

TREES IN PUBLIC AND RECREATIONAL SPACES AS A RISK FACTOR UNDER WEATHER ANOMALIES

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Abstract

Trees constitute a key component of urban landscapes and green infrastructure, providing numerous ecosystem services and enhancing the attractiveness of public recreational spaces. At the same time, their presence in intensively used areas—such as parks, promenades, squares, and pedestrian routes—requires careful consideration of public safety. In the context of climate change and the increasing frequency of weather anomalies, particularly severe windstorms, the issue of managing tree-related risk has become increasingly important.

The aim of this paper is to present the scale of hazards associated with trees in public spaces in Poland compared with England, in the context of balancing recreational use and landscape protection. The study compiles statistics on accidents and damages caused by trees during strong wind events in the years 2000–2022. Based on these data, a regional risk coefficient related to windthrows and uprooted trees was developed.

The results indicate that both the number and the consequences of tree-related incidents in Poland remain comparable to those observed in England and can be considered relatively low. The findings confirm that rational tree management, based on assessment of tree condition and potential risk, allows the reconciliation of public safety requirements with the need to preserve trees as an important element of the landscape and recreational environments. The results may contribute to the development of sustainable strategies for managing urban trees, supporting both landscape protection and improved quality of life in cities.

Key words: urban trees, public recreational spaces, windthrows and uprooting, trees and windstorms, tree risk management, fallen trees

Introduction

Public awareness of the important role of trees in the natural environment and cultural landscape has existed for centuries, but it is particularly significant today in the era of progressing climate change (Rosłon-Szeryńska 2019). Numerous scientific studies confirm the wide range of environmental, social, health, cultural, aesthetic, and economic benefits provided by trees, often expressed in monetary terms, enabling their inclusion in urban development strategies. Consequently, in many countries trees are recognized as national assets and green capital of cities (Szczepanowska, Sitarski 2015). The concepts of “ecosystem services” (Solon et al. 2017) and “green infrastructure,” with trees as key elements, have been widely discussed (Szulczewska 2018) and constitute an important priority in spatial policies worldwide, including in Asian countries (Mizgajski, Stępniewska 2009). Trees also play a significant climate-regulating role in cities (Czerwieniec, Lewińska 2000). Research shows that the benefits of trees outweigh their potential drawbacks (Rosłon-Szeryńska 2019).

Nevertheless, in Poland, trees in human environments are often perceived as a safety threat, which contributes to increasing numbers of tree removal decisions (Krynicky, Witkoś 2016). Public perception is frequently influenced by misconceptions regarding risks associated with windthrow and uprooting (Rosłon-Szeryńska 2019). This is further linked to the financial liability of landowners for damages caused by trees in cases of negligence. According to the Nature Conservation Act (Dz. U. 2022, item 916, as amended), trees posing threats to safety or infrastructure may be removed without fees (Art. 86.1, points 4–5 u.o.p.). However, the lack of precise risk assessment criteria leads to misuse.

The subject of this study is windthrow and uprooting in urban areas, understood as risks resulting in damage to property, health, or human life (Rosłon-Szeryńska 2019). The main objective is to present tree-related risk in Poland and explore its management. The study addresses the following research questions: 1) When does a tree constitute a hazard, and when is it merely damaged property due to weather anomalies? 2) What is the level of risk associated with windthrow in Poland? 3) How can risk be assessed at national and regional scales? 4) How can this knowledge be applied in urban tree management?

The main hypothesis assumes that identification of hazards and quantification of tree-related risk are fundamental for effective tree management systems. As part of this study, statistics on tree-related

accidents and damage during windstorms between 2000 and 2022 were compiled, which were contextualized in the context of climate change, including the increasing frequency of windstorms between 1979 and 2018. A regional risk index for windfall and uprooting was developed, which can be used as a tool for tree management. Risk management guidelines were presented. The research results, in addition to their cognitive value, can be used to more effectively manage trees in urban areas and improve human living conditions in cities.

