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The use of view analyses in shaping a forest landscape in the vicinity of water reservoirs

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Abstract

An increasing importance of the social functions of the forest entails the necessity to modify forestry management in a way which would ensure its social acceptance. This mainly concerns those parts of the forest that are "most visible", in the surroundings of roads, tourist trails, as well as water bodies. The article discusses the importance of view analyses in forest landscaping. On the basis of the adopted methodological assumptions, the assessment of landscape resources of the forest in the vicinity of a water reservoir in the Kielce Forest District (Radom Regional Forest Directorate) has been made. Available ortophotomaps and aerial photographs taken by UAVs were used for view analyses together with elevation data collected through airborne laser scanning. The results obtained allow to make recommendations for the protection of the reservoir exposure as well as engineering forest management and silviculture. Consequently, the inclusion of visual analyses into the planning stage enables verification of the quality of forest management plans.

Key words: *landscape, landscape assessment, spatial planning, water reservoir*

INTRODUCTION

Nowadays spatial planning which ensures the protection of natural and landscape values is becoming increasingly important. The European Landscape Convention ratified by Poland in 2005 [Europejska konwencja…. 2006] describes landscape as an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors. Sight, as the dominant sense in humans, is the fundamental source of information about the surrounding environment. Approximately 85% of sensory stimuli are perceived using this sense [KOWALCZYK 1992]. Therefore, simplifying, the landscape may be regarded as a physiognomic space. Landscaping means such land management that is in line with its characteristics and natural features. At the same time, it is the management of landscape resources. At present, following the amendment of the Forest Management Instruction [PGL LP 2012b], as well as the Forest Cultivation Principles [PGL LP 2012a], it can be seen that questions concerning landscaping are becoming increasingly important in forest management. This process is directly related to the rising public expectations towards forests, which can be seen in the long-term trend towards reducing multiple functions of the forest to one, namely social function [PASCHALIS-JAKUBOWICZ 2009]. The increasing importance of such non-productive functions lays upon foresters a responsibility for such management that wins social acceptance. First of all their actions concern the "most visible" parts of the forest, mainly in the vicinity of roads, tourist trails, leisure routes, as well as water bodies.

Shaping the landscape, according to [DRAPELLA-HERMANSDORFER 2004], is directly related with the problems of spatial order and indirectly to spatial planning with its tools and methods. It does not aim for bringing out elusive and subjective aesthetic values, but rather restoring or preserving a rational order. Water reservoirs, in particular those with the area of at least 0.5 ha, built on a land other than arable and located in areas under varied forms of nature protection or in their buffer zones, fall into the group of projects likely to always have significant effects on the environment (§ 2.1 of the Regulation of the Council of Ministers of 9 November 2010 on types of projects likely to have significant effects on the environment) [Rozporządzenie RM… 2010]. Therefore they should be subject to the environmental impact assessment report. The report, according to the Act of 3 October 2008 [Ustawa… 2008], should contain a description of the effect on the landscape, however – as FORCZEK-BRATANIEC [2013] notices, the part of the report concerning landscape is narrow in scope and usually comes down to a description of geographic regions and main forms of land cover. Since the principles of landscape impact assessment remain unspecified, the problem is disregarded. Similarly, in the case of water reservoirs smaller than 0.5 ha or located in forests outside conservation areas, landscape is not taken into account at any of the design stages. The same also applies to other engineering structures in forests. Setting the principles for forest landscape engineering entails the necessity to determine the scope of visual analyses to be carried out – depending on the character of the investment – on a micro and macro spatial scale [JANECZKO 2011]. At the same time it should be noted that the landscape perception is conditioned by movement velocity [BELL 1997], therefore all visual analyses need to address the problem of the so-called dynamic perception.

The aim of this article is to determine the scope of visual analyses necessary to develop recommendations concerning engineering forest landscaping in the vicinity of water bodies. The paper presents the possibilities of using available visualization and animation techniques which facilitate decision-making processes concerning forest management. The adopted methodological assumptions were verified using the example of a water reservoir in Bilcza forestry, Kielce Forest District, the Regional Directorate of the State Forests in Radom Figure 1.

