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Dynamics of the sanitary condition of Scots pine stands in the green zone of Kyiv (based on the example of the Sviatoshyn Communal Forest-Park Enterprise)

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Abstract. The relevance of the study is conditioned by the specifics of forest ecosystems in the green zone of Kyiv, which are located in a zone of intense anthropogenic stress and play a critical role in the urban environment. The purpose of the study was to analyse changes in the sanitary condition of green zone forests, identify key factors leading to their degradation, and develop recommendations for their improvement. The study used the analysis and generalisation of forest management materials, literature data, well-known methods of forestry and forest valuation (reconnaissance and detailed survey of plantings), and forest pathological methods for identifying and analysing the sanitary condition of pine plantations. During 2020-2024, a decrease in the overall stability of pine stands was found, since about 25% of them were mature and over-mature, which lose their environmental and aesthetic functions. The increase in dead wood volumes is the result of the colonisation of weakened plantings by stem pests, such as common pine shoot beetle (*Tomicus piniperda* L.), lesser pine shoot beetle (*T. minor* Hartig.), sharp-toothed bark beetle (*Ips acuminatus* Gyllenhal), six-toothed bark beetle (*Ips sexdentatus* Boerner), steelblue jewel beetle *(Phaenops cyanea* Fabricius), pine sawyer beetle (*Monochamus galloprovincialis* Ol.), and timberman beetle (*Acanthocinus aedilis* L.). The identified populations of xylophagous insects were characterised by a low to medium degree of infestation and were observed only on severely weakened trees. The largest area of pine stands (690.0 ha) covered by selective sanitary logging occurred in 2020, which indicates the impact of negative factors. Analysis of the typological structure showed that light pine forests were the most common (54.8% of the area), and fresh conditions predominate among hygrotopes (94.72% by area). High-performance stands of quality classes $1c^{-2}$ (99.1% of the area) and medium-aged stands (56.5% of the area) predominated. The total volume of accumulated dead wood was 285.4 thousand tonnes, of which 86.2% was concentrated in pine forests, with the largest carbon reservoir being the forest floor (65.1%). The average density of deadwood in pine stands was 2.61 $kg \cdot m^{-2}$. The results obtained can be used to develop effective measures to improve the sanitary condition of pine stands in the forests of green areas, increase their resistance to pests and diseases, and to optimise the recreational load

Keywords: recreational load; xylophagous insects; selective sanitary logging; deadwood; forest ecosystems

Introduction

The relevance of the study was conditioned by the need for a scientifically based assessment of the state of forests within the city of Kyiv, which were under the influence of intensive anthropogenic activity. Investigation of the productivity, composition, structure, and changes of forest stands will help to determine ways to optimise economic measures, ensure the stability of plantings, and increase their environmental efficiency. Research of the sanitary condition of forests in green areas of Kyiv is important for preserving valuable ecosystems, maximising their performance of ecosystem functions, and ensuring sustainable development of the city.

O. Tokarieva (2023) noted that the forests of urban green areas are functional natural objects that include the area outside the city, occupied by forests and other green spaces, the characteristic feature of which is manifested in the stabilising effect on the urban environment. They are important factors in the development and regulation of the urban and suburban environment, which is carried out by influencing the temperature, ionising regime of air, and its humidity and chemical composition, including the absorption of carbon dioxide with the subsequent release of oxygen, etc. The functions that the forests of green zones of cities perform can be grouped

into the following groups: ecological (environment-forming or climate-regulating, sanitary and hygienic), social (recreational, health-improving, aesthetic), ecological (development of recreation, satisfaction of the population's needs for wood). Thus, urban forests are multifunctional elements of urban infrastructure that require special attention to their sanitary condition.

V. Levchenko & V. Gumeniuk (2024) found that intensive human economic activity leads to the violation of the mechanisms of self-healing and self-regulation of the ecosystem, which, accordingly, facilitates its degradation. The study showed that excessive stress on forest ecosystems disrupts their natural balance, causing them to be vulnerable to biotic and abiotic factors. The sanitary condition of forests, in particular pine stands, is deteriorating, and this may be conditioned by the occurrence of outbreaks of mass reproduction of harmful insects. N. Puzrina *et al.* (2022) found that under favourable conditions, insects can multiply rapidly and reach numbers of up to several tens of thousands of individuals per tree, which, if untimely detection and lack of effective control measures, causes massive damage to stands and disrupts the ecological balance in forest biocoenoses, significantly affecting the general biological stability of plantings.

M. O. Lakyda *et al.* (2022) noted that the determination of the sanitary condition of forest stands also allows assessing the patterns of buildup of deadwood reserves, which is of ecological importance as a habitat for biological species, and also performs the function of carbon deposition. A significant accumulation of deadwood, in particular, at the objects of the nature reserve fund and urban forests, creates prerequisites for the rapid spread of forest fires, which requires the development of an appropriate strategy for the management of dead wood in these forests. In the course of the study, O. Soshenskyi *et al.* (2021) found that such zones pose an increased risk of uncontrolled ignition, which was confirmed by examples of large-scale fires in protected areas. The revealed relationship between the amount of deadwood and the intensity of fire propagation justifies the need for regulated management of dead biomass. S. Zhang *et al.* (2025) noted that global warming increases the risk of forest fires and insect outbreaks, potentially reducing the carbon storage function of coarse wood debris. The researchers focused on the interaction of forest fires and insect damage on carbon deposition, but the effect of xylophagous insects on the flammability of dead wood remains unexplored. Excessive reserves of wood detritus can create conditions for the reproduction of pests, however, the direct impact on the spread of diseases and pests of the forest was not described in detail in scientific sources.

Thus, scientific assessment of the sanitary condition of urban forests becomes particularly important in the context of increasing anthropogenic stress, climate change, and disruption of natural regulation mechanisms. The purpose of the study was to identify spatial and temporal changes in the sanitary state of forest ecosystems, identify the main factors of their degradation, and develop practical recommendations for stabilising and improving the ecological efficiency of urban forests.

Materials and Methods

In the course of research, materials of basic forest management were analysed (Kyiv City State Administration, 2023) Sviatoshyn Communal Forest-Park Enterprise, the volume of selective sanitary logging for the period 2020-2024 was analysed with subsequent surveys in the foci of drying of pine stands. During the reconnaissance survey, a general inspection of the sites was carried out (Goychuk *et al.*, 2012), in the examined plantings, visual inspection revealed a significant weakening of them (yellowing of needles, falling bark, dryness).

