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ORIGINAL PAPER

The type and extent of damages made by abiotic and biotic factors in managed forests of North-Eastern Poland

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ABSTRACT

Damages caused by external (biotic and abiotic) factors generally cause losses in forest management, negatively affect the continuity of providing various ecosystem services, and therefore play an important role in the management of forest resources. The aim of the study was to present the type and extent of natural damages of commercial forests in the temperate climate of north-eastern Poland (Central and Eastern Europe). In addition, a relationship between the occurrence of damage of a given type and the site type of forest, the age of the stand and species composition was investigated. The necessary information was obtained from the documentation of the State Forests National Forest Holding through an interactive form. Nearly 8% of the stands in north-eastern Poland were damaged. Vast majority of the damage were attributed to wild herbivores – 65%, followed by pathogenic fungi – 24% and insects – 8%. The degree of damage to stands depends on the source of damage, species and age of trees. 60% of damaged stands were damaged in 20%, and 1/3 in 10%. Animals most often damaged oaks; fungi – alders; insects – spruce. Fires most often damaged juniper, pine and birch. The most frequently damaged pine, oak and birch stands were characterized by the highest average age of trees (73.1; 56.0; 56.5 years, respectively). On the other hand, the least frequently damaged linden stands were characterized by the lowest average age of trees – 45.1 years. Taking into account the influence of the forest site on the probability of damage to stands caused by natural factors, there are no significant differences between most sites. A slightly higher probability of damage to stands occurs in the moist forest site type, but the importance of this site in the study area is small. The paper indicates the existence of a serious problem of damage to the young generation of the forest by wild herbivores. This poses a real threat to the preservation of forest sustainability – the renewal of some tree species, in the study area, animals caused significant damage to oak regeneration. We suggest discussing the necessity to limit the number of wild herbivores in commercial forests. The currently used felling age, adopted for individual tree species, also requires discussion. As we have shown, the higher age of the stands contributes to more frequent damage.

KEY WORDS

biotic and abiotic factors, ungulates, pathogenic fungi, insect pests, forest ecosystem, sanitary logging

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Introduction

Damage to the forest can arise from a single, sudden action of an external factor, both in the micro scale, *e.g.* the fall of a single tree by the wind, and the macro scale – the fall of hundreds of hectares of forest by the wind (Pickett and White, 1985) or as a result of long-term pressure of some factor, e.g. browsing by herbivores. In the first case, we are talking about natural disturbances in the forest. Extensive natural forest disturbances are very common in various forest ecosystems (Szwagrzyk, 2000). Natural disturbances that have always been present in forest history may play a positive role in forest ecology (Thorn *et al.*, 2017), especially in primeval forests (Trotsiuk *et al.*, 2014; Čada *et al.*, 2016; Meigs *et al.*, 2017; Mikoláš *et al.*, 2017), which are protected in Europe. Abundant natural regeneration of forests is often observed after various disasters, such as *e.g.* floods (Dobrowolska, 2008), strong winds (Dobrowolska, 2007), fires (Shatford *et al.*, 2007), insect pest outbreaks (Nováková and Edwards-Jonášová, 2015). In managed forests, all types of disturbances and pressures caused by external factors generally cause losses (Montagné-Huck and Brunette, 2018), negatively affect the continuity of providing various ecosystem services (Thom and Seidl, 2016; Fleischer *et al.*, 2017), thus playing an important role in the management of forest resources (Prestemon and Holmes, 2004). Due to fear of these losses, outbreaks of pathogenic fungi and insect pests are quickly eliminated in managed forests; local disturbances, which could develop into large-scale ones, are destroyed in the bud. Similarly, in fear of losses to forest management, factors that cause long-term pressure on the stand are counteracted (Sikora and Kaliszewski, 2021). In forests in this part of Europe, the factors causing the pressure are for example herbivores (Szukiel, 1993; Skorupski, 2018). Limiting the damage caused by herbivorous animals is usually limited to the use of fencing, the use of chemical personal protection or individual physical shields (Nasiadka *et al.*, 2004; Sikora and Kaliszewski, 2021). Research indicates that the higher activity of disturbances is the result of the growing maladjustment of forests to global climate change, with less disturbance in protected areas compared to commercial forests (Sommerfeld *et al.*, 2018). This may be related to the greater adaptive capacity of forest ecosystems when not in use for hundreds of years and facing many different natural disturbances and pressure from natural factors (Thom *et al.*, 2017), which is certainly influenced by the biodiversity of ecosystems shaped by these factors (Miller *et al.*, 2011; Wermelinger *et al.*, 2017). This is confirmed by the latest research on bark beetle disorders in the forests of Central Europe. In forests where bark beetle damage to trees is prevented by planned forest management activities, including sanitation harvesting, the risk of future large-scale bark beetle outbreaks decreases (Sommerfeld *et al.*, 2021). In addition, the observed climate change is exacerbating the likelihood of large-scale damage in European temperate forests (Senf and Seidl, 2018).

