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ORIGINAL PAPER

The cost of carrying out protection activities by private forestry companies on behalf of the State Forests

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ABSTRACT

The aim of the study was to analyse the costs of forestry activities contracted out to private forestry companies by the organisational units of the State Forests in Poland from 2006-2012 as more recent national data was not available. The costs of forest protection activities (including predicting the occurrence of pests such as insects, fungi and nematodes, as well as protection from insects, fungi, nematodes and animal browsing), the costs of nature conservation and biodiversity protection, and the costs of forest fire protection measures were examined. Data was extracted from the State Forests Information System using SQL for each forest district and then aggregated and analysed for each regional directorate of the State Forests. The analysis showed that the largest share of costs was for protecting the forest from animal browsing which accounted for 63.1% of all costs in this area on average and varied between 57.1% and 69.1% in individual years of the study period. The second most important group of measures was the reduction of the occurrence of insect pests, the total cost accounting for 14.7% of the total financial expenditures during the entire study period and varying between 8.9% and 21.0% in individual years. A smaller share of costs accounted for other forest protection measures and maintenance of forest protection machinery and equipment (10.2% on average), while the costs of biodiversity protection and nature conservation were even lower (3.6% and 3.2%, respectively). Costs of predicting the occurrence of pests (collection of biological material) were 3.0% of the total costs. The percentage of costs for protection from fungi and nematodes was 2.1%. The lowest percentage was for protection from rodents (0.2% on average). We found that the cost of implementing forest protection and forest fire protection carried out by private forestry companies in individual regional directorates of the State Forests from 2006-2012 varied greatly amongst years and regions of the country. We concluded that, given the lack of studies on the economic performance of forestry service enterprises, it is advisable to conduct further research to identify the factors that influence the level and differentiation of costs for activities contracted out by the State Forests to these companies at the local level as well as their variability over time.

KEY WORDS

fire protection, forest economics, forest protection, forestry companies, labour costs

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Introduction

Changes in the Polish economy initiated at the beginning of the 1990s, which consisted of the transition from the principles of a command and control economy to the rules of a market economy, led to profound changes in the forestry sector. One of these changes was the establishment of a private sector for forestry services (Nasiłkowski, 1995; Zastocki, 2019). Unlike other post-socialist countries, private contractors had a small but noticeable share in Polish forestry during the socialist economy period (1945-1989) although there is no complete and reliable data for the entire period. For example, the share of contractors from outside the State Forests National Forest Holding (hereinafter referred to as the State Forests) in timber skidding between 1965 and 1972 was 50-60%, however, in afforestation and forest regeneration, as well as in silviculture and forest protection, this proportion was much lower (Kocel, 2013). Intensive changes in forestry services began in 1990, when forestry services for state forests were privatized in several forestry districts of the State Forests. This triggered the process of establishing private forestry service companies with the newly established companies contracted to perform almost all forestry activities, with the exception of forest nursery work. Privatization of activities related to forest management allowed forest districts to reduce employment of labourers and, consequently, employees, which was important for improving the financial situation of forest districts and the State Forests as a whole (Kocel, 2005, 2013).

The process of privatization of forestry activities by forest districts varied greatly in different regions of the country and was subject to numerous general and local conditions and constraints. The basic indicator in the development of the process was the degree of privatization of activities, which represented the percentage of private economic entities implementing basic tasks of forest management in quantitative terms. For example, the privatization percentage of afforestation and forest regeneration activities increased from 26.8% in 1992 to 79.9% in 1996 and 99.3% in 2006, while the privatization percentage of silvicultural activities increased from 23.2% in 1992 to 75.9% in 1996 and 97.4% in 2006. On the other hand, timber skidding, which was already characterized by a high degree of privatization (50.4%) in 1992, increased to 79.8% in 1996 and 97.0% in 2006 (Kocel, 2013).

Privatization of forestry operations led to significant changes in the State Forests. Employment in the State Forests, the largest forest manager in Poland (managing a forest area of 7,115 thousand hectares or 76.9% of all forests), decreased employment in blue-collar positions from 81.3 thousand people in 1989 to 2.8 thousand people in 2010 and 1.9 thousand people in 2020, and in total employment from 116.5 thousand people in 1989 to 24.7 thousand people in 2010 and with a small increase to 25.9 thousand in 2020 (Sprawozdanie, 1993, 2011, 2021). Restructuring of employment and assets enabled the improvement of economic results and economic impacts of the State Forests (Kocel, 2000). As a result, the private forestry services sector emerged. The enterprises operating in this sector can be characterized as follows (Kocel, 2013):

- Established as enterprises out of the need to create jobs for private operators and their families, and operate as microenterprises.
- The owners are also managers who combine the dual function of making decisions and managing the activities of the company.
- Operate mainly in the local market of one or two forest districts. To ensure their success they are in direct and frequent contact with the forest administration, therefore, they are not anonymous.
- Provide their services according to the conditions set by the forest districts and try to work efficiently with the technical and human resources at their disposal.

– The owners of the forest enterprises and their employees come from small rural areas, which can be explained by the close business and private contacts in their enterprises.
– The enterprises practically do not use the available credit markets with the most common form of financing being the savings of the enterprise owner and their immediate family, as well as loans from relatives and friends (Kocel, 2013).

The private forestry service sector is required to perform the tasks entrusted by the State Forests in accordance with the applicable management regulations while taking into account modern and environmentally friendly technologies (Zastocki, 2019). The 1991 Law on Forests (Ustawa, 1991) lists the protection of forests, especially forests and forest ecosystems that are natural fragments of native nature or forests that are particularly valuable for the conservation of natural diversity including the conservation of forest genetic resources, as one of the main objectives of sustainable forest management, landscape value and the scientific requirements (Article 7.1.2). Since the 1990s the implementation of many activities related to broadly understood forest protection and biodiversity conservation in the State Forests has been assigned to private subcontractors referred to as forestry service companies (zakłady usług leśnych, ZUL). Analysis of the costs of forestry activities subcontracted to ZUL has not been the subject of comprehensive research.

Forest protection is an important, but not the most significant, cost category of the State Forests. In 2020, forest protection expenditures accounted for about 3.9% of total operating costs with both protection from animal browsing (46% of all forest protection costs) and fire protection (29%) accounting for the largest share (Sprawozdanie, 2021). The proportion of each cost category has remained at a steady level in recent years.

The studies carried out so far on the activities of ZUL were concerned with determining the state and direction of developments in this sector in Poland (Kocel, 1993a, b, 1994, 1995, 1996a, 2002a, 2005). Some studies also included economic aspects mainly related to the rationalization of operating costs of these private companies (Kocel, 1996b, 2000, 2002b, 2011). The evaluation of the activities of ZUL in forest dieback conditions in the Beskidy Mountains were studied by Sikora *et al.* (2016) and by Sikora *et al.* (2017). On the other hand, the work of Zastocki and Kaliszewski (2021) presented an analysis of the costs of performing silvicultural activities contracted by the State Forests to private forestry companies. However, no comprehensive study of the costs of performing activities by ZUL in the field of forest protection in the State Forests throughout the country has been conducted so far. This paper partially fills this gap.

Numerous authors have studied the costs and economic efficiency of forest protection and nature conservation in the State Forests focusing mainly on local objects or individual actions. For example, the work of Jabłoński (2003), who performed economic optimization of forest pest control treatments, should be mentioned here. Also, Sierota and Małecka (2004) compared the costs of a modified method of forest protection against the rootworm against the traditional method. Studies in in this area were also carried out by Rykowski *et al.* (2015) and Sikora and Ukalska (2014). On the other hand, Konieczny and Sikora (2019a, b) presented a comprehensive assessment of the economic efficiency of forest management in the Białowieża Forest Promotional Complex. An evaluation of the economic effectiveness of protection from animal browsing is also analysed by Sikora and Kaliszewski (2021), Ferens *et al.* (2021) and Balik *et al.* (2016).

