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ANALYSIS OF THE POSSIBILITY TO APPLY AIRBORNE AND TERRESTRIAL LASER SCANNING IN PROTECTING AREAS OF NATURA 2000[1]

Pelagia Gawronek, Bartosz Mitka, Tomasz Noszczyk, Magda Pluta, Maria Zygmunt

University of Agriculture in Krakow

Abstract. The Natura 2000 network is a fundamental element of EU policy in the field of nature protection and the example of Europe's enormous efforts to preserve biodeversity for future generations. Detailed principles of conduct in Natura 2000 areas are determined separately for each area and recorded in the plans for protection tasks. Planning effective action, and particularly identifying specific treatment of acitve protection requires monitoring and assessment of the conservation status of the natural environment and its factors. This paper is an analysis of the application of technology of airborne and terrestrial laser scanning in this context. Research carried out on a part of Natura 2000 area, Białka Valley (PLH120024), indicated that development conducted on point clouds allows for monitoring habitat enrichment, and supports the process of creating plans for protection tasks.

Key words: point cloud, nature protection, plans for protection tasks

INTRODUCTION

Currently, we are dealing with the fastest rate of species extinction in the Earth's history, which is a side effect of civilization – urbanization development, technological progress as well as intensification of agriculture and industry. According to the data of the International Union for Conservation of Nature, one in five bird species is endagered with extinction, and so is one in four mammal species or one in three amhibian species. Global rate of species extinction is increasing, and is now estimated to be exceeding one thousand times the natural rate [WWF 2012]. In the face of these threats, the need was recognized to strengthen legal protection of environmental resources. European integration enabled undertaking and coordinating activities to protect natural heritage of the continent [European Commission 2000]. Directives adopted by the European Union

Corresponding author – Adres do korespondencji: mgr inż. Maria Zygmunt, Department of Land Surveying, University of Agriculture in Krakow, Balicka 253a, 30-149 Kraków, e-mail: mary.zygmunt@gmail.com

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[Dyrektywa 2009/147/WE, Dyrektywa 92/43/EWG] involve creating a system of areas which would constitute a coherent network – the European Ecological Network Natura 2000, enabling the implementation of a common natural resource protection policy of the EU. As part of the EU initiative to protect the most endangered species of plants and animals and natural habitats, an obligation was imposed on all Member States to designate and protect areas of Natura 2000 [European Commission 2000].

The idea of functioning of the Natura 2000 network is based on the principle of a sustainable development [European Commission 2000]. It assumes development of the society in a way which would reduce as much as possible the negative impact on the environment. Detailed principles of conduct on particular Natura 2000 areas are determined and recorded in mandatory plans for protection tasks [European Commission 2009]. The mode and scope of developing plans for protection tasks in Polish legislation is defined in the Regulation of the Minister of Environment of 17th February 2010 on the preparation of the draft plan for protection tasks for Natura 2000 area, as well as in guidelines of the General Directorate for Environmental Protection 'Developing a plan for protection tasks for Natura 2000 area'.

Planning effective conservation activities, and in particular identifying specific active protection treatments requires having detailed information about the environment condition, the tendencies and dynamics of changes. It is essential that information, on which area protection plans are based, should be characterized by proper accuracy concerning both the position of spatial objects and spatial fidelity. Laser scanning is one of the most promising technologies in the field of measurement. This technology is used by devices called laser scanners which, depending on the use, determine two main types of laser scanning: airborne (Airborne Laser Scanning – ALS) and terrestrial (Terrestrial Laser Scanning – TLS). The principle of operations of airborne and terrestrial scanners is similar. Emitting a laser beam, and next registering its reflection, based on the measurement of distance and angles, scanner calculates spatial coordinates and, based on the strength of the returning signal, determines intensity value of the reflexion, which is called 'the fourth coordinate'. As a result of laser scanning, a huge number of observations (X, Y, Z, I) are obtained in a very short time in the form of the so-called 'point cloud'.