In managed forests, most of the damage is caused by disturbances and pressures from external factors; it cause losses related to the reduction of forest productivity, which is also associated with climate change (Reyer *et al.*, 2017). As reported by Seidl *et al.* (2014), in Europe, an increase in the amount of wood damaged by the forces of nature has been observed for decades. Long-term observations (1950-2000) show that an average of 35 million m^3 of wood is destroyed in Europe each year. Abiotic factors are responsible for the majority of these damages (77%), while biotic factors for approx. 16% of damages (Schelhaas *et al.*, 2003). An opportunity to change this unfavourable condition may be appropriate forest management with the promotion of mixed forests and species adapted to the current climate indicators (Seidl *et al.*, 2018) and uneven-aged stands (Diaci *et al.*, 2017).

Natural abiotic disorders are usually a random process occurring in a random place and time. Natural biotic damage may be a consequence of previous abiotic disorders (Hanewinkel *et al.*, 2008), human activity (Grodzki *et al.*, 2002), including forest management (de Groot *et al.*, 2019; Ochtyra, 2020), and are less frequently associated with randomness of natural phenomena. They are characterized by high temporal and spatial variability (Kautz *et al.*, 2017). An example is the gradation of the spruce bark beetle *Ips typographus* (L.). This species attacks spruce stands weakened e.g. as a result of air pollution (Grodzki *et al.*, 2002), as well as man-planted spruce monocultures (de Groot *et al.*, 2019; Ochtyra, 2020). It is noted that tree diseases, which can cause high mortality at landscape level, can consequently cause forest fires, wind impacts and other (Cobb and Metz, 2017).

The aim of the study was to present the structure of natural damages in managed forests growing in the temperate climate of north-eastern Poland, including pathogenic fungi, insect pests, forest animals, fires, water, climate factors (hurricane winds, hailstorms, lowering of the groundwater level, droughts). In addition, an attempt was made to check whether in these climatic conditions there is a relationship between the occurrence of damage of a given type and the site type of forest, the age of the stand and tree species composition.

Materials and Methods

The study was carried out in north-eastern Poland, in the stands of the Augustów Forest District (22°41'-23°27' E, 53°52'-53°38' N). The area of the forest inspectorate is 26,027 ha, 74% of which the Augustów Forest constitutes one forest area. This area is under the influence of a continental climate. In addition, numerous lakes have a large impact on the climate, which translates into average annual rainfall of 580 mm and average annual air humidity of 80%. The average annual air temperature is 6.6°C, with July being the warmest month (17.3°C) and January – the coldest one (3.8°C). The vegetation season is quite short: 200-205 days. West and north-west winds prevail in the summer season, while south-east and west winds in winter (Forest Management Plan, 2014; Tomczyk and Szyga-Pluta, 2016). The area is flat, slightly rolling, with slight terrain denivelations. Absolute elevations range from 118 to 157 m above sea level. Rusty (53%) and podzolic (13%) soils dominate here. Peaty (11%) and muck (8%) soils associated with marshy and wet habitats are also of great importance (Forest Management Plan, 2014). The forest sites are poor and moderately fertile, i.e. fresh coniferous, hemiboreal forest and mixed broadleaved--coniferous forest. In terms of moisture, fresh (60%) sites dominate, but marsh (25%) and wet (15%) sites also have a large share. The stands of older age classes from 60 to 100 years (45%) dominate, while the oldest stands over 100 years old constitute as much as 14% of the area. The average age of stands is 69 years, the average volume is 294 m^3/ha. The stands of the Augustów Forest District are composed of *Pinus sylvestris* L. (Scots pine, 67.14% of the area), *Alnus glutinosa* Gaertn. and *Alnus incana* Moench (black alder and gray alder, 17.99%), *Betula pendula* Roth (silver birch, 7.66%), *Picea abies* L. (Norway spruce, 5.99%), *Quercus robur* L. (Pedunculate oak, 1.05%).