More extensive research has been conducted with respect to the costs of forest conservation. Młynarski and Kaliszewski (2013) analysed the economic consequences of nature conservation in state, private and communal forests in the Mazowieckie voivodeship, and in two other papers

evaluated the opportunity costs of establishing nature reserves and bird sanctuaries in selected forest districts (Kaliszewski and Młynarski, 2014, 2015). The costs of nature conservation in the Forest Promotional Complexes were also studied by Janeczko (2004) and Janeczko and Parzych (2007). The opportunity costs of nature conservation in the Dukla Forest District were analysed by Kożuch *et al.* (2017). Piszczek (2007) calculated the unexpected costs of conservation in forests due to natural disasters such as fires and hurricanes. However, their work did not directly address the costs of carrying out protection activities by ZUL.

Studies on ZUL in other Central and Eastern European countries are rare. There are some studies from Slovakia, such as the work of Kovalčík (2020), which deals with an analysis of the forestry sector in Slovakia with an evaluation of profitability and efficiency of forestry entrepreneurs with a special focus on mountain and lowland regions using data envelopment analysis (DEA). In another study, the authors analysed the structure of revenues and costs in individual companies providing forestry services in Slovakia and identified types of contractor companies in the Slovak forestry services sector in terms of the size of the companies and their business strategy to achieve their objectives (Štěrbová and Kovalčík, 2020). Additionally, Šálka *et al.* (2006) analysed the impact of ownership transformation on innovation and entrepreneurship in the Slovak forestry sector. However, all of the aforementioned studies deal with different aspects of ZUL than those discussed in this paper.

The objective of the study was to analyse the costs of activities in the area of broadly defined forest protection from 2006-2012 which were contracted out to ZUL by the forest districts of the State Forests. Specifically, the study examined the costs related to the following: predicting the occurrence of pests (insects, fungi and nematodes), protection from insect pests, fungi and nematodes, nature conservation and biodiversity protection, protection from animal browsing and rodents, and forest fire protection. The study also aimed to show the differentiation of forest protection costs over the entire area of the State Forests.

Material and methods

Forest districts organize annual tenders in accordance with the applicable public procurement regulations for the performance of forest management activities and divide them into so-called packages. These may be specific to a type of forest management activity (*e.g.*, protection of the forest from insects or from forest fires) or include all activities performed in one or more forest sub-districts. The scope of activities proposed in the request for proposal (RFP) included in the package results from the specific forestry requirements in a particular forest district.

For the study, information was used on the cost of activities performed by ZUL for the State Forests, recorded in the forest accounting system according to adopted and adjusted categories including the following: a) forest protection (including predicting the occurrence of pests, protection from insects, fungi and nematodes, protection from animal browsing, nature conservation, and biodiversity protection) and b) forest fire protection. The data was extracted from the State Forests Information System (SILP) using SQL (Structured Query Language) for each forest district and then aggregated and analysed for each regional directorate of the State Forests (RDLP). In each of the aforementioned accounts, the place of origin of costs (mpk) was recorded which has a significant impact on the accurate analysis of the accounts and the information they record on the scope of activities carried out by ZUL. In this way, it was possible to distinguish, in the forest protection area, the costs associated with predicting the occurrence of pests, reducing the occurrence of insect and fungal pests, controlling nematodes, biodiversity protection and nature

conservation (such as nature reserves and other legally protected areas and habitats of plants, animals and fungi), protection from animal browsing and rodents, and other forest protection activities. On the other hand, the category associated with forest fire protection shows the costs of activities required to protect forest areas from fires, for the maintenance of a fire detection system, for rescue related measures, and for other forest fire protection activities. The collection of data for the period after 2012 turned out to be impossible due to the restrictive internal policy of the State Forests and making economic data available to external parties. Since it was difficult to assign the values obtained to specific forest areas covered by specific treatments and measures (many costs are not assigned to a specific forest sub-compartment or compartment and are not expressed in units of area), the data was presented in the form of aggregate values for individual activities and not calculated as averages per unit area.

Results

The costs of implementing forest protection and forest fire protection carried out by ZUL in each regional directorate of the State Forests during the period 2006-2012 are presented in Table 1 and Table 2.

The cost of forest protection measures implemented by ZUL nationwide during the years studied varied, ranging from PLN 128.7 million in 2006 to PLN 239.3 million in 2012 (Table 1). The lowest total costs incurred in almost all years were in the RDLP Warszawa, except for 2008 when the lowest costs were recorded in the RDLP Łódź. The highest costs were recorded annually in the RDLP Katowice.

The total cost of forest fire protection nationwide ranged from PLN 60.3 million in 2009 to PLN 74.6 million in 2012. The highest costs were incurred in the RDLP Szczecin from 2006-2011 and in the RDLP Katowice in 2012, and the lowest every year in the RDLP Kraków (Table 2).

Table 1.

Costs of forest protection measures carried out by private forestry companies (ZUL) in individual regional directorates of the State Forests (RDLP) from 2006-2012 (thousand PLN)

Year RDLP	2006	2007	2008	2009	2010	2011	2012
Białystok	11 456.9	13 230.1	14 631.1	8 232.8	10 221.6	14 111.1	18 417.2
Gdańsk	5 338.4	7 494.4	7 718.3	4 121.0	6 085.3	8 979.2	9 104.8
Katowice	15 538.1	21 382.0	25 135.7	20 898.4	20 129.8	26 756.2	28 105.9
Kraków	3 599.1	3 911.1	4 457.9	3 740.8	4 195.2	5 569.3	6 111.1
Krosno	5 545.4	6 560.6	7 854.5	7 137.0	8 560.8	10 471.9	12 756.4
Lublin	5 345.3	5 792.8	7 308.5	3 354.4	4 344.9	10 057.2	8 856.9
Łódź	3 259.7	6 021.8	4 356.5	3 543.8	3 808.8	8 185.7	7 292.2
Olsztyn	9 730.4	10 768.8	11 415.1	7 345.9	8 774.7	11 623.7	13 616.6
Piła	5 535.2	6 136.0	7 183.3	4 272.6	5 170.9	6 840.5	10 281.0
Poznań	6 106.8	6 979.9	7 706.3	7 089.3	9 004.6	11 585.8	14 701.0
Radom	3 828.9	5 132.6	5 986.9	3 851.2	4 236.2	9 991.5	10 210.9
Szczecin	13 086.1	15 280.8	18 124.8	12 864.8	18 810.6	18 147.0	19 610.1
Szczecinek	11 192.9	13 314.8	13 171.7	12 413.1	13 610.9	16 776.6	21 874.7
Toruń	8 358.6	9 213.7	11 864.9	9 467.5	12 396.9	21 899.9	18 955.5
Warszawa	2 914.1	3 405.8	5 434.2	2 942.9	2 802.2	4 733.3	4 745.7
Wrocław	11 224.4	15 113.5	22 137.9	14 643.5	16 923.3	19 785.8	23 620.5
Zielona Góra	6 624.1	9 398.2	10 447.5	8 183.9	8 498.2	10 143.3	11 061.7
Total	128 684.3	159 136.9	184 935.1	134 103.0	157 574.7	215 657.8	239 322.3

Table 2.