Detailed surveys of plots on an area of 91.9 hectares were accompanied by the determination of the species composition of xylophagous insects. The species composition of xylophagous

insects on dry and drying trees was determined by counting the population density: the average number of families of harmful insects per square decimetre of the trunk was calculated (Meshkova *et al*., 2020). When studying the species composition, each model tree was cleaned of knots. On the trunk, a 10 cm wide ribbon of bark was removed from the base to the top. Within the actual settlement areas of each species, accounting palettes were laid, on which the density of the infestation and real fertility were determined. The number of stem borer tunnels per 1 dm^2 on the barkless side of the stem was used to determine the areas and density of their settlement (Table 1).

Table 1. *Criteria for assessing the number of young generation or the production of stem pests*

Species	Number of the younger generation (p) per 1 dm^2		
	low	average	high
Monochamus galloprovincialis	0.2 or less	0.3-0.7	0.8 or more
Phaenops cyanea	0.2 or less	0.3-0.5	0.6 or more
Tomicus minor	4.9 or less	6.0-10.0	10.1 or more
Tomicus piniperda	2.9 or less	3.0-5.0	5.1 or more
Ips acuminatus	2.0 or less	2.1-5.0	5.1 or more
Acanthocinus aedilis	5.1 or less	6.0-10.0	10.1 or more

Source: developed by the authors based on V.L. Meshkova *et al*. (2020)

The relative density, i.e., the number of individuals of a certain pest species per unit of accounting (the number of trees examined (samples taken), was determined by the equation:

$$V_r = \frac{k}{n}, \quad (1)$$

where *Vr* – relative density; *k* – sum of all individuals of the species in all samples, units; *n* – number of samples taken (trees examined), units. Assessment of the volume of deadwood (or detritus) was carried out based on the materials of the specific taxation characteristics of forest fund plots (Kyiv City State Administration, 2023) using mathematical models of conversion coefficients (Bilous, 2018). Statistical processing of the obtained data was performed using the Microsoft Excel software suite. The study was conducted according to the Convention on Biological Diversity (1992).

Results and Discussion

In accordance with the systematic approach to forest management within the metropolitan area proposed by V.Yu. Yukhnovskyi *et al*. (2021), efficiency of forests in Kyiv should be evaluated primarily in terms of their ability to perform environmental functions. The state of green forests in the capital, in particular, on the territory of Sviatoshyn Communal Forest-Park Enterprise, should be considered through the prism of functional zoning and its impact on the environmental stability of plantings. According to the Ukrainian State Design Forestry Production Association (2022) and Resolution of the Cabinet of Ministers of Ukraine No. 733 (2007), the structure of green forests within this territory covers nature protection, scientific, historical and cultural, and recreational areas. Each of these categories has a specific functional load and usage mode, which is shown in Figure 1. The division of forests into functional categories allows for a more accurate assessment of the factors that affect their sanitary condition.

The largest share of the enterprise's territory is formed by national nature parks, the regulated recreation area is 38.1%, and green zone forests are 33.2%, respectively. The existing

structure, where more than 70% of forests have conservation and recreational purposes, is aimed at preserving ecosystem functions and ensuring sustainable development of the city. The main task of these forests is to regulate and stabilise soil, climatic and hydrological conditions, and to perform environmental functions. However, intensive anthropogenic impact and climate changes lead to a deterioration in the sanitary condition of pine stands and an increase in the volume of dead wood.

Forests of Sviatoshyn Communal Forest-Park Enterprise by 52.7% in area and by 57.0% in trunk stock are represented by artificial stands of seed origin. Natural stands of seed origin account for 36.9% of the area of forest areas covered with forest vegetation, which is 35.8% of the stem stock. The rest, 10.4% by area and 7.1% by stock, respectively, falls on stands of vegetative origin. During the analysis of the data bank of specific taxation characteristics of forests, it was found that the most common forest-forming tree species on the territory of the enterprise was Scots pine, the share of plantings in the area of which was 86.3% (9,759.2 ha). Plantings with a predominance of common oak make up 9.8% (1,112.9 ha) (Fig. 2).

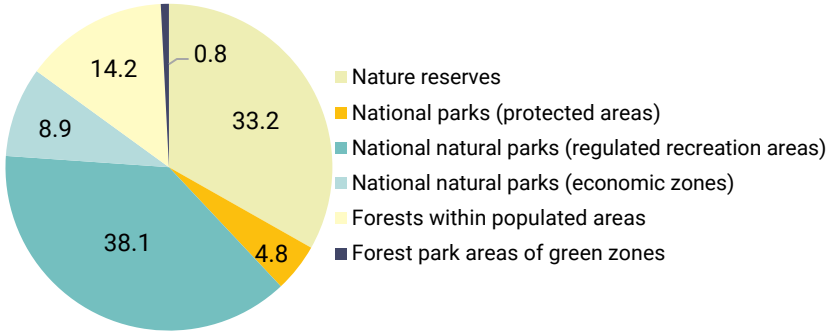

Figure 1. *Division of the forest area of Sviatoshyn Communal Forest-Park Enterprise into categories, %*

Source: developed by the authors based on materials of Kyiv City State Administration (2023)

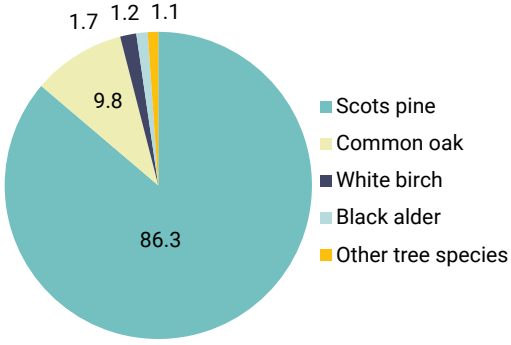

Figure 2. *Division of the area of forest areas covered with forest vegetation by dominant tree species, %*

Source: developed by the authors based on forest management materials (Kyiv City State Administration, 2023)

The data in Figure 2 indicate the dominance of Scots pine (86.3%) in the species composition of forests, which creates susceptibility to phytophagous insects, pathogens, and anthropogenic stress. Monospecific dominance of Scots pine reduces biodiversity and ecosystem sustainability, especially in the face of urban pollution and recreational stress, which exacerbate the weakening of trees and contribute to the spread of drying out. This creates a high need for continuous monitoring and adaptive forest management measures to maintain the viability of green area forests. Given that the bonus indicator reflects the influence of soil and climatic factors on the growth and development of tree species, Table 2 clearly shows the patterns of productivity of Scots pine plantings depending on the richness and humidity of the soil.