Esential information was obtained from the documentation of the Augustów Forest District and the Data Bank on Forests (https://www.bdl.lasy.gov.pl/), in the form of a set of inventory results of natural damages for forest stands in the board of forest districts The State Forests National Forest Holding, via an interactive form (https://www.bdl.lasy.gov.pl/portal/wniosek). These data concerned the period of the last 10 years with the results at the end of 2020. The data files selected for analysis were merged into an Excel spreadsheet using forest addresses. The analysis was developed with the Statistica 13.1 package (Analytical Software, Tallahassee, FL, USA) to calculate the number and share of stands according to the source and degree of damage, the share of damaged trees in the stand and tree species. Moreover, the Spearman correlation coefficients between the degree of damage, the source of damage, the species of trees, the share of damaged stands and the age of the trees were calculated. Taking into account the degree of damage, the share of damaged stands, homogeneous subsets of objects (forest site types) were distinguished using cluster analysis. The Euclidean distance was used as the measure of distance. Clusters were created using the agglomeration technique, in which each object – a forest site type – is initially a separate cluster. Then, the objects closest to each other are gradually combined into new clusters until one cluster is obtained. The distance between two clusters was determined by the single-link method by the distance between the two closest objects belonging to different clusters. The number of clusters was determined using the agglomeration diagram, which shows the distances between the clusters at the time they were joined. A longer vertical line indicates that the clusters are distant. This site was taken as the cut-off point (Stanisz, 2007).

Results

Nearly 8% of stands in north-eastern Poland (sample area: Augustów Forest District, 26,000 ha) were damaged by biotic and abiotic factors. Forest animals (deer, elk, wild boar, roe deer) caused the most damage to stands – over 65%, followed by pathogenic fungi – over 24% and insects – over 8% of damage. Fires, water and climate factors were the direct sources of only 2% of the damage. Nearly 60% of damaged stands were damaged in 20%, and slightly more than 30% were damaged in 10% (Table 1).

When analyzing the number of damaged stands, taking into account the species composition, it can be seen that the ungulates preferred oak (*Quercus robur* and *Quercus petraea* Liebl.),

Table 1.

The number and share [%] of damaged stands with respect to the source of damage and the degree of damage

Source of damage	Number of stands	Share [%]
Animals	3,547	65.30
Fires	32	0.59
Fungi	1,321	24.31
Water	32	0.59
Insects	444	8.18
Climate	55	1.01
Total damage	5,431	100.00
Missing observations – no visible damage	63,021	92.07 total observations
Total observations – number of stands	68,452	–
Degree of damage [%]	Number	Share [%]
≥60.0	15	0.28
50.0	63	1.18
40.0	67	1.25
30.0	464	8.66
20.0	3,075	57.37
10.0	1,676	31.27
Total damage	5,360	100.00
Missing observations – no visible damage	63,092	92.17 total observations
Total observations – number of stands	68,452	–

Source: own study based on data from the Data Bank on Forestsch, Augustów Forest District birch *Betula pendula* and pine *Pinus sylvestris*. A large number of damage was caused by fungi in spruce *Picea abies*, birch, pine and alder (*Alnus glutinosa* and *Alnus incana*). Insects preferred spruce. The other factors were of less importance (Table 2).

The greatest number of stands was damaged in 20%, the next group consisted of stands damaged in 10%. The least numerous group were forest stands damaged in 60% and more. The most susceptible to damage turned out to be pine, birch, oak and spruce; and the most resistant: juniper, rowan and linden (Table 3).

The degree of damage to stands depended on the species of trees. The highest share of damaged stands was observed in pine (nearly 10% of the stand). In terms of the discussed feature, the second and third species turned out to be birch and oak, nearly 9% were damaged. They were damaged the least often: juniper, rowan and linden (slightly over 6% of damage), but these are species that are of no economic importance. In all cases the damage was 20% (Table 3).