Costs of forest fire protection measures carried out by private forestry companies (ZUL) in individual regional directorates of the State Forests (RDLP) from 2006-2012 (thousand PLN)

Year RDLP	2006	2007	2008	2009	2010	2011	2012
Białystok	3 759.0	3 759.9	3 549.8	3 449.6	3 576.7	4 152.6	4 667.2
Gdańsk	1 560.7	1 630.4	1 916.1	1 618.3	1 703.5	1 756.9	2 016.3
Katowice	6 759.0	7 458.4	7 821.1	7 362.1	7 242.5	8 172.6	9 674.8
Kraków	387.0	416.0	486.7	314.2	237.4	291.8	405.1
Krosno	684.4	870.5	873.6	735.3	617.0	887.3	1 170.3
Lublin	2 045.9	2 419.8	2 366.0	1 857.0	1 867.2	2 349.3	2 658.7
Łódź	1 833.6	2 964.1	2 272.7	2 311.8	2 139.6	2 450.1	2 693.5
Olsztyn	2 944.7	3 124.6	3 285.8	2 828.0	2 955.4	3 523.4	3 839.2
Piła	3 878.0	3 269.3	4 023.5	3 249.7	3 352.2	3 255.0	3 672.4
Poznań	3 566.9	4 245.9	4 161.9	3 104.2	3 434.8	4 291.4	4 228.6
Radom	3 045.0	3 743.7	3 906.9	3 431.1	3 310.6	3 540.0	4 037.3
Szczecin	9 175.2	8 077.3	9 770.0	8 416.6	7 850.5	8 410.8	8 742.0
Szczecinek	3 974.4	4 381.1	3 938.3	4 062.9	4 825.8	4 969.0	4 647.1
Toruń	4 797.2	5 801.2	7 086.8	4 944.7	5 187.8	4 918.5	6 062.3
Warszawa	3 952.6	3 857.9	4 344.7	3 593.0	3 448.0	3 936.5	4 590.9
Wrocław	3 932.0	3 633.4	4 356.9	4 295.5	3 747.8	4 644.7	4 888.7
Zielona Góra	4 820.4	4 566.0	5 096.3	4 682.2	5 835.5	7 362.6	6 555.2
Total	61 115.9	64 219.8	69 257.0	60 256.0	61 332.3	68 912.3	74 549.7

The share of cost of each activity class for the total costs of forest protection and forest fire protection activities of ZUL are presented in Tables 3 and 4, respectively. The data analysis on the total cost of forest protection activities in the State Forests for each group of measures showed that the highest share of costs was for the protection of the forest from animal browsing which reached an average of 63.1% of total costs in this area and ranged from 57.1 to 69.1% in individual years. The second most important group of measures was the reduction of the occurrence of insect pests with the total costs accounting for 14.7% of the financial expenditures in the entire study period and varying from 8.9% to 21.0% in individual years.

The costs of other forest protection measures and maintenance of forest protection machinery and equipment had a lower share of total costs (on average 10.2% and between 8.0% and 13.7% in individual years). Significantly lower were costs for biodiversity protection (3.6% on average, ranging from 2.9% to 5.3% in individual years), as were costs for nature conservation (3.2% on average, ranging from 2.3% to 4.0% in individual years), costs of predicting the occurrence of pests such as collection of biological material (3.0% on average, from 2.3% to 3.9% in individual years), and costs of protection from fungi and nematodes (2.1% on average, from 1.4% to 3.3% in individual years). The lowest share of forest protection costs were from rodents (0.2% on average, ranging from 0.1% to 0.4% in individual years).

In the measures related to forest fire protection, the highest costs were incurred in the category of other costs. The share of this category was quite stable in each year, ranging from 44.8% in 2009 to 51.8% in 2012. The share of costs for the operation, maintenance and upkeep of the fire detection network and firefighting equipment was also stable, ranging from 21.7% in 2006 to 27.5% in 2008. The share of costs for emergency measures was significantly lower than the aforementioned ones, ranging from 5.1% in 2006 to 27.7% in 2009 and exceeding 20% for the entire 2007-2012 period. The cost of forest fire protection activities, including aerial patrols and

Table 3.

Share of costs of individual activity categories of the total costs of forest protection measures carried out by private forestry companies (ZUL) in the period 2006-2012 [%]

Year Activities	2006	2007	2008	2009	2010	2011	2012
Predicting the occurrence of pests	3.91	3.17	3.10	3.78	3.01	2.61	2.26
Protection from insect pests	15.48	20.96	18.87	11.90	8.89	14.03	12.94
Controlling fungi and nematodes	3.31	2.72	2.65	2.06	1.65	1.36	1.50
Biodiversity protection	5.26	4.04	3.61	3.47	3.77	3.02	2.89
Protection from animal browsing	60.77	57.74	60.72	67.17	69.07	63.85	62.65
Protection from rodents	0.38	0.24	0.16	0.14	0.18	0.24	0.14
Other protection measures	8.43	8.80	8.26	8.02	10.68	10.90	13.68
Nature conservation	2.46	2.31	2.63	3.46	2.76	3.99	3.93
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 4.

Share of costs of individual activity categories of the total costs of forest fire protection measures carried out by private forestry companies (ZUL) in the period 2006-2012 [%]

Year Activities	2006	2007	2008	2009	2010	2011	2012
Fire protection measures	25.16	5.49	3.35	4.35	3.39	3.30	3.30
Costs of other fire protection measures	47.98	46.75	45.46	44.80	45.75	49.25	51.83
Emergency measures	5.14	21.18	23.68	27.67	26.21	21.67	21.27
Operation and maintenance of monitoring equipment for rapid detection of fires; maintenance of technical equipment for firefighting	21.72	26.58	27.51	23.18	24.65	25.78	23.60
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

runway maintenance, also varied widely between years (from 3.3% to 25.2%) but was below 5.5% for the entire 2007-2012 period.

It was found that in the forest protection category the lowest total costs were incurred in the RDLP Warszawa with a total of PLN 29.9 million, *i.e.* 2.2% of all costs within the study period. The highest costs were incurred in the RDLP Katowice for the total sum of PLN 157.9 million (13.0% of all costs) within the study period.

The highest costs in the category of forest protection were incurred for protection from animal browsing which include the application of mechanical and chemical methods or fencing in newly established stands. In the State Forests as a whole, expenditures for protection from animal browsing increased from PLN 78.21 million to PLN 112.29 million from 2006 and 2008, decreasing to PLN 90.07 million the following year, and then increasing to PLN 149.98 million in 2012 (Fig. 1). Regionally the lowest costs in this category were incurred in the RDLP Warszawa and ranged from PLN 0.86 million to PLN 2.27 million. The highest costs were incurred from 2006-2008 and in 2010 in the RDLP Szczecin (ranging from PLN 9.94 million to PLN 14.43 million) and in 2009 in the RDLP Wrocław (PLN 11.40 million). In 2011 and 2012, the highest costs for protection of stands from animal browsing were recorded in the RDLP Katowice (PLN 16.75 million and PLN 17.65 million, respectively).

The costs of protection from insect pests in the State Forests were characterized by large fluctuations from year to year (Fig. 2). From 2006-2008 they increased from PLN 19.92 million

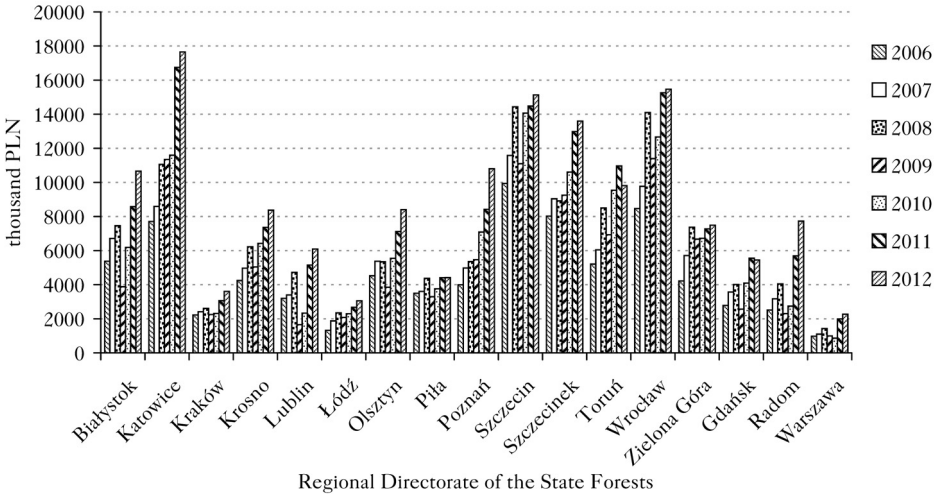

Fig. 1.

