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ORIGINAL PAPER

Economic aspects of silvicultural treatments in oak stands

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ABSTRACT

The aim of the study was to economically analyse the costs of silvicultural management treatments in oak stands. The basic research material was obtained from selected forest districts belonging to the Regional Directorate of State Forests in Poznań. The economic analysis concerned only stands in which the share of oak in the species composition of the stand was above 60%. In total, data from 1,644 silvicultural activities performed from 2015-2019 were used for the study. The study analysed five types of tending interventions (groups of activities) that occurred in all of the studied forest districts. In order to demonstrate significant differences in unit cost average values related to the group of activities, the analysis of variance test in a single classification was used. In addition, cluster analysis was used for a more complete interpretation of the data and grouping of the examined elements. After carrying out a significance test, it could be concluded that the group of activities had a significant impact on the unit cost of the activities performed (p<0.000). Cluster analysis made it possible to look for similarities in the overall multi-activity structure of unit costs assigned to individual habitats. The analysis showed how similar individual habitats are to each other in the entire structure of costs incurred for five unique groups of activities. A dissimilarity matrix between the studied factors (group of activities and forest habitat types) and its visualization via a heat map were used in this study. Sorting the map by differences in the dissimilarity matrix allowed us to detect relationships in the cost data. The data mining analysis presented in this paper enabled the identification of factors influencing the level, structure and variability of the costs of tending oak stands.

KEY WORDS

costs, economic analysis, oak stands, silviculture

Introduction

Currently, forest management in Poland due to social pressures and imposed legal standards is increasingly being redirected towards performing environmental functions including nature protection and social functions (Mandziuk *et al*., 2021). However, the economic function of forests continues to exist with a constantly growing demand for wood for the developing wood industry as well as the principle operations of the State Forests based on economic calculations (Gołos and Kaliszewski, 2016). Silviculture is the basic branch of forest management focusing on combining

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these multiple functions using natural assets. Conducting forest management activities, like any other economy, requires making decisions. The time dimension of forest production is important as the long period of stand growth means that forest management is often faced with making decisions in conditions of uncertainty (Oesten, 2014).

In recent decades, an important aspect of forestry has been the increasingly intensive conversion of forest stands. It has resulted from the current conditions of forests and the direction of further forest development. However, the extent of the stand conversion depends primarily on the possibility of financing these works. In Central European forests, the share of oak stands is systematically increasing as a result of the transformation of pine and spruce monocultures in fertile habitats into stands with more species diversity (Zerbe, 2002; Bernadzki, 2006). Oak forests with pedunculate oak *Quercus robur* L. and sessile oak *Quercus petraea* (Matt.) Liebl. are highly valued by forestry and nature conservation because they often provide both high-quality wood and rich biodiversity (Bolibok *et al*., 2021).

From a silvicultural management point of view, it is necessary to know the reaction of trees and stands to the applied stand tending. Developing a rational scope and frequency strategy for silvicultural measure procedures require precisely defined silviculture and economic goals for the cultivated tree stand (Andrzejczyk, 2009, 2014). However, from an economic point of view the economic projects undertaken increase the final value of the forest stand as an investment in the forest. The monetary evaluation of value changes in the forest ecosystems using economic calculations is a complex and problematic issue (Glura and Korzeniewicz, 2013; Kaliszewski, 2017; Ankudo-Jankowska *et al*., 2021). Forest tending requires significant financial outlays during the entire silviculture process. Therefore, increasing tending costs should be properly identified according to the type of silvicultural treatment.

The aim of the study was an economic analysis of the costs of tending interventions in oak stands carried out in selected forest districts located in the Regional Directorate of State Forests in Poznań in 2015-2019. These forest districts are located within the Krotoszyńska Plate which is characterized by unique soil conditions and the associated prevalence of very large complexes of dense oak forests.

Material and methods

The basic material for the research was data obtained from four forest districts belonging to the Regional Directorate of State Forests in Poznań: Jarocin, Krotoszyn, Piaski and Taczanów. The forest areas of the surveyed districts are mostly located in the Krotoszyńska Plate. This is an area with uniform habitat conditions, mainly in terms of geological structure and soil properties, where there are forest complexes with a predominant share of oaks.

