URBAN TREE CROWN PROJECTION AREA MAPPING WITH OBJECT BASED IMAGE ANALYSIS FOR URBAN ECOSYSTEM SERVICE INDICATOR DEVELOPMENT

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ABSTRACT. Urban tree crown projection area mapping with object based image analysis for urban ecosystem service indicator development. The continuous expansion of built-up areas in the urban environment at the expense of green spaces brings up numerous environmental problems, for which accurate and efficient solutions should be found. The assessment of ecosystem services developed within the field of landscape ecology is playing an ever more important role in environmental sciences and thus may offer suitable answers. Such assessments can be carried out by developing indicators. Accordingly, in the case of urban trees, an accurate quantitative characterization of their services (such as e.g. carbon sequestration, pollutant removal and microclimate regulation) is also needed. The aim of this study is to establish a generally applicable method based on indicator development, using widely available data. In the case of urban green spaces there are several services for which the development of proper indicators and evaluation methods requires a delineation of tree crowns, or at least the crown projection area. Accordingly, in our work, we map the crown projection area of a large and popular urban park of Szeged, Széchenyi square, using object-based image analysis on UltraCamD digital orthophotos. Following a multiresolution segmentation the classification of the resulting objects was carried out, using the eCognition image analysis software. Besides fulfilling the policy objectives related to the evaluation of urban ecosystem services, the produced crown base can also be used in several other types of urban ecological and urban climatological studies (e.g. urban climate modelling, human-comfort assessment). In this paper the first results are presented.

Keywords: ecosystem services, crown projection area, eCognition, object-based analysis

1. INTRODUCTION

These days remote sensing is the most often used way for the assessment of urban environments. By the 21th century, the spatial extent of the cities and the number of their citizens has increased. This ongoing process seriously affects the urban environment, leading to several land use conflicts, which need to be resolved in a fast and efficient way. The methodology of evaluating ecosystem services gains more and more importance in environmental science and management (TEEB, 2010). The field, rooting from traditional landscape ecology and ecological

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economics, had a breakthrough in the 1990’s and the early 2000’s (Balmford et al., 2002).

In the last few years more and more research is dealing with urban ecosystem services (Gómez-Baggethun et al., 2013; Haase et al., 2012;Hubacek and Kronenberg, 2013).These are mainly artificial ecosystems, but as they are situated in densely populated areas, they affect many people’s quality of life, and therefore, they should be taken into account both in monetary and non-monetary evaluations. In Germany or the Netherlands, the concept of landscape functions is used in landscape planning in order to delineate protection zones or to determinate priority areas for agricultural, forest, or recreational use. However for most planners it remains unclear how to bring natural science-based landscape functions together with the more valuation-centered ecosystem services (Bastian et al., 2012).

The evaluation of ecosystem services can be carried out through the development and quantitative assessment of proper indicators, which enable mapping and building complex models for scenario analyses (Petz et al., 2012). Urban ecosystem services should also be evaluated in this methodological framework (Dobbs et al., 2011).

The evaluation and mapping of urban ecosystem services is necessary, according to the ongoing current international environmental policy goals (implementing the targets of the EU Biodiversity Strategy 2020 on mapping ecosystem services and Green Infrastructure-based regional development). Most of the urban ecosystem services are connected to the arboreal vegetation. Their evaluation can be carried out quite precisely, based on the main structural parameters of the tree individuals and stands (e.g. crown size parameters, species composition) (Nowak et al., 2008). Photogrammetric and remote sensing methods provide a number of methodological possibilities for their quantification and some of these parameters can be regarded as direct ecosystem service indicators (e.g. leaf area). A part of these attributes derivable from aerial or satellite imagery characterizes the size of stand-alone trees (e.g. crown diameter or tree height, Iovan et al., 2013) and there are also some approaches for species recognition (Zhang and Hu, 2012). As most of these planted stands have very heterogeneous species composition, for the evaluation of wider areas (whole cities, quarter of the cities) indicators based on simple attributes need to be selected. This parameter can be the area of tree crowns (CPA: crown projection area), which characterizes the extent of the green spaces well, and provides a good basis for mapping several services by using transfer functions (McPherson et al., 2013). We can define the extent of CPA in different urban built-up types with object based image analysis, using different types of segmentation algorithms.