The issue of the use of laser scanning technology for monitoring and evaluating the condition of natural environment provides an ample scope for scientific research. Scientific literature clearly indicates an enormous potential of both research and practical ALS and TLS data in this context. Particularly promising are the results of studies on the use of ALS data in generating a Digital Terrain Model (DTM) and Digital Surface Models (DSM) [Axelsson 2000, Mandlburger *et al*. 2007]. The fact that the laser beam penetrates through vegetation and thus registers points both in tree crowns and on the ground, has contributed to the spread of ALS technology in forestry [Zimblea *et al*. 2003, Wężyk *et al*. 2008]. Many scientists also successfully raise the issue of using airborne laser scanning in determining the structure of natural habitats [Vierling *et al.* 2008, Hall *et al.* 2009, Miura and Jones 2010]. However, terrestrial laser scanning is used to obtain more accurate data on a smaller area. Terrestrial laser scanning is especially suitable for measuring characteristics of individual trees [Wężyk *et al.* 2007]. TLS technology has also been successfully adopted in the study of geomorphological processes and quantitative evaluation of changes in the terrain [Abellan *et al.* 2006]. Also, possibility to complete ALS point clouds with TLS data deserves special attention [Bremer and Sass 2012].

The authors of this article, inspired by the requirements to draw up a plan for protection tasks for Natura 2000 areas, and thus by the need to provide appropriate information on these areas and their surroundings, analyzed the possibility and usefulness of applying technology of terrestrial and airborne laser scanning in this context. The research was carried out on a part of the Natura 2000 area, Białka Valley (PLH120024). Widely available ALS data was used for analysis as well as TLS data obtained as part of a geoinformation summer school, GeoGorce 2013.

MATERIAL AND METHODS

Based on the European Directive 92/43/EEC *on the protection of natural habitats and of wild fauna and flora,* the decision of the European Comission of 25th January 2008, Białka Valley has been under nature conservation as part of Natura 2000 network. Thus, it constitutes complement of the European Network of protection of habitats of riverbank areas.

Natura 2000 area of Białka Valley PLH120024 is located in Małopolska Voivodeship, in the districts of Nowy Targ and Tatra. The surface area is 716 ha, which includes Białka creek bed, of a length of about 25 km, and a narrow strip of land within the floodplain terrace covered mainly with riparian forests and willow vegetation. Main objects of protection in Białka Valley are 11 natural habitats, which together constitute a river habitat complex, connected with a unique stones of a mountain river. Quick stream current and sudden and abundant water swell in spring and summer, cause a constant transport of rock materials and transformation of the river bed. As a result of the river dynamics, there occurs a restoration of riparian habitats and beginning of the processes of settling them again [Generalna Dyrekcja... 2014]. The dynamics of a mountain stream justifies the need for constant monitoring of the habitat transformations and analysis of changes in the boundaries of the protected landscape.

In accordance with the requirements of legal regulations, in February 2014 the first draft plan for protection tasks was produced for Natura 2000 area of Białka Valley. The basic content of the plan includes: numerical description of the area boundaries, identification of existing and potential threats for retaining an appropriate condition of natural habitats, objectives of protection measures, determination of protection measures aiming at active protection of natural habitats, and monitoring the condition of protected objects, as well as identifying neighbouring areas of Natura 2000 which fulfil requirements for being included in the discussed form of protection. Most of these demands may be satisfied on the basis of the analysis of spatial data from terrestrial and airborne laser scanners.

Data from the airborne laser scanning were obtained from the Geodetic and Cartographic Documentation Centre. Numerical recording of the terrain surface in the form of point cloud was made available in binary files according to the standard 1.2 published in 2008 by ASPRS (American Society of Photogrammetry and Remote Sensing). The files contain a point cloud in the .las format in the national coordinate system 1992. Point cloud density for the analyzed area was 10 points per m^2.