The data for the analysis was obtained from the IT system of the State Forests from 4 forest districts where silviculture treatments were carried out in 2015-2019 (Chlebowska, 2022). In the analysed period, the costs of these works were characterized by low variability due to the low level of wage inflation and the insignificant impact of other cost-intensive factors. However, the years following this period, showed significant fluctuations due to the COVID-19 pandemic. The differences between costs for the intermediate treatments performed in the studied forest districts were statistically insignificant.

Therefore, the inclusion of silviculture activities from the selected years and within these four forest districts allowed for the expansion of the number of records examined. It was important for the study that the economic analysis concerned only forest stands in which the share of oak in the species composition of the stand was above 60%. The research included stands that grew on four forest habitat types including the following: fresh mixed forest, moist mixed forest,

fresh forest and moist forest. In total, data from 1,644 tending interventions performed on the forest areas were used for the study.

The research analysed five types of silvicultural treatments (groups of activities) that occurred in all of the studied forest units including the following: crop care (PIEL), early cleaning (CW), late cleaning (CP), early positive thinning (TWP) and late positive thinning (TPP). For each of these intermediate treatments, the unit cost of its implementation was determined.

A database was constructed for the purposes of performing a statistical analysis of unit costs which included values for specific forest habitat types (TSL) and groups of stand tending. In order to demonstrate significant differences in the average values of unit costs depending on the silviculture activity and the type of habitat, the analysis of variance test in a single classification was used. Assumptions about compliance with the theoretical normal distribution were verified based on the Kolmogorov-Smirnov test. Homogeneous groups were determined based on Tukey's *post-hoc* test (TIBCO, 2017).

For a more complete interpretation of the data and to group the examined elements into similar groups, cluster analysis was used. It is a tool for exploratory data analysis with the purpose of grouping the examined costs in such a way as to isolate similar units into separate groups according to designated criteria. Cluster analysis (dendrograms and k-means) is a multivariate method that searches for patterns in a data set by grouping the observations into clusters (Novianti *et al*., 2017; Polowy and Molińska-Glura, 2023). This method partitions data to find a number of groupings (clusters), where the inter-point distances are smaller than distances to points outside (Bishop, 2006). While data points within the cluster are similar (homogeneous), the clusters themselves are dissimilar to each other (heterogeneous). The distance between the data points determines the data similarity. A small distance between data points indicates a high level of similarity in the data. In contrast, a greater distance between the data points represents a low level of similarity in the data (Novianti *et al*., 2017).

Results

The data obtained from the SILP (State Forests Information System) database showed that in the habitat structure of the 1,644 surveyed areas, fresh forest or Lśw (85% of all divisions) dominated followed by fresh mixed forest or LMśw (6%), moist forest or Lw (5%) and humid mixed forest or LMw (4%). The percentage of the analysed silvicultural treatments (groups of activities) were as follows: PIEL – 60%, CW – 11%, CP – 7%, TWP – 4% and TPP – 18%.

By conducting a one-dimensional significance test, it could be concluded that the groups of activities had a significant impact on the unit cost of procedures performed in the examined period (p<0.000). Figure 1 shows the distribution of average expected values for individual silviculture treatments with a 95% confidence interval. Variations in the costs of tending operations were found ranging from PLN 732/ha (CP) to PLN 1,308/ha (TPP). Table 1 shows the division of these treatments into homogeneous groups, according to Tukey's HSD test conducted after the analysis of variance.

Each habitat was characterized by a vector of average costs for each of the 5 considered tending intervention. Cluster analysis allowed for finding similarities in the overall, multi-functional structure of unit costs assigned to individual habitats. On this basis, it could be demonstrated how similar individual habitats are to each other in the entire structure of costs incurred for 5 unique groups of activities. Based on the cluster analysis using the Euclidean metric, it could be concluded that the Lw and Lśw forest habitats differ in the structure of costs incurred for the 5 silvicultural measure by at most 25%. A completely different structure of costs of silviculture treatments is observed in the forest habitat type LMw and LMśw type (Fig. 2).

