents, revealed a ranked evaluation of twenty-nine different green structure types. Evaluation considered relative relevance for an overall green impression in a range between zero and five. Exemplary photos were provided for each structure type to be assessed. Additionally the questionnaire contained questions concerning the general perception of urban green in the city. Interviews were carried out between June and July 2005, i.e. temporally coincide with the acquisition date of the QuickBird scene. Thirteen out of twenty-nine green structure types were then transformed into a cognition network and classified using object-based image analysis. The cognition network provides a transparent, yet flexible classification scheme, and it enables users to interact with this system. On top of that it is a graphical tool for communication and interaction with users or stakeholders. They can decide about the very semantic content of aggregated target classes as in our case *Green* or *Not-Green*. Depending on the threshold applied to the ranking among the respondents or any other decision rule, the classes are assigned to the target classes *Green* or *Not-Green*. The classification scheme finally contained eleven green structure types plus two classes not considered belonging to Green as such, namely *Sealed surface* and *Shadow* on non-vegetation.

Based on the classification result we calculated an overall green index (GI), which simply reflects the percentage of classified green in an arbitrary spatial unit (e.g. enumeration blocks, city quarters or regular, analytical cells). The results from the survey were used to derive a weighted green index, GI_w, which represents an averaged 'green impression' per cell. To achieve this, the following metric was applied: (1) percentages of each structure type in relation to the total area of green were calculated within each unit. (2) Ranks assigned to the structure types were normalized in an interval [0|1] for obtaining weights. The percentages of each type were then multiplied by the assigned weight to derive, as an intermediate measure, GI_{w0}. (3) Finally, to derive GI_w, values of GI_{w0} of each structure were summed up within each unit and then re-transformed to the original range of rankings. GI_w, like GI, can be calculated for any spatial reference unit, and thus spatially aggregated or disaggregated at will.

3. Results and discussion

Point-based accuracy assessment of the classification (stratified random using 300 points and 20 points minimum per class) revealed an overall accuracy of 81.7 % (K^ = 0.8005). This value increases to 87.2 %, when merging the structure types *Lawn* and *Meadow*. *Lawn* has been classified using form features, which cannot be evaluated as such by point-based accuracy assessment (see Lang et al., 2006 for details).

GI_w was calculated for a mosaic of raster cells, each 50 * 50m in size (in sum 4,692 cells). Altogether, values for GI_w ranged from 2.1 to 4.3, in 3,400 cells (8.5 sqkm) GI_w exceeded 3.9. For comparative reasons, the green index GI has been contrasted with GI_w by using the initial weight product GI_{w0}. Lang et al. (2006) showed that by this 'greenness' of a cell can be evaluated much more specifically as being reflected by an undulated curve representing GI_{w0}. At a considerable portion of the cells (about 44%), GI_{w0} exceeds GI. This is the case where a relative small percentage of green is contrasted with a high relevance of the occurring structure types. Figure 1 shows a modified picture of the distribution of urban green as presented in earlier publications, now taking into account the relative importance of the respective green type. Considering the relevance of the respective classes, a cell can be covered completely by green, but by structure types which are rather poorly acknowledged. Vice versa, the coverage of green can be rather small, but the appreciation of the respective type may be high. This may be useful for planning and management purposes, as being indicative for the preservation of relatively small portions of green, which otherwise may be eradicated through densification activities.

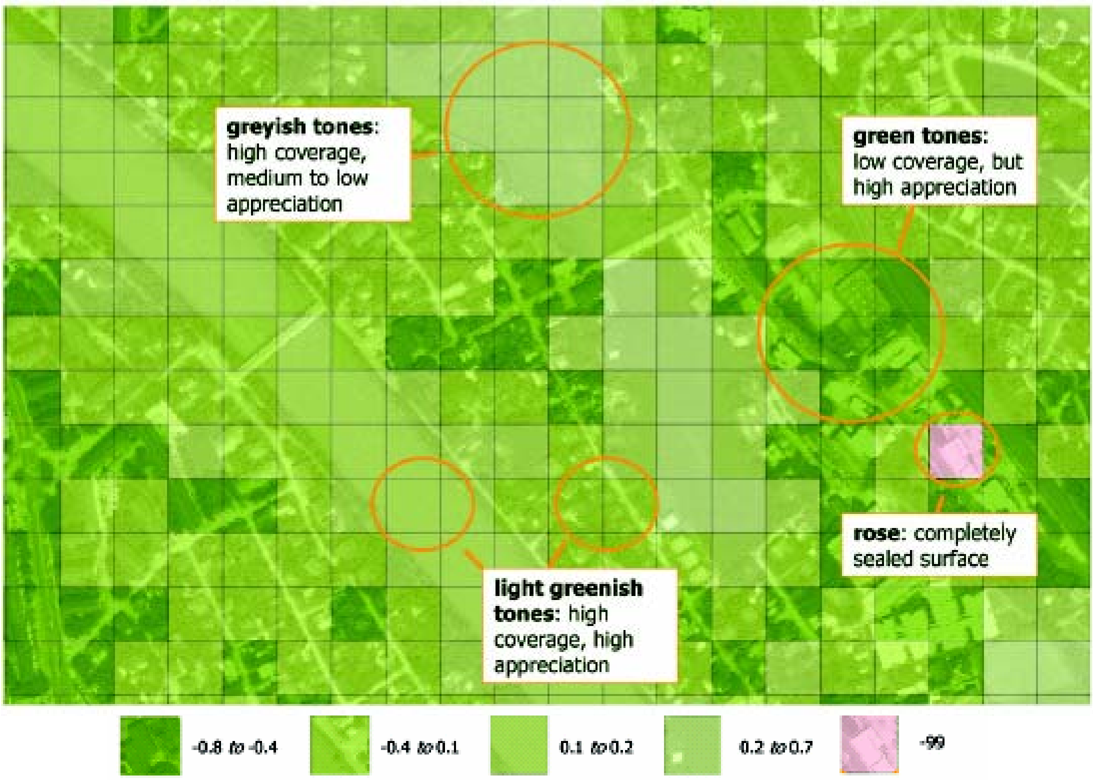

Figure 1: Relative importance of green areas, as calculated by subtracting values of GI_{w0} from GI (see text for further explanation).

The method discussed has been designed for monitoring urban green in a repeatable and transferable manner by comprising (1) automated feature extraction from remotely sensed data, (2) spatial explicit measures for distribution and spatial characterization, and (3) subjective, social science data reflecting the perception of green structure types and by this, the quality of some aspects of urban life and residential satisfaction. Future work focuses on the realization of this approach within management activities of urban green spaces and its implementation into framework programs of urban spatial planning.

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