Data from the terrestrial laser scanning was obtained with a terrestrial laser scanner Riegl VZ 1000. Point cloud density was 128 points per m^2. For the need of ALS and TLS data integration, the file containing spatial data of Białka Valley was saved in .las format in the national coordinate system 1992. Georeference of the point cloud was

possibile thanks to RTK satelite measurements with a simultaneous measurement of the north direction, carried out while scanning with GNSS receiver mounted on the scanning device.

Development of the research material for the entire Natura 2000 area of Białka Valley in the form of a 3D point cloud from the airborne and terrestrial laser scanning would be extremely time-consuming. For analyses, a part of the area was designated, located in the central and north-eastern part of Białka Valley (Fig. 1). The designated test area constitutes 23% (162 ha) of the protected area. It consists of 4 km of Białka stream and 6 types of protected natural habitats [Generalna Dyrekcja... 2014].

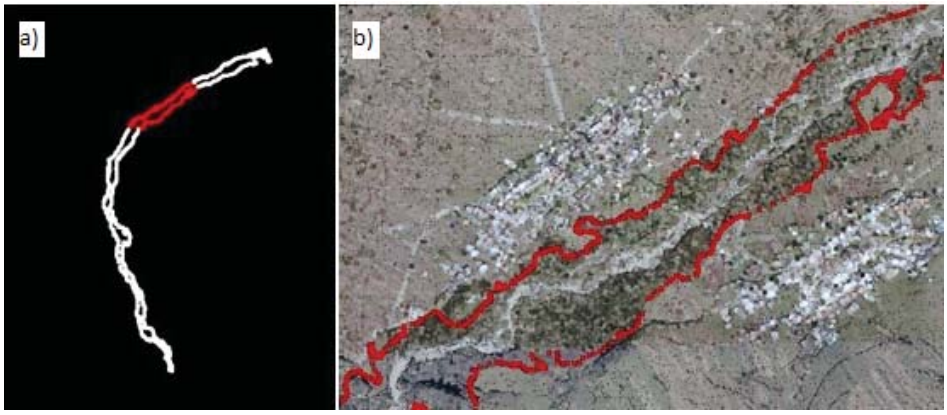

Fig. 1. Study area: a) location of the study area with reference to the whole Natura 2000 area of Białka Valley, b) study area in comparison to ALS data
Rys. 1. Obszar opracowań: a) lokalizacja obszaru opracowań w odniesieniu do całego obszaru Natura 2000 Dolina Białki, b) obszar opracowań na tle danych ALS

Development of numerical data from the airborne laser scanning was carried out in the program Microstation V8i with TerraScan and TerraModeler overlays. The first report was analysis of boundaries of Natura 2000 area of Białka Valley. The description of the area's boundaries was used for research in the form of coordinates of their breakdown points in the 1992 system (Annex 1 to the plan for protection tasks). Using a variety of display modes of the point cloud, a natural course of the area's boundaries was determined, and their compliance with the boundary was established by the decision of the European Commission [Decyzja Komisji... 2008]. Each display mode of the point cloud used its different properties: classification (segmentation of the point cloud according to appropriate elevation sets), intensity (segmentation of the point cloud according to the value of the coordinate of reflection of the signal intensity), echo (segmentation of the point cloud according to the number of reflections for an individual impulse), and RGB (segmentation of the point cloud according to RGB pixel values from the apparatus matrix designated to a point cloud) (Fig. 2).

In another study an attempt was made to determine habitat structure based on the ALS and TLS data. In order to do this, habitats on the research area, which were presented in the plan for protection tasks, were identified on point clouds. For each of them, cross-sections and visualizations were made from the point cloud, which allowed for dimensioning and determining characteristic features of these areas.