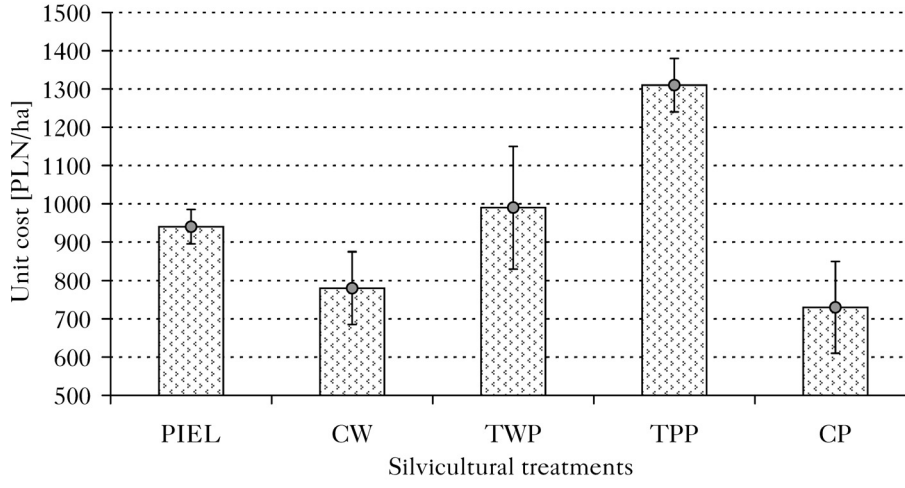

Fig. 1.

The average unit cost of silvicultural treatments with a 95% confidence interval by forest district from 2015--2019

Table 1.

Statistical homogeneous groups performed with Tukey's HSD test for unit cost including specific silvicultural treatments

Group of activities	Unit cost [PLN/ha] – Mean	1	2	3
Late cleaning (CP)	732.11	****		
Early cleaning (CW)	787.94	****		
Crop care (PIEL)	942.19		****	
Early positive thinning (TWP)	991.45		****	
Late positive thinning (TPP)	1307.70			****

Cluster analysis based on the Euclidean metric was also used to analyse the structure of unit costs of silviculture treatments in the selected habitat types. In this case, it could be observed that only the cost structures for early and late cleaning treatments (CW and CP) performed are very similar in the 4 habitats considered as they differ by less than 20%. The structure of costs incurred for other tending interventions (TWP, TPP, PIEL) differed significantly depending on the forest habitat type (Fig. 3).

In the research analysis, a dissimilarity matrix was used as a peer-to-peer comparison of the dissimilarity values between the studied factors (group of activities and forest habitat type). The presented heat map is a visualization of this matrix, where dissimilarity is expressed in colour. Organizing the map by heat dissimilarity detected structures and relationships in the data. Based on the heat map, it could be observed that the average costs of the silviculture procedure for the late thinning for positive selection (TPP) performed in the LMśw habitat differed significantly from all other activities (cost of approximately PLN 1,700/ha). A group of similar costs includes the combinations of habitat Lw for TPP and TWP activities as well as Lśw for TWP and PIEL activities (at the level of PLN 900/ha). The LMśw and Lśw habitats are characterized by the same costs for CW and CP treatments. The TPP treatment for the LMw habitat was the least cost-intensive activity (Fig. 4).