Geographic object-based image analysis (GEOBIA) has been proposed as a method to bridge the gap between the increasing amount of detailed geospatial data and complex feature recognition problems. GEOBIA formulates the processing and analysis of homogeneous regions, referred to as image objects, which interact and envolve during the classification process. Within a GEOBIA approach, context is modeled through the topologic relations of neighboring image objects which are generated with a segmentation technique. This is an advantage over pixel-based analysis, where context is limited to the local interaction of individual pixels within a window of a specific size (Ardila et al., 2012).

2. MATERIALS AND METHODS

2.1. Study area

The Széchenyi square, study area of our analysis is a downtown urban greenspace, mostly a pedestrian zone partly separated from the traffic, with an extent of ca. 5 hectares. In the main axis of the square there is a wide concrete walkway, accompanied by 20-30 meter high sycamore trees on both sides. The rest of the square is occupied by grass blocks separated by paved pedestrian walkways. Most of the grass blocks have statues in the center. There are different types of tree stands(intermingled canopy trees, groups of different species, stand-alone trees, tree lines), thus the study area is suitable for laying down the methodological basis for tree crown projection measurements and crown delineation works in wider urban areas (Fig. 1).

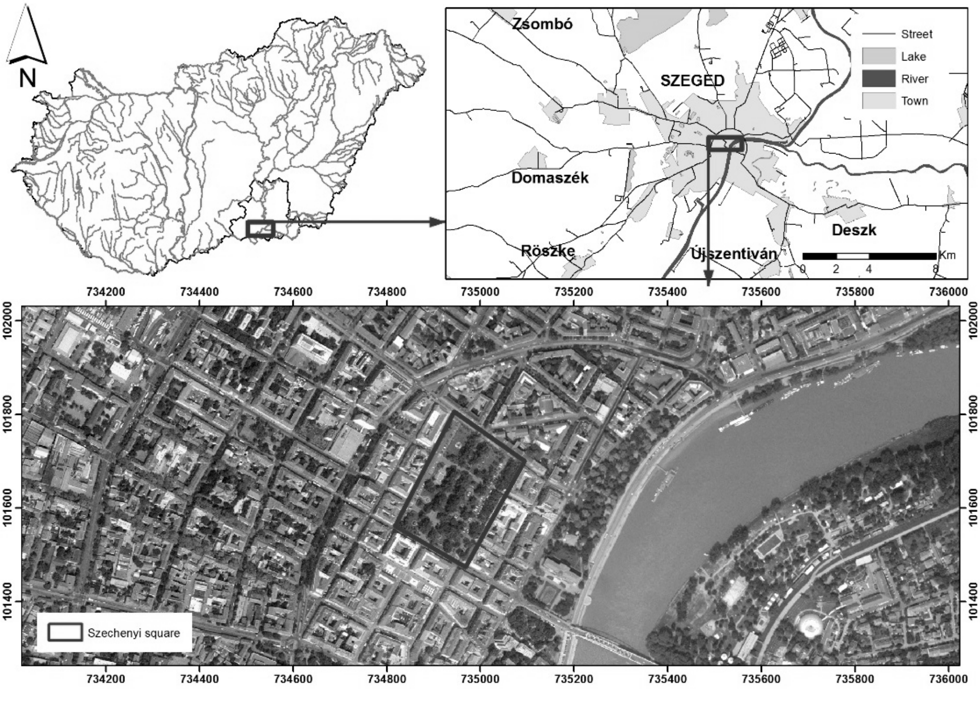

Fig. 1. The layout of the investigated Széchenyi square

2.2. Methods

In the selected study area it's easy to separate the artificial surfaces from those with vegetation cover with the help of the Normalized Difference Vegetation Index (NDVI). However separating tree crowns from other green surfaces (e.g. grass) and especially the (planned) delineation of individual tree crowns is a difficult task, for which we need to use more complex image analysis methods. The goal of the object-based image analysis is to retrieve information, unavailable when using only pixel-based methods.