Table 2.

The number of damaged stands, according to tree species and source of damage

Species	The source of damage						Sum of damaged stands	Total number of stands
	animals	fire	fungi	water	insects	climate		
LP	72	3	28	1	11	0	115	1,700
SO	540	7	180	1	59	5	792	7,840
DB	319	1	37	1	21	8	387	4,373
OL	193	0	176	7	34	2	412	5,480
ŚW	974	5	376	10	165	14	1,544	19,452
JAŁ	61	3	29	0	9	0	102	1,637
BRZ	736	9	258	4	80	11	1,098	12,199
JRZ	72	0	29	1	7	4	113	1,756
KRU	246	1	90	1	23	4	365	4,583
Other	332	3	114	6	35	7	503	9,432
Sum	3,545	32	1,321	32	444	55	5,431	68,452

Source: own study based on data from the Data Bank on Forests, Augustów Forest District. LP – *Tilia cordata* Mill., SO – *Pinus sylvestris* L., DB – *Quercus robur* L. and *Quercus petraea* Liebl., OL – *Alnus glutinosa* Gaertn. and *Alnus incana* Moench, ŚW – *Picea abies* L., JAŁ – *Juniperus communis* L., BRZ – *Betula pendula* Roth, JRZ – *Sorbus aucuparia* L., KRU – *Frangula alnus* Mill.

Table 3.

The number of damaged stands according to species and the degree of damage

Species	Degree of damage [%]						Sum of damaged stands	Total number of stands	Share of damaged stands [%]
	10	20	30	40	50	≥60			
LP	31	53	18	4	2	2	110	1,700	6.47
SO	211	445	91	11	13	3	774	7,840	9.87
DB	123	219	27	5	7	2	383	4,373	8.76
OL	136	247	21	4	1	1	410	5,480	7.48
ŚW	513	848	126	20	15	2	1,524	19,452	7.83
JAŁ	29	60	10	1	1	1	102	1,637	6.23
BRZ	325	631	102	13	13	2	1,086	12,199	8.90
JRZ	33	70	9	0	1	0	113	1,756	6.44
KRU	122	208	28	4	3	0	365	4,583	7.96
Other	153	294	32	5	7	2	493	9,432	5.23
Sum	1,676	3,075	464	67	63	15	5,360	68,452	7.83

Source: own study based on data from the Data Bank of Forests, Augustów Forest District

The use of the Sperman rank correlation allowed to observe that the degree of damage to stands significantly correlated with the source of damage, species and age of the stand. The share of damaged stands significantly correlated with the species and age of trees. The age of the stands was significantly related to the source of damage and the tree species (Table 4). The most frequently damaged stands with pine, oak and birch were characterized by the highest average age of trees (respectively: 73.1; 56.0; 56.5). And the least frequently damaged linden stands were characterized by the lowest average age of trees – 45.1 years (Table 5).

When analyzing the results of the Spearman correlation coefficient among the examined features (Table 4), some dependencies can be noticed, however, in all cases, except for the age of the stand and the source of damage, there is no linear relationship (r<0.2). The age of damaged stands turned out to be positively correlated with the source of damage. The animals that are responsible for most of the damage more often cause damage to the youngest stands, while fungi and insects to the oldest stands.

The cluster analysis for the forest habitat types of the Augustów Forest District (Figs 1-2) showed that the BMW and OL habitat types turned out to be the most similar in terms of percentage share and percentage of damage. In the next step, the BŚW type was added to this cluster. Further habitat types were included in the next steps. The last two were LW and BMB. Based on the agglomeration diagram, it can be concluded that the types LMW, LMB, BMŚW, LMŚW, LŚW, BŚW, BMW, OL, BW, OLJ and BB formed one cluster of similar objects. Two separate clusters – the least similar objects are LW and BMB habitat type. Damage to the BMB habitat was the lowest and the most severe damage to the LW habitat.

It turned out that the LW habitat type had the highest mean value for all the features considered, and the BMB habitat type the lowest (Table 6). It should be noted here that the importance of these habitats in the study area is very low, they constitute less than 2% of the area.

