Using LiDAR in analyzing the relationship between vegetation and built space – influences and interdependence.

Case Study: Bucharest Municipality

PhD Student Ing. Sofia Scăunaș,
University of Bucharest, Faculty of Geography, Doctoral School "Simion Mehedinți"
sofia_scaunas@yahoo.com

Dr. Ing. George-Laurențiu Merciu
University of Bucharest, Faculty of Geography
merciugeorge@yahoo.co.uk

Abstract. Under increased urban settlement density, the central areas of cities are usually the main targets of the regeneration process. This action involves modern urban modelling methods to emphasize the buildings structures and vegetation assessment. One of the methods is represented by LiDAR (Light Detection And Ranging) technology. LiDAR offers high-resolution imagery for very detailed information on object attributes, such as spectral signature, texture and shape, very accurate position and height information. Recently, remote sensing techniques are being increasingly used for inventory, monitoring and management of vegetation. Precise and up to date spatial information on the current status of green areas is a requirement for the sustainable conservation of urban vegetation. Correct information of urban vegetation is important to preserve the ecological environment within urban spaces. The aim of this study is to expose the utility of the LiDAR technique for assessment of urban vegetation in relation with built-up space in Bucharest Municipality. The results show that spectral details of data reflect the relationships between green areas and their surrounding environment. Urban evolution of Bucharest municipality was very rapid, especially starting with the second half of the 19th century, which led in time to a reduction of the green spaces. Although the capital city has a rich patchwork of green spaces (parks, public gardens, urban lawns, squares) and varied in terms of functionality (for recreation, for decorative purposes, with ecological function), we can observe they are diminishing in the recent years, due to the tendency for expansion of the residential areas.

Keywords: urban vegetation mapping, built-up space, modified environments, spatial data, LiDAR, Bucharest municipality

OVERVIEW

Urbanization is a complex process that determines important changes in land use of urban areas (Petrisor et al., 2010; Ianos et al., 2012; Le Roux et al., 2014; Bonthoux et al., 2014; Salvati, 2014; Ianos et al., 2014), modifying the environment and creating numerous human-altered landscapes (Digby, 2000; Popovici et al., 2013; Demiroz Kiray, Yildizci, 2014; Chase, Chase, 2016).

In this context, urbanism has the role to establish several rules for sustainable development in order to restrain urban sprawl, to promote sustainable land use policies, to conserve urban green areas (Antrop, 2004; Lundgren Alm, 2007; Grecea et al., 2010; Gridan et al., 2013; Feltynowski, 2015; Lafortezza et al., 2013; Chase, Chase, 2016; Nita, 2016).

Urban green areas constitute an element of urban environmental system within the city’s area (Lundgren Alm, 2007; Suárez-Cáceres, Cariñanos,
Due to the fact that greenery is spread all over the urban landscape and in various scales, it is also potentially important as a key to understand and manage urban development (e.g. Antrop, 2004; Lundgren Alm, 2007; Colusca, Alpopi, 2011).

The urban green areas have not only a decorative or aesthetic role, but also are designed to accomplish specific services (e.g. ecological, social, economic and systemic) (Dobbs et al., 2011 quoted by Suárez-Cáceres, Cariñanos, 2014; Petrisor, 2015).

Greeneries serve as an indicator of the environmental quality and ecological advantages, in that they contribute to the health and the quality of its surrounding land convers, they directly influence local climate conditions, moderating the effect of urban heat islands (Lundgren Alm, 2007; Lafortezza et al., 2009; Bowler et al., 2010; Adinolfi, Suárez-Cáceres, Cariñanos, 2014; Sirodoev et al., 2015; Nita, 2016; Davies et al., 2016).

Very often urban green areas constitute public space, where there is an interaction between the people (Adinolfi, Suárez-Cáceres, Cariñanos, 2014; Feltynowski, 2015).

In numerous studies, the role of urban vegetation in the population's health improvement is indicated (Jackson, 2003; Pretty, 2004; Velande et al., 2007; Ward Thompson, 2011 quoted by Adinolfi, Suárez-Cáceres, Cariñanos, 2014; Ambrey, 2016).

In this study the authors examine the relationships established between vegetation and the built environment in Bucharest municipality.

STUDY AREA

Bucharest is Romania's largest city, gathering, according to the last census in 2011, about 1.9 million inhabitants (ISSN, 2011). Also, Bucharest is one of the great metropoles of South Eastern Europe (Grosse-Espion project, 2014).

We selected a study area located in the center of Bucharest municipality (fig. 1).

The area is bordered by Victoria Avenue in the north, Polona street in the eastern axis, Unirii Quai – Independentei Quai in the south and, in the west, Berzei street (fig. 2).