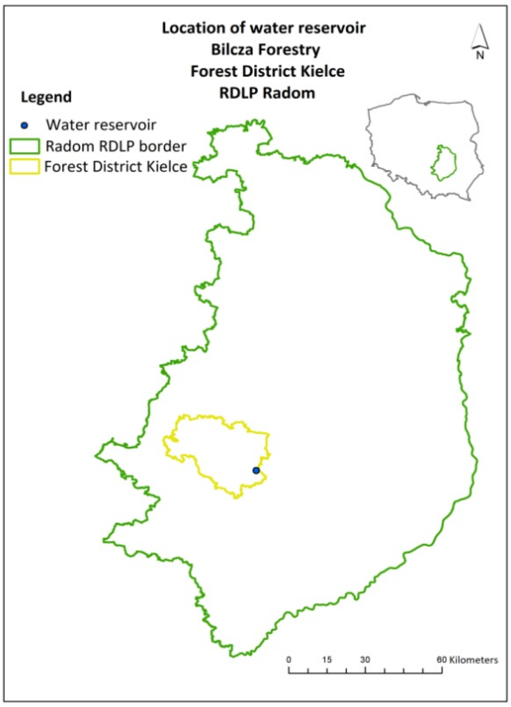

Fig. 1. Map of water reservoir Bilcza Forest District Kielce of the Regional Directorate of the State Forests in Radom; source: own elaboration

MATERIALS AND METHODS

The total area of an impounding reservoir in the Bilcza forest district is 43 ares. The area of the water surface is 41 ares. The maximum length of the reservoir is 92.36 m, the maximum width – 80.02 m, the maximum depth – 1.5 m, the average depth – 1.37 m, and the volume is 5,600 m^3. To the south, in the vicinity of the reservoir there is a dirt forest road used for leisure walking and bicycle riding. The forest stand on the east and west consists of scots pines aged about 80, the majority of them located at a fresh coniferous forest site. To the south of the reservoir there is wet mixed forest. In the last years (2008–2017) both north and south of the reservoir tree felling was carried out which resulted in new forest plantations. The reservoir was chosen for the testing of adopted methodological assumptions due to the accessibility of cartographic material, the size, and the immediate vicinity of the road allowing to include, apart from static visual analyses, the aspect of dynamic perception.

The view analyses were based on a method that integrated cartographic and photographic data as well as data that include the issue of dynamic perception. They included choosing the right techniques and research tools for available source materials, determining the range of static sight, analysis of the variability of land use structure and relief features by means of cross-sections, as well as analysis of a sequence of views from the road, taking into consideration the speed of movement, and their transformation into the land plan.

View analyses were made with the use of ArcGIS 10.3.1 software. An orthophotomap was used as the basic source material. Apart from it the view analyses were based on elevation data in the form of a point cloud obtained during laser scanning from a plane, performed as part of ISOK program [ISOK undated]. The data were taken from the Geodesic and Cartographic Documentation Center (Pol. Centralny Ośrodek Dokumentacji Geodezyjnej i Kartograficznej).

The obtained elevation data had the “1992” plane rectangular coordinates system, the height referred to the “Kronsztadt 86” normal height system. The data were made available in a digital form in LAS format (classified point cloud) and ARC/INFO ASCII GRID format (a text file containing values of points in a regularly-spaced grid of 1 m squares). On the basis of the obtained data it was possible to interpolate a Digital Terrain Model (DTM) and a Digital Surface Model (DSM).

The range of the “static” sight analyses that were performed was specified at a maximum of 800 m, due to the fact that at a distance greater than 800 m objects are perceived as elements of the background [NIEMIRSKI *et al*. 1993]. In addition, due to the forest surroundings of the reservoir the perceptive capabilities are constrained and do not reach beyond the designated site. A division onto three perception range zones was adopted:
Zone A; up to 250 m, objects are perceived individually, in various detail particularizations;
Zone B; from 250 to 550 m, objects are perceived individually, details become less and less clear;
Zone C; from 550 to 800 m, objects are perceived as elements at the back.

Figure 2 presents a diagram with the adopted sight ranges.

On the basis of the sight zone ranges thus defined a longitudinal land section was made, 1,600 m in length, taking into account the furthest view openings (Fig. 2). Perpendicularly to the longitudinal section the cross-sections were made, 500 m in length. The cross-sections were made every 10 m. The distance between cross-sections allowed to determine in great detail the landscape variability in the vicinity of the reservoir. Moreover, the size of the reservoir and its maximum length were also vital in setting the distance.