Costs of protection from animal browsing by private forestry companies (ZUL) in each Regional Directorate of the State Forests (RDLP) from 2006-2012

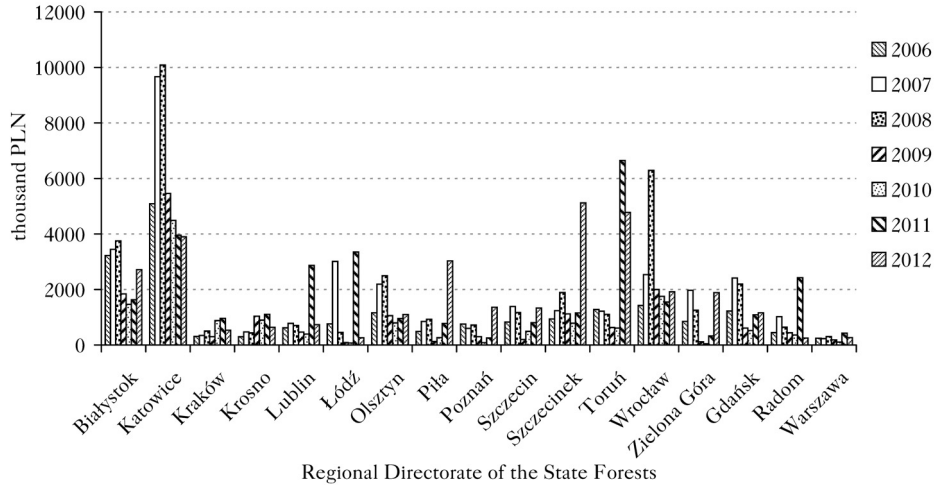

Fig. 2.

Costs of protection from insect pests by private forestry companies (ZUL) in each Regional Directorate of the State Forests (RDLP) from 2006-2012

to PLN 34.90 million and in 2010 they decreased to PLN 14.00 million. However, in 2011 and 2012 there was a drastic increase in costs in this category from PLN 30.26 million to PLN 30.96 million, respectively. From 2006-2008, the lowest costs were recorded in the RDLP Warszawa (from PLN 0.23 million to PLN 0.30 million). In 2009 and 2010, the lowest costs for protection from insect pests were recorded in the RDLPs Łódź and Zielona Góra and amounted to PLN 0.09 million and PLN 0.05 million, respectively. In 2011 and 2012, the lowest costs for pest control amounted to PLN 0.25 million annually in the RDLPs Poznań and Radom. The highest costs were recorded from 2006--2010 in the RDLPs Katowice (from PLN 4.49 million to PLN 10.08 million) and in the following two years in the RDLPs Toruń (PLN 6.65 million and PLN 4.78 million, respectively).

In the biodiversity protection category, which includes feeding birds and creating suitable conditions for the existence of beneficial forest animals, costs fluctuated significantly (Fig. 3). Initially, they increased to PLN 6.67 million in 2008 and decreased to PLN 4.65 million the following year. From 2010 onwards the costs gradually increased, reaching PLN 6.91 million in 2012. The lowest costs in 2007 and 2008 and from 2010-2012 were recorded in the RDLPs Kraków (from PLN 0.13 million to PLN 0.16 million). In 2006, the lowest costs were recorded in the RDLPs Radom (PLN 0.14 million) and in 2009 in the RDLPs Piła (PLN 0.09 million). The highest costs were recorded in 2006 and 2007 in the RDLPs Olsztyn (PLN 1.39 million and PLN 0.68 million, respectively). In turn, in 2008, 2009, 2011 and 2012 the highest costs of performing activities in this category were incurred in the RDLPs Katowice (between PLN 0.69 million and PLN 0.94 million). In 2010, the highest costs of PLN 0.76 million were incurred in the RDLP Lublin.

Nature conservation includes a range of protection related activities in nature reserves and other legally protected areas and habitats as well as the protection of plant, animal and fungal species. It also includes activities related to the maintenance of bird and European bison breeding centres as well as the maintenance of wildlife shelters and demonstration farms. From 2006-2008, the costs of carrying out the aforementioned work increased from PLN 3.16 million to PLN 4.86 million (Fig. 4). In 2009 and 2010, the costs decreased to PLN 4.64 million and PLN 4.34 million, respectively, and in the following two years there was a significant increase to as high as PLN 9.40 million in 2012. A detailed analysis of the conservation expenditures in the RDLPs showed that labour costs in the RDLP Lublin were the lowest for the entire period studied, ranging from PLN 0.7 thousand to PLN 36.8 thousand. Conversely, the highest costs were recorded in 2006, 2007 and 2012 in the RDLP Białystok (between PLN 0.78 million and PLN 2.24 million). In 2008, the highest costs related to nature conservation were recorded in the amount of PLN 1.13 million in the RDLP Warszawa and from 2009-2011 in the RDLP Katowice (PLN 1.02-1.50 million).

Predicting the occurrence of pests related to forest protection includes monitoring insect occurrence using pheromone traps, control and sub-canopy plots and sample trees as well as searching for pest larvae and soil infestations, and monitoring for fungal and nematode occurrence.

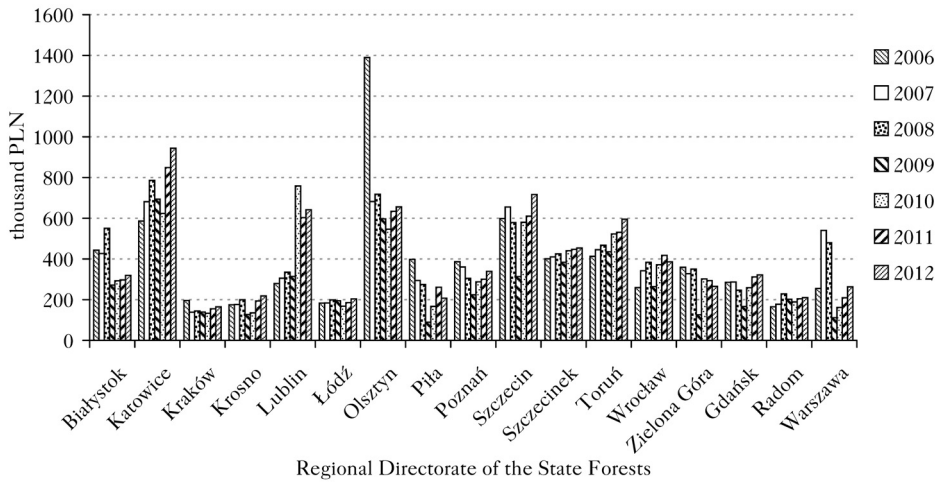

Fig. 3.

Costs of biodiversity protection by private forestry companies (ZUL) in each Regional Directorate of the State Forests (RDLP) from 2006-2012

Expenditures related to these activities in the State Forests varied greatly from region to region and their total annual amount ranged from PLN 4.74 million to PLN 5.73 million in the period studied (Fig. 5). The lowest costs related to predicting the occurrence of pests were recorded in the RDLP Kraków (from PLN 42.8 thousand in 2007 to PLN 68.0 thousand in 2012). Conversely, the highest costs were incurred in 2006 and 2007 in the amounts of PLN 0.49 million and PLN 0.47 million, respectively, in the RDLP Toruń. In turn, from 2008-2012 the highest costs in this category were incurred in the RDLP Katowice and ranged from PLN 0.64 million to PLN 0.73 million.

