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ORIGINAL PAPER

Harvesting Scots pine wood in the state-owned forests in 2006-2020, taking into consideration abiotic disasters

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ABSTRACT

The article shows the assortment structure of Scots pine *Pinus sylvestris* wood harvested in the state-owned forests from 2006 to 2020, separated into Regional Directorates of The State Forests National Forest Holding (commonly known as State Forests), as well as the influence of natural disasters on varying pine wood harvesting. The analyses were performed on the basis of data from reports generated by the State Forests Information System (SILP). During the examined timeframe, the Regional Directorate of The State Forests (RDSF) in Szczecin exhibited the highest rate of pine wood harvesting, while RDSF in Kraków demonstrated the lowest rate in both the large-size and medium-size wood assortments groups, with a few limited exceptions. In general, from 2006 to 2020, more medium-size timber was harvested than large-size timber. Lower production costs and the convenience of wood extracting operations are driving the assortment change from W0 to WK. The lengths of WK logs are better suited to current market demands.

KEY WORDS

abiotic damage, assortment structure, *Pinus sylvestris*

Introduction

Depending on the intensity of the occurrence, natural disasters brought on by dynamic natural processes as well as by intentional or unintentional human activities affect several facets of forest management. Despite possessing substantial expertise, humanity can merely mitigate the disastrous consequences of powerful and unpredictable natural events. The global community has witnessed a substantial number of exceptional natural incidents during the initial two decades of the twenty-first century, resulting in a multitude of diverse catastrophic phenomena. Strong winds are the most damaging weather events in Poland, resulting in increased harvesting of windthrown wood and disruptions of the sequential and spatial arrangement of forest stands. Zajączkowski (1991) split the country into three zones based on the forest damage inflicted by the wind. According to the author's classification, the moderate wind zone is the largest and

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encompasses the majority of central Poland. The increased risk zone encompasses the first and second natural-forest regions, the northern part of the third region, and parts of the north-eastern section of the RDSF in Lublin, the central part of the RDSF in Radom, as well as the Carpathians and Sudetes foothills. The worst disaster (Dmyterko and Bruchwald, 2020) occurred on August 11-12, 2017 as a result of winds reaching 150 km/h. The initial estimate of the losses was 12 million cubic metres, while the total volume of wind-broken and wind-thrown wood as well as deadwood obtained in 2017 and 2018 reached 9 million m^3. The aforementioned calamity covered a narrow strip of the country running from south to north, causing losses in six RDSFs. As a consequence, an estimated quantity of five million cubic meters of windthrown timber was harvested in the RDSF in Toruń. Similarly, approximately one point five million cubic meters were obtained in RDSF in Poznań, around one point four million cubic meters in RDSF in Gdańsk, roughly zero point eight million cubic meters in RDSF in Wrocław, and approximately zero point six million cubic meters in RDSF in Szczecinek.

In 2006, damages due to abiotic factors were observed in forest stands over 20 years old on an area of 211,000 hectares, of which 94,000 ha. were induced by changes in groundwater level. Snowfall caused losses in 81 thousand ha. of forest, while severe winds were responsible for losses in 28 thousand ha. of forest. In 2006, SF (State Forests) harvested 2.28 million m^3 of pine wood as part of sanitary cutting, most of which came from forest stands in RDSF in Katowice (Raport, 2007).

Damage to forest stands over 20 years old was observed in 2007 on an area of 365 thousand hectares. Strong winds damaged forest stands covering approximately 273,000 hectares, and groundwater level variations affected 65 thousand hectares of forest-covered land. Snowfall was responsible for damage to the forest area of 17,000 hectares, while 9 thousand hectares of forest suffered from the extreme air temperatures. In terms of the area, the most damage was found in the forests subordinate to the RDSFs in Wrocław and Katowice, where, only from the foothill areas, 947 and 219 thousand cubic meters of timber was harvested, respectively. Hurricane Kyrill, passing over Poland on January 18 and 19, 2007, with wind speeds reaching up to 150 km/h, caused an almost tenfold increase in the level of damage to forest stands compared to the previous year. 6,054,242 m^3 of pine wood was harvested as a result of sanitary cuts in pine stands, 76% of which originated from wind-broken and windthrown trees. The amount of Scots pine wood harvested as part of sanitary cutting increased by 261.4% compared to 2006 (Raport, 2008).

In 2008, in forest stands older than 20 years, damage caused by abiotic factors was found in stands covering a total area of 117,000 hectares. The wind, which damaged 61,000 hectares of forest, was the factor that caused the most damage among the aforementioned variables. A somewhat lesser area of the forest (53,000 ha) than that previously reported has been damaged as a result of changes in water relations in the soil. The largest areas of forests damaged as a result of the adverse effects of abiotic factors were recorded in the forest areas of the RDSF in Wrocław, where 568,000 m^3 of wood was obtained from wind-broken and windthrown trees, and in the RDSF in Olsztyn with 722,000 cubic meters. As a result of sanitary cuts, 3,284,000 cubic meters of wood raw material was obtained, of which 66% originated from wind-broken and windthrown trees. The aforementioned level of harvested wood volume turned out to be lower by 46% compared to the volume recorded in 2007. In 2008, SF decided to lower the prices of timber delivered to the market in response to the slowdown in the global timber sector caused by the crisis in the US economy observed since the middle of the previous year (Raport, 2009).

In 2009, on 125.9 thousand hectares of forest stands over 20 years old, the State Forests recorded damage caused by abiotic factors. Unfavourable shifts in groundwater level were identified as the main cause of damage to forest stands on an area of 47 thousand hectares, while snow damaged 33 thousand hectares of forest, primarily in areas administered by RDSF in Lublin. 42 thousand hectares of forest were damaged by strong winds. Because of the substantial amount of wind-broken and windthrown trees caused by the aforementioned damage, the level of timber harvest increased in regions such as RDSF in Katowice, where 413 thousand cubic metres were recovered, followed by RDSF in Olsztyn with 360 thousand m^3 and RDSF in Wrocław with 341 thousand m^3. The SF obtained 2,133,000 cubic metres of pine wood from sanitary cuts in pine stands, 57% of which came from wind-broken and windthrown trees. The volume of pine timber obtained in this way turned out to be 35% lower than the volume recorded in 2008. In 2009, the largest amount of wood was obtained from forests located in the Olsztyn and Katowice RDSFs. In 2009 the downward trend in market demand for wood raw material in Poland initiated two years earlier continued and the State Forests reduced the price of wood through a system of discounts. The e-drewno application, which allowed 30% of previously held wood material to be placed on the market, was a new factor favourably impacting the increase in the value of the amount of wood sold (Raport, 2010).