Analysis was carried out with the DefinienseCognition Developer 8.7 object-based image analysis software, which was originally developed to process remotely sensed and medical images. When using multiresolution segmentation, the objects in the image constitute a hierarchical system. The lowest level is the level of the pixels. The objects are set up based on that level, but the number of operations is restricted at this level.

The input data are a 4-band UltraCam D orthophoto of the study area (with visible red, green, blue and near-infrared bands and a spatial resolution of 0.5 m), and a 3D point cloud derived from the overlapping images, originally generated for Sky View Factor calculations (Gál and Unger, 2012).

3. RESULTS

The processing of the data was carried out in three steps. The first step was to work out the proper segmentation method and parameters for the task. The aim of the segmentation is to delineate the different objects and surfaces found in the square.

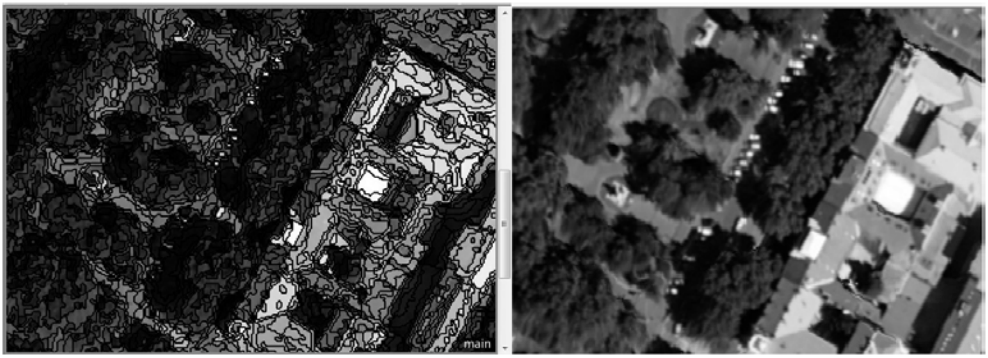

Fig. 2. Result of the multiresolution segmentation

The eCognition software offers several methods but in this case multiresolution segmentation proved to be the best since it allowed a hierarchical approach. We carried out the segmentation on the visible blue, red and infrared bands where the scale parameter was set to 10. We set the emphasis on the spectral information and didn't take notice of the texture and shape of the segments therefore we set the shape parameter to 0.01 and compactness to 0.1 (Fig. 2).

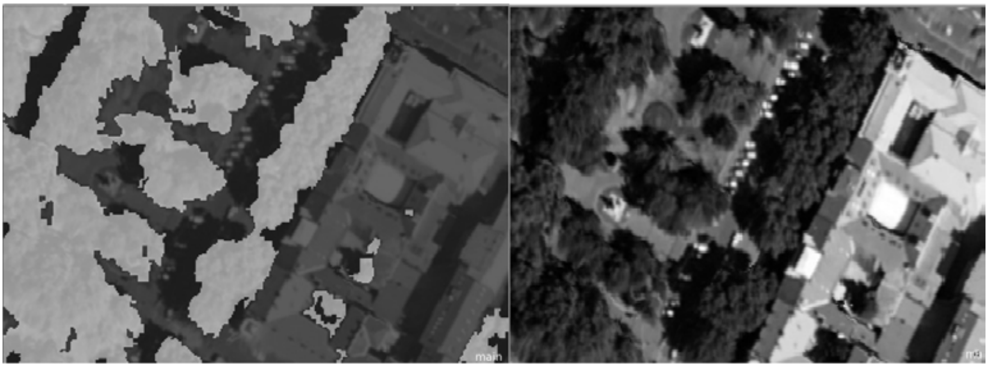

Fig. 3. Result of the classification (artificial and vegetated surfaces)

After the segmentation the objects were classified in two groups, artificial (and bare) and vegetated surfaces. In this case we calculated the NDVI (Normalized Difference Vegetation Index) of the objects and set a threshold limit of 0.17 (objects with their mean NDVI higher than that were considered vegetated surfaces) (Fig. 3).

