Barometr Regionalny
Tom 15 nr 3

Using LiDAR Data to Assess the Character of Landscape in the Suburban Zone of Poznań

Anna Dudzińska, Anna Gałecka-Drozda, Barbara Szpakowska
Poznań University of Life Sciences, Poland

Abstract

The intensive development of urban agglomerations causes the need to search for new precise methods which will determine the most important features of landscape and monitor changes in suburban zones. The aim of the study was to identify, characterize and assess the structure of landscape units based on LiDAR data. The research was conducted in the village of Napachanie, Wielkopolskie Voivodship. Although the village is located in the suburban zone of Poznań, it has retained the rural character of landscape in this region, with expanses of fields, a park and palace complex and a grange. There are valuable natural elements in the village, such as forests, buffer strips, ponds and the Samica River valley. The research combined techniques of GIS analysis and the traditional method of Landscape Character Assessment (LCA). The data for analysis of the rural landscape structure were acquired from airborne laser scanning (LiDAR). They were used to identify 16 landscape units of different characters, was determined according to specific elements of landscape, scenic connections and composition. The units were visualized by means of a point cloud. The spatial model of the landscape enabled definite delimitation of individual landscape units, which supplemented field investigations. Visualizations show the most important features of landscape, such as terrain, the arrangement of tall vegetation, the number and layout of buildings. The spatial model enables initial analysis of the landscape composition, including the range of views and the degree of compactness of landscape interiors.

Keywords: GIS, airborne laser scanning (LiDAR), Landscape Character Assessment method (LCA), suburban zone of Poznań

JEL: R14

Introduction

Due to dynamic changes in the landscape of villages located within the range of influence of large urban agglomerations it is necessary to use new, precise and quick methods, which will determine the most important features of landscape and enable assessment of its sensitivity in the context of land use plans (Van Eetvelde and Antrop 2009). First, the character of a landscape should be specified. According to the Landscape Character Assessment method (LCA), it is understood as a distinct, recognizable system of elements, which are permanently related with a particular type of landscape (Swanwick 2002). By defining the character of a landscape, it is possible to monitor it (Jaworek 2012). The identification of the features which distinguish one landscape unit from another is regarded as an objective description of landscape. Subjective valuation takes place only at the second stage of LCA. It is possible to use various scales to divide landscape into units of different characters. However, their hierarchy is taken into consideration. LiDAR data enable projection of the most important features of landscapes by generating 3D models. The use of these models may significantly enrich the process of assessment of landscape structures. 3D models are commonly used in architecture, spatial planning, multimedia activities, Spatial Information Systems and satellite navigation. When 3D models are constructed, it is very important to make sure that they are precise and can be used for various purposes (Fryśkowska 2011).

The aim of the study was to identify, characterize and assess the structure of landscape units based on LiDAR data. The article shows how 3D models can be used for analyzing the landscape structure. The visualizations which correctly reflect cartographic data make it possible to understand structures and dependences in landscape (Kolecka 2008). The authors indicate the possibility to use these models for spatial planning, spatial and statistical analyses concerning changes in land use.

1 Research material and methods

The data for landscape structure analysis were acquired by airborne laser scanning. They were source data in the form of LAS files received from the Chief Geodetic and Cartographic Documentation Centre, which contain altitude and spectral data (fig. 1). This allowed the author to create 3D models. For many years laser scanning (Light Detection and Ranging, LiDAR) has been used worldwide to make maps, analyses and to monitor changes in the environment (Andersen 2002; Kwoczyńska and Bryś 2012; Pham, Brabyn, and Ashraf 2016; Rieg et al. 2014; Zarzecki and Pasierbiński 2009). LiDAR is an active remote sensing system that uses near-infrared electromagnetic radiation or green light. It enables quick acquisition of large amounts of precise spatial data for 3D modelling and visualization of complex buildings and structures (Michałowska 2015). ENVI (feature extraction module), ArcMap 10.2 and ArcScene are computer programs used for LiDAR data processing, landscape structure analysis and visualizations.