In 2010, in forest stands older than 20 years, SF recorded damages on an area of 164.4 thousand hectares of forest. Strong winds damaged more than 38 thousand hectares of forest, while more than half, or 68,000 hectares of forest, were badly impacted by variations in groundwater levels observed over the whole country. 54,000 hectares of forest stands were damaged as a result of the heavy snowfall. In terms of the area of forest stands that were harmed by abiotic factors, snow and disruption of the equilibrium in water relations put RDSF in Katowice in first place. With a harvest of 1045 thousand m^3 of wood from wind-broken and wind-thrown trees, RDSF in Katowice again claimed first place in the country in 2010. RDSF in Wrocław, where 939 thousand m^3 of wood were obtained from the same source, came in second. As a part of sanitary cuts 3,077,000 m^3 of pine wood was obtained, of which 81% originated from wind-broken and wind-thrown forest stands. RDSF in Katowice and in Wrocław were at the forefront of obtaining wood with the use of sanitary cuts (Raport, 2011).

In 2011, in forest stands over 20 years old, State Forests recorded damage caused by abiotic factors on an area of 104.6 thousand hectares. Nearly half of the recorded regions experienced wind damage, and 40,000 hectares of the forest were adversely affected by unfavourable fluctuations in groundwater levels. The greatest extent of forest damage occurred within the boundaries of RDSF in Lublin. In the case of RDSF in Katowice, an unprecedented one million cubic meters of timber, a quantity that sets a national record, was extracted from wind-damaged and wind-thrown trees within forest stands. 2,843,000 cubic metres of wood were harvested as a result of the sanitary cuts made in forests throughout the country, 79% of which came from wind-broken and wind-thrown trees. The majority of the pine wood originating from the aforementioned cuts came from forest areas managed by RDSF in Katowice and in Olsztyn (Raport, 2012).

In 2012, in forest stands older than 20 years, damage caused by abiotic factors was recorded on 65.3 thousand hectares of forest. More than half of the area, *i.e.*, 33,000 hectares, suffered from strong winds, while 27,000 ha. of forest stands displayed damage caused by unfavourable changes in the groundwater level. In the same year, RDSF in Szczecin obtained the highest amount of wood (394 thousand m^3), RDSF in Katowice ranked right behind it, acquiring 387 thousand m^3 of raw timber, and RDSF in Białystok with a harvest at the level of 372,000 cubic meters of wood. The total volume of pine wood harvested in 2012 as a part of sanitary cuttings amounted to 2.3 million m^3, of which 72% of the wood originated from wind-broken and wind-thrown trees. In terms of volume of harvested wood, RDSF in Katowice, Szczecin, Toruń, and Szczecinek were in the top four places in the country (Raport, 2013).

In 2013, damage caused by the adverse effects of abiotic factors was recorded on an area of 71.5 thousand hectares of forest stands aged 20 years and older. The source of damages in more than half of the mentioned area of stands was the crown snow load, while 26 thousand ha. of the forest was suffered as a result of disturbances in the groundwater level. The largest amount of forest affected by severe snowfall and related crown snow-load was recorded in the RDSF in Lublin, totalling 21.1 thousand hectares. Damage to forest stands caused by cyclone Xaver, particularly a large number of wind-broken and windthrown trees, contributed considerably to the high level of wood harvest in RDSF in Szczecinek, calculated at 213.7 thousand cubic metres. The situation in the forests managed by the RDSF in Szczecin was fairly similar to that described above; nevertheless, the overall volume of wood harvested there was about half as large, at 105,000 m^3. In 2013, in all forests under the State Forests administration, 1,537.2 thousand m^3 of pine wood was harvested as part of sanitary cuts. Most of this material, as much as 205.2 thousand m^3, was obtained from forests located in the area of RDSF in Lublin. The RDSFs in Krosno and in Katowice could also take pride in producing wood in large quantities, with respective yields of 204.7 thousand m^3 and 155.6 thousand cubic metres. As in previous years, also in 2013, the threat to forests from unfavourable biotic factors was considered high (Raport, 2014).

In 2014, damage caused by abiotic factors was recorded in forest stands with a total area of 38.1 thousand hectares. On 21,000 hectares of forest, unfavourable changes in the groundwater level were considered the main cause of damage. As part of sanitary cuts, almost 2 million m^3 of wood were obtained, of which 71% came from wind-thrown and wind-broken trees. The RDSF in Szczecinek and RDSF in Szczecin forests yielded the most wood in this manner, totalling 364,000 m^3 and 308,000 m^3, respectively (Raport, 2015).

The total area of damage caused by abiotic factors in tree stands recorded by the State Forests in year 2015 amounted to 48 thousand hectares. During the described period, forests suffered mainly from drought, while damage caused by strong winds was found on 17,000 hectares of forest under the SF administration. The greatest damage to tree stands in terms of area was recorded in forests within the RDSF in Wrocław. The harvest of pine wood as part of sanitary cutting increased from the previous year to 2,236 thousand m^3, with RDSF in Szczecin harvesting the most wood in the country (281 thousand m^3) and Białystok harvesting 201 thousand m^3 (Raport, 2016).

Similar to year 2015, 2016 saw a lack of rain, which led to tree stands covering a total of 92.8 thousand hectares of forest managed by the State Forests being damaged by the drought. Forests in numerous RDSFs, including those in Białystok, Katowice, Olsztyn, and Wrocław, had the biggest losses as a result of a lack of water. The harvest of pine wood as part of sanitary cuts increased to the level of 3 million m^3, of which 30% was obtained from forest stands located within the borders of RDSF in Białystok and in Katowice (Raport, 2017).

One of the worst storms to ever hit Poland struck in August 2017, causing damage to 89.9 thousand hectares of forest stands. The total area of forests in which damage caused by abiotic factors was recorded amounted to 131.7 thousand hectares. In 2017 the State Forests harvested about 5 million m^3 of pine wood as a result of tending cuts, 78% of which came from wind-broken and windthrown trees. The majority of the pine wood has been obtained from forest stands in the Regional Directorates of SF in: Toruń, Gdańsk, Poznań, Katowice, and Szczecinek (Raport, 2018).