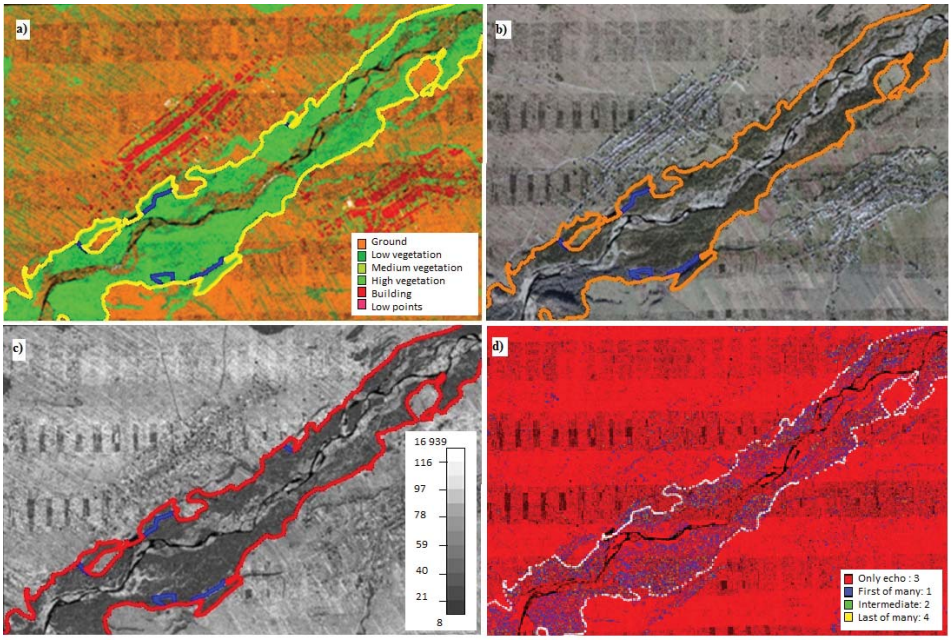

Fig. 2. Area boundaries based on analyses of cloud points compared to the existing boundary: a) elevation (classification), b) RGB, c) intensity, d) echo
Rys. 2. Granice obszaru wyznaczone na podstawie analiz punktów chmury w zestawieniu z obowiązującą granicą: a) wysokości (klasyfikacja), b) RGB, c) intensywności, d) echo

In order to analyze the relief of the terrain, DTM (Digital Terrain Model) was made based on the *Ground* layer in the form of TIN network with the use of Delaunay's algorithm. The terrain's elevation analyses were expanded with colour visualization.

The point cloud from the terrestrial laser scanning was used in the study of the particularly valuable natural objects. TLS data was used in developing a detailed TIN model of a rocky slope. Triangular network and a model based on it were created in 3D Reshaper program with the use of Delaunay's algorithm. Construction of the model was preceded with a process of cleaning the point cloud in Cyclone 8.1.1 program (Fig. 3).

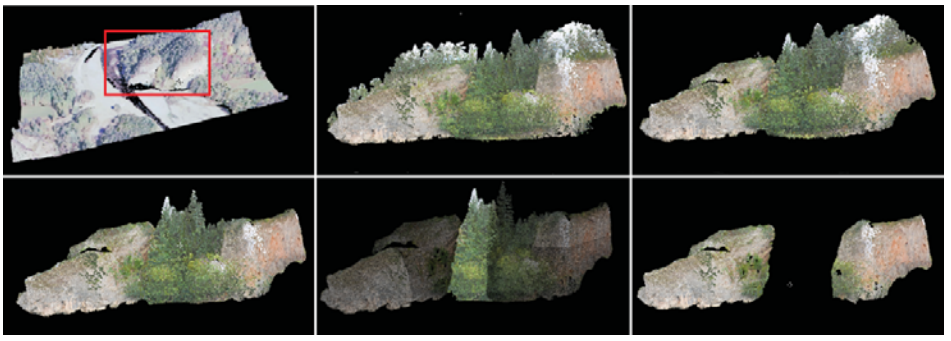

Fig. 3. Stages of cleaning the point cloud
Rys. 3. Etapy czyszczenia chmury punktów