The analysis showed that from 2006-2008, the costs of activities meant to reduce the occurrence of fungi and control nematodes increased from PLN 4.26 million to PLN 4.91 million. In the

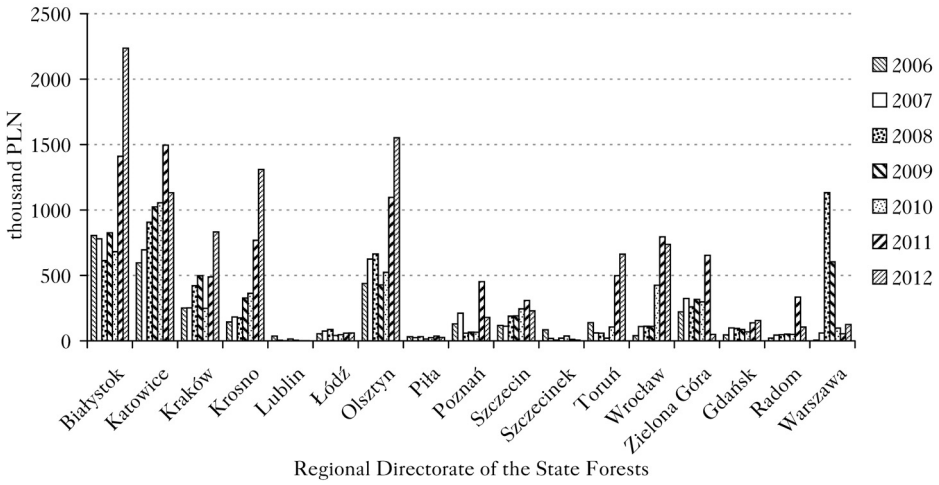

Fig. 4.

Costs of nature conservation by private forestry companies (ZUL) in each Regional Directorate of the State Forests (RDLP) from 2006-2012

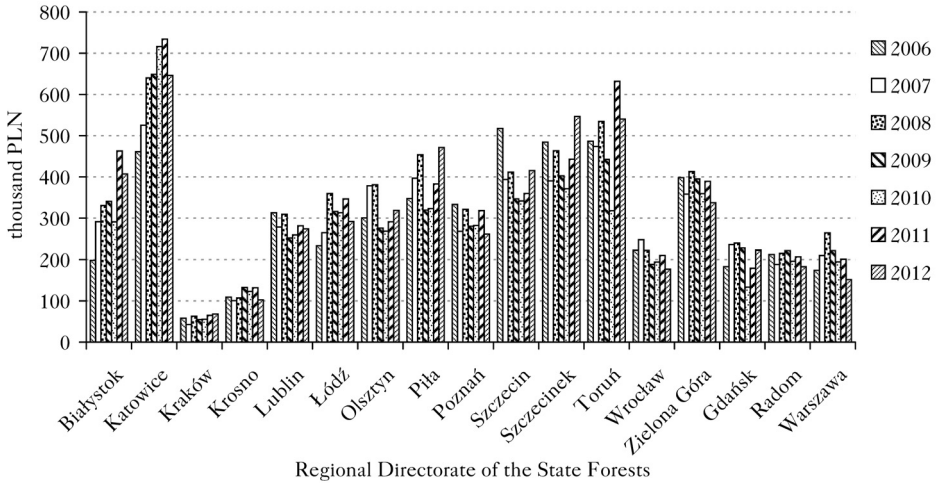

Fig. 5.

Costs of predicting the occurrence of pests by private forestry companies (ZUL) in each Regional Directorate of the State Forests (RDLP) from 2006-2012

following two years they decreased, with costs of PLN 2.60 million in 2010 and then increasing to PLN 35.89 million in 2012 (Fig. 6). In individual RDLPs costs in this category varied significantly with the lowest ranging from PLN 2.8 to 21.1 thousand in the RDLP Kraków and the highest ranging from PLN 0.71 to 1.12 million in the RDLP Szczecinek.

The lowest costs in forest protection were associated with reducing the incidence of rodents damaging tree roots. The results show that the implementation of these treatments by employees of forestry companies from 2006-2012 had costs ranging from PLN 183.4 thousand to PLN 510.1 thousand (Fig. 7). In the RDLP Warszawa no rodent control treatments were carried out, while in the RDLPs Białystok, Kraków and Radom the treatments were carried out once in this same

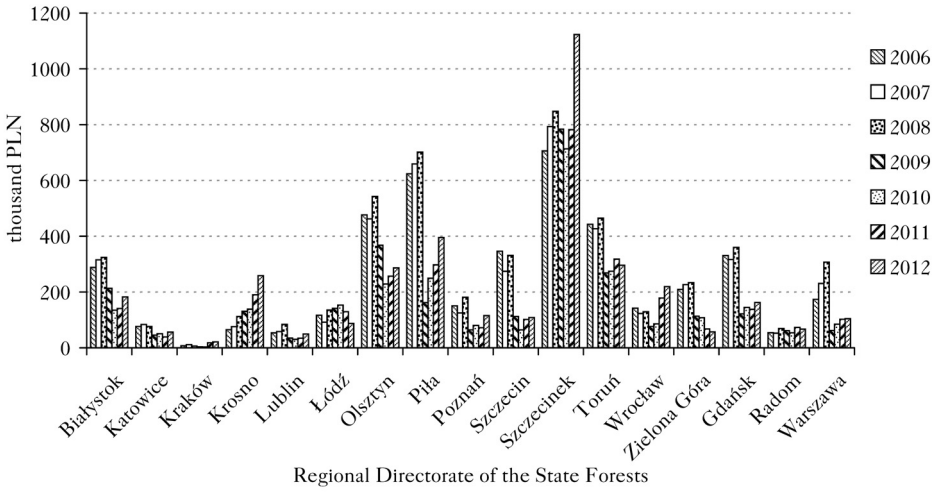

Fig. 6.

Costs of controlling fungi and nematodes by private forestry companies (ZUL) in each Regional Directorate of the State Forests (RDLP) from 2006-2012

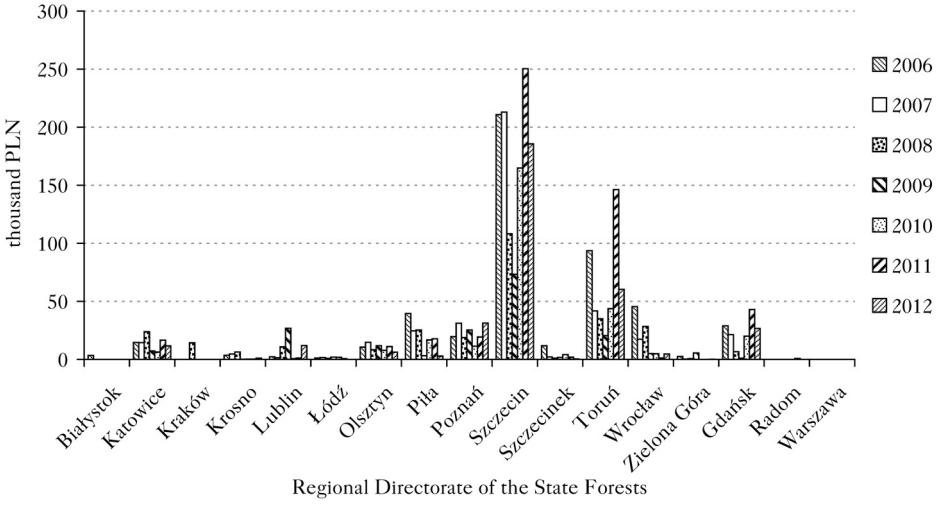

Fig. 7.

Costs of protection from rodents by private forestry companies (ZUL) in each Regional Directorate of the State Forests (RDLP) from 2006-2012

period with costs ranging from PLN 0.8 thousand to PLN 14.2 thousand. In the whole study period, the highest costs were recorded in the RDLP Szczecin (PLN 73.3-250.4 thousand).

A large share of the total costs were recorded in the category of other costs for forest protection which includes various activities such as sanitation services (removal of garbage from forest areas), maintaining machinery and equipment for forest protection, and cleaning up military areas. Analysis of available data shows a slow increase in the costs from 2006-2008 from PLN 10.76 million to PLN 15.28 million, followed by a slight decrease in 2009, and then finally a significant increase to PLN 32.73 million (Fig. 8). The lowest costs in the period from 2006-2011 were in the RDLP Piła (between PLN 0.11 million and PLN 0.66 million) and in 2012 in the RDLP Kraków (PLN 0.89 million). The highest costs were recorded in the RDLP Olsztyn in 2006 (PLN 1.43 million), in the RDLP Wrocław in 2007 and 2012 (PLN 1.97 and 4.71 million, respectively), and in the RDLPs Białystok (PLN 1.60 million) and Szczecin (PLN 2.86 million) in 2008 and 2010. In 2009 and 2011, the highest expenditures were recorded in the RDLP Katowice (PLN 1.68 million and PLN 2.92 million, respectively).