In 2018, in forest stands older than 20 years, damage caused by abiotic factors was recorded on an area of 76.2 thousand hectares, of which unfavourable changes in water conditions were responsible for damage on an area of 43.5 thousand hectares. Strong winds caused damage to forest stands covering an area of 29.4 thousand hectares. The most extensive damage was recorded in the forests of RDSF in Wrocław, where 1 million cubic metres of wood was harvested. 0.95 million m^3 of wood was obtained from forests in the RDSF in Poznań and 0.6 million m^3 from the forests of RDSF in Katowice. As part of sanitary cuts in coniferous forest stands, a total of 10.1 million cubic meters of wood were harvested (Raport, 2019).

In 2019, changes in the water table's levels and severe winds were the main sources of abiotic damage to forest stands older than 20 years. A total of 62.5 thousand hectares of forest have been impacted by unfavourable changes in the water table, while 42.3 thousand hectares were damaged by wind. A total of 113.2 thousand hectares of forest stands aged 20 years and older managed by State Forests were damaged as a result of abiotic factors. The most severe damage was observed in the forests of RDSFs in Katowice and Wrocław. 3.5 million cubic metres of pine wood has been extracted as part of sanitary cuts around the country, with deadwood accounting for 2 million cubic metres (Raport, 2020).

In 2020, the area of forest stands damaged by abiotic factors decreased compared to the area recorded in the previous year and amounted to 79.3 thousand hectares. Unfavourable fluctuations in water table levels were responsible for forest damage on an area of 62.4 thousand hectares, while high winds damaged forest stands on an area of 10.7 thousand hectares. Abiotic factors caused the most damage to forests in the Regional Directorate of State Forests in Wrocław, affecting 23.6 thousand hectares of forest stands. As part of sanitary cuts, 2.8 million m^3 of wood was obtained, of which 2.2 million m^3 was classified as deadwood (Raport, 2021).

Over time, the average temperature rises as the growth season's humidity declines. According to Urban *et al.* (2022), more frequent and longer times of moisture scarcity are expected, which is expected to have a severe influence on numerous sectors of the country's economy. Climate change, which is more evident in coniferous forests (Seidl *et al.*, 2017), may increase the power and frequency of violent weather phenomena such as storms or hurricanes (Ornes, 2018). These occurrences will be distinguished by slower resolution and higher air humidity. The expected growth in the extent of European forests will exacerbate the increase in damage to forest stands (Schelhaas *et al.*, 2003). Enriching databases on current weather conditions will allow for the development of more realistic weather simulations in the future (Gutmann *et al.*, 2018), which will allow for the development of better methods for assessing the risk of damage to forest stands, ultimately reducing forest damage (Heinonen *et al.*, 2009). However, we must remember that natural interference of abiotic factors in ecosystems is an excellent tool for evolution and acceleration of matter circulation (Aber and Melillo, 1991), which has a good impact on sustaining high biodiversity (Attiwill, 1994). Changes in local ecosystems produced by extreme weather events boost the diversity of plant, animal, and soil microfauna populations. Imitating nature in logging processes through the formation of small gaps similar to those created during storms or hurricanes, according to Ehnes and Keenan (2002), can positively influence the forest ecosystem. Duelli *et al.* (2002) discovered a 50% increase in the number of living organisms in the ensuing gaps as compared to forest fragments with uninterrupted spatial structure. The Puszcza Piska Forest in the Regional Directorates of State Forests in Białystok and Olsztyn was severely damaged in July 2006 as a result of the 'White Squall' hurricane. Furthermore, significant snowfall in November of the same year caused forest damage, resulting in 1.5 million m^3 of harvested wood. Hurricane winds in the south-western parts of Poland in 2007 also contributed to 2.5 million m^3 of wood damage (Bruchwald and Dmyterko, 2012).

Because Scots pine *Pinus sylvestris* L. is the most common forest-forming species in our country any impact on its health and numbers will be most visible from the financial side of State Forests and the economy on the timber market. External factors, such as weather anomalies or natural disasters, have a substantial impact on the market price of wood. The anticipated price for large-size wood is higher than the actual price due to poor raw material quality, although the price of medium-size S2A assortments continues to rise decisively (Górna, 2021).

In the event of a calamity, faster raw material production protects it against depreciation. It is preferable to use harvesters, which are safer and approximately 7 times more efficient than chainsaw methods (Dvorák *et al*., 2011). Other authors (Frutig *et al*., 2007) emphasise that these techniques are more financially profitable.

The aim of this work is to examine the harvesting of pine wood in the State Forests National Forest Holding, divided into Regional Directorates, from 2006 to 2020, taking into consideration natural disasters events.

Materials and methods

Data on pine wood harvesting utilised in the analyses here presented was obtained from reports generated by the State Forests Information System (SILP) concerning all 17 RDSFs. Each forest district's information was reviewed, organised, and compiled collectively for each RDSF and the entire State Forests. Data were also compiled for individual assortments of medium- and large-size pine wood as well as for total volume in the subsequent years from 2006 to 2020.

Based on the information gathered in this manner, a ranking of RDFSs for Scots pine wood harvesting was created, and the pattern of changes over a 15-year period was examined.

For timber production purposes State Forests has implemented a merchantable wood standards where the assortments are divided in to a medium-size and large-size wood (assortments group S and assortments group W respectively). In the abovementioned standards medium-size wood (S) is defined as wood with a minimum upper diameter of 5 cm, measured without bark. This products have been further categorized in to 4 groups depending on the measurements and quality of harvested wood (S1, S2, S3 and S4). Large-size wood (W) is a round wood with a minimum upper diameter of 14 cm, measured without bark, that adheres to specific quality requirements. Based on the dimensions and extent of defects large-size wood logs are divided into four quality classes: A, B, C and D. Large-size general-purpose timber is denoted by the symbol W0. Round wood with a minimum upper diameter of 14 cm, measured without bark, produced in logs and meeting specific quality requirements is marked as WK. These logs are produced in lengths ranging from 2.4 to 6.0 metres.