Research Method and Data Sources

Tree-related risk is analyzed based on windstorm frequency (Lorenc 2012; Chmielewski, Szer 2018) and the frequency and scale of damage caused by falling trees (Roslon-Szeryńska 2019; National Tree Safety Group 2011; Tazarek, Brooks 2015).

Risk is defined as the possibility of loss or occurrence of a harmful event, characterized by a known probability distribution. Risk assessment includes probability and severity of consequences. Both qualitative (risk matrices, indicators) and quantitative methods (event trees, statistical and simulation methods) are used (Romanowska-Słomka, Słomka 2002).

The study applies the **Risk Score method**, where:

$$R = S \times E \times P$$

where:

- S – severity of consequences,
- E – exposure,
- P – probability.

Potential consequences (S) are determined by the arithmetic mean of the human and material losses assessed on a scale of 1 to 100 points. A minor loss (1 point) is considered to be the provision of first aid and a material loss of less than PLN 5,000. A very major loss (15 points) is associated with a fatality equivalent to material losses of PLN 5,000 to 5 million. A major disaster is considered (100 points) to be multiple fatalities or a loss estimated at over PLN 30 million.

The duration of exposure (E) of the impact of harmful factors on humans is measured on a scale of 0.5 to 10; the lowest value is obtained with negligible exposure (exposure once a year), and the highest value (10 points) with constant contact between the potential target and the source of the threat. Occasional exposure, with a frequency of once a week, is considered a major disaster.

As part of the study, the **P index** was estimated. The probability of a human hazard (P) is based on combinatorics and is measured on a scale of 0.1–10 points. The probability of an event occurring (0.0001%) to high (50%). The probability of a catastrophic event (A) is localized by the locations of fatalities and all names of residents $|\Omega|$, an area calculated as follows:

$$P(A) = |A|/|\Omega| \quad (2)$$

where:

$|A|$ - to the number of favorable events (emergency casualties $|A|$)

$|\Omega|$ - to the number of all accidental events (total number of residents $|\Omega|$)

The risk value (R) is measured on a scale of 0.05–10,000. A risk value >400 indicates a very high risk and indicates the need to remove trees that pose a safety risk and take intervention measures to improve safety. A negligible risk is defined as a very low risk when $R < 20$.

Our own research analyzed the frequency of windstorms and their effects, including those caused by windfalls and uplifts. Data from the Institute of Meteorology and Water Management (IMGW) and daily reports from the Government Center for Security were used. Information on accidents caused by falling trees was supplemented with details about the circumstances, location, and victims based on local press reports.

From IMWM reports, the frequency of winds during the growing season, i.e., during full leaf-out, in Poland from 1979 to 2018 was analyzed to assess climate change. Data on windstorms with wind speeds above 15 m/s (recognized by the Government Center for Security and Climate Change) from 23 years, from 2000 to 2022, was collected from press reports. The frequency of damage caused by windfalls and uplifts was assessed. The locations and regions of the country where such events most frequently occur were analyzed, and the results were compared with data from England (National Tree Safety Group 2011).

Based on data on the population of the country and individual voivodeships, and on the number of deaths from windfall and uprooting, a regional risk factor was estimated, which is an algorithm that determines the probability of an event occurring per million inhabitants.

Results

Tree as a Hazard vs. Property Loss

Strong winds are the primary source of hazard, while trees are often elements affected by wind forces. According to Lorenc (2012), destruction of even healthy trees may occur at ≥ 29 m/s, while extensive damage appears above 33 m/s. Other classifications (Eiber, TORRO, Fujita) indicate that only very strong winds (>50 m/s) damage stable trees. Strong winds cause natural disasters, which are covered by the National Crisis Management Program. The Government Security Center (RCB) monitors events such as "strong winds," defining three levels of threat posed by strong winds: (I) first degree - $V_{avg} > 15$ m/s and gusts > 20 m/s, which damage buildings and break branches and trees; (II) second degree, with $V_{avg} > 20$ m/s and gusts > 25 m/s, which break and uproot trees; (III) third degree, with $V_{avg} > 25$ m/s or gusts > 35 m/s, which causes significant damage to trees.