The research was conducted on the village of Napachanie, which is situated in the Commune of Rokietnica, about 25 km away from Poznań. It is a representative area of the suburban zone of Poznań. The authors analyzed a rural settlement surrounded by farmlands and forests. Although the village is located in the suburban zone of Poznań, it has retained the rural character

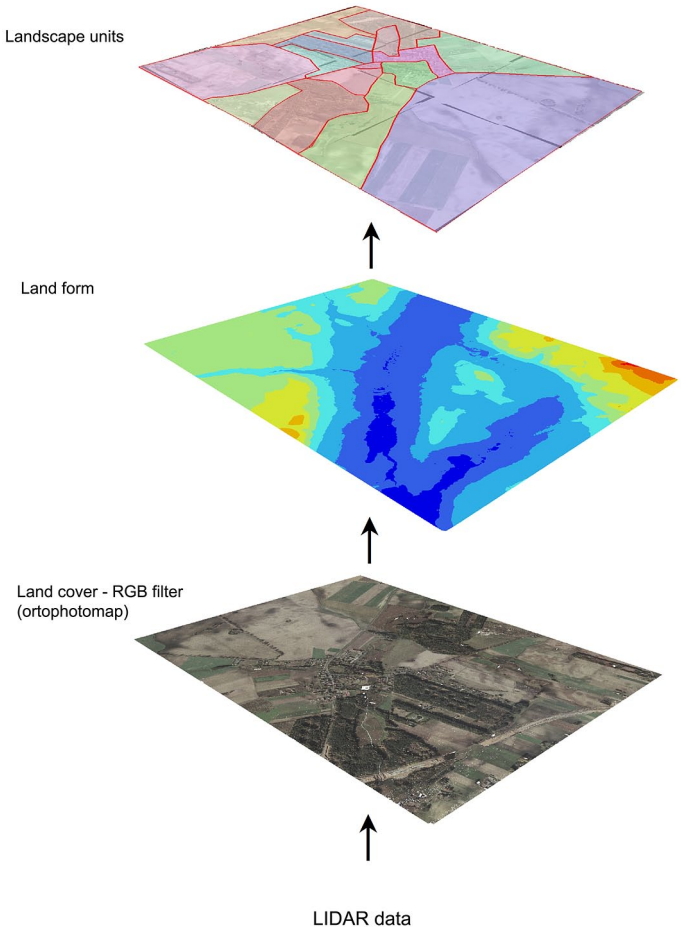

Fig. 1. Delimitation of landscape units

of landscape, with expanses of fields, a park and palace complex and a grange. There are valuable natural elements in the village, such as forests and the Samica River valley.

The character of each unit was determined according to specific elements of landscape, scenic connections and composition. The assumed method of delimitation of units was in agreement with the guidelines concerning the LCA method (Swanwick 2002) where the landscape character is understood as the distinct, recognizable and consistent pattern of elements in the landscape. These patterns give each locality its 'sense of place', making one landscape different from another, rather than better or worse. The following elements of landscape were taken into consideration: components of the natural environment, such as terrain and hydrological elements; land cover, such as tall vegetation, crops, buildings and elements of infrastructure. As far as the visual features of landscape are concerned, the scale of landscape, landscape macro-interiors, enclosure, landscape complexity, landscape borders legibility and exposure of the most important elements in landscape and scenic connections were determined.

2 Results and discussion

The first stage of the research involved the filtering of data in the form of LAS files in order to obtain a digital terrain model (DTM), digital land cover model (DLCM) and an orthophoto map. They were used for the identification of landscape units (fig. 1). The analyses resulted in the identification of 16 landscape units of different character. The landscape units were identified within a small scale (i.e., the village and its nearest surroundings). Landscape was differentiated according to the following criteria: different character resulting from the terrain and land cover as well as compositional dependences, including the ranges of visibility for individual units (fig. 2). There was high concentration of units in the rural settlement, where consecutive parts of the village appeared according to its spatial development (medieval village, grange village, the 1960s multi-family housing, contemporary suburban buildings). The legibility of individual parts of the village, which were established at specific points in time, results from the fact that they were located in new places. As a result, the village lacks big accumulations, which would make landscape interpretation difficult.

The landscape of Napachanie is considerably diversified. This fact resulted in a corresponding number of units due to the location of the village in the Samica River valley and the presence of forests near the rural settlement. The river valley and forest complexes cause considerable fragmentation of landscape macro-interiors and they determine complex compositional relations in the landscape. The landscape units located outside the rural settlement occupy larger areas. Their borders were delimited according to the specificity of the expanses of fields, diverse forms of tall vegetation and scenic dependences resulting from the terrain. The presence of dispersed suburban buildings and other new infrastructural items were other distinguishing factors taken into consideration.