In the category of forest fire protection, other forest fire protection activities accounted for the majority of the costs contracted to ZUL. This is a broad category that includes, among other things, the creation, maintenance and renewal of firebreaks, as well as the construction of roadsides, manning look out towers, the installation and maintenance of video surveillance equipment, fire watches, and the construction of water intake points and access roads. The study showed that the costs in this category increased from PLN 29.32 million to PLN 31.48 million from 2006-2008 and decreased to PLN 26.99 million in 2009. From 2010 onwards the costs increased and reached the amount of PLN 38.64 million in 2012 (Fig. 9). The lowest costs were recorded in the RDLP Kraków (from PLN 0.18 million to PLN 0.34 million). The highest financial expenses were recorded from 2006-2009 and in 2011 and 2012 in the RDLP Katowice (from PLN 3.08-4.64 million). The highest costs were recorded in the RDLP Zielona Góra of PLN 3.17 million in 2010.

The costs of operation and maintenance of monitoring equipment for rapid fire detection, technical equipment for firefighting (including landing sites), observation and water intake points,

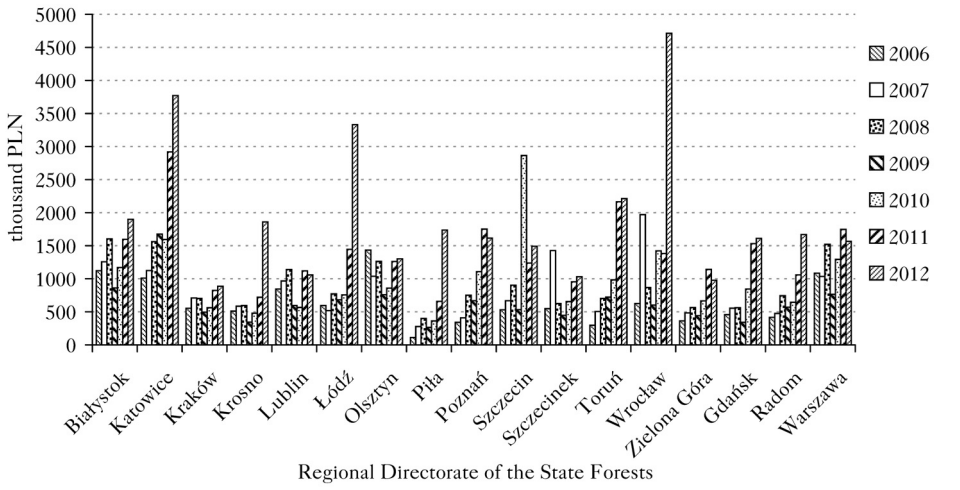

Fig. 8.

Costs of other protection measures by private forestry companies (ZUL) in each Regional Directorate of the State Forests (RDLP) from 2006-2012

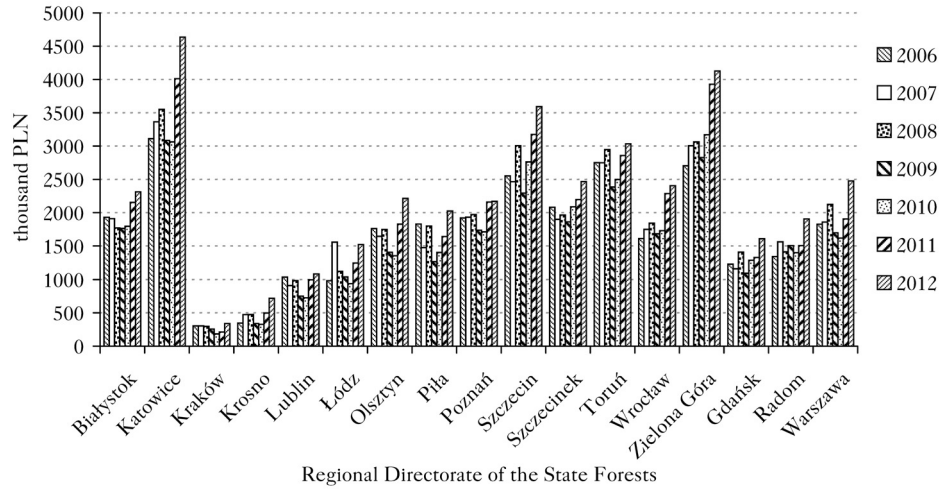

Fig. 9.

Costs of other fire protection measures by private forestry companies (ZUL) in each Regional Directorate of the State Forests (RDLP) from 2006-2012

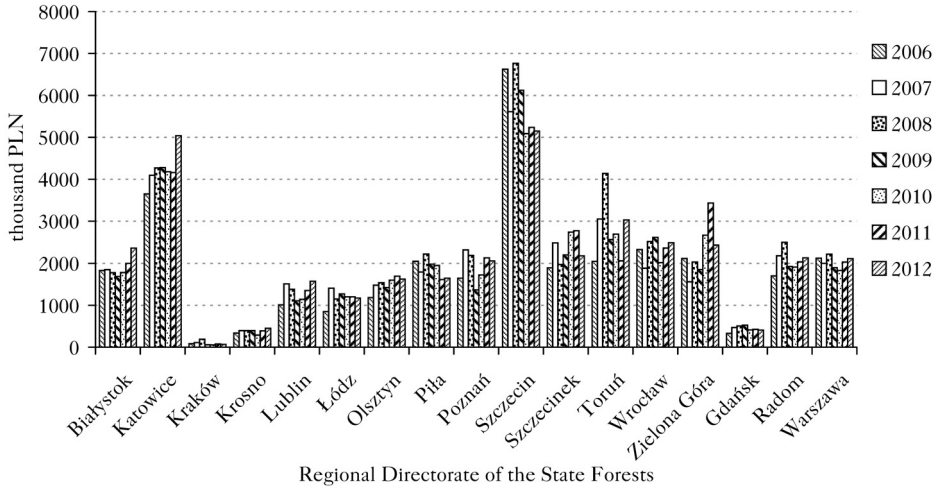

Fig. 10.

Costs of fire prevention measures, maintenance of fire protection network and rescue measures by private forestry companies (ZUL) in each Regional Directorate of the State Forests (RDLP) from 2006-2012

and protection of forests from fires increased from PLN 31.79 million to PLN 37.77 million from 2006 to 2008 and decreased to PLN 33.26 million in 2009. In the following years, the costs increased again reaching PLN 35.91 million in 2012 (Fig. 10). The lowest costs, which ranged from PLN 54.0 thousand to PLN 190.2 thousand, were recorded in the RDLP Kraków, while the highest costs (from PLN 5.09-6.76 million) were recorded in the RDLP Szczecin.

Discussion

The research analysed the costs of comprehensive forest protection activities in the period from 2006-2012, based on the two overarching categories of forest protection and forest fire protection,

contracted by the organizational units of the State Forests to ZUL. However, they do not represent the total costs of forest protection and forest fire protection incurred by the State Forests, as some activities in these areas are carried out by the State Forests organizational units themselves. Overall, contracted to ZUL forest protection costs accounted for 2.83% in 2009 and 3.51% in 2008 of the total costs of the State Forests and remain at a similar level today (3.14% in 2020 and 2.75% in 2021). The most significant costs are related to protection from animal browsing ranging from 54.72% (2007) to 64.19% (2009) of the total contracted sums to ZUL, and 64.57% in 2020 and 64.62% in 2021. The share of forest fire protection costs in total costs ranged from 1.20% in 2011 to 1.55% in 2006 (1.15% in 2021). It should be noted that the costs in these areas are lower than the costs of seed production and silviculture (Sprawozdanie, 2007-2013, 2021, 2022).