The above data indicates that wind speeds exceeding 15 m/s pose a "threat" as a potential threat to human health, life, or property or the environment. The source, and therefore the cause, of the threat in this case will be the wind. A damaged tree, building, or other structure constitutes damage and is considered property damage. A falling tree, as a source of danger (not a consequence), will apply to damage at lower wind speeds.

Insurance practice recognizes wind speeds above 17.5 m/s or 24.5 m/s as thresholds for random events (Maciążek 2005). At this speed, even healthy trees and their parts can break. Otherwise (at lower wind speeds), the tree's condition may have been neglected.

Risk in Poland

A report prepared by the Institute of Meteorology and Water Management indicates that the number of days with violent gales with wind speeds ≥ 25 m/s is estimated at approximately 40 per year in the southern part of Poland. Observations show that on average, about 15 cycles per year pass through Poland, during which wind gusts reach at least 11 m/s (Lorenc 2012). This means that the share of days with such winds is approximately 5% of the year. The highest winds can occur in December, January, and March – an average of two per month. Some regions in Poland are more frequently hit by gales from November to March than others. Foehn and foehn winds blow from October to February. During the summer (or from May onwards), the activity of tornadoes, defined as rotating columns of air in contact with the ground and clouds, increases (Lorenc 2012). Based on reports from the Institute of Meteorology and Water Management, the frequency of winds blowing during the growing season, i.e., during full leaf-out, in Poland from 1979 to 2018, was analyzed. These are most common tornadoes, with an average annual number of 4 between 1979 and 2000. A significant increase in the number of tornadoes was observed between 2003 and 2018. The number of tornadoes in the last quarter-century has almost doubled compared to the 1980s, which is associated with an increased risk of damage caused by windbreaks and upheavals (Fig. 1).

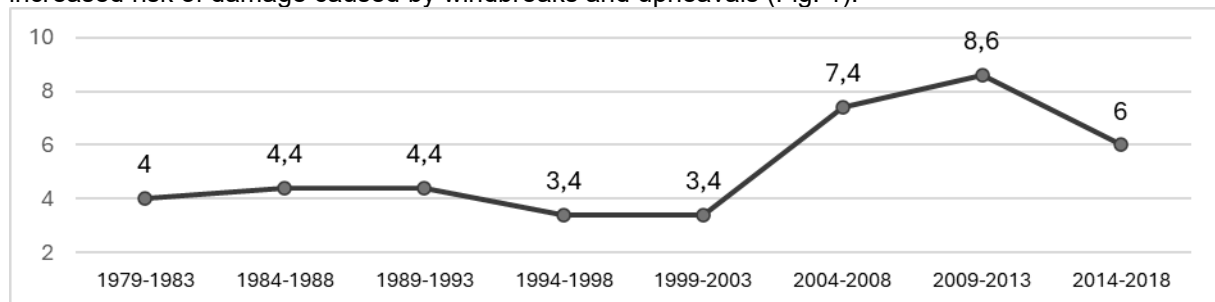


Fig. 1: Average annual number of tornadoes in five-year periods from 1979 to 2018 in Poland. Source: prepared based on RCB reports.

Analysis of data from 2000–2022 shows an average of 8.1 major windstorms per year. The average number of injuries over the 23-year period was 23. However, these data reflect injuries from all storm events, not just those involving trees. An increased number of injuries due to windfalls was observed in 2002, 2007, 2009, 2015, and 2017. The average annual number of fatalities from falling trees is 3.8. Other causes (e.g., falling roof tiles during storms) account for an average of two deaths per year. This means that every other storm ends in a fatal accident involving trees. Each storm results in more than three injuries, with nearly two-thirds of these fatalities involving trees (Fig. 2).