The next stage of works was to establish whether the reservoir and the area around was visible from a nearby road. The road is used sporadically by motor vehicle drivers and more frequently by cyclists and walkers. Perception is a function of time and distance. As the speed increases, the angle of sight changes as does the amount of external stimuli reaching the observer. In this study it was assumed that the analyzed sight range shall refer to a speed of 12 km·h^{-1} (average velocity of the bike routes users) and a 130° angle of sight with the skyline at 175 cm. The reservoir exposition time as well as parts of the land most visually exposed were established on the basis of DTM and DSM. The analysis was conducted from 22 artificially generated points located along the road center line. The distance between the points was 25 m – Figure 3.

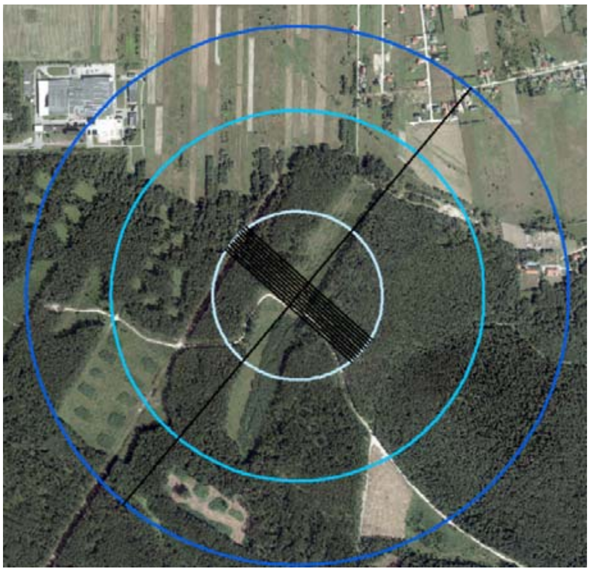

Fig. 2. Diagram of the adopted sight zone ranges around an object on an orthophotomap base; source: own elaboration

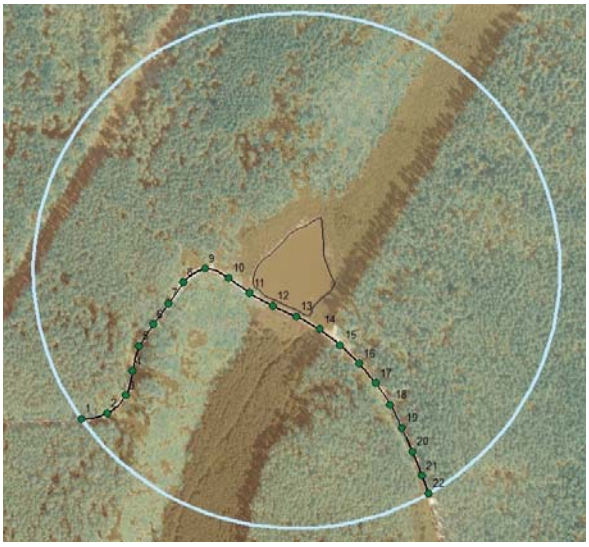

Fig. 3. A diagram of the adopted points along the road centre line on the orthophotomap base and on the basis of a Digital Surface Model; source: own elaboration

RESULTS

Cross sections of the terrain (Fig. 4) served as the basic element of view analyses. They allowed to determine the tree stand structure (its density, stratification, the presence of undergrowth and shrub layer), and consequently the so-called visual barriers and the maximum perceptive capacity.

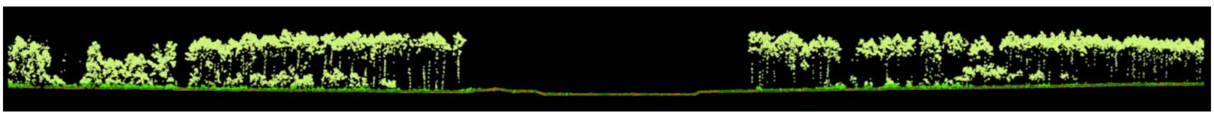

Fig. 4. An example of a cross section made from a point cloud obtained from airborne laser scanning running through the middle of the water reservoir; source: own elaboration