Source

Table 2. *Distribution of the area and stock of Scots pine stands by type of forest-growing conditions and bonus*

FST index	Quality class	Area		Stem stock	
		ha	%	thous. m³	%
		A			
A_1	2	1.1	0.01	0.26	0.008
	3	8.3	0.09	1.35	0.041
	4	4.6	0.05	0.58	0.018
	5	1.6	0.02	0.12	0.004
A_2	2	47.4	0.49	11.92	0.362
	3	39.1	0.40	8.33	0.253
	4	0.4	0.00	0.04	0.001
Total	-	102.5	1.05	22.6	0.686
		B			
B_1	2	23.7	0.24	1.41	0.043
	3	6.7	0.07	1.51	0.046
B_2	1^b	0.3	0.00	0.09	0.003
	1^a	1,641.7	16.82	630.59	19.148
	1	2,575.4	26.39	822.23	24.967
	2	788.2	8.08	232.68	7.065
	3	24.6	0.25	5.35	0.162
B_3	1^a	31.1	0.32	8.31	0.252
	1	204.4	2.09	70.56	2.143
	2	50.4	0.52	12.46	0.378
Total	-	5,346.5	54.78	1,785.19	54.208
		C			
C_2	1^c	1.3	0.01	0.33	0.010
	1^b	136.3	1.40	46.03	1.398
	1^a	1,797.6	18.42	696.80	21.158
	1	1,897.7	19.45	609.34	18.503
	2	292.3	3.00	80.04	2.430
	3	2.1	0.02	0.42	0.013
C_3	1^b	9.2	0.09	2.57	0.078
	1^a	82.4	0.84	23.23	0.705
	1	44.3	0.45	16.01	0.486
	2	46.6	0.48	10.64	0.323
	3	0.4	0.00	0.05	0.002
Total	-	4,310.2	44.17	1,485.46	45.106
Total	-	9,759.2	100.00	3,293.25	100.000

Note: A, B, C, D – soil fertility (from poor to fertile) and 0,1,2,3,4,5 – soil moisture (from very dry to very wet)
Source: developed by the authors based on forest management materials (Kyiv City State Administration, 2023)

In the course of the analysis of the typological structure of pine forests, it was found that the most common forest site type on the territory of Sviatoshyn Communal Forest-Park Enterprise are light pine forests, which occupy 54.8% of the area of forest areas covered with forest vegetation. There are no oak forest stands on the enterprise's territory. Among the hygrotopes, fresh conditions predominate – 94.72% by area and 95.47% by stock. There are no xerophilic, hygrophilic, or ultra-hygrophilic hygrotopes. Analysis of the distribution of areas of Scots pine stands by quality of locality shows that the enterprise is dominated by high-performance stands 1^c- 2 quality classes,

which cover 99.1% of the area. Light pine forests, which occupy 54.78% of the area, are the most favourable for pine plantations, which is confirmed by high quality classes, however, it is in these conditions that intensive growth is observed, which can lead to the development of overgrown stands.

Pine plantations in spruce-fir forest conditions (44.17% of the area) are less adapted to heavier loamy soils, which can lead to stagnation of water after heavy precipitation, or, conversely, to excessive compaction during dry periods and makes plantings in spruce-fir forests vulnerable to root decay. After analysing the age structure of pine stands of Sviatoshyn Communal Forest-Park Enterprise, it can be concluded that the age distribution is dominated by middle-aged stands with a share of 56.5% of the area of forest areas covered with forest vegetation and 62.2% of the total stem stock of tree stands. The area of young stock is only 5.8% (Table 3).

Table 3. *Distribution of the area and stock of Scots pine stands by age groups*

Age group	Area		Stem stock	
	ha	%	thous. m³	%
Young stock	568.9	5.8	10.5	0.3
Middle-aged	5,515.6	56.5	2,048.16	62.2
Maturing	1,305.3	13.4	516.52	15.7
Fully mature	1,164.7	11.9	378.64	11.5
Overmature	1,204.7	12.3	339.43	10.3
Total	9,759.2	100.0	3,293.25	100.0

Source: developed by the authors based on Kyiv City State Administration (2023)

The distribution by age group indicates a suboptimal forest structure of Sviatoshyn Communal Forest-Park Enterprise from the standpoint of environmental sustainability. The predominance of middle-aged and the presence of a significant proportion of overmature plantings in combination with a low proportion of young animals creates prerequisites for mass drying out and deterioration of the sanitary condition. The largest share of the area (56.5%) and stem stock (62.2%) is occupied by middle-aged stands. This age period is often critical for pine stands from the standpoint of sanitary condition, because there is an intense crown closure, competition for light, water, and nutrients increases. Trees that lag behind in growth or are weakened begin to die intensively, creating prerequisites for the development of pathological processes. In the urban environment under the influence of additional stress (air pollution, soil compaction, recreational load), middle-aged plantings are particularly vulnerable to colonisation by stem pests (bark beetles, barbels) and the development of wood-destroying fungi. Figure 3 shows the distribution of pine forests of the enterprise by relative density, which reflects the efficiency of using the occupied space by tree stands.

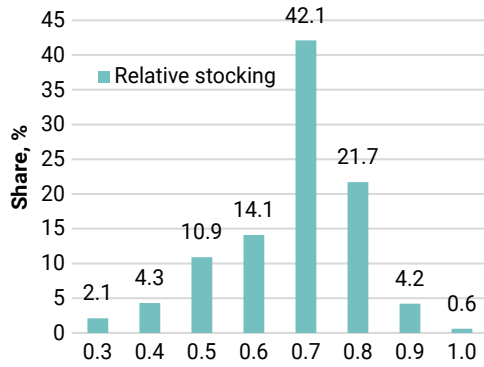

Figure 3. *Distribution of the area of Scots pine stands by relative density*

Source: developed by the authors based on Kyiv City State Administration (2023)

In general, Sviatoshyn Communal Forest-Park Enterprise is dominated by medium-sized stands with a relative density of 0.7 – more than 40% both in area and in stock. High-quality stands with a fullness index of more than 0.8-26.5% are also common. The high density of pine stands on 26.5% of the area can create favourable conditions for the development of fungal diseases and weakening of trees by reducing the intensity of sunlight and increasing humidity. For pine stands of green zone forests in conditions of intensive recreation, the optimal density is 0.6-0.7**.** Given the significant recreational load on the forest park economy and to assess the sanitary condition, the dynamics of carrying out a set of measures to improve the sanitary condition of forests for pine plantations to perform protective, water-regulating, aesthetic, and sanitary-hygienic functions, namely, sanitary selective logging for the period 2020-2024 (Fig. 4).