Table 4.
Correlation among the examined features according to Spearman coefficient

Feature	Degree of damage	Source of damage	Tree species	Share of damaged stands	Age of stands
Degree of damage	×	–0.077*	–0.027*	–0.019	–0.049*
Source of damage	–0.077*	×	–0.003	0.007	0.331*
Tree species	–0.027*	-0.003	×	0.095*	–0.087*
Share of damaged stands	0.019	0.007	0.095*	×	0.033*
Age of stands	–0.049*	0.331*	–0.087*	0.033*	×

Source: own study based on data from the Data Bank of Forests, Augustów Forest District;
*Coefficients significant at p<0.05

Table 5.
Age of stands, according to tree species

Species	Mean	Number	SD	Range	Median	Mode
LP	45.1	1,360	30.7	162.0	45.0	65.0
SO	73.1	7,672	41.4	263.0	70.0	65.0
DB	56.0	2,835	41.8	262.0	45.0	35.0
OL	54.8	4,952	30.8	165.0	55.0	65.0
ŚW	53.9	14,420	29.8	205.0	50.0	30.0
BRZ	56.5	9,097	27.0	149.0	55.0	65.0
JRZ	5.9	41	1.1	7.0	6.0	6.0

Source: own study based on data from the Data Bank of Forests, Augustów Forest District (no data on age for common buckthorn)

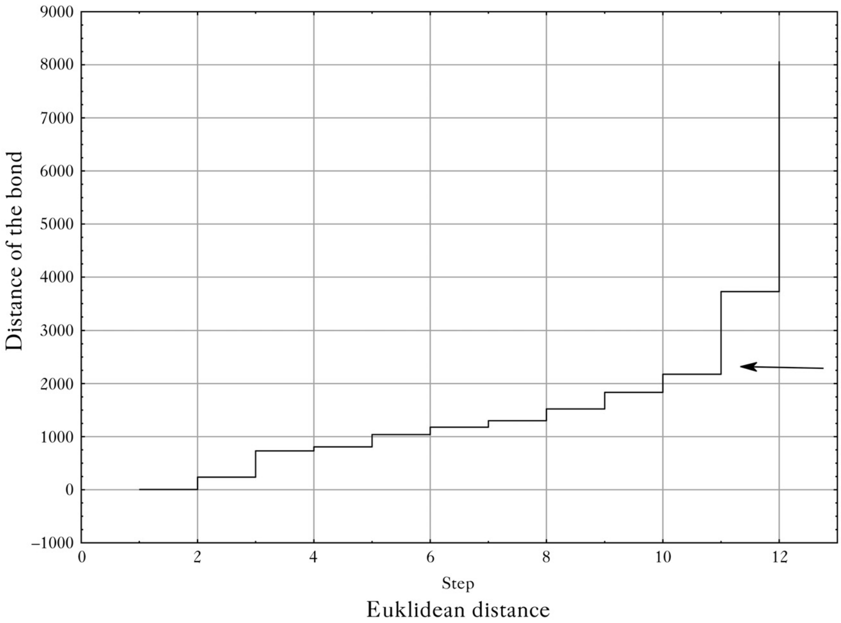

Fig. 1.

Graph of bond distance versus bonding steps: forest habitat types according to degree of damage
Source: own study based on data from the Data Bank of Forests, Augustów Forest District