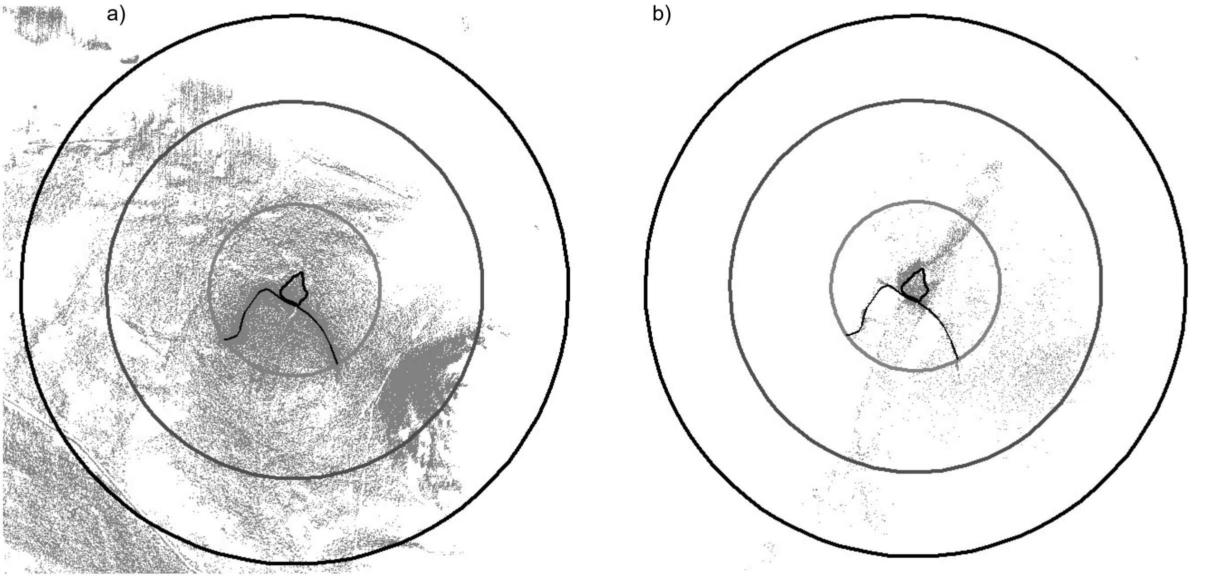

Fig. 5. The results of the visibility analysis within the range of 3 buffers: a) the results established on the basis of Digital Terrain Model, b) the effect of the Digital Surface Model application; grey colour represents visible areas, the remaining areas are invisible; source: own elaboration

On the basis of a detailed analysis of cross sections it was found that the average range of sight was 115 m. On both sides of the reservoir the visibility is limited by the forest stand. Dense undergrowth limits the view into the forest to a maximum of 25 m. The perceptive capacity is slightly better on the left hand side. The maximum range of sight is 30 m.

The next stage of the analysis was to determine the actual and potential visibility of the reservoir. For this purpose the data provided by the digital terrain model and digital surface model were used. The DTM contributed to the determination of the potential visibility (Fig. 5a) resulting from land relief. The actual sight range was determined on the basis of the elements of land cover (forests, meadows, constructions etc.) provided by the DSM (Fig. 5b).

The analyses performed with the use of DTM and DSM show that potential possibilities of improving the visibility of the reservoir in the landscape are vast. The greyscale presents the possibilities of the reservoir exposition. As can be seen, due to the land relief the reservoir is potentially best visible from the north, from a road in the vicinity or from the fragment of a hill located in the southeast. Taking into account the existing elements of land cover it was discovered that the actual visibility potential is small and limited almost exclusively to the immediate vicinity of the reservoir. Only the north-eastern part of land is slightly more visible.

Taking into consideration the issues of dynamic perception, the time of exposition of the reservoir at the speed of 12 km·h^{-1} was determined to be 30 s. The reservoir is not equally well visible from each of the analyzed points along the road axis. After taking into account both opposite directions of the movement (Tab. 1), only four sections of the road were found to allow a view of the reservoir.