In accordance with the aforementioned classification of SF's wood products, the subsequent abbreviations employed in the analyses carried out in this study are hereby presented:

S2A – medium-size industrial wood with a length of 1-3 m and a minimum upper diameter without bark of 5 cm and a maximum lower diameter without bark of 35 cm sold in stacks,

WC0 – large-size general-purpose timber of medium to low quality. Includes timber with quality characteristics that do not appreciably diminish the natural properties of wood,

WCKP – WK timber in quality group C sold in separate logs.

Results

The State Forests harvested more than 17 million m^3 of pine wood in 2006 (Table 1), with over 7.4 million m^3 being large-size wood and 9.7 million m^3 being medium-size wood (Table 2, 3). The overall amount of pine wood harvested in 2007 increased by more than 2.3 million m^3 over the previous year, owing mostly to a rise in the volume of large- and medium-size material (Table 2, 3).

Table 1.

Total volume of harvested pine wood in the years 2006-2020 in the State Forests, divided into RDSF units [thous. m^3]

RDSF	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Białystok	1357	1490	1364	1376	1521	1366	1374	1421	1493	1556	1635	1583	1549	1608	1631
Katowice	1371	1468	1421	1526	1944	1885	1538	1638	1657	1713	1805	1928	1900	1950	1832
Kraków	181	212	180	184	213	230	219	237	237	235	228	224	224	228	192
Krosno	426	452	458	423	535	560	568	656	630	603	624	652	643	652	628
Lublin	895	927	873	848	977	1077	1117	1088	1134	1227	1299	1288	1295	1359	1411
Łódź	780	914	942	867	894	887	828	860	921	898	1005	1088	1194	1213	1119
Olsztyn	1334	1988	1659	1352	1371	1442	1472	1490	1617	1713	1645	1765	1676	1660	1637
Piła	1078	1203	1118	1121	1123	1120	1191	1309	1505	1556	1564	1634	1564	1566	1528
Poznań	1216	1332	1276	1376	1403	1412	1365	1409	1473	1516	1495	1741	1890	1640	1409
Szczecin	1967	2155	2011	2048	2087	2167	2153	2342	2491	2607	2714	2847	2776	2722	2400
Szczecinek	1346	1500	1449	1487	1590	1773	1820	1877	1931	1863	1899	2171	2061	1996	1817
Toruń	1240	1305	1302	1377	1421	1385	1499	1467	1548	1542	1621	2980	3736	1940	1953
Wrocław	894	1177	915	1284	1186	929	897	926	993	1061	1126	1168	1157	1203	1168
Zielona Góra	1142	1319	1239	1331	1382	1491	1472	1518	1561	1576	1598	1701	1687	1715	1532
Gdańsk	554	535	581	616	713	704	713	794	812	832	891	1218	1297	832	862
Radom	857	940	848	880	1014	996	1034	1095	1133	1180	1201	1213	1270	1304	1245
Warszawa	476	508	529	538	563	647	629	641	659	693	688	745	736	773	776
Total	17114	19425	18166	18633	19937	20070	19890	20768	21794	22369	23039	25946	26656	24363	23140

Table 2.
Volume of harvested large-size pine wood in the years 2006-2020 in the State Forests, divided into RDSF units [thous. m^3]

RDSF	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Białystok	526	645	549	476	670	657	671	711	770	789	858	794	789	842	871
Katowice	627	714	707	714	809	696	722	791	803	852	873	970	947	996	1028
Kraków	112	146	116	113	137	149	143	149	152	152	145	142	141	148	124
Krosno	290	304	322	283	361	376	391	436	435	416	425	446	436	449	476
Lublin	461	498	459	417	515	596	640	584	617	652	684	655	671	723	798
Łódź	345	449	379	362	405	398	369	381	438	423	471	487	575	571	531
Olsztyn	648	1009	750	585	638	658	671	724	836	883	830	894	852	855	874
Piła	370	404	379	377	386	365	381	433	487	466	445	463	450	447	438
Poznań	451	488	465	499	527	534	525	541	554	552	565	632	687	617	564
Szczecin	815	834	792	815	832	813	773	867	982	1075	1075	1162	1090	1099	1045
Szczecinek	616	642	626	648	672	819	783	818	819	775	789	892	903	880	839
Toruń	557	560	528	592	613	579	591	574	619	595	621	1200	1211	704	812
Wrocław	344	512	381	457	449	365	366	352	375	395	412	440	422	428	437
Zielona Góra	358	420	401	420	426	425	421	412	402	404	461	492	469	477	458
Gdańsk	234	221	215	215	291	284	279	331	335	347	362	534	569	396	412
Radom	457	530	444	468	543	521	539	575	629	677	690	671	711	725	738
Warszawa	191	208	213	213	226	250	239	251	250	285	274	299	292	315	358
Total	7400	8584	7726	7655	8501	8487	8506	8929	9503	9738	9981	11173	11214	10672	10803

Table 3.
Volume of harvested medium-size pine wood in years 2006-2020 in the State Forests, divided into RDSF units [thous. m^3]

RDSF	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Białystok	832	845	815	899	851	708	703	710	723	767	776	789	760	766	761
Katowice	744	754	715	812	1135	1189	815	847	854	861	932	958	953	955	804
Kraków	69	66	64	71	76	80	75	88	85	83	83	82	83	80	68
Krosno	136	149	136	140	175	183	177	220	195	187	199	206	207	203	152
Lublin	434	430	414	431	462	481	478	503	517	575	615	633	624	636	612
Łódź	435	465	563	504	489	489	458	480	483	475	535	602	619	642	588
Olsztyn	686	979	909	768	732	784	801	766	782	830	815	871	824	805	763
Piła	707	799	740	743	737	755	810	877	1018	1090	1118	1170	1115	1119	1090
Poznań	766	844	811	878	876	878	841	869	919	964	930	1109	1204	1024	845
Szczecin	1151	1320	1220	1233	1254	1354	1380	1475	1509	1532	1639	1686	1686	1624	1355
Szczecinek	730	858	822	839	918	954	1037	1059	1111	1087	1110	1279	1158	1116	978
Toruń	682	745	774	785	808	806	908	893	929	947	1000	1780	2526	1236	1141
Wrocław	550	665	534	827	737	564	531	574	618	666	714	728	735	776	731
Zielona Góra	785	899	837	912	956	1066	1050	1106	1159	1173	1137	1208	1218	1238	1073
Gdańsk	320	315	366	400	422	420	435	463	476	485	529	684	728	436	450
Radom	400	410	404	412	471	474	496	520	504	502	511	542	559	579	507
Warszawa	285	299	316	325	338	397	390	390	408	408	414	446	443	458	418
Total	9714	10842	10440	10978	11436	11584	11385	11838	12291	12631	13058	14773	15442	13692	12337

When data from 2007 and 2008 are compared, a 6.5% decline can be seen in pine wood harvesting (Table 1). The harvest of large-size wood decreased in 2007 by over 850 thousand m^3, while the harvest of medium-size wood in the same year decreased by just over 400 thousand m^3 (Table 2, 3). The harvest of medium-size wood increased by 538 thousand m^3 in 2009 (Table 3), whereas the harvest of large-size wood decreased by almost 71.5 thousand m^3 (Table 2). This directly contributed to the overall rise in the harvest of pine wood, with a merchantable volume of over 466,000 m^3 (Table 1).