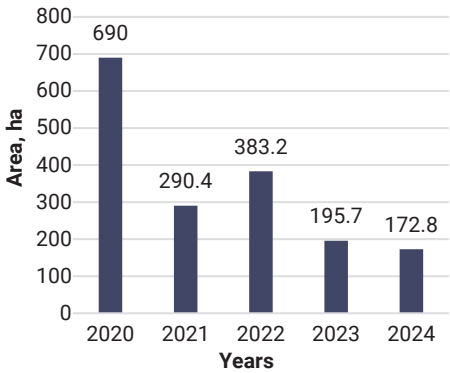

Figure 4. *Volumes of selective sanitary logging for the period 2020-2024*

Source: compiled by the authors

Analysis of logging volumes by year allows tracing the dynamics of the sanitary state of forests. For carrying out selective sanitary logging by removing dead trees and their groups, cleaning up clutter in those plantings where it is several times higher than the natural level, soil trophicity increases, conditions for root nutrition of plants and the general sanitary condition improve, the stability of the ecosystem's biological diversity and its balance are restored. It should be noted that the largest area of pine stands passed through selective sanitary logging (690.0 ha) was in 2020, which can be explained by the influence of negative factors of a reversible and irreversible nature (Fig. 5).

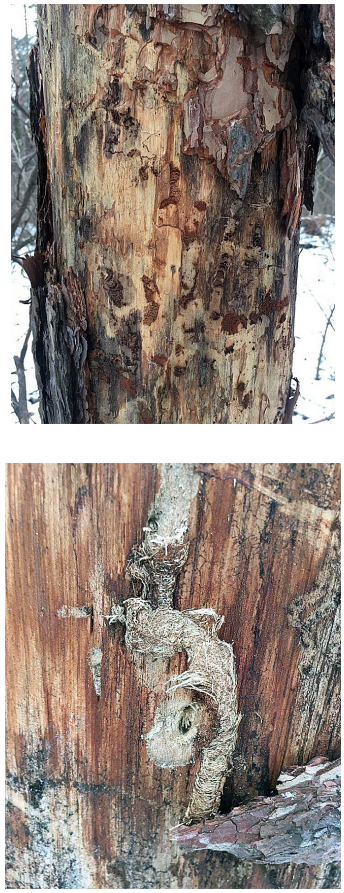

Figure 5. *Typical signs of colonisation by xylophagous insects*

Source: compiled by the authors

As a result, these processes have led to an increase in STEM pest populations, in particular, sharp-toothed bark beetle *Ips acuminatus*, six-toothed bark beetle *Ips sexdentatus*, common pine shoot beetle *Tomicus piniperda* and lesser pine shoot beetle *T. minor*, steelblue jewel beetle *Phaenops cyanea,* pine sawyer beetle *Monochamus galloprovincialis*, and timberman beetle

Acanthocinus aedilis. The damage of pine trees and an increase in the volume of dead wood is a consequence of the infestation of weakened plantings by stem pests with their subsequent spread to nearby stands. All trees inhabited by xylophagous insects belong to the 4-6 quality class. The involvement of the pests listed above in the drying and death of individual trees was confirmed by the bores found in nature under the bark, insect frass, shoots on the soil under the crown projections after passing additional nutrition to adults and their entrance and exit flight holes on tree trunks. Due to the intensive feeding of xylophages on weakened trees and the dynamic distribution of populations, the forest pathology situation in plantings has significantly worsened (Fig. 6). The surveyed areas with the established reasons for the deterioration of the sanitary condition are shown in Table 4.

a  b 

Figure 6. *Foci of drying of Scots pine stands*

Note: a – 2022, b – 2024
Source: compiled by the authors

Table 4. *Summary of the surveyed stands (2024 survey)*

Compartment	Stratum	Area, ha	Stand composition	Pathological signs of weakening and drying out
Sviatoshyn Forestry				
89	3	11.6	100% Scots pine (95)+ Scots pine (165)	Dead wood from previous years, clutter
89	4	2.9	100% Scots pine	Drying of plantings (stem pest complex)
89	5	0.4	90% Scots pine (71)10% Witch elm + Scots pine (85)	Drying of plantings (stem pest complex)
101	1	0.5	100% Scots pine + Littleleaf Linden	Dead wood from previous years, clutter
101	2	0.3	100% Scots pine	Drying of plantings (stem pest complex)
101	3	0.4	100% Scots pine	Drying of plantings (stem pest complex)
101	5	3.3	100% Scots pine	Dead wood from previous years, clutter
101	6	1.0	100% Scots pine +Northern Red Oak	Drying of plantings (stem pest complex)
101	7	0.4	100% Scots pine + Witch elm + Common Oak + + Norway Maple	Drying of plantings (stem pest complex)
101	8	1.7	100% Scots pine	Drying of plantings (stem pest complex)
101	10	0.5	80% Scots pine 20% Witch elm+ Northern Red Oak	Drying of plantings (stem pest complex)
101	12	0.2	100% Scots pine	Dead wood from previous years, clutter
101	14	4.8	100% Scots pine + Norway Maple	Drying of plantings (stem pest complex)