This of course could have been done using a pixel-based approach too, however in this way the salt-and-pepper effect could be avoided.

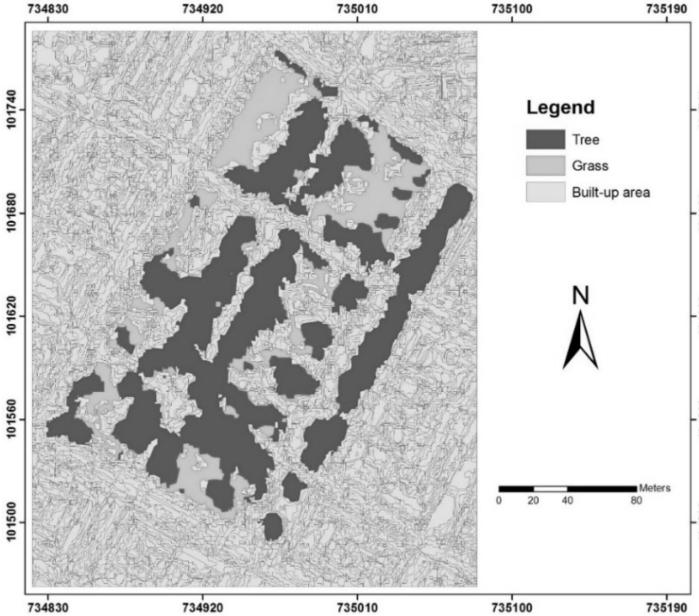

Fig. 4. Result map of classified vegetation types of the study area

The main sources of misclassification were branches overhanging the concrete walkways and some rooftops probably covered by moss.The latter were solved by introducing another threshold limit, for the visible blue layer. The next step was to create smaller subsegments for only the green surfaces, based on height data in order to separate tree crowns from the grass. In this case the shape parameter was set to 0.2 and the compactness to 0.3 in order to better include texture and to get less asymmetric objects. The scale parameter was set to 3 in order to lessen the edge effect at the border of the tree crowns. The next step of the process was to classify the objects at this smaller scale; for this a height threshold value of 2.5 m was applied for only the green surfaces. For validation we exported the results of the classification to a shapefile, which is suitable for further processing in geographic information systems (Fig. 4).

Fig. 5. Thematic map of the classification's accuracy

Our classification's accuracy was 84%, which can be considered good enough, as the validation dataset was created 6 years later, and the delineation of the crowns from the point cloud was made manually by the interpreter. The other main source of our classification's error was the inaccurate delineation of CPA in some shaded areas, which should be improved in our future work (Fig. 5).

4. CONCLUSIONS

Our results show that image segmentation is a useful tool to carry out precise urban green space delineation, from relatively cheap and widely available spatial datasets. There are several examples of similar work from different types of urban tree stands in the world (Moskal et al., 2011; Verőné Wojtaszek and Ronczyk, 2012). The accuracy of the classification is obviously strongly affected by the quality of the baseline data. It is particularly important in the case of elevation data, which, when available, significantly facilitates differentiation between vegetation types (trees, grass). From this point of view, LIDAR data can be considered the best, since it enables derivation of ecosystem service indicators directly (e.g. crown volume: Lim, 2007). However, our results underpin that canopy projection area, which can form a basis for mapping ecosystem services in wider urban areas, may also be delineated from 4-band aerial photographs and elevation data derived from them.

ACKNOWLEDGEMENT. We would like to thank Tamás Gál (Department of Climatology and Landscape Ecology, University of Szeged) for providing us the aerial imagery and elevation data for the study area.