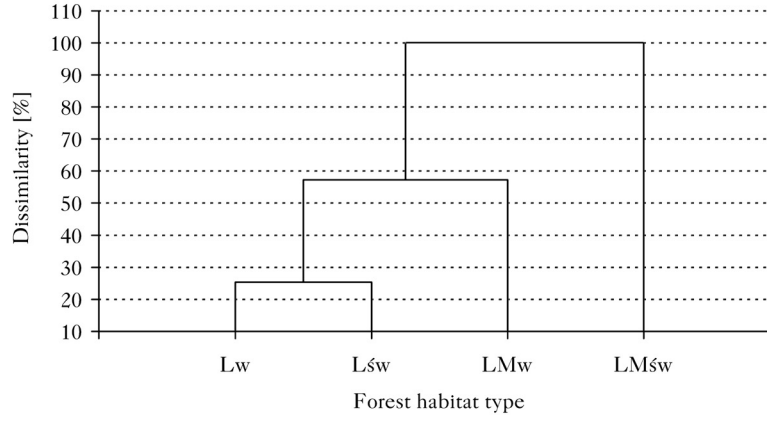

Fig. 2.
Dendrogram of variables by forest habitat type

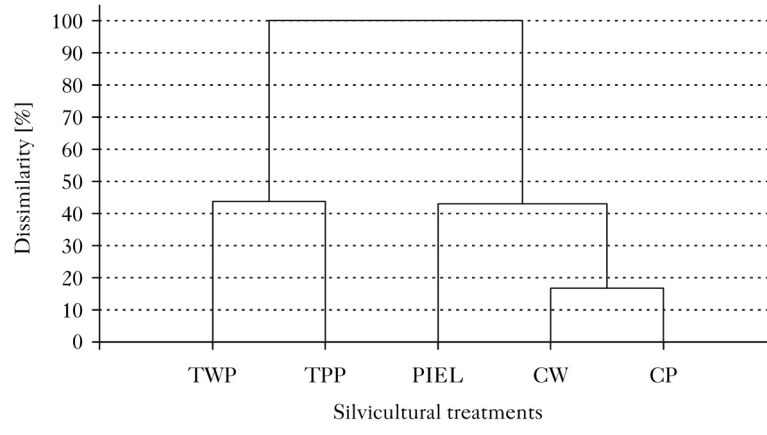

Fig. 3.
Dendrogram of variables for silvicultural treatments (group of activities)

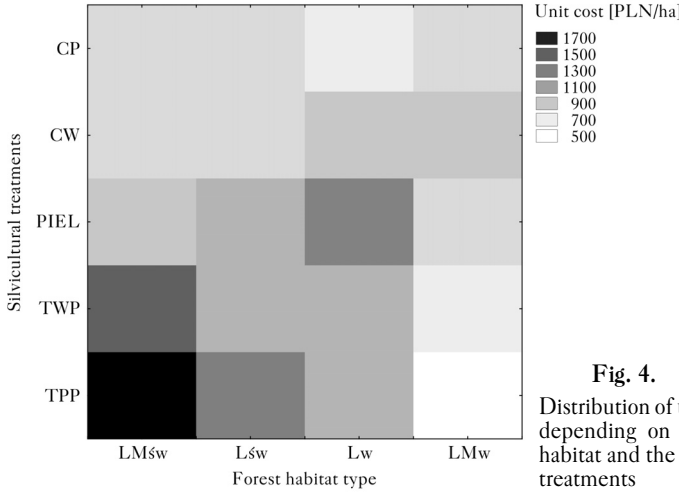

Fig. 4.
Distribution of unit costs [PLN/ha] depending on the type of forest habitat and the type of silvicultural treatments

Discussion

Managers of wood production companies, much like other entrepreneurs, must have a solid economic basis for their decisions. People deciding when trees and stands should be felled do not always have the full economic data necessary to make such a decision. Also, when choosing forest management methods the economic effects should be determined and taken into account which include various direct and opportunity costs, *i.e.* 'lost opportunities' related to economic, social and environmental benefits (Zając and Kaliszewski, 2014).

In Polish forests, as in other European countries, intensive conversion of forest stands is currently underway with the aim of adapting the species composition to habitat conditions. As a result, the share and role of deciduous species has increased especially pedunculated oak and sessile oak (Schelhaas *et al*., 2015; Andrzejczyk and Sewerniak, 2016). The economic consequences of increasing the share of deciduous species in the species composition of tree stands may result not only from increased production costs (tending, protection and harvesting) of deciduous or mixed stands that contain a predominance of deciduous species as well as a reduction in revenues. The value of wood production in deciduous stands is lower compared to that obtained from coniferous stands due to the longer rotation period and lower average price of wood raw material (Zając and Kaliszewski, 2014).

For effective forest management a systematic analysis of forestry related work costs is necessary including those based on the care of tree stands. The data mining analysis presented in this study (as a process of discovering information in data sets) allows the identification of factors influencing the level, structure and variability of the costs for the tending oak stands. Based on the analysis performed, it was found that both the types of silviculture treatments performed and the habitat type of the forest in which the trees grow influenced the costs of their implementation.

The initial period of stand development is very costly. Based on the research conducted, it can be concluded that the cost of activities related to the care of oak crops oscillated between the costs of cleaning and the costs of thinning. The analysis conducted indicated that the cost of oak crop care ranged from PLN 700/ha in the LMw habitat to PLN 1,147/ha in Lw (an average of PLN 942/ha). Similar values of tending costs in forest crops (tree stands with different shares of oak) were shown by research conducted by Ankudo *et al*. (2021). The average cost of these treatments for LMśw habitats was PLN 702/ha and in the case of Lśw PLN 713/ha.