RESULTS AND DISCUSSION

The basis for conscious management of Natura 2000 network, including the extent of essential and necessary protection measures is accurate information about the condition of habitats, as well as about tendencies and dynamics of their changes. Drawing up a draft plan for protection tasks requires collecting data about the area and protection objects. To do this, all available sources of information about the given Natura 2000 area should be used. It is essential that the data on basis of which plans for protection tasks are created, should be characterized by an appropriate accurracy in both position of spatial objects and fidelity of recreating the space. Sources of information, which should be used in plans for protection tasks are included in Annex 1 to the guidelines of the General Directorate of Environmental Protection 'Development of the plan for protection tasks for Natura 2000 area'. The data from the laser scanning are not included in this list, however, according to the authors, point cloud may prove to be useful in many stages of the process of drawing the project. When analyzing possibilities of applying laser scanning technology in the protection of Natura 2000 areas, three major methods of using point clouds may be distinguished. The first one involves analyses of properties of points obtained with the laser scanner, enabling classification of the stored content. The following two methods are based on the use of geometric information contained in point clouds. They are analyses conducted directly on the point cloud (in two-dimentional cross-sections or 3D images) or on interpolated (from point data) models.

The work necessary for drawing the draft plan for protection tasks includes description of the area's boundaries. Boundaries of PLH120024 area were designated based on the information about properties of an ALS point cloud (RGB, intensity, classification, echo). Various modes of displaying point clouds automatically grouping spatial data, allowed for designating the boundaries of riparian forests constituting area boundaries. The obtained boundaries were characterized by a huge cross compliance. Comparing them with the obliging boundary of Natura 2000 area of Białka Valley indicated a high compliance of bondary breakdown points established by the European Commission with the area's boundary designated in a point cloud (Fig. 2). Slight differences occurred only in places where the established area's boundary omitted parts of riparian forests. In the process of drawing a draft plan for protection tasks, there may occur demands for the correction of the area's boundaries, included in the plan for protection tasks as one of the tasks. Comparing boundaries of the protected area with the boundary designated based on the analyses of point clouds may be useful in the process of defining boundaries of Natura 2000 areas, and also in social consultations conducted in this context.

While evaluating the condition of the protected natural habitats, a system of parameters and indicators adopted for monitoring should be used in Natura 2000 area. Annex to the Regulation of the Minister of the Environment of 17th February 2010 on drawing the draft plan for protection tasks for Natura 2000 area provides three main parameters characterizing the condition of habitat protection and these are: habitat area, structure and function as well as chances for preserving the habitat. ALS data allowed for determination of the parameters of the area and natural habitat distribution in the area, taking into consideration their fragmentation. On the other hand, periodic comparison of point clouds will enable determination of the tendency in the occurring changes. Cross-section made from point clouds allowed for indicating structural

parameter of natural habitats (Fig. 4). Measurements of the habitat of olive willow shrubland on pebbles and gravel of mountains streams (habitat: 3240) showed high compatibility with the information included in the Standard Data Form of Natura 2000 area. One of the objectives of protection of a particular type of natural habitat is maintaining or restoring typical species, the key ones in preserving biological diversity and also determining this habitas's local specificity. Laser scanning allows for determining any type of structural changes, including disappearance of single trees. The information provided by ALS is of enormous value, especially in areas where taking measurements is impossible because of the unavailability of the area or because of substantial labour input and costs. Analyses of the habitat condition may also use cyclical TLS measurements, allowing for determining parameter of evaluation of chances to preserve natural habitat in the future. For example, habitat 3240 should be periodically regenerated, otherwise it transforms into riparian forest. Prospects for preserving it in an appropriate protection status are rather poor; enriching methods of monitoring used so far with laser scanning technology may allow for a faster and more comprehensive detection of dangerous changes occurring in the protected area. Both TLS and ALS data may be also used to determine optimum habitat conditions for certain animal groups. While analyzing spatial structure of a point cloud, it is possibile to designate zones, in which vegetation density meets the biocenotic demands of particular species, which will allow for predicting location of breeding grounds in a given area.