Table 4. *Continued*

Compartment	Stratum	Area, ha	Stand composition	Pathological signs of weakening and drying out
101	15	0.7	60% Scots pine 40% Witch elm	Dead wood from previous years, clutter
101	16	1.5	100% Scots pine + Scots pine +Norway Maple	Dead wood from previous years, clutter
115	2	0.9	60% Scots pine 20% Witch elm 20% Silver Maple + Norway Maple; 100% Scots pine – single trees	Dead wood from previous years, clutter
115	3	3.0	100% Scots pine	Dead wood from previous years, clutter
125	1	8.8	100% Scots pine 100% Norway Maple – of natural origin	Drying of plantings (stem pest complex)
125	2	2.7	100% Scots pine +Black Locust	Dead wood from previous years, clutter
125	3	1.0	30% Scots pine 30% Witch elm 30% Black Locust 10% Silver Maple +Sycamore Maple + + Common pear Black Locust – of natural origin	Dead wood from previous years, clutter
125	4	0.2	100% Scots pine + European Aspen	Drying of plantings (stem pest complex)
Total		**46.8**		
Kyiv Forestry				
114	2	2.4	90% Scots pine 10% Common Oak +Silver Birch Common Oak – of natural origin	Dead wood from previous years, clutter (planned selective sanitary cutting-2025)
114	4	1.0	90% Scots pine 10% Common Oak Common Oak – of natural origin	Dead wood from previous years, clutter (planned selective sanitary cutting -2025)
117	2	1.0	60% Scots pine 40% Common Oak	Dead wood from previous years, clutter (planned selective sanitary cutting -2025)
117	5	2.6	90% Scots pine 10% Common Oak	Dead wo od from previous years, clutter (planned selective sanitary cutting -2025)
117	6	3.6	80% Scots pine20% Common Oak	Dead wood from previous years, clutter (planned selective sanitary cutting -2025)
117	15	3.7	60% Scots pine 40% Common Oak	Dead wood from previous years, clutter (planned selective sanitary cutting-2025)
117	17	0.5	100% Scots pine	Drying of plantings (stem pest complex)
117	18	4.5	70% Scots pine 30% Common Oak	Dead wood from previous years, clutter (planned selective sanitary cutting-2025)
120	1	3.1	100% Scots pine	Drying of plantings (stem pest complex)
120	2	4.0	50% Scots pine 50% Common Oak	Drying of plantings (stem pest complex)
120	3	2.3	60% Scots pine 40% Common Oak 100% Scots pine – single trees	Drying of plantings (stem pest complex)
120	4	7.8	60% Scots pine 40% Common Oak	Drying of plantings (stem pest complex)
122	1	0.4	70% Scots pine 30% Common Oak + Black alder	Drying of plantings (stem pest complex)
122	2	1.2	60% Scots pine 40% Common Oak	Drying of plantings (stem pest complex)
122	4	0.8	100% Scots pine	Drying of plantings (stem pest complex)
122	8	2.4	100% Scots pine	Drying of plantings (stem pest complex)
122	9	1.0	100% Scots pine	Drying of plantings (stem pest complex)
122	14	1.2	100% Scots pine	Dead wood from previous years, clutter (planned selective sanitary cutting-2025)
122	15	1.2	100% Scots pine	Dead wood from previous years, clutter (planned selective sanitary cutting-2025)
122	16	0.4	100% Scots pine	Dead wood from previous years, clutter (planned selective sanitary cutting-2025)
Total		**45.1**		
Total, ha		**91.9**		

Source: compiled by the authors

Sites for conducting a detailed survey were selected based on reconnaissance survey and forest pathology surveys of previous years. To determine the species composition of xylophagous insects on dry and drying trees, the completeness of the settlement was recorded, that is, average number of families of different types of harmful insects per square decimetre of trunk surface was determined (Table 5). The identified populations of xylophagous insects were characterised by a low and medium degree of infestation, and they were also observed only on very weakened trees. Density of *Phaenops cyanea* indicates isolated cases or early stages of infestation. Average degree of infestation of *Monochamus galloprovincialis* and *Ips acuminatus* indicates an increase in numbers, which can cause significant damage to weakened trees. Despite the mostly low and average infestation rates, the presence of xylophagous populations on weakened trees confirms their role in the deterioration of the sanitary condition of forest stands, especially in conditions of intense anthropogenic pressure and climate changes that contribute to the weakening of trees. During the monitoring studies for the period 2020-2024, it was revealed, that pine stands have a reduced level of overall stability, since about 25% of plantings are mature and over-mature, which have practically lost or are losing their environmental and aesthetic functions (Table 6).

Table 5. *Degrees of tree infestation by xylophagous insects (2024 survey)*

Species	Settlement density, units · dm^{-2}/ average number of shoots per 1 m^2	Degree of infestation/number of beetles of the younger generation
Phaenops cyanea	0.1 ± 0.5	low
Monochamus galloprovincialis	0.5 ± 0.3	average
Tomicus minor Tomicus piniperda	5	average
Ips acuminatus	0.7 ± 0.4	average
Acanthocinus aedilis	4.5 ± 0.2	low

Source: compiled by the authors

Table 6. *Existing distribution of Scots pine forest stands by age group, %*

Species groups	Young stock	Middle-aged	Maturing	Fully mature
Regulated recreation area				
Coniferous	11.3	54.6	11.6	22.5
Economic zone				
Coniferous	3.2	61.2	11.4	24.2

Source: developed by the authors based on Kyiv City State Administration (2023)

The existing division of stands by age groups differs significantly from the optimal one. Overall, there are significantly fewer young trees than the optimal number, while the middle-aged trees are the most numerous and there is a certain shortage of maturing plantations. There is a significant shortage of young trees, especially in the economic zone of 3.2%, which indicates insufficient natural or artificial renewal of forests. A low proportion of young plantings may indicate a shortage of mature and over-mature stands in the future, which will lead to a suboptimal age structure of the forest fund. Forest ecosystems are degraded due to regular recreational loads, so intensive recreation leads to negative changes in biocoenoses. Despite the fact that tree stands are the most resistant component of forests to recreational loads, under certain conditions physiological processes become irreversible (Ukrainian State Design Forestry Production

Association, 2022). The volume of selective sanitary logging in various functional areas of the municipal enterprise Sviatoshyn Communal Forest-Park Enterprise is shown in Figure 7.