The selection of this area was determined by the fact that it is characterized by a long territorial evolution, marked by different stages that generated changes in the urban fabric. At present, the studied area shows a high density of built space, including old cores alternating with areas of modern housing style and with urban green areas (parks, public gardens, urban lawns, squares, aso).

METHODOLOGY

In the past years, teledetection techniques are used more and more frequently for different applications in the urban environment: map updating at large scale, communication analysis, virtual modelling,

The LiDAR (Light Detection And Ranging) measurement technique, has the advantage of being able to penetrate beyond the vegetation courtain, using filtering techniques (Vengadeswari, Rajalakshmi, 2013; Sánchez-Lopera, Lerma, 2014; Iordan, Popescu, 2015), obtaining points on which it can be represented the 3D model of the terrain.

LiDAR is a detection technology through remote sensors. It utilizes its own source of energy (laser) to illuminate a target aiming at obtaining reliable measurements without having direct physical contact (Höfle, Hollaus, 2010; Popescu, Iordan, 2016; Chase, Chase, 2016).

Observations on vegetation zones, are based on multiple pulse returns that can be used for describing the structure of the canopy, emergent layer and forest debris (Popescu, Wynne, Nelson, 2003; Iordan, Popescu, 2015). Also, the LiDAR measurements offers the possibility to perform additional analysis of the forest inventory as they may investigate tree height and density of vegetation due to high resolution, 3D vegetation information, the average diameter of the tree trunk, the vertical profile of the sheath foliage, the canopy volume or interactions between vegetation and topography (Dubayah, Drake, 2000; Popescu, Wynne, Nelson, 2003; Sánchez-Lopera, Lerma, 2014; Apostol, 2015; Iordan, Popescu, 2015; Lim et al., 2003 in Tiede et al., 2005).

In addition, if sufficient return pulses are received from forest debris, a terrain model may be obtained as well.

Air data collection system LiDAR offers several advantages over conventional topographical studies, which are necessary but time-consuming. Elevation and location information are the most important components of LiDAR data (Iordan and Docan, 2013).

Data collection and transfer with this technology ensures better handling and efficient data management.

In this study the data obtained from the LiDAR measurements were used to map both green and built spaces and to analyze the relationships established between the built and green areas located within the study area.

After preprocessing the results obtained through measurements made using LiDAR technique, the next step was to classify the objects. The study is based on a classification of measured objects which involved dividing them into three categories: buildings, vegetation and other objects (roads, vehicles, shrubs).

The data obtained after LiDAR measurements were processed and mapped using GIS.

RESULTS AND DISCUSSIONS

Urban evolution of Bucharest municipality was very rapid, especially starting with the second half of the 19th century (Mihailescu, 2003).

The study area is a mix of old and new identifying the stages of the city development: from areas that retain the architectural imprint pattern of the XVIII-th and XIX-th centuries (both in terms of the built environment and the manner of arrangement of green spaces: the oldest public garden Cismigiu is arranged in English style) (Marcus, 1958).

During the Communist regime a massive demolition work of old stock houses was instituted in order to construct modern residential areas or headquarters of public institutions. Also, the most obvious urban changes were made during this period when the neighborhood Uranus was demolished to construct the megalomaniac building Palace of Parliament. In its vicinity, headquarters for public institutions were built (National Institute of Statistics, Ministry of Regional Development and Public administration, Ministry of Finance etc.). Also, during communism, urban parks were not a priority, resulting in large gaps in their share between different residential areas of the city - the central area (old) and new neighborhoods.

Bucharest Municipality has registered intense transformation, also in the last twenty-six years, caused mostly by the political changes (after 1989 the market-oriented economy system replaced the communist regime, which allowed a greater flexibility in applying territorial planning rules). Territorial dynamics recorded by the capital city in recent years...
Using LiDAR in analyzing the relationship between vegetation and built space – influences and interdependence

has also been driven by the high value of land, which exerted pressure on green spaces surfaces, leading to their diminishing in favor of building new residential and commercial areas.

As the vegetation is an important component of urban space through the functions it performs (environmental, social, economic, systemic), it was mapped along with buildings, to highlight the relationships established between the two elements. Thus we created an urban model which aims to identify and measure the characteristics of buildings and trees using LiDAR.

The number of trees within the limits of the study area is 32,745 (Fig. 3).

Figure 3. The trees’ position established on the basis of the point cloud resulted from the LiDAR measurements

The total surface of the study area is 347 ha, of which the built environment owns 174 ha (i.e. 50.1%), the traffic arteries (boulevards, streets, entrances) and sidewalks 92.8 ha (i.e. 26.7%), and the green spaces occupy an area of 23.2% (80.2 ha.) (Fig. 4).