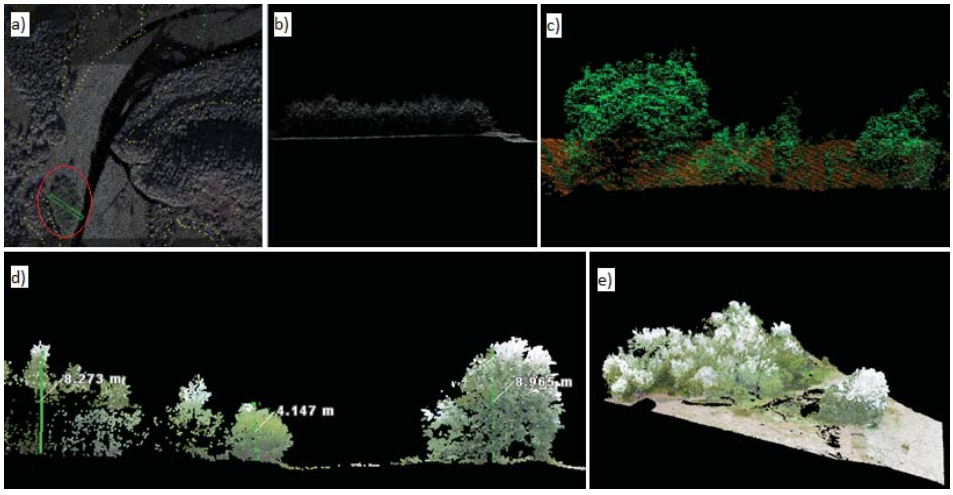

Fig. 4. Analysis of natural habitats: a) cross-section of habitat 3240 in a horizontal projection of ALS data, b) cross-section of habitat 3240 in a vertical projection of ALS data, c) classification of the habitat 3240 based on ALS data, d) dimensioned vertical cross--section of habitat 3240 obtained from TLS data, e) structure of habitat 3240 presented in the TLS point cloud

Rys. 4. Analiza siedlisk przyrodniczych: a) przekrój siedliska 3240 w rzucie horyzontalnym danych ALS, b) przekrój siedliska 3240 w rzucie wertykalnym danych ALS, c) klasyfikacja siedliska 3240 na podstawie danych ALS, d) zwymiarowany przekrój wertykalny siedliska 3240 pozyskany z danych TLS, e) struktura siedliska 3240 przedstawiona w chmurze punktów TLS

While preparing the draft plan for protection tasks for Natura 2000 area, evaluation of the existing and potential threats should be made to preserve or achieve an appropriate condition of protection objects. The greatest threat to Białka Valley is destruction of the natural character of the river through regulating the river bed or badly conducted works on the anti-flood protection, which as a result may cause disturbance of its natural dynamics. Numerical model of the terrain generated from ALS data allowed for an accurate analysis of the river valley terrain (Fig. 5). Temporary changes in the course of the river are visible on the produced NMT in the form of numerous depressions. Even the dense forest cover was no obstacle for light signals sent by the scanner, which allowed for developing an accurate model of the surface of areas covered with thick vegetation. The use of ALS data allowed for a detailed documentation of the river valley relief. Comparative analysis of NMT developed in successive measuring stages will enable to create a characteristics of the dynamics of changes in the area, evaluation of the erosion and of accummulating material on particular sections of the river, and also it will provide control over regulation of the river bed and over the conducted works on anti-flood protection.