In 2010, 1.3 million m^3 more pine wood was harvested than the previous year (Table 1), with large-size wood making up about two-thirds of the increase (Table 2) and medium-size wood accounting for the remaining one-third (Table 3). Despite a modest decline (by 14.2 thousand m^3) (Table 2), the volume of wood harvested in 2011 grew by 133,800 m^3 (Table 1) compared to the previous year. A slight decrease in the harvest of merchantable volume wood by little over 180 thousand m^3 (Table 1) resulted from a decrease in the harvest of medium-size wood (Table 3) by almost 200 thousand m^3 and an increase in the harvest of large-size wood by just under 19 thousand m^3 compared to the year 2010 (Table 2).

In 2013, the harvest of merchantable volume pine wood increased (Table 1), reaching 20.76 million m^3 with a nearly equal percentage share of medium-size and large-size wood (Table 2, 3). Due to a rise in the amount of large-size wood harvested (over 573 thousand m^3) and medium-size wood harvested (452.6 thousand m^3) in 2014, an upward trend in the harvesting of merchantable volume pine wood was maintained (Table 1). The growth trend from previous years also continued in 2015. The harvest of merchantable wood totalled over 22.3 million m^3, an increase of over 400 thousand m^3 for medium-size wood (Table 3) and 235 thousand m^3 for large-size wood (Table 2) over the previous year. Wood harvest grew by 3% in 2016 compared to 2015 (Table 4), reaching almost 427 thousand m^3 for medium-size wood (Table 3) and just over 243 thousand m^3 for large-size wood (Table 2). The increase in merchantable volume wood harvest in 2017 to the level of almost 26 million m^3 (Table 1) was mostly due to increases in medium-size wood harvest (Table 3) by over 1.7 million m^3 and large-size wood (Table 2) by almost 1.2 million m^3.

Pine wood harvesting reached a record volume in 2018, totalling 26,656 thousand m^3. Medium-size wood accounted for 58% of the total volume of wood harvested, which grew by just over 669 thousand m^3 over the previous year. The total volume of pine wood harvested in 2019 dropped by just little of 2.3 million m^3 compared to 2018 (Table 1). In comparison to 2018, there was 1.75 million m^3 drop in medium-size wood obtained (Table 3), as well as over 542 thousand m^3 decrease in large-size wood harvested (Table 2). Despite a 131.5 thousand m^3 rise in large-size wood harvest (Table 2), the negative trend from the previous year continued in 2020 (Table 1). In the analysed year, the total harvest of merchantable pine wood amounted to just over 23 million m^3. In comparison to the previous year, the harvest of medium-size wood dropped by over 1.3 million m^3 (Table 3).

RDSF in Szczecin harvested the highest quantities of harvested merchantable volume pine wood in the country during the analysed period (Table 4). It coincided with the largest harvest of medium-size wood, with the exception of 2017 and 2018, when RDSF in Toruń obtained the most medium- and large-size wood (Table 5, 6). RDSF in Szczecinek was the national leader in the volume of large-size wood harvested in 2011 and 2012 (Table 5), obtaining 146,485.09 m^3 more wood than in 2010. RDSF in Szczecin retained its top spot in the S2A wood assortment harvest (Table 6) for the years 2006-2009, 2012-2016, and 2019-2020.

Table 4.
Share in the total volume of harvested pine wood in the years 2006-2020 in the State Forests, divided into RDSF units [%]

RDSF	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Białystok	7.93	7.67	7.51	7.38	7.63	6.80	6.91	6.84	6.85	6.96	7.10	6.10	5.81	6.60	7.05
Katowice	8.01	7.56	7.82	8.19	9.75	9.39	7.73	7.89	7.60	7.66	7.83	7.43	7.13	8.01	7.92
Kraków	1.06	1.09	0.99	0.99	1.07	1.14	1.10	1.14	1.09	1.05	0.99	0.86	0.84	0.93	0.83
Krosno	2.49	2.33	2.52	2.27	2.69	2.79	2.86	3.16	2.89	2.70	2.71	2.51	2.41	2.68	2.71
Lublin	5.23	4.77	4.80	4.55	4.90	5.37	5.62	5.24	5.20	5.48	5.64	4.97	4.86	5.58	6.10
Łódź	4.56	4.70	5.18	4.65	4.48	4.42	4.16	4.14	4.23	4.01	4.36	4.19	4.48	4.98	4.84
Olsztyn	7.80	10.23	9.13	7.26	6.87	7.19	7.40	7.17	7.42	7.66	7.14	6.80	6.29	6.81	7.07
Piła	6.30	6.19	6.16	6.01	5.63	5.58	5.99	6.31	6.91	6.96	6.79	6.30	5.87	6.43	6.60
Poznań	7.11	6.86	7.03	7.39	7.04	7.04	6.86	6.79	6.76	6.78	6.49	6.71	7.09	6.73	6.09
Szczecin	11.49	11.09	11.07	10.99	10.47	10.80	10.83	11.28	11.43	11.65	11.78	10.97	10.41	11.17	10.37
Szczecinek	7.86	7.72	7.97	7.98	7.97	8.83	9.15	9.04	8.86	8.33	8.24	8.37	7.73	8.19	7.85
Toruń	7.24	6.72	7.17	7.39	7.13	6.90	7.54	7.06	7.10	6.89	7.04	11.49	14.02	7.96	8.44
Wrocław	5.22	6.06	5.04	6.89	5.95	4.63	4.51	4.46	4.56	4.74	4.89	4.50	4.34	4.94	5.05
Zielona Góra	6.68	6.79	6.82	7.14	6.93	7.43	7.40	7.31	7.16	7.05	6.94	6.55	6.33	7.04	6.62
Gdańsk	3.24	2.76	3.20	3.31	3.58	3.51	3.59	3.82	3.72	3.72	3.87	4.69	4.87	3.41	3.73
Radom	5.01	4.84	4.67	4.72	5.09	4.96	5.20	5.27	5.20	5.27	5.21	4.67	4.77	5.35	5.38
Warszawa	2.78	2.61	2.91	2.89	2.83	3.23	3.16	3.08	3.02	3.10	2.98	2.87	2.76	3.17	3.35
Total [%]	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table 5.
Share in the volume of harvested large-size pine wood in the years 2006-2020 in the State Forests divided into RDSF units [%]