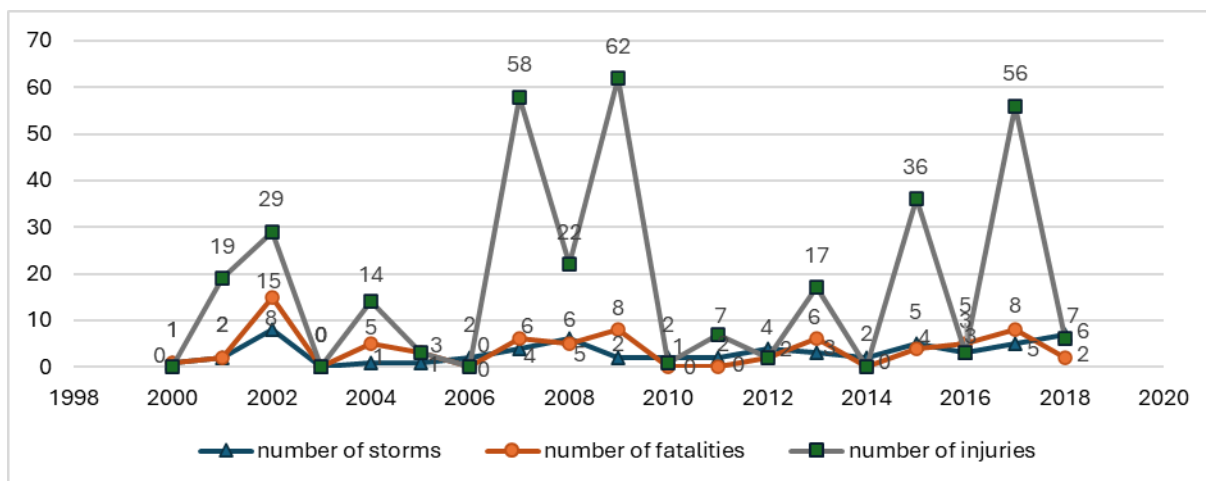


Fig. 2: Average annual number of storms and their consequences (fatalities and injuries caused by falling trees) in the period from 2000 to 2022 in Poland (Rosłon-Szeryńska 2023).

Although every second windstorm results in a fatal accident involving trees, the overall number of such incidents remains low compared to other risks. According to the statistical yearbook of the voivodeships, in 2020 the total number of fatal accidents at work amounted to 190 people, the number of fatalities in road accidents was 2491 (e.g., road accidents; GUS 2021).

The locations where such incidents most frequently occur were analyzed and the results compared with data from England (National Tree Safety Group 2011). Vehicle-involved tree accidents most often occur on roads and car parks (Fig. 3). In Poland most incidents occur on roads and parking areas (51.3%), similarly to England (National Tree Safety Group 2011). Fatalities resulting from falling roadside trees on pedestrians in Poland account for 17.6% of incidents, compared to 10% in England. Compared to England, a lower percentage of accidents in Poland involve falling trees on motorcyclists and cyclists (4.2%), and slightly more accidents occur in forests and parks (7.6% each) and in unmanaged green areas (4.2%). Isolated incidents occur in single-family home gardens (2.5%) and in school gardens and playgrounds (0.8%).