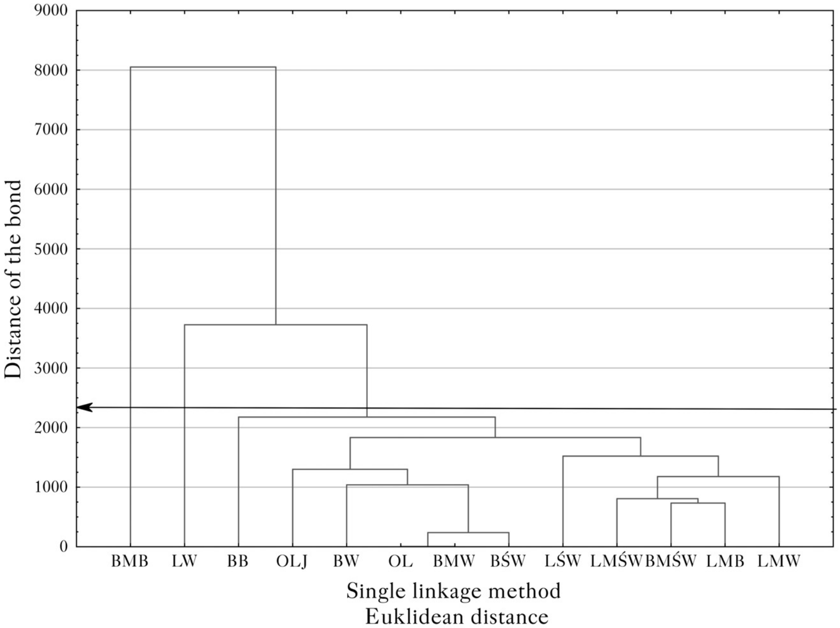

Fig. 2.

Clustering/Grouping of forest habitat types according to degree of damage
BMB – boggy mixed coniferous forest; LW – moist forest; LŚW – fresh forest; BB – boggy coniferous forest; LMB – boggy mixed forest; OLJ – alder-ash forest; BW – moist coniferous forest; OL – alder car forest; BMW – moist mixed coniferous forest; BŚW – fresh coniferous forest; LMŚW – fresh mixed forest; BMŚW – fresh mixed coniferous forest; LMW – moist mixed forest. Source: own study based on data from the Data Bank of Forests, Augustów Forest District

Table 6.
Cluster analysis results

Feature	Group 1	Group 2	Group 3
X_1 – degree of damage	12553.8	22720.4	108.0
X_2 – share of damaged stands	53.4	53.6	48.2

Group 1: LŚW – fresh forest; BB – boggy coniferous forest; LMB – boggy mixed forest; OLJ – alder-ash forest; BW – moist coniferous forest; OL – alder car forest; BMW – moist mixed coniferous forest; BŚW – fresh coniferous forest; LMŚW – fresh mixed forest; BMŚW – fresh mixed coniferous forest; LMW – moist mixed forest; Group 2: LW – moist forest; Group 3: BMB – boggy mixed coniferous forest

Discussion

Observing forest damage and drawing the right conclusions for forest managers in different parts of the world faces similar difficulties. In our study, the number of damaged stands includes forests in which damaged trees have been identified, however these stands were not completely damaged, applied percentage of damage is used to explain it. Similarly, Meddens *et al.* (2012) note that, using aerial photogrammetry, forests identified as damaged include healthy trees among damaged ones, which should be taken into account when interpreting the results.

Our study indicated that the most susceptible to damage were coniferous or mixed stands with a predominance of conifers (Scots pine and Norway spruce). This result is in line with expectations and current knowledge. Various authors have already reported that forests dominated by conifers are prone to natural disturbance (Kurz *et al.*, 2008; Moen *et al.*, 2014). However, our study proved that mixed forests with a large share of silver birch and oaks (pedunculate and sessile) are equally susceptible. This result, initially surprising to us, was nevertheless referenced in the publication by Jactel *et al.* (2017). These authors found that mixed forests are more resilient to minor-scale disturbances, while mixed forests no longer show markedly greater resilience in the event of large-scale disturbances. In our study, wild animals had the largest share in the disturbances of the forest ecosystem, which were responsible for 65% of all recorded damage to stands (they damaged about 5.2% of stands), and in the case of oaks for as much as 82% of damage. The percentage of forest stands damaged by wild animals in the area studied by us is much higher than the average for state-owned forests in Poland – 0.85% (Skorupski, 2018). A large forest complex, which is the Augustów Forest (over 19 thousand ha), favors high status of forest animals. It should be noted here that wild animals cause the highest losses in stands of the youngest age classes (up to 20 years) and make forest regeneration difficult. In Poland, the protection of tree stands against the negative impact of wild herbivores usually consists in fencing the young generation of the forest with a net or individual protection of the most endangered tree species with the use of repellents (chemical agents that deter animals). As noted by Sikora and Kaliszewski (2021), forest protection measures taken to protect crops and young stands against game cause a reduction in the economic efficiency of forest management, and the most expensive way to reduce damage is fencing entire crops. Taking into account the high protection efficiency (over 90%) when using selected repellants, they can replace fencing (Nasiadka *et al.*, 2004; Nasiadka and Lipski, 2006). The second equally used remedy is to maintain an appropriate number of animals through properly conducted hunting management. However, at present in Poland there are strong pressures of pro-ecological organizations to stop shooting wild animals. Also Montagné-Huck and Brunette (2018), who conducted an extensive review of the literature on the subject, pointed to the problem of meeting the needs of all social groups (foresters, ecologists, hunters, etc.) in terms of maintaining the population of wild animals in forests. The authors rightly point out that, compared to other natural factors, wildlife damage has a very low degree of uncertainty: as wildlife populations increase, the level of damage to forests is likely to increase.