RDSF	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Białystok	7.11	7.51	7.11	6.22	7.89	7.75	7.89	7.96	8.10	8.10	8.60	7.10	7.03	7.89	8.06
Katowice	8.47	8.32	9.15	9.32	9.52	8.20	8.49	8.86	8.45	8.75	8.75	8.68	8.44	9.33	9.52
Kraków	1.52	1.70	1.50	1.47	1.61	1.76	1.69	1.67	1.60	1.56	1.45	1.27	1.26	1.38	1.15
Krosno	3.91	3.54	4.17	3.69	4.24	4.43	4.60	4.88	4.58	4.27	4.25	4.00	3.88	4.21	4.40
Lublin	6.23	5.80	5.94	5.45	6.06	7.03	7.52	6.55	6.49	6.70	6.85	5.86	5.98	6.78	7.39
Łódź	4.66	5.23	4.91	4.74	4.76	4.70	4.34	4.26	4.61	4.34	4.71	4.35	5.12	5.35	4.92
Olsztyn	8.76	11.75	9.70	7.64	7.51	7.76	7.89	8.11	8.79	9.07	8.31	8.00	7.60	8.01	8.09
Piła	5.01	4.70	4.90	4.93	4.54	4.30	4.48	4.84	5.12	4.79	4.46	4.15	4.01	4.19	4.06
Poznań	6.09	5.68	6.02	6.51	6.20	6.29	6.17	6.06	5.83	5.67	5.66	5.65	6.12	5.78	5.22
Szczecin	11.02	9.72	10.25	10.65	9.79	9.58	9.09	9.71	10.33	11.04	10.77	10.40	9.72	10.30	9.67
Szczecinek	8.32	7.48	8.11	8.47	7.91	9.65	9.20	9.16	8.62	7.96	7.91	7.98	8.06	8.25	7.76
Toruń	7.53	6.53	6.83	7.74	7.21	6.82	6.95	6.43	6.51	6.11	6.23	10.74	10.80	6.60	7.52
Wrocław	4.65	5.96	4.93	5.97	5.28	4.30	4.31	3.94	3.94	4.05	4.13	3.94	3.76	4.01	4.04
Zielona Góra	4.83	4.89	5.20	5.48	5.01	5.01	4.96	4.61	4.23	4.14	4.62	4.41	4.19	4.47	4.24
Gdańsk	3.16	2.57	2.78	2.81	3.42	3.34	3.28	3.70	3.53	3.57	3.63	4.78	5.07	3.71	3.82
Radom	6.17	6.18	5.75	6.11	6.38	6.14	6.33	6.44	6.62	6.96	6.91	6.00	6.34	6.79	6.83
Warszawa	2.58	2.43	2.76	2.79	2.66	2.95	2.81	2.81	2.64	2.93	2.74	2.67	2.61	2.96	3.31
Total [%]	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table 6.
Share in the volume of harvested medium-size pine wood in the years 2006-2020 in the State Forests divided into RDSF units [%]

RDSF	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Białystok	8.56	7.80	7.81	8.19	7.44	6.11	6.18	6.00	5.88	6.07	5.95	5.34	4.92	5.59	6.16
Katowice	7.66	6.95	6.84	7.40	9.93	10.27	7.16	7.16	6.95	6.82	7.14	6.49	6.17	6.97	6.52
Kraków	0.71	0.61	0.62	0.65	0.67	0.69	0.66	0.74	0.69	0.66	0.64	0.55	0.54	0.59	0.55
Krosno	1.40	1.37	1.30	1.28	1.53	1.58	1.56	1.86	1.58	1.48	1.52	1.39	1.34	1.48	1.23
Lublin	4.47	3.96	3.96	3.93	4.04	4.15	4.20	4.25	4.20	4.55	4.71	4.29	4.04	4.64	4.96
Łódź	4.48	4.29	5.39	4.59	4.28	4.22	4.03	4.05	3.93	3.76	4.10	4.07	4.01	4.69	4.77
Olsztyn	7.06	9.03	8.71	6.99	6.40	6.77	7.03	6.47	6.36	6.57	6.24	5.89	5.34	5.88	6.18
Piła	7.28	7.37	7.09	6.77	6.44	6.52	7.12	7.41	8.29	8.63	8.56	7.92	7.22	8.18	8.83
Poznań	7.89	7.79	7.77	8.00	7.66	7.58	7.39	7.34	7.48	7.63	7.12	7.51	7.80	7.48	6.85
Szczecin	11.85	12.18	11.68	11.23	10.97	11.68	12.12	12.46	12.28	12.13	12.55	11.41	10.92	11.86	10.98
Szczecinek	7.52	7.91	7.88	7.64	8.02	8.24	9.11	8.94	9.04	8.61	8.50	8.66	7.50	8.15	7.93
Toruń	7.02	6.87	7.42	7.15	7.06	6.96	7.97	7.54	7.56	7.50	7.65	12.05	16.35	9.03	9.25
Wrocław	5.66	6.14	5.12	7.53	6.44	4.87	4.66	4.85	5.03	5.27	5.47	4.93	4.76	5.67	5.93
Zielona Góra	8.08	8.29	8.02	8.30	8.36	9.20	9.22	9.34	9.43	9.28	8.71	8.18	7.89	9.04	8.70
Gdańsk	3.30	2.90	3.51	3.65	3.69	3.63	3.82	3.91	3.88	3.84	4.05	4.63	4.71	3.18	3.65
Radom	4.12	3.78	3.87	3.76	4.12	4.09	4.35	4.39	4.10	3.97	3.91	3.67	3.62	4.23	4.11
Warszawa	2.94	2.76	3.03	2.96	2.95	3.43	3.42	3.29	3.32	3.23	3.17	3.02	2.87	3.34	3.39
Total [%]	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