A comparison with state forest enterprises in other countries is difficult because of the size of the enterprises, their organizational structure and scope of activities as well as the structure and scope of activities of the forest administrations. In addition, many companies do not publish such data in their annual financial statements or present it in a form that makes comparisons impossible. This is the case, for example, with Bayersiche Staatsforsten in Bavaria (Bayerische Staatsforsten Statistikband, 2022; Jahresabschluss, 2022), Lesy České republiky in the Czech Republic, or Metsähallitus in Finland. Only partial information is available for other companies.

In the Niedersächsische Landesforsten in Lower Saxony, the costs of protecting and restoring forest ecosystems in 2021 amounted to € 25.1 million, which was more than 13% of the company's total costs. However, these costs are covered by financial assistance from the Lower Saxony state budget (Geschäftsbericht, 2021, 2022). On the other hand, the state enterprise Sachsenforst has allocated € 24.9 million for forest protection and restoration measures in 2021 which corresponds to 16.6% of the total costs. However, about 85% of this expenditure (21.1 million) was financed from the budget of the Saxony (Sachsenforst, 2021). In the Czech Republic, the state also supports the protection of forests from hazards and risks. In 2020, support amounted to 31.2 million Czech crowns (CZK) which included aerial liming and fertilization (22.8 million CZK), aerial firefighting (8.0 million CZK), and large-scale forest protection measures (0.4 million CZK) (Information, 2020, 2021).

The State Forests expenditures, and thus the cost of work contracted to ZUL, depend largely on the occurrence, nature and intensity of stressors that negatively impact forests. The effects of stressors are complex and often act synergistically. In addition, the response is sometimes delayed after the stressor has occurred. This leads to difficulties in interpreting the observed phenomena, especially when direct cause-effect relationships are involved. The simultaneous effect of many stress factors can lead to a high, continuous susceptibility of forests to disease and destructive processes in the forest environment with the periodic amplification of at least one factor (insect outbreak, drought or fire) leading to an imbalance in the entire ecosystem (Raport, 2021). Therefore, the mix of activities related to forest protection and the cost of their implementation by the ZUL for the State Forests varies greatly in different years and regions of the country.

The results presented in this study are difficult to compare with the results of other studies as they refer to all forest districts in the country, while other authors focused on individual cases or detailed issues of forest protection. Many authors have conducted studies on the costs and economic efficiency of forest protection and conservation measures in the State Forests. For example, Konieczny and Sikora (2019a, 2019b) presented a comprehensive assessment of the economic efficiency of forest management in the Forest Promotional Complex 'Puszcza Białowieska'.

The studies by Sikora *et al.* (2016) and Sikora *et al.* (2017) dealt with the economic assessment of forestry services functioning under conditions of forest dieback in several forest districts in the Beskidy Mountains. Research contributions on forest protection costs were also published by Rykowski *et al.* (2006) and Sikora and Ukalska (2014). The study by Sierota and Małecka (2004) compared the costs of a modified method of forest protection against root rot versus the traditional method, while Jabłoński (2003) dealt with the economic optimization of forest protection measures which was limited to harmful forest insects. Therefore, it is not possible to compare the results obtained here with the studies of other authors.

The regional distribution of costs for activities performed by ZUL depends on many factors, including the spatial occurrence of pests and their harmful impacts on forests, regional differentiation in tree species composition and stand age structure, and local economic conditions which include the existence of numerous competitive ZUL that influence price levels.

The costs of protecting the forest against animal browsing has had the largest share of the total forest protection costs, ranging from 57.1 to 69.1%, in each year. The problem of excessive populations of large herbivorous mammals and at the same time a low number of their natural predators (such as wolf and lynx) as well as the progressive change of their biotopes and the aggravation of stress for deer due to overcrowding and human presence has been observed for many years (Jędrzejewska *et al.*, 1994; Balik *et al.*, 2016). Annually, various browsing protection measures (mostly repellents) are used to treat 90 thousand hectares of young stands in the State Forests (Skrzecz and Perlińska, 2016). Prior to 2010 a slowly decreasing trend had been observed related to deer pressure on forest stands but since 2010 the area of damaged tree stands is increasing both in the young and older generations of the forest (Raport, 2012) which is reflected in the increased costs in this category in 2011 and 2012. Heavy animal pressure on forest ecosystems has serious natural consequences leading to changes at the level of individual organisms and populations as well as that of ecosystems and landscapes (Jezierski, 1996; Spake *et al.*, 2020). It is also a growing problem in forest management and contributes to increasing expenditures for conservation measures. Therefore, from an economic point of view it is advisable to maintain the reduced animal population and to look for alternative methods of forest protection (Szpakowski, 2020) which allow for the reduction of costs and at the same time to achieve the objectives of silviculture (Szpakowski, 2020; Sikora and Kaliszewski, 2021).

The spatial distribution of forest areas threatened by insect pests shows that the most endangered stands are found in the northern part of Poland (in the western part of the Masurian Lake District), in the northwest (in the Pomeranian and Wielkopolska Lake Districts), and in four regions in the southern part of the country (Sudetes, Opole, Silesia and Beskid Wysoki). The most serious threat to forests in southern Poland during the study period are almost exclusively related to secondary pests and in the remaining areas to primary pests (mainly the nun moth) (Raport, 2010; Małek, 2013; Skrzecz and Perlińska, 2016). The costs of protective measures from insect pests in regional terms partially coincide with the spatial distribution of forest hazard zones. The highest costs during the whole study period were incurred in the RDLP Katowice which is likely related to the spruce bark beetle outbreak in the Beskidy Mountains (Dmyterko and Bruchwald, 2018, 2019) High costs were also incurred in the RDLP Wrocław which is due to climatically induced stand mortality (strong winds and drought) and the influence of insect pests (mainly the bark beetles) in the Sudetes (Bruchwald *et al.*, 2019) and the RDLP Białystok which has the Białowieża Primeval Forest (Brzeziecki *et al.*, 2018). In these three RDLPs the highest threat to spruce stands from secondary pests and abiotic factors was found in 2012 expressed by the volume of spruce timber removed during sanitary felling

(Raport, 2012). On the other hand, the high costs incurred in 2011 and 2012 in the RDLP Toruń were related to the nun moth outbreak control measures required (Raport, 2011, 2012). The high cost of protection against insect pests may also be due to damage to pine stands by *Phaenops cyanea* (F.) which infested stands in the RDLPs Wrocław, Katowice, Łódź and Toruń. Further, in the RDLPs Olsztyn and Białystok large areas of oak stands were threatened by secondary pests from 2011-2013 which were mainly *Agrilus biguttatus* (F.) and geometrid moths (Geometridae) (Skrzecz and Perlińska, 2016). The regional differentiation of costs for activities contracted to ZUL is also evident in the activities related to predicting the occurrence of pests.

The highest nature conservation costs were incurred in the RDLPs Białystok, Olsztyn, Katowice and Krosno which can be related to the large surface of protected areas such as nature reserves, landscape parks and Natura 2000 sites (Statistics Poland, 2022). This distribution is also partially reflected in the distribution of costs for activities contracted to ZUL for biodiversity protection.

The highest costs related to fungi and nematode protection were incurred in the RDLP Szczecinek and in the RDLPs Piła and Olsztyn from 2006-2008. While in the latter two cases might be connected with the increased fungal risk to the stands in 2006 and 2007, the high costs of activities in the area of the RDLP Szczecinek are difficult to explain (Raport, 2007, 2009).

The costs of fire protection, maintenance of the fire protection network, and rescue operations as well as other costs of fire protection were the highest in the RDLPs Katowice and Szczecin and in the RDLPs Zielona Góra and Toruń. These areas are characterized by the highest number of fires along with high fire risk, therefore forest protection expenditures are high (Raport, 2008-2010).

Conclusions

- The research has shown that the cost of forest protection and fire protection activities contracted out by the State Forests to ZUL varies widely across the RDLPs in different years.
- In regard to the category of forest protection, the costs of protection from animal browsing had the highest share in total costs (63.1% on average) while rodent reduction costs had the lowest (0.2% on average) throughout the country.
- In regard of the forest fire protection category, the costs included in the broad category of other costs had the highest share nationwide. The costs of operating, maintaining and repairing the fire detection network along with the firefighting equipment had the lowest share .
- Given the lack of studies on the economic performance of ZUL, it is prudent to take further action to identify the factors that influence the level and differentiation of costs for activities contracted out by the State Forests to these contractors at the local level as well as their variability over time.