REFERENCES

1. Ardila, J.P., Bijker, W., Tolpekin, V.A., Stein, A. (2012), *Context-sensitive extraction of tree crown objects in urban areas using VHR satellite images,* International Journal of Applied Earth Observation and Geoinformation 15, 57-69.
2. Balmford, A., Bruner, A., Cooper, P., Costanza, R., Farber, S., Green, R.E., Jenkins, M., Jefferiss, P., Jessamy, V., Madden, J., Munro, K., Myers, N., Naeem, S., Paavola, J., Rayment, M., Rosendo, S., Roughgarden, J., Trumper, K., Turne, R.K. (2012), *Economic Reasons for Conserving Wild Nature*, Science 297, 950-953.
3. Bastian, O., Haase, D., Grunewald, K. (2012), *Ecosystem properties, potentials and services – The EPPS conceptual frame work and an urban application example,* Ecological Indicators 21, 7-16.
4. Dobbs, C., Escobedo, F.J., Zipperer, W.C. (2011), *A framework for developing urban forest ecosystem services and goods indicators,* Landscape and Urban Planning 99, 196-206.
5. Gál, T., Unger, J. (2012), *Surface geometry mapping for SVF calculation in urban areas,* In: Proceedings '8th International Conference on Urban Climates and 10th Symposium on the Urban Environment. Paper 168. Dublin, Ireland, 6-10 August 2012.
6. Geodézia Ltd. (2013), *Mobil Térképező Rendszer hazai felhasználása (The use of Mobile Mapping System in Hungary),* Geodézia Ltd., Budapest, 6 p.
7. Gómez-Baggethun, E., Barton, D.N. (2013), *Classifying and valuing ecosystem services for urban planning,* Ecological Economics 86, 235-245.
8. Haase, D., Schwarz, N., Strohbach, M., Kroll, F., Seppelt, R. (2012), *Synergies, trade-offs, and losses of ecosystem services in urban regions: an integrated*

multiscale framework applied to the Leipzig-Halle region, Germany, Ecology and Society 17, Art. 22.

9. Hubacek, K., Kronenberg, J. (2013), *Synthesizing different perspectives on the value of urban ecosystem services,* Landscape and Urban Planning 109, 1-6.
10. Iovan, C., Cournède, P.H., Guyard, T., Bayol, B., Boldo, D., Cord, M. (2013), *Model-Based Analysis–Synthesis for Realistic Tree Reconstruction and Growth Simulation,* IEEE Transactions on geoscience and remote sensing 99.
11. Lim, C. (2007), *Estimation of urban tree crown volume based on object-oriented approach and LIDAR data,* Master's Thesis. International Institute for Geo-Information Science and Earth observation, Enschede, Netherlands, 83 p.
12. McPherson, E.G., Xiao, Q.,Aguaron E.(2013), *A new approach to quantify and map carbon stored, sequestered and emissions avoided by urban forests,* Landscape and Urban Planning 120, 70-84.
13. Moskal, L.M., Styers, D. M., Halabisky, M. (2011), *Monitoring Urban Tree Cover Using Object-Based Image Analysis and Public Domain Remotely Sensed Data*, Remote Sensing 3, 2243-2262.
14. Nowak, D.J., Crane, D.E., Stevens, J.C., Hoehn, R.E., Walton, J.T., Bond, J. (2008), *A Ground-Based Method of Assessing Urban Forest Structure and Ecosystem Services*, Arboriculture& Urban Forestry 34, 347-358.
15. Petz, K., van Oudenhoven, A.P.E. (2012), *Modelling land management effect on ecosystem functions and services: a study in the Netherlands,* International Journal of Biodiversity Science, Ecosystem Services & Management 8, 135-155.
16. TEEB, (2010), *The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A synthesis of the approach, conclusions and recommendations of TEEB,* Earthscan, London-Washington.
17. Verőné Wojtaszek, M., Ronczyk, L. (2012), *Object-based Classification of Urban Land Cover Extraction Using High Spatial Resolution Imagery,* International Scientific Conference on Sustainable Development & Ecological Footprint. Sopron, Hungary, 26-27 March 2012.
18. Zhang, K., Hu, B. (2012), *Individual Urban Tree Species Classification Using Very High Spatial Resolution Airborne Multi-Spectral Imagery Using Longitudinal Profiles*, Remote Sensing 4, 1741-1757.