After analysing the data contained in the study, it was observed that subsequent silvicultural treatments differed in terms of their costs. The cost of early cleaning ranges from PLN 715/ha for LMśw to PLN 843/ha for LMw (average PLN 788/ha). Later cleanings turned out to be slightly cheaper the cost of which ranged from PLN 655/ha for Lw to PLN 790/ha for LMśw (average PLN 732/ha). The most cost intensive activities were early thinnings ranging from PLN 665/ha for LMw to PLN 1,413/ha for LMśw (average PLN 991/ha) as well as late thinnings ranging from PLN 492/ha for LMw to PLN 1,828/ha for LMśw (average PLN 1,308/ha). A similar trend of increasing silviculture treatment costs with increasing age of stands can be observed in other studies (Molińska-Glura and Glura, 2021). For comparison, for example, in the LMśw habitat, the cost of the CW treatment was PLN 394/ha, for CP was PLN 506/ha, TWP was PLN 928/ha, and for TPP was PLN 1,144/ha. However, for the Lśw habitat the cost of the CW treatment was PLN 366/ha, PLN 530/ha for CP, PLN 663/ha for TWP, and PLN 1,237/ha for TPP. The aforementioned differences in the costs of tending tree stands may result not only from different species composition, age or habitat conditions, but also from the production purpose.

In turn, Loginov (2012) examined the economic effect of tending oak stands based on the species composition. According to this study, the highest total income from thinning was obtained in oak monoculture stands, followed by oak-larch, oak-linden and oak-spruce stands. The highest total income from felled trees was obtained in the oak-larch stand, the oak-spruce model and the group-planted oak with spruce.

An additional negative economic factor in the cultivation of stands containing oak is its susceptibility to dieback. High oak mortality can have serious consequences in regenerating mixed stands. The costs of subsequent silviculture procedures may often exceed the value of the harvested wood especially in less productive and dry areas where oak dieback is concentrated (O'Brien *et al*., 2002). This has been confirmed by the research of Mölder *et al*. (2019) which showed that to ensure long-term ecological continuity in oak forests oak regeneration should preferably take place in close proximity to old oak stands or directly in them. Also, Rousseau (2008) and Gonçalves and Fidalgo Fonseca (2023) found that the most economical option in oak stands is natural regeneration. Another factor that increases the cost of oak farming is strong game pressure. Preventative protection of large areas of crops and young forests against animals is very expensive and not fully effective, unfortunately, when the density of deer is high.

The method of cost management by forest management companies has a decisive impact on the efficiency of forest management. Each tree stand has specific characteristics and requires individualized treatments. Proper control of forest management costs can significantly increase the economic effect of establishing future forest stands. The results of the analysis of the individual silviculture treatment costs presented in this study can serve as an economic basis for considering a potential change in the way forest stands are managed in a specific area in order to better adapt the forest in both ecological and economic terms. The perpetual problem of the forest manager is how to reconcile the unknown expectations of future generations, the applicable (but also variable) principles of forest management, the need to adapt to climate change and, moreover, the protection of species and natural habitats.

Conclusions

- Reducing the expenditure on tending oak stands can be achieved through greater use of natural regeneration processes occurring in forests.
- Taking into account the changing economic conditions of forestry, it is necessary to look for more cost effective solutions for the tending of tree stands.
- Economic factors can be improved by silvicultural treatments in multi-spacies stands by introducing appropriate share of oaks in the species composition and an individualized approach stand management.
- Economic calculations should be taken into account when producing oak stands which may consequently lead to an increase in the efficiency of managing deciduous forests.

Authors' contributions

J.G. – conceptualized the article, performed the data analysis and drafted the article; M.Ch. – provided the raw data.

Conflicts of interest

The authors declare no conflict of interest.

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References

Andrzejczyk, T., 2009. Dąb szypułkowy i bezszypułkowy. Hodowla. Warszawa: PWRiL, 301 pp.

Andrzejczyk, T., 2014. Pielęgnowanie lasu – aspekty przyrodnicze i gospodarcze. (Forest maintenance – natural and economic aspects). In: W. Gil ed. Zimowa Szkoła Leśna przy IBL, VI Sesja „Przyrodnicze, społeczne i gospodarcze uwarunkowana oraz cele i metody hodowli lasu", 18-20 marca 2014 r. Sękocin Stary: Instytut Badawczy Leśnictwa, pp. 349-367.

Andrzejczyk, T., Sewerniak, P., 2016. Gleby i siedliska drzewostanów nasiennych dębu szypułkowego (*Quercus robur*) i dębu bezszypułkowego (*Q. petraea*) w Polsce. [Soils and forest site types of the seed stands of common (*Quercus robur*) and sessile (*Q. petraea*) oaks in Poland]. *Sylwan*, 160 (8): 674-683. DOI: https://doi.org/10.26202/sylwan.2016001.