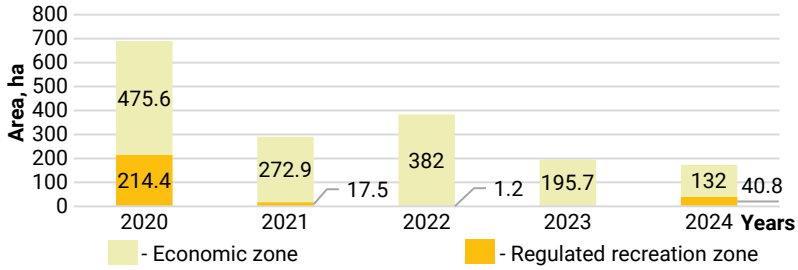

Figure 7. *Volumes of selective sanitary logging in various functional areas*
Source: compiled by the authors

Measures to improve the sanitary condition of forests were also carried out in areas that were damaged due to adverse anthropogenic factors, natural phenomena (snowstorms, windbreaks) of previous years, leading to drying of trees. Notably, middle-aged stands with high density are also significantly damaged. For the purpose of further research is to establish a pattern between the volumes of accumulated dead wood and the drying of Scots pine stands in Sviatoshyn Communal Forest-Park Enterprise, the volume of deadwood (or detritus) was estimated using mathematical models of conversion coefficients (Bilous, 2018) and specific taxation characteristics of forest fund plots. The total volume of dead organic wood accumulated in the forests of Sviatoshyn Communal Forest-Park Enterprise is 285.4 thousand tonnes, of which 86.2% of deadwood is concentrated in pine forests (Table 7).

Table 7. *Distribution of deadwood of forests of Sviatoshyn Communal Forest-Park Enterprise by components and groups of rocks*

Species group, tree type	Deadwood, thous. tonnes				
	drywood	clutter	dry branches	forest floor	total
Coniferous	24.5	7.4	55.1	159.4	246.4
including Scots pine	24.5	7.4	55.1	159.1	246.1
Hardwood	2.8	1.3	4.9	23.4	32.3
including common oak	2.6	1.2	4.6	22.0	30.6
Softwood	1.5	1.2	0.8	3.1	6.7
including silver birch	0.4	0.4	0.2	1.2	2.2
black alder	0.9	0.7	0.5	1.3	3.5
Total	28.8	9.9	60.8	185.9	285.4

Source: compiled by the authors

Analysing the data in Table 5, it was found that the largest reservoir of carbon storage in all tree groups is the forest floor. The participation of this component in the distribution of deadwood is 65.1%. The vast majority of deadwood (86.2% of the total volume) is concentrated in coniferous plantations dominated by Scots pine (246.1 thousand tonnes), which is consistent with data on the deterioration of the sanitary condition caused by anthropogenic load and exposure to stem pests.

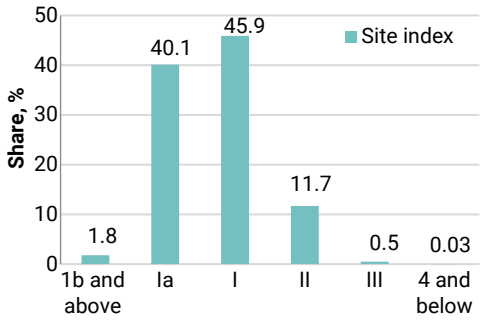

Figure 8. *Distribution of deadwood of pine forests by Sviatoshyn Communal Forest-Park Enterprise by quality classes*

Source: developed by the authors based on forest management materials

The largest volumes of deadwood in the forest stands of Scots pine were characteristic of both 1 and 1ª site index, the total share of which was 86%. This distribution is explained by a similar distribution of areas covered with forest vegetation of forest areas by site index. Regarding the quality indicators of deadwood, it is worth noting that the average density per unit area in Scots pine stands was 2.61 kg$(m^2)^{-1}$. M.M. Kutia & O.A. Hirs (2012) noted the constant growth of the population of Kyiv, and therefore, the volume of recreation, which significantly affects the state of urban forests. The influence of the anthropogenic factor on woody phytocenoses is implemented through direct (mechanical damage, insect pests and phytopathogens) and indirect (soil degradation and depletion, atmospheric air pollution) mechanisms. Recreational load, in particular, causes significant changes in the forest floor and soil, which are expressed in compaction of the upper layer, changes in mechanical composition, and a decrease in humidity and aeration, which, in turn, negatively affects the root nutrition and overall sanitary condition of plantings. When studying pine stands, N. Puzrina *et al.* (2022) established the dependence of the increase in the index of sanitary condition of pine plantations and the deterioration of forests due to changes in weather conditions and climate aridity, and mass reproduction of stem pests after dry periods, which indicates the complex nature of the problem in the forests of green areas, where recreational load can increase the negative effects of climate change and pests. According to N. Puzrina *et al.*, the death of trees occurs in the stand as a result of natural selection mainly by the grassroots type, but in the case of adverse biotic, abiotic, or antrogenic factors, not only trees from the lower part of the canopy are lost, but also trees of the dominant (Kraft classes I-II) type. Low-top pine stands of artificial origin, clean in composition and simple in shape in all types of forest, dry up mainly in middle-aged and older age groups, which was confirmed by research. After logging and limiting the food supply, bark beetles can populate young stands. Initially, single and group foci of drying occur near the edges, in forest walls, narrow strips and low-density pine forest stands, and then expand and penetrate deep into woodlands.

F. Brovko *et al.* (2023) noted that intensive recreational loads lead to compaction of the soil, changes in its mechanical composition, a decrease in moisture and air, which negatively affects the root nutrition and general condition of trees, which was confirmed by studies in the area of intensive recreation. The reasons for the deterioration of the sanitary condition of the examined plantings are the weakening and drying of trees, a significant recreational load and unfavourable environmental factors, accompanied by the colonisation and damage of wood by xylophagous insects, which are carriers of other pathogenic microorganisms. According to the V.L. Meshkova & O.I. Borysenko (2018), the proportion of pine trees in the forest and the age of pine trees are the most important factors in predicting the threat of drying caused by bark beetles, which was confirmed by research, i.e., the relative density of the stand is less important as a risk factor than its sudden decline. Selective sanitary logging allows the extraction of freshly populated xylophages of dead trees and their groups. This was confirmed by a number of researchers, in particular, V. Melnyk (2019) noted that pine plantations where

forest management measures were carried out in a timely and appropriate manner were more structurally sustainable. Faulty and wind-damaged trees, which are primarily removed during selective sanitary logging, are a substrate for the development of many microorganisms and fungi and a reservoir for forest pests.