Table 1. Summary of the surface of the water reservoir seen from the selected 22 viewpoints depending on the direction of driving with barriers (Digital Terrain Model – DSM) and without barriers (Digital Surface Model – DTM)

Visible water surface					
Direction of movement	DTM	DSM	Direction of movement	DTM	DSM
1–2	0	0	22–21	9	0
2–3	0	0	21–20	12	0
3–4	0	0	20–19	26	0
4–5	0	0	19–18	36	0
5–6	1	0	18–17	25	0
6–7	11	0	17–16	41	0
7–8	19	0	16–15	50	0
8–9	41	0	15–14	73	11
9–10	48	3	14–13	90	75
10–11	85	13	13–12	53	47
11–12	59	0	12–11	15	14
12–13	31	27	11–10	0	0
13–14	1	1	10–9	0	0
14–15	0	0	9–8	0	0
15–16	0	0	8–7	0	0
16–17	0	0	7–6	0	0
17–18	0	0	6–5	0	0
18–19	0	0	5–4	0	0
19–20	0	0	4–3	0	0
20–21	0	0	3–2	0	0
21–22	0	0	2–1	0	0
22	0	0	1	0	0

Source: own study.

Additionally, when approaching the reservoir from southwest in the northeast direction, the visibility is rather poor. The largest fragment of the reservoir (27%) is visible from the section between the points 12 and 13. The visibility is slightly better from the opposite direction. On each occasion, at the section between points 15 and 11, more than 10% of the water surface can be seen. The section between the

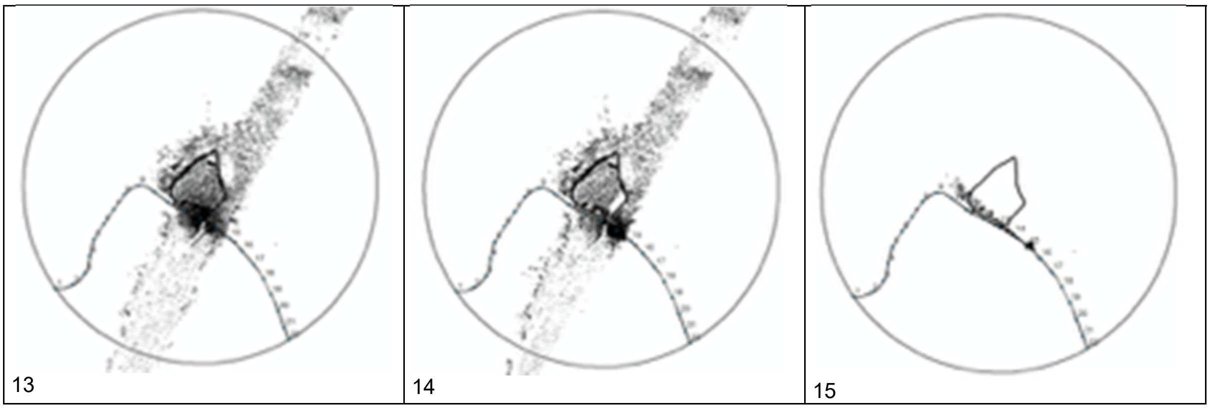

Fig. 6. Diagrams presenting exposition of the reservoir from the points 13–14–15 designated along the axis of the road; source: own elaboration

points 14 and 13 offers the best view. From this part of the road more than 75% of the reservoir is visible. Example diagrams showing ranges of sight from designated points along the center line of the road are presented in Figure 5.

Hypothetically, as shown by the DTM analysis, without all the barriers in the form of shrubs, single trees, groups of trees etc., the duration of exposition would be twice as long (more than 1 min). Moreover, the reservoir could be visible from the greater number of points: nine (northwest to northeast direction) or eleven (the opposite direction) – Table 1. The best view would be delivered by the road section between the points 10–11 (85% of the surface visible) and 14–13 (90% visible).

DISCUSSION

In significant number of studies concerning landscape evaluation [BAJKIEWICZ-GRABOWSKA, MIKULSKI 2006; DEJA 2001; JANECZKO 2002; MARKIEWICZ, SZUŻMOW 1992] water is listed as a factor enhancing the attractiveness of the landscape. For this reason, location plans and specifications for engineering structures including but not limited to forest water reservoirs should be discussed thoroughly with respect to their influence on the landscape. According to SMOLEŃSKI [2007] it is the large diversity of ecotones that decides that watercourses as natural corridors and water reservoirs are visually one of the most attractive elements of forest landscape. Landscape analyses allow for the adoption of such solutions that will ensure the integration of a reservoir with the surrounding landscape. The lack of legal regulations and visual analyses at the technical design stage as well as no requirement to present different variants of the solutions applied result in too strong geometrization of the reservoir, excessive exposition of hydraulic structures such as weirs, dams, artificial rapids, levees etc., or in accidental location of recreation facilities connected with the reservoir (viewpoints, relaxation spots, educational trails etc.). View analyses constitute a valuable tool for the formulation of guidelines in respect of vegetation planning, thus contributing to forest management. As demonstrated in the article, they allow to precisely indicate areas of key significance for the exposition of landscape and places which offer best views.