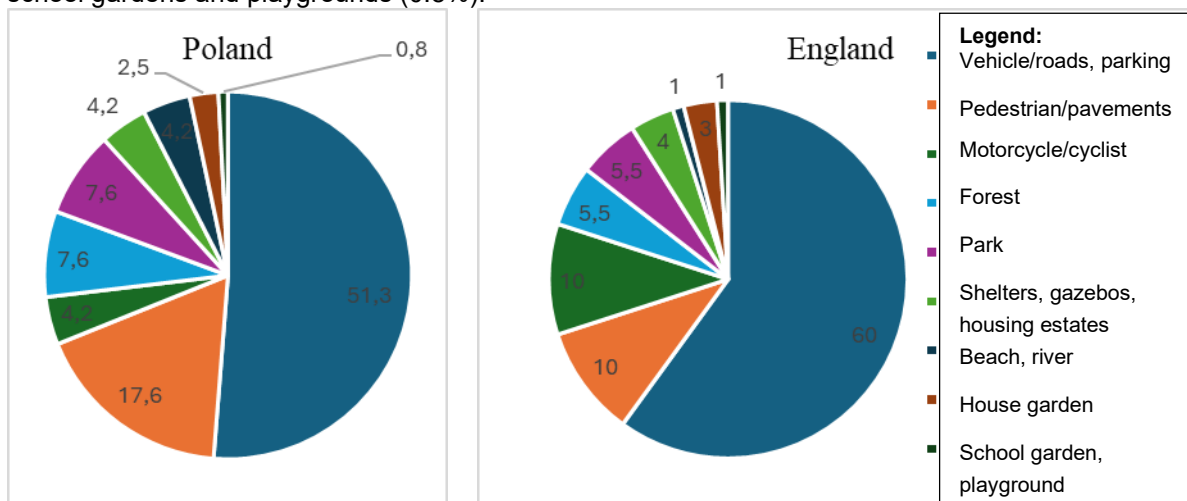


Fig. 3: Locations of fatal accidents involving windfalls and overturns in Poland (from 2000 to 2022) and England from 2000 to 2008 (data update, Rosłon-Szeryńska 2019).

National Risk Assessment

A windbreak and overturning risk index was calculated for the country based on data on windstorms and accidents from 2000-2022. The accident risk index (Risk Score) was used, defined as the product of three parameters (event consequences, hazard exposure, and probability of occurrence):

$$R = 15 \times 2 \times 0.1 = 3$$

The S (effect severity) value is 15, indicating very high damage associated with fatalities and property damage of PLN 500,000-5,000,000;

The E (hazard exposure) value is 2 for central Poland (windstorms once a month), 2.5 for the northern part (on average twice a month), and 3 for the southern part of the country (three times a week).

The P value (accident probability) is 0.1, indicating a theoretically possible event and a chance of less than 1 in 1,000,000 that a fatal accident will occur due to falling trees. The probability of a fatal accident due to a falling tree in Poland is 1 in 10,162,921.

A value of 3 indicates a negligible risk (widely accepted). In principle, there is no need for intervention. Monitoring is recommended. Similar accident statistics and the level of risk associated with the presence of trees in urban areas are observed in England, where the NTSG [National Tree Safety Group] presented the results of research on the effects of windfall and uprooting from 1999 to 2008. The overall risk to society from falling trees is very low, with the probability of a tree or part of a tree causing a fatal accident being approximately 1 in 10 million (NTSG, 2011).

Regional Risk Assessment

Windfall and uprooting accidents from 2010 to 2022 were analyzed in terms of their distribution across the country's voivodeships (Table 1).

Tab. 1: Effects of storms from 2010-2022. Number of fatalities and injuries from this period, along with an estimate of the probability of the event (P)

region/ area	Fatalities due to windfalls		Numer of inhabitants	Population density	Numer of inhabitants in millions (N) per event	Average annual wind speed (m/s)	Regional risk factor (P=1/N)
	Total numer in years 2010-2022	Average annual number					
Dolnośląskie	6	0,462	1994670	145	4,32	5,5	0,231
Kujawsko-pomorskie	0	0,067	1797134	115	26,96	3	0,037
Lubelskie	1	0,077	2512246	83	32,66	3,5	0,031
Lubuskie	3	0,231	1398793	72	6,06	4	0,165
Łódzkie	1	0,077	1821895	134	23,68	3,5	0,042
Małopolskie	1	0,077	1518279	225	19,74	2,5	0,051
Mazowieckie	5	0,385	3555847	153	9,25	4	0,108
Opolskie	1	0,077	941187	104	12,24	3,75	0,082
Podkarpackie	2	0,154	1784576	119	11,60	3,75	0,086
Podlaskie	1	0,077	2018702	58	26,24	3	0,038
Pomorskie	13	1,000	1832368	128	1,83	4,5	0,546
Śląskie	2	0,154	1233309	364	8,02	3,75	0,125
Świętokrzyskie	1	0,077	1171050	105	15,22	2,75	0,066
Warmińsko-mazurskie	1	0,077	2417347	59	31,43	3,75	0,032
Wielkopolskie	2	0,154	2982650	117	19,39	3,5	0,052
Zachodniopomorskie	1	0,077	2290472	74	29,78	2,75	0,034
Polska	40	3,077	31270525	122	10,16	-	0,098