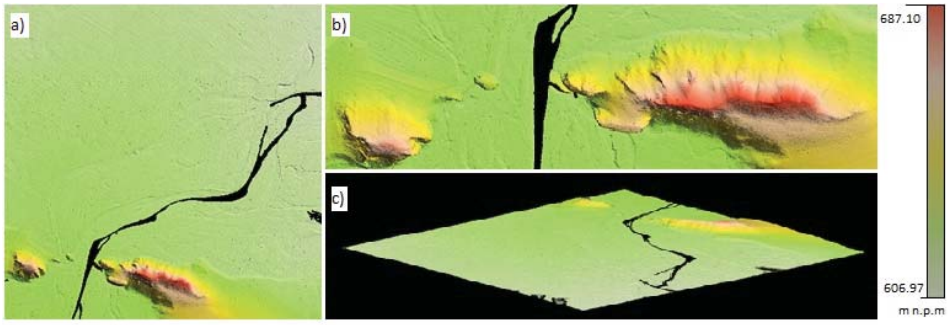

Fig. 5. a) numerical model of terrain in a horizontal projection, b) space and time changes in the course of the river bed, c) NMT in a perspective

Rys. 5. a) numeryczny model terenu w rzucie horyzontalnym, b) czasoprzestrzenne zmiany przebiegu koryta rzecznego, c) NMT w perspektywie

In the draft plan for protection tasks, works within the range of habitat monitoring are included as one of the protection tasks. In particular, a program for local monitoring should be designed, with the use of methods suitable for the local needs, so as it could in good time provide 'warning signals' about possible threats to protection objects. TLS measurements proved to be highly useful in this respect. The use of the terrestrial laser scanner, enabling measurement with milimetr accuracy and high frequency of sampling to monitor the condition of natural monuments or other particularly valuable natural objects, seems to be necessary and justifiable. The possibility to take multiple, repetitive and very accurate measurements, makes this system a very promising monitoring tool. TIN model of a stony slope, developed based on TLS data, showed high quality and accuracy of this method (Fig. 6a). As part of monitoring, also measurements on a point cloud may be used (Fig. 6b). Repeating measurements in the successive research period will enable recording the occurrence of changes. They may be designated not only in cross-sections, but what is absolutely essential, in a spatial representation. Spatial

monitoring will allow for obtaining data concerning rate, tendencies and size of changes occurring in Natura 2000 area, saving the whole object history in a digital form.

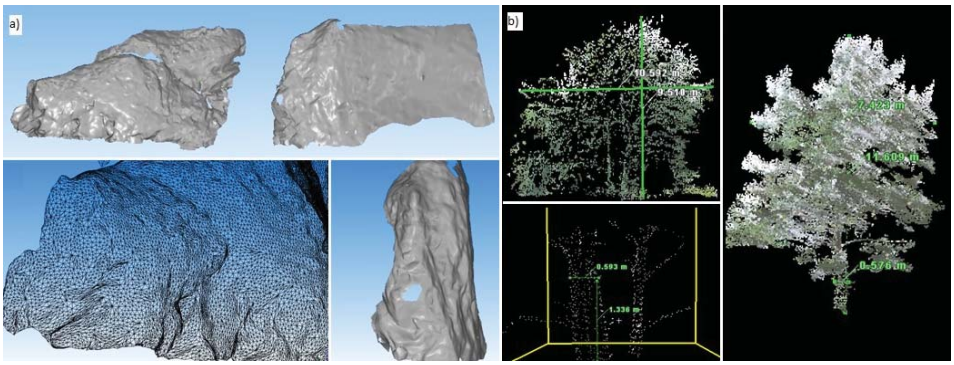

Fig. 6. Monitoring based on TLS data: a) stony slope – TIN model, b) single tree-measurements of taxation characteristics of a tree

Rys. 6. Monitoring na podstawie danych TLS: a) kamienistego zbocza – model TIN, b) pojedynczego drzewa – pomiary cech taksacyjnych drzewa