In years 2010 and 2011, most of the S2A pine wood assortment was obtained in RDSF in Katowice, and in 2017-2018, in RDSF in Toruń. During the 15 years under analysis, the largest amount of S2A assortment was obtained in RDSF in Toruń in 2018, when the volume of S2A pine wood harvested exceeded the volume of this assortment harvested in years 2006, 2007, and 2008 combined. RDSF in Kraków registered the lowest values of harvested merchantable volume wood and medium-size wood from 2006 to 2020. In the mentioned Regional Directorate, the lowest harvesting of S2A wood was recorded in 2020 and amounted to over 27,5 thousand m^3. In 2018-2019, RDSF in Toruń experienced the greatest reduction (28.39%) in the percentage share of volume of harvested Scots pine wood (Table 4). Large-size wood of quality class C (WC0) prevailed over other large-size wood assortments in all RDSFs until 2012. The production of individually measured large-size logs (WCKP) in RDSF in Zielona Góra increased dramatically (by 73.25%) in 2013. This increase had a direct impact on the reduction of the WC0 wood assortment to 19.21% (Fig. 1). There was a gradual increase in the share of WCKP assortment in the remaining RDSFs (Fig. 2) until 2019, when there was a total fall in the WCKP and its place was taken by a log assortment measured and sold in a group (WCK).

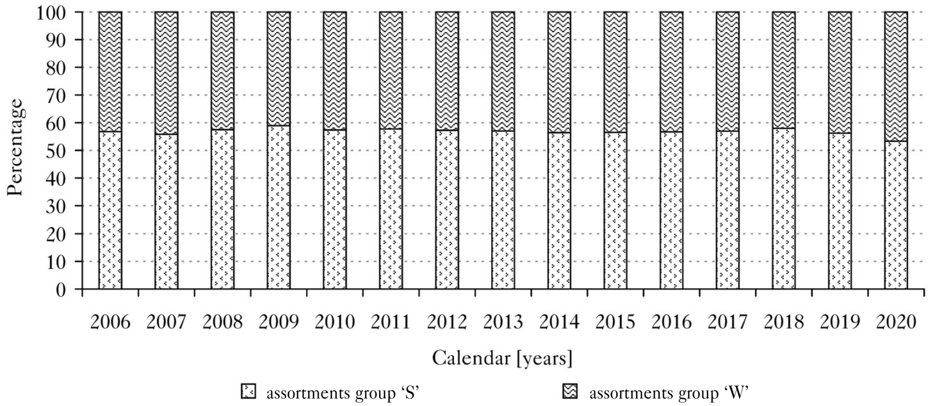

Fig. 1.
Assortment structure in percentage of harvested pine wood in the years 2006-2020 in the State Forests [%]

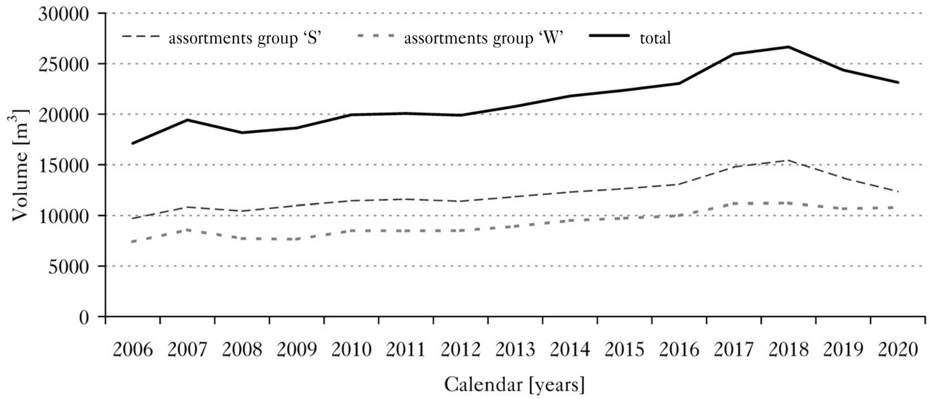

Fig. 2.
Assortment structure of harvested pine wood in years 2006-2020 in the State Forests [thous. m^3]

Discussion

Damage to forest stands caused by the 'White Squall' hurricane in July and significant snowfall in November of the previous year might be attributed to the abrupt increase in the harvest of pine wood from the woods of the Regional Directorate of State Forests in Olsztyn in 2007. The harvest of the S2A wood assortment increased by almost 293 thousand m^3 (Table 3), while the harvest of the W0 assortment ascended by over 360 thousand m^3 (Table 2). The year 2009 at RDSF in Olsztyn was marked by a sharp fall in the harvesting of W0 and S2A wood assortments, allowing us to conclude that priority was given to the manufacturing of large-size wood in 2008. A similar trend was observed in the RDSF in Białystok in 2007, when, as a result of Hurricane Kyrill damage, the harvest of W0 pine wood increased by over 167 thousand m^3 (Table 2) and then fell in the following two years. Similarly, the harvesting of S2A pine wood assortment in RDSF in Wrocław climbed by 115,239 m^3 in 2007, before declining the following year (Table 3). The increased harvest of large-size assortments in RDSF in Katowice in 2007 (Table 2) can be linked to forest damage caused by Hurricane Kyrill, as well as the year's greatest overall area of forest fires. Damage caused by the hurricane's destructive force in the forests of the Regional Directorate of State Forests in Zielona Góra could account for an increase of 114,505 cubic meters in the harvest of the S2A assortment (Table 3) as well as, to a lesser extent, an increase in the harvest of the W0 pine wood assortment (Table 2). The RDSF in Katowice forests provided the majority of the country's pine wood in 2009 and 2010, as part of sanitary cuts. In the aforementioned RDSF, the harvest of the S2A assortment rose by almost 323 thousand m^3 in 2010, but declined by just under 374 thousand m^3 in 2012. The amount of the W0 assortment increased by 95 thousand m^3, while its harvesting dropped by 113,1 thousand m^3 the following year.