The forests of the green zone of Kyiv, especially pine stands, play a key ecological role, but their sanitary condition is unsatisfactory. This is due to the predominance of artificial pine stands, suboptimal age structure (many middle-aged and over-mature trees, few young ones), high density, which makes them vulnerable to pests and diseases. A significant increase in deadwood and the presence of stem pests, such as the large and small pine bark beetle, the top bark beetle, and the impact of anthropogenic and recreational pressure, have been identified. The accumulation of deadwood (or detritus), which includes dead wood, wood breakage, rough branches, and forest floor, can change the living conditions of pests by affecting their numbers and distribution in plantings. It consists of organic matter from dead woody plants or isolated dead parts of living trees. The accumulation of deadwood (detritus) in forest stands is an important process that affects the ecosystem functions of forests, including their resistance to pests and diseases. The sanitary condition of plantings also determines the features of the development of stocks of deadwood, which serves as a habitat for numerous biological species (Pelyukh *et al.*, 2019). This confirms the importance of preserving different types of dead wood in forest ecosystems, as it creates microbiotopes for many rare and common species, which increases overall biodiversity. J. Sandström *et al.* (2019) noted that proper management of deadwood can help to maintain the stability of trophic connections in the forest, which is especially important for protected areas. It was considered as a reservoir of carbon, while P. Yavorovsky & S. Sendonin (2019) and M.O. Lakyda (2022) also emphasised that deadwood plays a role in nutrient accumulation and the development of a sustainable soil environment. Wood detritus is a long-term carbon storage and nitrogen source due to its long biodestruction period, which ensures a stable cycle of elements in forest biocoenoses and slows down their degradation. In the study by V.Y. Yarotskiy *et al.*, 2019), the spatial distribution of dead wood in the oak forests of the Left-Bank Forest-Steppe of Ukraine was estimated, which established the characteristic volumes of wood detritus accumulation depending on the type of plantings, age, and management regime. The researchers emphasised that dead wood is a critical component for maintaining ecosystem balance. Similar conclusions were obtained by L. Bujoczek *et al.* (2021), which shows that the amount of deadwood in non-exploited forests is six times higher than in forest ecosystems where active farming is carried out, indicating the need for a careful balance between forest management and natural recovery processes. In the Polish context, L. Bujoczek *et al.* systematised the types of dead wood according to morphological and stage signs of decomposition, and also revealed the spatial unevenness of its distribution, which was associated with forestry practices and the protected status of territories.

Thus, the presence of deadwood not only contributes to carbon accumulation, but also forms foci of biodiversity, especially for xylophages, fungi, and mosses, which was confirmed by many European studies. However, excessive detritus accumulation without a monitoring and regulatory system can create fire risks in climate change, which requires adaptive approaches to managing dead wood in forests of various functional categories.

Conclusions

In the forest fund, the predominance of high-quality (1c – 2 classes – 99.1%) and high-density (more than 0.8-26.5%) plantings in fresh forest conditions (94.72% of the area) with a monospecific dominance of Scots pine (86.3% of the area) in combination with a suboptimal age structure (the predominance of medium-aged plantings of

56.5% and a low proportion of young stands of 5.8%) creates prerequisites for deterioration of the sanitary condition. There was a deterioration in the sanitary condition and a decrease in the overall stability of pine stands during 2020-2024. About 25% of forests are mature and over-mature, which lose their conservation and aesthetic functions. The distribution of deadwood in pine forest stands showed that its largest volumes (86% of the total amount) fall on the 1 and 1a quality classes. This distribution directly correlates with a similar proportion of forest areas covered with forest vegetation for these quality classes.

The total volume of dead organic wood accumulated in the forests of Sviatoshyn Communal Forest-Park Enterprise is 285.4 thousand tonnes, of which 86.2% of the deadwood is concentrated in pine forests. According to qualitative indicators, the average density of deadwood per unit area in Scots pine stands was 2.61 kg/m^2. The increase in dead wood volumes is a direct result of the colonisation of weakened plantings by stem pests, such as *Tomicus piniperda, T. minor, Ips acuminatus, Ips sexdentatus, Phaenops cyanea, monochamus galloprovincialis and Acanthocinus Aedilis*. However, the identified populations of xylophagous insects were characterised mainly by a low and medium degree of infestation, they were observed on very weakened trees, which, in this case, indicates their role as secondary pests that complement the weakening caused by other factors. The results obtained confirmed the need to develop and implement effective measures to improve the sanitary condition of pine stands in the forests of green areas, increase their resistance to pests and diseases, and to optimise the recreational load by conducting systematic monitoring.

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Conflict of Interest

None.

References

[1] Bilous, A.M. (2018). *Woody detritus of Ukrainian Polissia forests*. Kyiv: NUBiP of Ukraine.

[2] Brovko, F., Yukhnovskyi, V., Brovko, O., Brovko, D., Urliuk, Yu., & Khryk, V. (2023). The influence of anthropogenic trampling of gray forest soils on their physical properties. *Central European Forestry Journal,* 69(4) 224-232. doi: 10.2478/forj-2023-0017.

[3] Bujoczek, L., Bujoczek, M., & Zięba, S. (2021). How much, why and where? Deadwood in forest ecosystems: The case of Poland. *Ecological Indicators,* 121, article number 107027. doi: 10.1016/j.ecolind.2020.107027.

[4] Convention on Biological Diversity. (1992, June). Retrieved from https://zakon.rada.gov.ua/laws/show/995_030#Text.

[5] Goychuk, A.F., Reshetnyk, L.L., & Maksymchuk, N.V. (2012). *Methods of forest pathology examinations*. Zhytomyr: Polissya.

[6] Kutia, M.M., & Hirs, O.A. (2012). Characteristics of recreational load and recreational capacity of forest park landscapes of Kiev. *Scientific Bulletin of the National Forestry University of Ukraine,* 22(12), 86-90.

[7] Kyiv City State Administration. (2023). *Project of organization and development of forestry of the Sviatoshyn Communal Forest-Park Enterprise"*. Irpin: State Enterprise "Ukrderzhlisproekt".

[8] Lakyda, M.O. (Ed.). (2022). *Plant biomass and ecosystem functions of Kyiv region forests*. Kyiv: LLC "CP "Comprynt".

[9] Levchenko, V., & Gumeniuk, V. (2024). Regarding the issue of growing Scots Pine forests in Polissya. *Ukrainian Journal of Forest and Wood Science*, 15(4), 25-39. doi: 10.31548/forest/4.2024.25.

[10] Melnyk, V.V. (2019). Assessing the sanitary condition of pine stands in the zone of unconditional resettlement in fresh pine forests of The Ukrainian Polissia. *Scientific Bulletin of UNFU*, 29(3), 39-43. doi: 10.15421/40290308.