Protection of Natura 2000 area will only last when it is based on 'common understanding' of the needs and conditioning of the area's protection [Wytyczne... 2004]. 3D visualization of the protected area, made based on the integrated TLS and ALS data (Fig. 7), will allow for minimizing one of the basic threats to Natura 2000 network, which is a low level of social awareness concerning the area and its protection. Point clouds and visualizations made on their basis may prove to be useful in the process of approving plans for protection tasks, which must be preceded with a procedure of the society's participation in making decisions according to principles and procedures defined in the Act of 3rd October 2008 on the disclosure of information on the environment and its protection, participation of the society in environmental protection and evaluation of the environmental impact. Social consultations are especially important as tasks directly serving to achieve the goals of the plan may concern introduction of modifications in the managing methods which were previously used in natural habitats. Although including farmland into Natura 2000 network does not mean the necessity to end agricultural activity, there may occur necessity requiring that farmers change their management methods, or perform additional tasks ensuring an appropriate state of preservation of protection objects. 3D visualizations conducted on the basis of a point cloud may serve as an effective and clear communication of the content included in the plan for protection tasks, enabling proper and quick understanding of the dependences defined in it.

Fig. 7. The result of integrating data from the airborne and terrestrial laser scanning
Rys. 7. Wynik integracji danych z lotniczego i naziemnego skaningu laserowego

CONCLUSION

Protection of the natural biodiversity is a more and more frequently highlighted priority task, because of the requirement for providing balance in the ecosystem, and as a result, social and economical safety. Natura 2000 network is a fundamental component of EU policy in the field of nature protection, and an example of an enormous European effort to preserve biodiversity for future generations. The results of the presented research indicate that technology of airborne and terrestrial laser scanning may facilitate reasonable management of Natura 2000 areas and planning their functioning in the future, and thus they will allow for predicting, preventing and fighting against causes of a decrease or decline in biodiversity. 3D visualizations carried out on the basis of point clouds enabled reducing one of the fundamental threats to Natura 2000 network, which is a low level of social awareness concerning the area and its protection. TLS and ALS data also allowed for reducing other serious threats to preserving Natura 2000 areas, which is insufficent knowledge on the protection objects, leading to the risk of making a mistake in their protection. The use of point cloud properties to determine the course of the area's boundaries enabled making them more accurate. Cross-sections, created based on point clouds, provided detailed information about habitats, which is irreplaceable in their structural analysis, documenting their condition or monitoring changes. A modern measuring method proved to be useful in generating NMT and models of particularly valuable objects. Wide range of information contained in the point cloud will certainly allow for increasing effectiveness of the plan for protection tasks, it will serve in planning protection, monitoring protection objects, and reliable verification of the effectiveness of undertaken activities. Accurate ALS and TLS data describing the condition of habitats and changes occurring in them, will facilitate formulating indications for optimizing conducted protection activities, ensuring at the same time appropriate allocation of limited financial resources intended for the protection of natural areas in Poland.

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ANALIZA MOŻLIWOŚCI ZASTOSOWANIA NAZIEMNEGO I LOTNICZEGO SKANINGU LASEROWEGO W OCHRONIE OBSZARÓW NATURA 2000

Streszczenie. Sieć Natura 2000 to podstawowy element polityki Unii Europejskiej w dziedzinie ochrony przyrody i przykład ogromnego wysiłku Europy na rzecz zachowania różnorodności biologicznej dla przyszłych pokoleń. Szczegółowe zasady postępowania na obszarach Natura 2000 są ustalane odrębnie dla każdego terenu i zapisywane w planach zadań ochronnych (PZO). Planowanie efektywnych działań, a zwłaszcza wskazywanie konkretnych zabiegów ochrony czynnej wymaga monitoringu i oceny stanu zachowania środowiska przyrodniczego oraz jego czynników. Praca stanowi analizę możliwości zastosowania technologii naziemnego i lotniczego skaningu laserowego w tym zakresie. Prace badawcze przeprowadzone na fragmencie obszaru Natura 2000 „Dolina Białki" (PLH120024) dowiodły, że wykonane na chmurach punktów opracowania pozwalają na wzbogacenie monitoringu siedlisk przyrodniczych i wspomagają proces tworzenia planów zadań ochronnych.

Słowa kluczowe: chmura punktów, ochrona przyrody, plany zadań ochronnych

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