Ankudo-Jankowska, A., Starosta-Grala, M., Szylin, M., 2021. Wpływ siedliska i wieku uprawy na różnicowanie się kosztów pielęgnowania upraw leśnych w Nadleśnictwie Mieszkowice. (The influence of forest habitat and age of crop on the variation of forest crops tending costs in the Mieszkowice forest district). *Acta Scientiarum Polonorum Silvarum Colendarum Ratio et Industria Lignaria*, 20 (1): 5-14. DOI: https://doi.org/10.17306/J.AFW.2021.1.1.

Bernadzki, E., 2006. Cele hodowlane i ich realizacja w przebudowie drzewostanów. (Silvicultural aims and their realisation in stand conversion). *Sylwan*, 150 (12): 3-11. DOI: https://doi.org/10.26202/sylwan.2006022.

Bishop, C.M., 2006. Pattern recognition and machine learning. Berlin/Heidelberg: Springer, 778 pp.

Bolibok, L., Andrzejczyk, T., Szeligowski, H., Liziniewicz, M., 2021. New methods of oak planting require modification of tending prescriptions under high browsing pressure – A case study from north-eastern Poland. *Forest Ecology and Management*, 497 (5): 119449. DOI: https://doi.org/10.1016/j.foreco.2021.119449.

Chlebowska, M., 2022. Ekonomiczne aspekty cięć pielęgnacyjnych na przykładzie wybranych nadleśnictw Regionalnej Dyrekcji Lasów Państwowych w Poznaniu. (Economic aspects of intermediate cutting on the example of selected ones forest districts in Regional Directorate of State Forests in Poznań). Master's thesis. Poznań: Department of Economics and Forest Technology, Faculty of Forestry and Wood Technology, Poznań University of Life Sciences.

Gonçalves, A.C., Fidalgo Fonseca, T., 2023. Influence management and disturbances on the regeneration of forest stands. *Frontiers in Forests and Global Change*, *Sec. Forest Management*, 6: 1-16. DOI: https://doi.org/10.3389/ffgc.2023.1123215.

Glura, J., Korzeniewicz, R., 2013. Hodowlana i ekonomiczna ocena zakładania upraw sosnowych z wykorzystaniem sadzonek z zakrytym systemem korzeniowym. (Silvicultural and economic evaluation of Scots pine plantations establishment using container-grown and bare-root seedlings). *Sylwan*, 157 (3): 177-186. DOI: https://doi.org/10.26202/sylwan.2011024.

Gołos, P., Kaliszewski, A., 2016. Społeczne i ekonomiczne uwarunkowania realizacji publicznych funkcji lasu w Państwowym Gospodarstwie Leśnym Lasy Państwowe. (Social and economic conditions for providing public forest services in the State Forests National Forest Holding). *Sylwan*, 160 (2): 91-99. DOI: https://doi.org/10.26202/sylwan.2015084.

Kaliszewski, A., 2017. Analiza kosztów sztucznego i naturalnego odnowienia dębu w wybranych nadleśnictwach. (Cost analysis of artificial and natural oak regeneration in selected forest districts). *Forest Research Papers*, 78 (4): 315-321. DOI: https://doi.org/10.1515/frp-2017-0035.

Loginov, D., 2012. Oak in mixtures and monocultures – results from the Snogeholm study area in southern Sweden. Master's Thesis. Alnarp: Southern Swedish Forest Research Centre. Available from: https://stud.epsilon.slu.se/3971/1/Loginov_D_120314.pdf [accessed: 01.09.2023].

Mandziuk, A., Fornal-Pieniak, B., Ollik, M., 2021. The willingness of inhabitants in medium-sized city and the city's surroundings settlements to pay for recreation in urban forests in Poland. *iForest – Biogeosciences and Forestry*, 14 (5): 483-489. DOI: https://doi.org/10.3832/ifor3758-014.

Mölder, A., Sennhenn-Reulen, H., Fischer, Ch., Rumpf, H., Schönfelder, E., Stockmann, J., Nagel, R.V., 2019. Success factors for high-quality oak forest (*Quercus robur, Q. petraea*) regeneration. *Forest Ecosystems*, 6: 49. DOI: https://doi.org/10.1186/s40663-019-0206-y.