In recent years, digital laser scanning data (LiDAR) and high resolution orthophotos are becoming increasingly available. GIS systems, on the basis of a point cloud which is the result of the application of these techniques to scan land surface, allow to generate a 3D numerical model with layers representing land surface and its cover. The use of digital data enables to make summaries of the results including, among other things, the calculation of visibility range for given objects. In view analyses the issue of dynamic perception is of key significance. Humans perceive landscape not only in a static manner. Movement and pace of movement are also factors conditioning the reception of the landscape. Digital data, as demonstrated in this paper, allow for spatial visualization of the sight range at a specified velocity. The study presents the scope of landscape analyses which covers only the speed of 12 $km \cdot h^{-1}$ (the angle of sight of approximately 130°) due to the fact that the forest road in the vicinity of the reservoir is used not only for economic purposes but also for leisure and bicycle riding. In the case of other types of roads (a walking route, a public road of high technical quality) view analyses should cover different angles of sight. Digital data offer an unquestionable opportunity to acquire the information on landscape reception at various speeds of movement. Initial civil users of geographic information systems were geologists and foresters, however, in a relatively short period of time the capabilities of GIS systems have been recognized as a useful tool in tracking, scheduling and spatial planning, the supply of water and wastewater treatment, pollution monitoring, environmental protection, health care, administration, geomarketing, education and science. Nowadays GIS systems are used in all areas of modern life as a tool improving decision making processes. The scope of diagnostic characteristics should be expanded together with the increasing opportunities for obtaining spatial data concerning water management in forests, local physical development plans, as well as other relevant information on landscaping which influence the planning of works in forest management.

SUMMARY AND CONCLUSIONS

The documentation providing the framework for multifunctional forest management covers only general principles of forest landscaping. At the same time no guidelines can be found for the modification of forest management methods which would take into consideration identified landscape assets. Plans and specifications for engineering structures – including water reservoirs – unsatisfactorily address the issue of landscape values and the necessity to tie a facility with its surroundings. The scope of visual and landscape analyses presented in the article may find application in forest management for tourism and recreation, planning linear engineering structures, and determining acceptable visual transformations (deforestation/afforestation).

The analyses undertaken as well as the results entitle to formulate the following remarks and conclusions.

1. Landscape analyses require the use of modern techniques of recording and processing information about the environment.

2. The perception of space, and most importantly so called dynamic perception, plays vital role in the formulation of modern views on landscape engineering principles.

3. Landscape analyses constitute a tool which in an objective manner contributes to defining possibilities of shaping the landscape in the immediate vicinity of engineering structures, including forest water reservoirs.

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Zastosowanie analiz widokowych w kształtowaniu krajobrazu leśnego w sąsiedztwie zbiorników wodnych

STRESZCZENIE

Wzrost znaczenia społecznych funkcji lasu powoduje konieczność modyfikacji gospodarki leśnej w kierunku gwarantującym jej społeczną akceptację. Dotyczy to przede wszystkim tych fragmentów lasu, które są „najbardziej widoczne”, w otoczeniu dróg samochodowych, szlaków turystycznych, jak również zbiorników wodnych. W artykule omówiono znaczenie analiz widokowych w kształtowaniu krajobrazu leśnego. Na podstawie przyjętych założeń metodycznych dokonano oceny zasobów krajobrazowych lasu w sąsiedztwie wybranego zbiornika retencyjnego zlokalizowanego w Nadleśnictwie Kielce (RDLP Radom). Do analiz widokowych wykorzystano dostępne ortofotomapy, zdjęcia lotnicze wykonane przez UAV oraz dane wysokościowe pozyskane w ramach lotniczego skanowania laserowego. Uzyskane wyniki dają podstawy do określenia rekomendacji w zakresie ochrony ekspozycji zbiornika oraz inżynieryjno-hodowlanego zagospodarowania lasu. Rezultaty pracy wskazują, że włączenie analiz widokowych do grupy narzędzi planistycznych umożliwi weryfikację jakości planów urządzeniowych lasu.

Słowa kluczowe: *krajobraz, planowanie przestrzenne, waloryzacja krajobrazu, zbiornik retencyjny*