Authors' contributions

D.Z. – general conception of the study, literature review, methodology, data collection, data analysis, drafting and preparing the manuscript, reviewing and editing the text; A.K. – literature review, drafting and preparing the manuscript, reviewing and editing the text.

Conflicts of interests

The authors declare no conflict of interest.

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STRESZCZENIE

Koszty realizacji zadań z zakresu ochrony lasu zlecanych przez Lasy Państwowe prywatnym firmom leśnym

Celem pracy była analiza kosztów prac z zakresu szeroko pojętej ochrony lasu zleconych zakładom usług leśnych przez jednostki organizacyjne Lasów Państwowych w latach 2006-2012. W szczególności badaniom poddano koszty zbierania materiałów prognostycznych z zakresu ochrony lasu, koszty ograniczania występowania szkodliwych owadów, grzybów i nicieni, koszty ochrony przyrody i różnorodności biologicznej, koszty ochrony przed zwierzyną oraz gryzoniami, a także ochrony przeciwpożarowej lasu. Celem pracy było również przedstawienie zróżnicowania kosztów pracy z zakresu ochrony lasu na całym obszarze zarządzanym przez Lasy Państwowe.

W badaniach wykorzystano informacje o kosztach zadań wykonywanych przez zakłady usług leśnych na rzecz Lasów Państwowych zewidencjonowanych w działach zagospodarowania lasu, zgodnie z przyjętą i przystosowaną klasyfikacją obejmującą: a) ochronę lasu (w tym działania prognostyczne, ochronę przed owadami, grzybami i nicieniami, ochronę przed zwierzyną, ochronę przyrody i różnorodności biologicznej), b) ochronę przeciwpożarową lasu. Dane zostały pobrane z Systemu Informatycznego Lasów Państwowych (SILP) przy pomocy SQL (Structured Query Language) dla każdego nadleśnictwa, a następnie zagregowane i przeanalizowane dla poszczególnych regionalnych dyrekcji Lasów Państwowych (RDLP). W każdym koncie odpowiadającym wyżej opisanej klasyfikacji zadań wyodrębniono tzw. miejsce powstawania kosztów (mpk), co ma istotny wpływ na właściwą i dokładną analizę kont oraz księgowanych na nich informacji dotyczących zakresu czynności wykonywanych przez zakłady usług leśnych. Mimo podjętych prób nie udało się uzyskać nowszych danych dla obszaru całego kraju. Z uwagi na trudności w przypisaniu uzyskanych wartości do konkretnych powierzchni lasu objętych poszczególnymi zabiegami i czynnościami dane przedstawiono kwotowo dla poszczególnych zadań.

Wysokość kosztów realizacji prac z zakresu ochrony lasu i ochrony przeciwpożarowej lasu wykonanych przez prywatne firmy leśne w poszczególnych regionalnych dyrekcjach Lasów Państwowych w latach 2006-2012 przedstawiono w tabelach 1 i 2. W tabelach 3 i 4 ukazano natomiast

udział kosztów poszczególnych grup czynności w całkowitych kosztach ochrony lasu i ochrony przeciwpożarowej lasu. Przeprowadzona analiza danych dotyczących sumarycznych kosztów wykonania prac z zakresu ochrony lasu w Lasach Państwowych dla poszczególnych grup czynności wykazała największy procentowy udział kosztów związanych z ochroną lasu przed zwierzyną, sięgających średnio 63,1% wszystkich kosztów w tym dziale, a w poszczególnych latach wahających się od 57,1 do 69,1%. Drugą najważniejszą grupę czynności stanowiło ograniczenie występowania szkodliwych owadów, którego łączne koszty dla całego badanego okresu stanowiły 14,7% nakładów finansowych, a w poszczególnych latach wynosiły od 8,9 do 21,0%. W dziale ochrona przeciwpożarowa lasu najwyższe koszty poniesiono w kategorii pozostałych kosztów. Udział nakładów w tej kategorii wyniósł średnio 60,1%. Koszty zabiegów ratowniczych miały o ponad połowę niższy udział, sięgający średnio 26,6% i charakteryzujący się dużą zmiennością w poszczególnych latach (w zakresie od 5,1 do 27,7%).

Wysokość kosztów ponoszonych w poszczególnych latach we wszystkich regionalnych dyrekcjach Lasów Państwowych przedstawiono na ryc. 1-10. W szczególności ryciny przedstawiają:

- koszty ochrony przed zwierzyną (zastosowanie metod mechanicznych, chemicznych lub grodzeń upraw) – rycina 1;
- koszty związane z ograniczeniem występowania szkodliwych owadów – rycina 2;
- koszty zachowania różnorodności biologicznej (m.in. dokarmianie ptaków i tworzenie odpowiednich warunków do bytowania pożytecznej fauny leśnej) – rycina 3;
- koszty ochrony przyrody (ochrona rezerwatów przyrody i innych obszarów objętych ochroną prawną, ochrona siedlisk, ochrona gatunkowa grzybów, roślin i zwierząt) – rycina 4;
- koszty prac prognostycznych (monitorowanie występowania owadów za pomocą pułapek feromonowych, powierzchni kontrolnych i podokapowych oraz drzew próbnych, a także poszukiwanie larw zasnui, kontrola zapędraczenia gleby oraz występowania grzybów i nicieni) – rycina 5;
- koszty ograniczenia występowania grzybów oraz zwalczania nicieni – rycina 6;
- koszty ograniczania występowania gryzoni – rycina 7;
- pozostałe koszty ochrony lasu (m.in. utrzymanie porządku w lesie, utrzymanie maszyn i urządzeń związanych z ochroną lasu, uprzątanie terenów wojskowych) – rycina 8;
- koszty pozostałych zabiegów ochrony przeciwpożarowej lasu (m.in. zakładanie, konserwacja i odnowienia pasów przeciwpożarowych oraz porządkowanie terenów przyległych do dróg, obserwacje w dostrzegalniach i punktach obserwacji telewizyjnej oraz w punktach alarmowo-dyspozycyjnych i patrolowania przeciwpożarowego, wykonanie punktów czerpania wody i dojazdów do nich) – rycina 9;
- koszty obsługi i utrzymania monitoringu związanego z szybkim wykrywaniem pożarów, a także koszty utrzymania zaplecza technicznego do zwalczania pożarów, koszty konserwacji oraz utrzymania w pełnej gotowości obiektów sieci wykrywania pożarów i obiektów służących ochronie lasu przed pożarami oraz punktów obserwacyjnych i czerpania wody – rycina 10.

Badania wykazały duże zróżnicowanie kosztów prac z zakresu ochrony lasu i ochrony przeciwpożarowej lasu zlecanych zakładom usług leśnych przez Lasy Państwowe w poszczególnych latach w regionalnych dyrekcjach Lasów Państwowych. W grupach czynności w zakresie ochrony lasu największy udział w skali kraju miały koszty ochrony przed zwierzyną (średnio 63,1%), a najniższy koszty ograniczania występowania gryzoni (średnio 0,2%). W grupach czynności w zakresie ochrony przeciwpożarowej lasu największy udział w skali kraju miały koszty zarejestrowane w szerokiej kategorii pozostałych kosztów (60,1% wszystkich kosztów). Najmniejszym udziałem

charakteryzowały się koszty obsługi, konserwacji i utrzymania sieci do wykrywania pożarów oraz sprzętu przeciwpożarowego (średnio 4,8%). Z uwagi na niewielką liczbę badań dotyczących ekonomicznych aspektów realizacji prac przez zakłady usług leśnych wskazane jest podejmowanie dalszych działań mających na celu określenie czynników wpływających na wysokość i zróżnicowanie kosztów prac zlecanych zakładom usług leśnych przez Lasy Państwowe na poziomie lokalnym i ich zmienności w czasie.