In the case of the buildings, we could only measure the external elements, due to their opacity (roofs, exterior walls) (fig. 5).

After repeated scans from different angles, more of the features of the trees could be measured, based on the point cloud, that captured not only the upper surface of the canopies, but also the inner and under crown; it was highlighted together with their geometry.

Figure 4. The share of land surfaces by category in study area

Figure 5. LiDAR measurements for buildings

The spatial distribution of green areas within the analyzed area, highlights their location near the old buildings, as well as the modern ones, individualizing them as discontinuous areas in a densely built area (Fig. 5).

Figure 6. Density map of green spaces
In terms of functional typology of urban green spaces (Czarnecki 1968, Davies et al. 2006 quoted by Feltynowski, 2015), the studied area has a large representation of public green areas, among them being the urban parks: (Izvor, Circului, Ion C. Brătianu, Nicolae Iorga s.a.), gardens (Icoanei, Cismigiu), and squares (Ateneu).

Another category is represented by green areas for a specific purpose (screening green trips, gardens, green areas accompanying communication along the main boulevards: Regina Elisabeta, Lascar Catargiu, Gheorghe Magheru); accompanying green areas, among others: in the scope of cultural-social services (the green space around the Romanian Opera), technical-economic services and housing estates (residential areas that have a higher density of green spaces Sala Palatului area); sightseeing-recreation areas (among others: public forests, historical parks and various forms of nature conservation).

Within the study area is the oldest public garden in the city, Cismigiu, designed in 1850, in order to ensure a recreational area for the population (Marcus, 1958). The Garden was founded by landscape artist Carl Friedrich Wilhelm Meyer and shows a high degree of compositional complexity (El Shamadi et al., 2009). It was built after the English model, representing the type of garden promenade with irregular geometry that is closer to the meaning of park (Baciu, 2014).

Cismigiu garden is an 'enclave' of green island in a densely built urban fabric.

Although the number of green spaces is not relatively large, their surface ranges from 17 ha (Izvor Park) to 0.25 ha (Atheneum square). However it is observed that the ratio between the built and green spaces, reflects a predominance of land occupied by buildings (fig. 7).

In the study area, the pressure of the built space was not so big on urban vegetation compared to other areas of Bucharest. This situation is explained also due to the fact that some green spaces in the study area were protected (e.g. Cismigiu Garden) because they are within the limits of protected urban ensembles or are located near the cultural objectives (Atheneum Square). For example, Cismigiu Garden is the only public green space arranged that keeps the original stylistic features imprinted by their creator in the nineteenth century (El-Shamali et al., 2009).

![Figure 7. The ratio between built space and green areas](image)

**CONCLUSIONS**

Recent studies have demonstrated the benefits of combining imagery and LiDAR acquisition data to accomplish urban land cover classifications, especially for providing increased class separability between spectrally similar classes like buildings, roads, vegetation, etc. Accurate and up-to-date land cover data, particularly in cities characterized by accelerated dynamics, is a very important tool for urban planning.

Efforts have been made to build, develop, and conserve urban vegetation in order to adequately provide better living conditions for the urban population (e. g. mitigating urban heat island effects through increasing the amount of urban trees).

The multiple functions of urban vegetation indicate its role as resource of the urban environment, regardless of the scale of its registered transformation.

Bucharest, due to the role of capital city, which has conferred to it the status of most important urban center at national level, from the socio-economic and cultural point of view, registered an accelerated
urban development. This led, in time, to an increased surface of the built space while reducing the green spaces.

In the current period, the evolution of the city is dominated by the prevailing building of residential complexes, usually on the periphery, and the green areas have a more individual character, being so constructed as buffer zones between the built perimeters and the playgrounds.

The area selected as a case study is characterized by a long urban evolution, showing within its limits buildings from periods of different urban planning, alternating with green spaces with various functions (entertainment, social function, ecological, aesthetic role, and decorative), some of which were landscaped after classical models (Cismigiu Garden, Garden Icoanei).

REFERENCES


Feltynowski M. (2015), Spatial information systems - a tool supporting good governance in spatial planning processes of green areas, J. of Urban and Regional Analysis, 7(1), 69-82.


Iordan D., Popescu G. (2015), The accuracy of LiDAR measurements for the different land cover categories, Land Reclamation, Earth Observation & Surveying, Environmental Engineering, 4, 158-164.


Lafortezza R., Davies C., Sanesi G., Konijnendijk C. C. (2013), Green infrastructure as a tool to support spatial planning in European urban regions, iForest 6, 100-106.


Petrisor A. I., Ianos I., Talanga C. (2010), Land cover and use changes focused on the urbanization process in Romania, Environmental Engineering and Management J., 9(6), 659-771.