Molińska-Glura, M., Glura, J., 2021. Analiza kosztów prac hodowlanych w wybranych nadleśnictwach. (Cost analysis of breeding in selected forest divisions). *Acta Scientiarum Polonorum Silvarum Colendarum Ratio et Industria Lignaria*, 20 (4): 217-223. DOI: https://doi.org/10.17306/J.AFW.2021.4.21.

Novianti, P., Setyorini, D., Rafflesia, U., 2017. K – Means cluster analysis in earthquake epicenter clustering. *International Journal of Advances in Intelligent Informatics*, 3 (2): 81-89. DOI: https://doi.org/10.26555/ijain.v3i2.100.

Oesten, G., 2014. Wartość lasu poza przychodami i kosztami. O ograniczeniach oceny ekonomicznej we wspieraniu decyzji hodowlanych. (The value of the forest beyond revenues and costs. By limiting the economic assessment, we support the decision to treat tree stand diagnosis and maintenance nutrition). In: W. Gil ed. Zimowa Szkoła Leśna przy IBL, VI Sesja „Przyrodnicze, społeczne i gospodarcze uwarunkowana oraz cele i metody hodowli lasu", 18-20 marca 2014 r. Sękocin Stary: Instytut Badawczy Leśnictwa, pp. 380-393.

O'Brien, J.G., Mielke, M.E., Oak, S., 2002. Sudden oak death. Pest Alert Publication NA-PR-02-02. Newton Square: U.S. Department of Agriculture, Forest Service, State and Private Forestry, Northeastern Area. Available from: https://www.invasive.org/publications/usfs/SODE.html [accessed: 01.09.2023].

Polowy, K., Molińska-Glura, M., 2023. Data mining in the analysis of tree harvester performance based on automatically collected data. *Forests*, 14 (1): 165. DOI: https://doi.org/10.3390/f14010165.

Rousseau, R.J., 2008. Twenty-year-old results from a bottomland oak species comparison trial in western Kentucky. Proceedings 16th Central Hardwood Forest Conference. NRS-P-24, pp. 223-232. Available from: https://www.fs.usda.gov/research/treesearch/14017 [accessed: 01.09.2023].

TIBCO Software Inc., 2017. Statistica (data analysis software system), version 13. Available from: http://statistica.io.

Schelhaas, M.J., Nabuurs, G.J., Hengeveld, G., Reyer, C., Hanewinkel, M., Zimmermann, N.E., Cullmann, D., 2015. Alternative forest management strategies to account for climate change-induced productivity and species suitability changes in Europe. *Regional Environmental Change*, 15: 1581-1594. DOI: https://doi.org/10.1007/s10113-015-0788-z.

Zając, S., Kaliszewski, A., 2014. Ekonomiczne aspekty ekologizacji zagospodarowania lasu. (Economic aspects of greening forest management). In: W. Gil ed. Zimowa Szkoła Leśna przy IBL ,VI Sesja „Przyrodnicze, społeczne i gospodarcze uwarunkowana oraz cele i metody hodowli lasu", 18-20 marca 2014 r. Sękocin Stary: Instytut Badawczy Leśnictwa, pp. 195-209.

Zerbe, S., 2002. Restoration of natural broad-leaved woodland in Central Europe on sites with coniferous forest plantations. *Forest Ecology and Management*, 167 (1-3): 27-42. DOI: https://doi.org/10.1016/S0378-1127(01)00686-7.