The landscape units (fig. 3), which differed in character, were gathered and described in consecutive subsections. Each unit received an individual name, which characterizes its landscape synthetically. The determinants of the landscape character were also identified.

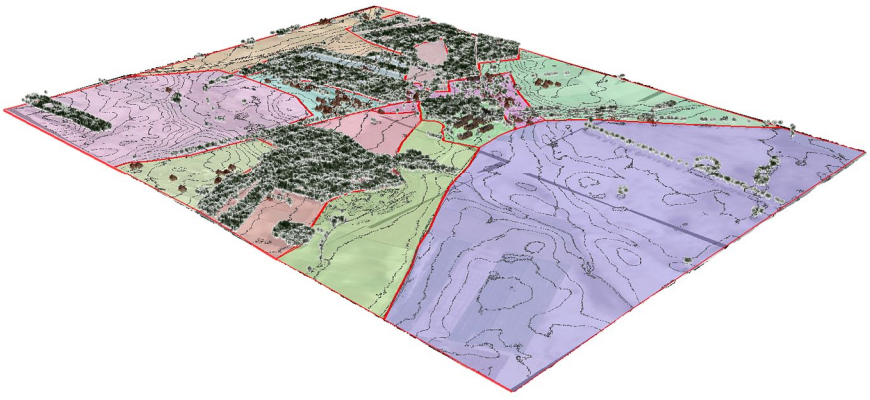

Fig. 2. A visualization of different types of landscape in individual units

Fig. 3. A map with division into landscape units

The landscape units in the village of Napachanie and their features:

I. Grange fields — a large flat farmland with linear tree alleys and trees in endorheic hollows. Large scale of landscape, extensive views.

II. The palace and park complex and the grange — the flat area along the Samica River valley is used in different ways, which result from the old land estate: the palace surrounded by a park, grange buildings and a farmyard, a residential colony for grange workers. Numerous scenic connections with the Samica River valley and large farmland areas.

III. Meadows and fields in the Samica River valley — the valley area is partly used for farming. It is partly covered by natural meadows, marshes and trees. Legible landscape interiors, small scale of landscape, numerous scenic openings to the opposite side of the valley.

IV. Blocks of flats belonging to former state-owned farms — a flat area with multi-family houses built in the 1960s and 1970s as well as farm buildings and green space arrangements combining different styles. Minimal exposure in the landscape: the buildings are partly hidden between the park and forest.

V. Farmlands between the park and forest — the area descends towards the Samica River, medium-sized farmlands. A legible landscape interior formed by the wall of the forest, park and alley. Scenic connections with the opposite side of the valley.

VI. Forest on the side of the village of Rokietnica — a flat valley area or valley slope is covered by the forest or used as permanent grassland. Small scale of landscape, legible meadow landscape interior.

VII. Farmlands with houses under construction — a farmland descending westwards, with individual single-family houses under construction. Medium-sized farmlands. Large scale of landscape. Heavy scenic exposure of new buildings.

VIII. Farmlands with individual trees — undulated farmland with individual trees. Small scale of landscape, extensive views.

IX. Settlement between the forest and Rokietnicka Street — a flat area with single-family houses which are being built in small plots. High diversity of architectural styles and garden greenery. Small scale of landscape, exposure limited by the wall of the forest.

X. Timberland — a flat area covered by a pine-tree monoculture.

XI. Manorial houses near the forest — an undulated area with strips of forests and manorial buildings which are being constructed between them. Small scale of landscape, minimal scenic exposure.

XII. Meadows in the Samica River valley — a valley with natural meadows and trees surrounded by a forest. Small scale of landscape, minimal landscape interiors.

XIII. Village centre — a valley with traditional enclosures and single-family houses of different ages. The area is intersected by the 184 Road. Limited scenic exposure.

XIV. Forest and expressway — a valley with partly undulated land covered by a forest, intersected by the S11 expressway and the 184 Road.

XV. Small farmlands — a flat farmland, descending partly towards the river valley, with individual single-family houses under construction. Small farmlands, few trees. Small scale of landscape, extensive views.

XVI. Dispersed enclosures — a farmland descending westwards, with dispersed enclosures. Small farmlands. Medium scale of landscape, extensive views.