We found that 8% of forests in study area were damaged to a varying degree by natural factors, including biotic factors, 7.8% of forests (97% of all damages). Kautz *et al*. (2017), based on a review of publications on biotic factors damaging the forests of the northern hemisphere, found that these factors caused damage to 2.6% of forests, while for Europe alone this result was higher – 3.6%, and in some countries, damage form biotic factors affect more than 20 % of forests (Romania, Moldova, Albania). In our research, we found that wild herbivores (5.2%) most often damaged forests, followed by pathogenic fungi (1.9%) and insects (0.7%). On the other hand, Kautz *et al*. (2017) report that the most common source of biotic damage in forests are insects (2.2%), followed by pathogens (0.2%) and wild herbivores (0.2%). Similarly, Sierota *et al*. (2019) indicate that insects are the most common cause of forest damage in north-west Poland. Such large differences in the obtained results are not surprising as they concern different sizes of areas. In the forests of the entire northern hemisphere reviewing the work of Kautz *et al*. (2017), differences in the size and structure of biotic damage can be noticed between the regions under consideration. The comparison shows that conclusions for forest management regarding the damage caused by natural factors in forests cannot be drawn for very large areas (e.g. the northern hemisphere), but should apply to a given climatic zone, e.g. forests of temperate climate in Central and Eastern Europe. One should also take into account the observed climate changes – climate warming. Due to this phenomenon, epidemics of insects and pathogens are expected to increase in the coming decades (Sturrock *et al*., 2011; Weed *et al*., 2013).

Conclusions

- In the temperate climate of north-eastern Poland, wild animals (65% of all damage) are responsible for the vast majority of damage recorded in forests in the last 10 years. Secondly, pathogenic fungi cause over 24% and insects – over 8% of damage. In order to limit the level of damage to managed forests in the investigation area, the number of wild herbivores should be limited.
- The degree of damage to stands depends on the source of damage, species and age of trees. More than half (60%) of damaged stands were damaged in 20%, and $^{1}/_{3}$ in 10%. Animals most often damage oaks; fungi – alders; insects – spruce. Fires most often damage juniper, pine and birch. Other natural factors have little influence on the amount of damage recorded in forests.
- The most frequently damaged stands with pine, oak and birch were characterized by the highest average age of trees (respectively: 73.1; 56.0; 56.5). On the other hand, the least frequently damaged linden stands were characterized by the lowest average age of trees – 45.1 years. At the same time, it should be added that animals that are responsible for most of the damage, causing damage to the youngest stands more often, while fungi and insects to the oldest ones. In order to limit the damage to the study area, the cutting age of spruce and alder should be lowered and the young oak regeneration should be protected against herbivorous animals (e.g. mesh fencing).
- Taking into account the influence of the forest habitat on the probability of natural damage in the stands, there are no significant differences between most of habitats. A slightly higher probability of damage to stands occurs in the moist forest habitat, but the importance of this habitat in the study area is small due to the area covered.

- The currently used felling age, adopted for individual tree species, also requires discussion. As we have shown, the higher age of the stands contributes to more frequent damage.

Authors' contributions

Conceptualization – T.D.; methodology – T.D. and A.G.; formal analysis – T.D.; statistical analysis – A.G.; resource management – A.G. and T.D.; data curation – A.G. and T.D.; writing original draft preparation – T.D.; writing review and editing – T.D.; visualization – T.D. and A.G.

Conflicts of interest

The authors declare the absence of potential conflicts of interest.