STRESZCZENIE

Ekonomiczne aspekty zabiegów pielęgnacyjnych w drzewostanach dębowych

W lasach Polski, podobnie jak innych krajów europejskich, prowadzona jest obecnie na szeroką skalę przebudowa drzewostanów, która ma na celu dostosowanie składu gatunkowego do warunków siedliskowych. W jej wyniku wzrasta udział i rola gatunków liściastych, w tym zwłaszcza dębu szypułkowego i dębu bezszypułkowego. Zwiększenie udziału gatunków liściastych w składzie gatunkowym drzewostanów generuje ekonomiczne konsekwencje (zwiększanie kosztów produkcji drzewostanów liściastych bądź mieszanych z przewagą gatunków liściastych), a jednocześnie może powodować zmniejszenie przychodów z ich hodowli. Do efektywnego zarządzania gospodarką leśną niezbędna jest zatem systematyczna analiza kosztów wykonywanych prac gospodarczo-leśnych, w tym związanych z pielęgnacją drzewostanów. Celem pracy była ekonomiczna analiza kosztów zabiegów pielęgnacyjnych w drzewostanach dębowych. Podstawowy materiał do badań uzyskano z 4 nadleśnictw należących do Regionalnej Dyrekcji Lasów Państwowych w Poznaniu: Jarocin, Krotoszyn, Piaski oraz Taczanów. Analiza ekonomiczna dotyczyła tylko drzewostanów, w których udział dębu w składzie gatunkowym wyniósł powyżej 60%. Łącznie do badań wykorzystano dane z 1644 zabiegów pielęgnacyjnych przeprowadzonych w latach 2015-2019. W badaniach analizowano 5 rodzajów zabiegów pielęgnacyjnych (grup czynności), które występowały we wszystkich badanych jednostkach: pielęgnowanie upraw, czyszczenie wczesne, czyszczenie

późne, trzebież wczesną pozytywną oraz trzebież późną pozytywną. W celu wykazania istotnych różnic średnich wartości kosztów jednostkowych w zależności od grupy czynności zastosowano test analizy wariancji w klasyfikacji pojedynczej. Ponadto dla pełniejszej interpretacji danych oraz połączenia badanych elementów w podobne grupy zastosowano analizę skupień, gdzie każdy z 5 rozważanych zabiegów hodowlanych został scharakteryzowany przez wektor średnich kosztów dla poszczególnych siedlisk i odwrotnie.

Po analizie danych i przeprowadzeniu testu istotności stwierdzono istotny wpływ grupy czynności na koszt jednostkowy wykonanych zabiegów (p<0,000). Na podstawie danych z ryciny 1 można odczytać rozkład średnich oczekiwanych wartości dla poszczególnych czynności hodowli lasu oraz 95-procentowy przedział ufności. W tabeli 1 przedstawiono podział tych zabiegów ze względu na grupy jednorodne, zgodnie z przeprowadzonym po analizie wariancji testem HSD Tukeya. Zastosowana w pracy analiza skupień oparta o metrykę euklidesową umożliwiła znalezienie podobieństwa w całościowej wieloczynnościowej strukturze kosztów jednostkowych przypisanych dla poszczególnych siedlisk. Na tej podstawie wykazano, jak poszczególne siedliska podobne są do siebie w całej strukturze ponoszonych kosztów dla 5 wyróżnionych grup czynności (ryc. 2). Za pomocą analizy skupień wskazano ponadto, jakie struktury kosztów poszczególnych zabiegów były do siebie zbliżone (ryc. 3). Dodatkowo w analizie badawczej została zastosowana macierz niepodobieństwa pomiędzy badanymi czynnikami w celu przeanalizowania interakcji pomiędzy grupą czynności a typem siedliskowym lasu. Zaprezentowana mapa ciepła to wizualizacja tej macierzy, gdzie niepodobieństwo wyrażone jest kolorem. Uporządkowanie mapy według niepodobieństwa pozwoliło wykryć struktury i zależności w danych kosztowych. Na podstawie mapy ciepła ustalono, że średnie koszty zabiegu hodowlanego dla trzebieży późnej (TPP) wykonywane na siedlisku LMśw odbiegały znacznie od wszystkich pozostałych czynności i wykazały najwyższą wartość. Grupę kosztów podobnych stanowią kombinacje siedliska Lw dla czynności TPP i TWP oraz Lśw dla czynności TWP i PIEL. Natomiast siedliska LMśw i Lśw charakteryzują się tymi samymi kosztami dla zbiegów hodowlanych CW i CP. Najtańszy i różny od pozostałych jest zabieg TPP dla siedliska LMw (ryc. 4).

Przedstawiona w pracy analiza *data mining*, jako proces odkrywania informacji w zbiorach danych, pozwala na identyfikację czynników wpływających na poziom, strukturę oraz zmienność kosztów pielęgnacji drzewostanów, w tym przypadku dębowych. Poszukiwanie informacji o kosztach i przychodach umożliwia wykonywanie rachunku ekonomicznego przy produkcji drzewostanów dębowych na pniu, co w konsekwencji może prowadzić do podniesienia efektywności gospodarowania lasami liściastymi. W miarę możliwości należy zmniejszać nakłady na pielęgnowanie drzewostanów dębowych poprzez szersze wykorzystanie naturalnych procesów zachodzących w lasach.