The collected data indicate that the area with the most frequent accidents caused by windfall and uprooting is the Pomeranian Voivodeship, where a total of 13 fatalities were recorded, or an average of one per year. This means that the risk of a fatal accident caused by trees is 1 in 1,832,368. This is still a broadly tolerable risk level, at a minimal (negligible) level, but it is more than five times higher than the national average. Increased numbers of fatal accidents also occurred in the Lower Silesian Voivodeship (6 in total, with an average of 0.46 per year), the Mazowieckie Voivodeship (5 in total, with an average of 0.38 per year), and the Lubusz Voivodeship (3 in total, with an average of 0.23 per year). Safe voivodeships, with low or zero fatalities resulting from windstorms during the study period, include the Kuyavian-Pomeranian Voivodeship (0), Lublin Voivodeship, Łódź Voivodeship, Lesser Poland Voivodeship, Podlaskie Voivodeship, and Opole Voivodeship (1). The lowest probability of a

fatal accident caused by windbreaks and upheavals occurs in the Lublin Voivodeship and the Warmian-Masurian Voivodeship. Here, the chance of an undesirable event is 1 in 32 million.

Risk Monitoring in Urban Tree Management

Safety management can be divided into several stages. The foundations include risk analysis, risk identification, which involves determining the type of risk, its characteristics, and duration, and quantification, which involves measuring its level. Decisions and actions taken to improve safety will be proportionate to the risk. Tree removal is a last resort, acceptable in the event of a catastrophic risk. In the case of minimal or very low risk, risk control, including ongoing tree monitoring, is crucial.

Data on the effects of storms and interventions related to damaged trees can be used at the local level to assess the situation of local government units or even specific buildings (e.g., a historic park). This is made possible by statistics maintained by fire departments. Based on this data, it is possible to determine the locations where accidents occur most frequently and where trees require more intensive inspections and maintenance due to the high rate of tree breakage in a given location.

For effective tree management, a good solution is to create a map of the municipal area containing so-called risk zones, i.e., zones with varying risk levels within the unit. In addition to knowledge about interventions related to damaged trees, the terrain classification developed by Roślon-Szeryńska (2012) was used, based on the ISA (International Society of Arboriculture) classification used in tree diagnostics. Trees growing in high-risk zones, e.g. along main roads, at intersections or in heavily frequented city centre areas, are inspected more often than trees in low-risk zones (growing in home gardens or in sparsely frequented areas).

Conclusion

The benefits of trees should be balanced with associated risks. Identification and quantification of risk are essential for effective tree management. The study confirms that tree-related risk in Poland is low and socially acceptable (approx. 1 in 10 million).

However, risk cannot be eliminated entirely, as even healthy trees may fail under extreme conditions. Therefore, management should focus on monitoring and proportional actions rather than excessive removal.

The proposed guidelines for risk management at regional and local levels can improve urban tree management, enhance safety, and contribute to better living conditions. Future research should address economic losses related to tree damage and removal.

References

- Chmielewski T., Szer J. (2018). Możliwe straty spowodowane w Polsce wichurami, trąbami powietrznymi i szkwałami. *Inżynier Budownictwa*: 26 – 31.
- Maciążek A. (2005). Pomiary wiatru. „Gazeta Obserwatora IMGW” nr 3: 39 – 41
- Taszarek M., Brooks H. E. (2015). Tornado climatology of Poland. *Monthly Weather Review*, 143: 702 – 717.
- Lorenc H. (2012). Struktura maksymalnych prędkości wiatru w Polsce, [w:] H. Lorenc (red.), *Klęski żywiołowe a bezpieczeństwo wewnętrzne kraju*. IMiGW, Warszawa, 33 – 59.
- Mizgajski A., Stępniewska M. (2009). Koncepcja świadczeń ekosystemów a wdrażanie zrównoważonego rozwoju, [w:] D. Kiełczewski, B. Dobrzańska (red.), *Ekologiczne problemy zrównoważonego rozwoju*. WSE, Białystok, s. 12-23.
- Wessolly L. (1997). Metody bezinwazyjnego określania statyki drzew. *Sztuka ogrodów w krajobrazie miasta*. Konferencja Naukowa 20-22 czerwiec 1997. VI Targi Zieleni Miejskiej, Wrocław: 213-219.
- Ball D.J., Ball- King L. (2011). *Public Safety and Risk Assessment: Improving Decision Making*. London, Earthscan.
- Czerwienic M., Lewińska J. (2000). *Zieleń w mieście*. Instytut Gospodarki Przestrzennej i Komunalnej, Kraków.
- Dygulska A., Perłańska E. (2015). *Mapa wietrzności Polski*. Projekt Czysta Energia. Akademickie Centrum Czystej Energii, Słupsk.
- Eiber T. (1998). *Forest Insects and Disease*. Internet: <http://www.dnr.state.mn.us/fild/june98/06309816.html>.
- GUS (Główny Urząd Statystyczny) (2021). *Rocznik Statystyczny Województw*, Warszawa (online: stat.gov.pl)
- Krynicky M., Witkoś K. (2016). *Monitoring standardów w zarządzaniu zielenią wysoką w największych miastach Polski*. Fundacja Ekorozwoju, Wrocław.