The RDSF in Lublin saw an increase in pine wood harvest of 98 thousand cubic metres, which may have been caused by snow damage to this RDSF's forests the previous year. Abiotic factors played a major role in the rise in the amount of merchantable volume pine wood harvested across the country in 2011. The forests of RDSF in Toruń, Gdańsk, Poznań, Katowice, and Szczecinek were damaged by the hurricane that passed through Poland in 2017. In the mentioned Regional Directorates of the State Forests, in the same year, a sharp increase in Scots pine wood harvesting was recorded. This trend was especially noticeable in RDSF in Toruń, where the harvest of W0 pine wood assortment surged by almost 579 thousand m^3 in 2017 before dropping precipitously two years later (Table 2). In the same RDSF, the S2A wood assortment harvest climbed by 780.7 thousand m^3 in 2017, 745.3 thousand m^3 in 2018, and subsequently fell in 2019. In 2018, there was also a decrease in the growth in harvest levels of medium-size wood from RDSF in Szczecin – managed forests, which had been ongoing since 2008 (Table 3). Downward trends in medium-size wood harvesting were observed in RDSFs such as in Toruń, Gdańsk, and Poznań in 2019, with the highest decline reported in RDSF in Toruń, amounting to almost 1.3 million m^3. The harvest of the W0 wood assortment grew in numerous RDSFs between 2017 and 2018. This harvest decreased in 2019, and only a few RDSFs, such as in Katowice, Warszawa, Lublin, and Szczecinek maintained upward trends.

New regulations issued by the General Director of State Forests in 2013, 2018, and 2019 on changes in operational standards for large-size timber had a direct impact on the level of harvest of W0 assortment wood and an increase in the amount of log wood produced (Figs. 1, 2).

Conclusions

- RDSF in Szczecin, in 2018 harvested the most pine wood in both assortment groups between 2006 and 2020, whereas RDSF in Kraków in 2009 has obtained the least.

- During the analysed time period, more medium-size wood was harvested than large-size wood.
- The distribution of forest damage caused by abiotic factors is not uniform, and certain regions of the country exhibit higher susceptibility than others. Considering the escalating frequency and extent of subsequent calamities, it is logical to anticipate a rise in the magnitude of forest damages.

Authors' contributions

A.K.-P. – manuscript preparation; D.Z. – research concept and methodology development, results analysis; W.B. – English manuscript preparation and revision; H.L. – the study concept and methodology development, manuscript revision and the analysis of the results.

Conflicts of interest

The authors declare the absence of potential conflicts of interest.

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STRESZCZENIE

Pozyskanie drewna sosny zwyczajnej w Lasach Państwowych w latach 2006-2020 z uwzględnieniem klęsk żywiołowych

Klęski żywiołowe spowodowane przez dynamiczne zjawiska przyrodnicze, jak i przez umyślną lub nieumyślną działalność człowieka, mają wpływ, w zależności od zasięgu występowania, na wiele aspektów funkcjonowania gospodarki leśnej. W przypadku klęsk wywołanych przez gwałtowne, trudno przewidywalne zjawiska naturalne, człowiek mimo szerokiej wiedzy może jedynie niwelować ich katastrofalne skutki. W ciągu zaledwie dwóch dekad XXI wieku wystąpiło na świecie wiele ekstremalnych zjawisk przyrodniczych generujących różnego rodzaju zjawiska klęskowe. Spośród zjawisk pogodowych w Polsce silne wiatry przyczyniają się do powstawania największych szkód w lasach, co przekłada się na zwiększone pozyskanie drewna poklęskowego oraz zaburza ład czasowy i przestrzenny drzewostanów.

Celem niniejszej pracy jest analiza pozyskania drewna sosny zwyczajnej *Pinus sylvestris* L. według struktury sortymentów drewna wielkowymiarowego i średniowymiarowego w Lasach Państwowych z podziałem na regionalne dyrekcje LP w latach 2006-2020 z uwzględnieniem klęsk żywiołowych.

Dane dotyczące pozyskania drewna sosny wykorzystane do przeprowadzenia badań pochodzą z raportów generowanych przez System Informatyczny Lasów Państwowych (SILP). Informacje z każdego nadleśnictwa zostały sprawdzone, uporządkowane, a następnie zestawione tak, aby można było zaobserwować zmiany pozyskania drewna zgodnie z założeniami badań. W tym celu przedstawiono sumaryczną miąższość pozyskanego drewna sosny zwyczajnej w latach 2006-2020 w Lasach Państwowych z podziałem na jednostki RDLP w m^3 (tab. 1), jak również podobny sumaryczny procentowy udział miąższości pozyskanego surowca sosnowego (tab. 4). W dalszej kolejności zaprezentowano miąższość w m^3 oraz procentowy udział pozyskanego sosnowego

drewna wielkowymiarowego w latach 2006-2020 z podziałem na jednostki RDLP w Lasach Państwowych (tab. 2 i 5). Takie samo zestawienie wykonano dla drewna średniowymiarowego (tab. 3 i 6). Strukturę sortymentową pozyskanego drewna sosny zwyczajnej w analizowanym okresie ilustrują ryciny 1 i 2.

Wykazano, że na przestrzeni lat 2006-2020 najwięcej drewna sosnowego w obu grupach sortymentów pozyskała RDLP w Szczecinie, a najmniej RDLP w Krakowie. W analizowanym okresie pozyskano więcej drewna średniowymiarowego niż drewna wielkowymiarowego. Szkody w lasach wywołane czynnikami abiotycznymi nie są równomiernie rozmieszczone, a lasy w niektórych regionach kraju są bardziej zagrożone od pozostałych.

Przejście z sortymentów W0 na WK spowodowane jest niższymi kosztami pozyskania oraz łatwością wyrobu i zrywki, a wymiary drewna kłodowanego są lepiej dostosowane do potrzeb odbiorców.

Biorąc pod uwagę zwiększającą się częstotliwość występowania kolejnych klęsk, jak również ich zasięg, można wnioskować, że miąższość drewna pozyskanego w ich następstwie będzie wzrastała. Należy spodziewać się, że rosnące w warunkach przewlekłego stresu drzewa sosny zwyczajnej będą bardziej podatne na choroby grzybowe i działalność szkodników owadzich, których populacje będą wzrastać w obliczu globalnego ocieplenia. Biorąc pod uwagę wzrost temperatury powietrza oraz spadek wilgotności powietrza i gleby, która jest kluczowa dla rozwoju roślin, przewiduje się również zmniejszony przyrost miąższości drzew oraz pogorszenie jakości pozyskiwanego surowca drzewnego.