[11] Meshkova, V.L., & Borysenko, O.I. (2018). Prediction for bark beetles caused desiccation of pine stands. *Forestry and Forest Melioration*, 132, 155-161. doi: 10.33220/1026-3365.132.2018.155.

[12] Meshkova, V.L., *et al.* (2020). *Methodological guidelines for monitoring, recording, and forecasting the spread of forest pests and diseases for the flat part of Ukraine*. Kharkiv: Planeta-Print.

[13] Pelyukh, O., Paletto, A., & Zahvoyska, L. (2019). People's attitudes towards deadwood in forest: Evidence from the Ukrainian Carpathians. *Journal of Forest Science*, 65(5), 171-182, doi: 10.17221/144/2018-JFS.

[14] Puzrina, N., Karpuk, A., Vasylyshyn, R., Melnyk, O., & Tokarieva, O. (2022). Thirty-year dynamics of the pine stand sanitary conditions of Boyarka forestry research station. *Scientific Horizons*, 25(10), 43-52. doi: 10.48077/scihor.25(10).2022.43-52.

[15] Resolution of the Cabinet of Ministers of Ukraine No. 733 "On Approval of the Procedure for Dividing Forests into Categories and Allocating Specially Protected Forest Areas". (2007, May). Retrived from https://zakon.rada.gov.ua/laws/show/733-2007-%D0%BF#Text.

[16] Sandström, J., Bernes, C., Junninen, K., Lõhmus, A., Macdonald, E., Müller, J., & Jonsson, B.G. (2019). Impacts of dead wood manipulation on the biodiversity of temperate and boreal forests: A systematic review. *Journal of Applied Ecology*, 56(7), 1770-1781. doi: 10.1111/1365-2664.13395.

[17] Soshenskyi, O., Zibtsev, S., Terentiev, A., & Vorotynskyi, O. (2021). Consequences of catastrophic landscape fires in Ukraine for forest ecosystems and population. *Ukrainian Journal of Forest and Wood Science*, 12(3), 21-34. doi: 10.31548/forest2021.03.002.

[18] Tokarieva, O.V. (2023). Categories of tree condition under recreational load. In *International scientific and practical conference "Forestry, woodworking and landscaping: State, achievements and prospects"* (pp. 72-75). Kharkiv: State Biotechnological University.

[19] Ukrainian State Design Forestry Production Association. (2022, July). *Instructional and methodological guidelines for forest management*. Retrieved from https://lisproekt.gov.ua/fileadmin/user_upload/Instruktivno-metodichni_vkazivki.pdf.

[20] Yarotskiy, V.Y., Pasternak, V.P., & Nazarenko, V.V. (2019). Deadwood in the oak forests of the Left Bank Forest-steppe of Ukraine. *Folia Forestalia Polonica*, 61(4), 247-254. doi: 10.2478/ffp-2019-0024.

[21] Yavorovsky, P., & Sendonin, S. (2019). *Recreational forestry*. Kyiv: Scientific Capital.

[22] Yukhnovskyi, V.Yu., Zibtseva, O.V., & Debryniuk, I.M. (2021). Evaluation of green space systems in small towns of Kyiv region. *Bulletin of Geography. Socio-Economic Series*, 53(53), 7-16. doi: 10.2478/bog-2021-0019.

[23] Zhang, S., Dekker, F., van Logtestijn, R.S.P., & Cornelissen, J.H.C. (2025). Do wood-boring beetles influence the flammability of deadwood? *Ecology: Ecological Society of America*. doi: 10.1002/ecy.4508.

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Анотація. Актуальність дослідження зумовлена специфікою лісових екосистем зеленої зони м. Київ, які перебувають у зоні інтенсивного антропогенного навантаження та відіграють критичну роль у міському середовищі. Мета дослідження полягала в аналізі змін санітарного стану лісів зеленої зони, визначенні ключових факторів, що призводять до їх деградації, та розробці рекомендацій щодо їх покращення. У дослідженні застосовано аналіз та узагальнення матеріалів лісовпорядкування, літературних даних, загальновідомі методи лісівництва та лісової таксації (рекогносцирувальне та детальне обстеження насаджень), а також лісопатологічні методи для виявлення та аналізу санітарного стану соснових насаджень. Протягом 2020-2024 рр. виявлено знижений рівень загальної стійкості соснових насаджень, оскільки близько 25 % з них відносяться до стиглих та перестійних, які втрачають свої природоохоронні та естетичні функції. Збільшення обсягів сухостою є результатом заселення ослаблених насаджень стовбуровими шкідниками, такими як великий сосновий лубоїд (*Tomicus piniperda* L.), малий сосновий лубоїд (*T. minor* Hartig.), верхівковий короїд (*Ips acuminatus* Gyllenhal), шестизубчастий короїд (*Ips sexdentatus* Boerner), синя соснова златка (*Phaenops cyanea* Fabricius), чорний сосновий вусач (*Monochamus galloprovincialis* Ol.) та сірий

довговусий вусач (*Acanthocinus aedilis* L.). Виявлені популяції комах-ксилофагів характеризувалися низьким та середнім ступенем заселення і були відмічені лише на дуже ослаблених деревах. Найбільша площа соснових насаджень (690,0 га), охоплена вибірковими санітарними рубками, припала на 2020 рік, що свідчить про вплив негативних чинників. Аналіз типологічної структури показав, що найбільш поширеними є субори (54,8 % площі), а серед гігротопів переважають свіжі умови (94,72 % за площею). Переважають високопродуктивні деревостани Iв-II класів бонітету (99,1 % площі) та середньовікові деревостани (56,5 % площі). Загальний обсяг накопиченої мертвої деревини становить 285,4 тис. т, з яких 86,2 % зосереджено у соснових лісах, причому найбільшим резервуаром вуглецю є лісова підстилка (65,1 %). Середній показник щільності мортмаси у соснових деревостанах становить 2,61 кг·м$^{-2}$. Отримані результати можуть бути використані для розробки ефективних заходів із покращення санітарного стану соснових насаджень у лісах зелених зон, підвищення їх стійкості до шкідників та хвороб, а також для оптимізації рекреаційного навантаження

Ключові слова: рекреаційне навантаження; комахи-ксилофаги; вибіркові санітарні рубки; мортмаса; лісові екосистеми