National Tree Safety Group, (2011). Estimating the costs and benefits of changing the approach to tree safety management and the role of local risk/benefit evaluation. Centre for Decision Analysis and Risk Management Middlesex University, ss. 14

Romanowska-Słomka I., Słomka A. (2002). Zarządzanie ryzykiem zawodowym. Wydanie II, Tarbonus, Tarnobrzeg.

Roslon -Szeryńska E. (2012). Ocena zagrożenia bezpieczeństwa ludzi i mienia powodowanego przez drzewa o osłabionej statyce. Uprawa i Ochrona drzew. Czasopismo Międzynarodowego Towarzystwa Uprawy i Ochrony Drzew, Kluczbork, Zeszyt nr 27, ss: 89.

Roslon-Szeryńska E. (2019). Drzewa w przestrzeni zurbanizowanej. Korzyści a zagrożenia. Wyd. SGGW, Warszawa

Roslon-Szeryńska E. (2023). Drzewa jako element ryzyka związanego z anomaliami pogodowymi. Rozwój Regionalny i Polityka Regionalna 64: 253-271 <https://doi.org/10.14746/rrpr.2023.64.15>

Szczepanowska H.B., Sitarski M. (2015). Drzewa. Zielony kapitał miast. Jak zwiększyć efektywność pracy drzew. IGPiM, Warszawa.

Szulczewska B. (2018). Zielona infrastruktura – czy koniec historii? STUDIA Tom CLXXXIX, Polska Akademia Nauk Komitet Przestrzennego Zagospodarowania Kraju. Warszawa.

Souhrn

Stromy představují klíčovou součástí městské krajiny a zelené infrastruktury, poskytují řadu ekosystémových služeb a zvyšují atraktivitu veřejných rekreačních prostor. Současně však jejich přítomnost v intenzivně využívaných oblastech – jako jsou parky, promenády, náměstí a pěší trasy – vyžaduje pečlivé zvážení otázky veřejné bezpečnosti. V kontextu klimatických změn a rostoucí četnosti meteorologických anomálií, zejména silných vichřic, nabývá otázka řízení rizik spojených se stromy na významu.

Cílem tohoto článku je představit rozsah rizik spojených se stromy ve veřejných prostranstvích v Polsku ve srovnání s Anglií, a to v kontextu vyvážení rekreačního využití a ochrany krajiny. Studie shrnuje statistiky o nehodách a škodách způsobených stromy během silných větrných událostí v letech 2000–2022. Na základě těchto údajů byl vypracován regionální rizikový koeficient týkající se polomů a vyvrácených stromů.

Výsledky ukazují, že jak počet, tak následky incidentů souvisejících se stromy v Polsku zůstávají srovnatelné s těmi, které byly pozorovány v Anglii, a lze je považovat za relativně nízké. Zjištění potvrzují, že racionální správa stromů, založená na posouzení stavu stromů a potenciálního rizika, umožňuje sladit požadavky na veřejnou bezpečnost s potřebou zachovat stromy jako důležitý prvek krajiny a rekreačního prostředí.

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