The area of landscape units in Napachanie is considerably diversified. The area of the smallest unit is 2,33 ha.[1] It encompasses blocks of flats belonging to former state-owned farms (fig. 4). There is a small landscape interior between the manor park and forest. The largest landscape unit (i.e., grange fields), occupies an area of 224,1 ha (i.e., more than 30% of the area under analysis).

New buildings appeared in Units VII and IX (fig. 5). The study revealed high diversity of architectural styles and different forms of greenery, which have negative influence on the perception of rural space. There is a noticeable increase in the number of buildings as we move towards the village of Rokietnica, which is the seat of the commune authorities (Dudzińska, Szpakowska, and Szumigała 2016). It is noteworthy that there are two historically different parts of the settlement. One is related with the colonization of the village in the Middle Ages (Unit XIII). The other encompasses the grange and palace complex (Unit II). New buildings under construction are located in the north-eastern part of the area under study. They do not disorder the function of historical settlement centers, which are located in the neighboring landscape macro-interior and are separated by the river valley and forest complexes. The S11 expressway is a Poznań bypass, which runs along the border of the area under study, near Units VIII and XVI. It is a distinct east border of the village of Napachanie. To the south the landscape under study is integrated with the farmlands in the commune of Tarnowo Podgórne. Lines and clusters of trees are the elements which significantly increase the landscape coherence.

The spatial model of landscape based on LiDAR data enabled definite delimitation of individual landscape units, which supplemented field investigations. Visualizations show the most important

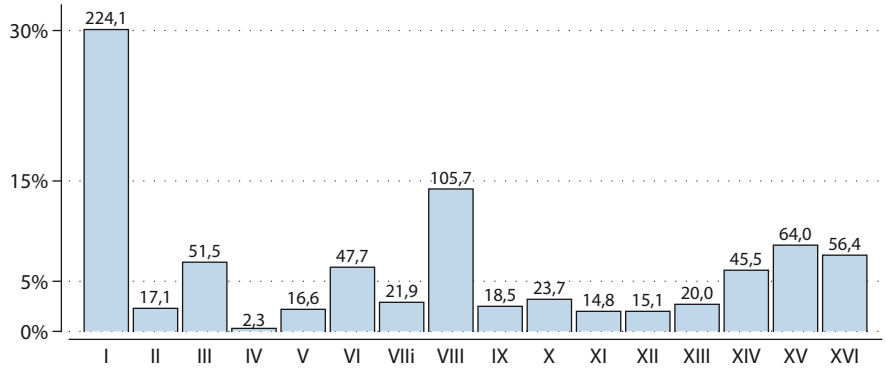

Fig. 4. The area of individual landscape units

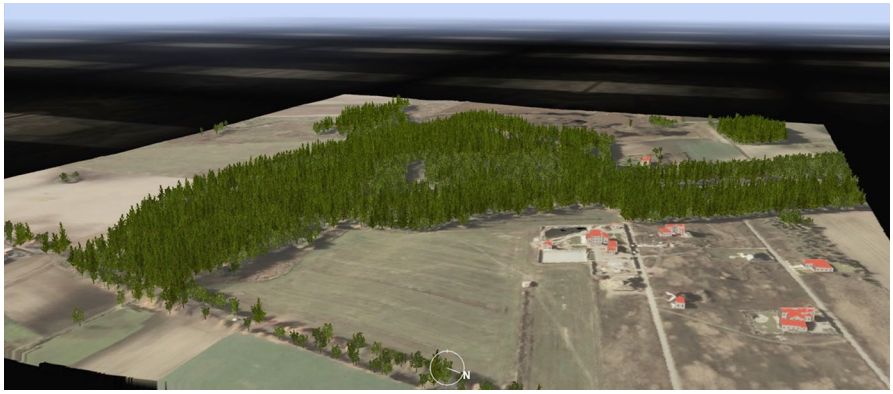

Fig. 5. A visualization of new buildings which are being constructed in Landscape Unit IX

1. [In the journal European practice of number notation is followed — for example, 36 333,33 (European style) = 36 333.33 (Canadian style) = 36,333.33 (US and British style). — Ed.]

features of landscape, such as terrain, the arrangement of tall vegetation, the number and layout of buildings. The spatial model enables initial analysis of the landscape composition, including the range of views and the degree of compactness of landscape interiors.