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STRESZCZENIE

Struktura naturalnych uszkodzeń w lasach gospodarczych klimatu umiarkowanego północno-wschodniej Polski

Uszkodzenia wywołane czynnikami naturalnymi, obecne od zawsze w historii lasów, na ogół powodują straty w gospodarce leśnej i negatywnie wpływają na ciągłość zapewnienia różnych usług ekosystemowych, przez co odgrywają istotną rolę w gospodarowaniu zasobami leśnymi. Celem badań było przedstawienie struktury naturalnych uszkodzeń lasów gospodarczych w klimacie umiarkowanym północno-wschodniej Polski. Ponadto postanowiono sprawdzić, czy w tych warunkach klimatycznych istnieje związek między występowaniem uszkodzeń danego rodzaju a siedliskowym typem lasu, wiekiem drzewostanu i składem gatunkowym. Niezbędne informacje pozyskano z dokumentacji PGL LP dla lasów Nadleśnictwa Augustów poprzez interaktywny formularz. Wybrane do analizy pliki danych scalono w arkuszu Excel, korzystając z adresów leśnych. W analizie wykorzystano pakiet Statistica 13.1 (Analytical Software, Tallahassee, FL, USA), obliczając liczebność i strukturę drzewostanów ze względu na źródło i stopień uszkodzeń, udział uszkodzonych drzew w drzewostanie oraz gatunek drzew. Ponadto obliczono współczynniki korelacji Spearmana pomiędzy stopniem uszkodzeń, źródłem uszkodzeń, gatunkiem drzew, udziałem uszkodzonych drzewostanów i wiekiem drzew. Uwzględniając stopień uszkodzeń i udział uszkodzonych drzewostanów, wyodrębniono jednorodne podzbiory obiektów (typów siedliskowych lasów), wykorzystując analizę skupień (tab. 6). Blisko 8% drzewostanów na badanym terenie zostało uszkodzone. Za zdecydowaną większość uszkodzeń odpowiadają dzikie zwierzęta

roślinożerne – 65%, następnie grzyby patogeniczne – 24% i owady – 8% uszkodzeń (tab. 1). Stopień uszkodzeń drzewostanów zależy od źródła uszkodzenia, gatunku i wieku drzew (tab. 3, 4). 60% uszkodzonych drzewostanów miało uszkodzenia w 20%, a $^{1}/_{3}$ w 10% (tab. 1). Zwierzęta najczęściej uszkadzają dęby; grzyby – olsze; owady – świerk. Pożary najczęściej uszkadzają jałowiec, sosnę i brzozę (tab. 2). Najczęściej uszkadzane drzewostany z sosną, dębem i brzozą cechowały się najwyższym średnim wiekiem drzew (odpowiednio: 73,1, 56,0, 56,5 lat; tab. 5). Natomiast najrzadziej uszkadzane drzewostany z lipą cechowały się najniższym średnim wiekiem drzew – 45,1 lat. Biorąc pod uwagę wpływ siedliska leśnego na prawdopodobieństwo wystąpienia naturalnych uszkodzeń w drzewostanach, nie da się zauważyć istotnych różnic pomiędzy większością siedlisk (ryc. 1, 2).

W artykule przedstawiono strukturę naturalnych uszkodzeń lasów gospodarczych klimatu umiarkowanego północno-wschodniej Polski. Ponadto wskazano związki, które mogą stanowić ważne źródło informacji dla gospodarzy lasów. W przyszłości otrzymane wyniki mogą przyczynić się do modyfikacji zasad prowadzonej gospodarki leśnej. W pracy wskazano na istnienie poważnego problemu uszkodzeń młodego pokolenia lasu przez dzikie zwierzęta roślinożerne. Stwarza to realne zagrożenie zachowania trwałości lasów – odnawiania niektórych gatunków drzew: na badanym terenie zwierzęta powodowały duże uszkodzenia w odnowieniach dębowych. Sugerujemy, aby podjąć dyskusję nad koniecznością ograniczenia pogłowia dzikich zwierząt roślinożernych w lasach gospodarczych. Dyskusji wymaga również stosowany obecnie wiek rębności przyjęty dla poszczególnych gatunków drzew. Jak wykazano, wyższy wiek drzewostanów przyczynia się do częstszych uszkodzeń.