Summary

The research based on LiDAR data enabled assessment of the character of landscape in the village of Napachanie, which is a representative area of the suburban zone of Poznań. The authors analyzed the terrain and land cover. They identified 16 landscape units of different character, which they analyzed in detail and described their features. The units were visualized by means of a point cloud. The analyses showed that laser scanning (LiDAR) could be used in research on landscape architecture. The data can be used for various purposes, such as land inventory as well as analyses of the landscape structure and character. They are an important source of information for visualizations. They can be used to monitor changes in the landscape of suburban zones. According to the European Landscape Convention, it is an important element of protection of unique areas. Among the most important benefits of the Lidar System are: weather independence (scanning at night), penetration through the vegetation layer, high density of measurement points, short wait for delivery of the final product and relatively low cost of this technology for large areas. These benefits stand out from other measurement technologies. Moreover, the important advantage of this method is the opportunity to map the landscape in 3D technology.

References

Andersen, H.-E. 2002. The Use of Airborne Laser Scanner Data (LIDAR) for Forest Measurement Applications. Washington: WFCA.

Dudzińska, A., B. Szpakowska, and P. Szumigała. 2016. "Ocena zmian krajobrazu wsi Napachanie (woj. wielkopolskie) za pomocą analizy historycznej GIS." *Nauka Przyroda Technologie* 10 (3): 1–8. doi: 10.17306/J.NPT.2016.3.31.

Fryśkowska, A. 2011. "Analiza możliwości wykorzystania danych z lotniczego skaningu laserowego do opracowywania trójwymiarowych modeli miast." *Biuletyn Wojskowej Akademii Technicznej* 60 (3): 261–276.

Jaworek, J. 2012. "Ocena historycznych cech krajobrazu jako podstawa dla ich ochrony w gospodarowaniu i planowaniu." *Czasopismo Techniczne. Architektura* 109 (7-A): 57–66.

Kolecka, N. 2008. "Integracja GIS i wirtualnej rzeczywistości do wizualizacji i eksploracji danych geograficznych." *Archiwum Fotogrametrii, Kartografii i Teledetekcji* 18a (241–250): 241.

Kwoczyńska, B., and M. Bryś. 2012. "Ocena zastosowania integracji danych lidarowych i fotogrametrycznych do generowania NMT dla okolic zbiornika wodnego Chańcza." *Infrastruktura i Ekologia Terenów Wiejskich* (2, cz. 2): 171–186.

Michałowska, K. ed. 2015. *Modelowanie i wizualizacja danych 3D na podstawie pomiarów fotogrametrycznych i skaningu laserowego, Monografia/Wyższa Szkoła Inżynieryjno-Ekonomiczna.* Rzeszów: Wyższa Szkoła Inżynieryjno-Ekonomiczna.

Pham, L.T.H., L. Brabyn, and S. Ashraf. 2016. "Combining QuickBird, LiDAR, and GIS Topography Indices to Identify a Single Native Tree Species in a Complex Landscape Using an Object-Based Classification Approach." *International Journal of Applied Earth Observation and Geoinformation* 50: 187–197. doi: 10.1016/j.jag.2016.03.015.

Rieg, L., V. Wichmann, M. Rutzinger, R. Sailer, T. Geist, and J. Stotter. 2014. "Data Infrastructure for Multitemporal Airborne LiDAR Point Cloud Analysis—Examples from Physical Geography in High Mountain Environments." *Computers Environment and Urban Systems* 45: 137–146. doi: 10.1016/j.compenvurbsys.2013.11.004.

Swanwick, C. 2002. "Landscape Character Assessment. Guidance for England and Scotland." In. heritagecouncil.ie: Scottish Natural Heritage; The Countryside Agency. http://www.snh.org.uk/pdfs/publications/LCA/LCA.pdf (accessed 2017.11.09).

Van Eetvelde, V., and M. Antrop. 2009. "Indicators for Assessing Changing Landscape Character of Cultural Landscapes in Flanders (Belgium)." *Land Use Policy* 26 (4): 901–910. doi: 10.1016/j.landusepol.2008.11.001.

Zarzecki, M., and A. Pasierbiński. 2009. "Zastosowanie GIS i teledetekcji w badaniach szaty roślinnej." *Wiadomości Botaniczne* 53 (3/4): 53–66.