Received: 28.03.2022, Revised: 15.07.2022, Accepted: 11.08.2022

UKRAINIAN JOURNAL OF FOREST AND WOOD SCIENCE

UKRAINIAN JOURNAL OF FOREST AND WOOD SCIENCE

Journal homepage: https://forestscience.com.ua/en
Ukrainian Journal of Forest and Wood Science, 13(3), 41-49

UDC 504.5;631.459:712.253
DOI: 10.31548/forest.13(3).2022.41-49

The influence of recreational load on the anti-erosion properties of the soils of park stands

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Abstract. Changes related to urban infrastructure directly affect the ecological environment, including soil properties. The purpose of this study is to investigate the anti-erosion and flow-regulating effect of park stands in complex terrain conditions of Kyiv. Forestry and tax indicators of plantings are established according to recognized tax methods. The upper layers of the soil were studied by determining the hardness, water permeability, density, and humidity on paths and in stands. Soil hardness in plantations increases from 9.1 ± 0.76-10.8 ± 1.01 kg/cm^2 to 15.4 ± 0.25-30.8 ± 0.15 kg/cm^2, which is associated with the intensity of trampling them. Therewith, the soil changes from loose to medium loose and even dense. Determination of water permeability also showed a significant discrepancy, from 18.6 ± 0.76-20.6 ± 0.66 mm/min to 1.9 ± 0.10-5.7 ± 0.33 mm/min, respectively. Research has confirmed the inverse correlation between soil hardness and water permeability. The obtained indicators of soil density in the stands (1.12-1.20 g/cm^3) and on the paths (1.34-1.66 g/cm^3), albeit without sharp differences, in both cases indicate their criticality for further normal development of stands. Changes in soil moisture data in stands (16.9-20.6%) are decreasing in comparison with paths (11.2-12.6%), which also indicates the deterioration of growing conditions. The presence of active roots in the upper thickness of the soil on the control was 5.8-9.8 g, and on the paths, depending on the intensity of trampling, from 0.0 to 2.2 g. The territories under study were surveyed to identify characteristic erosion processes. It was established that the park spaces are in a satisfactory condition and fully perform an anti-erosion effect. The threat of erosion processes occurs on paths of intense load. The results obtained can be used for monitoring and regulating anthropogenic load

Keywords: complex terrain, test network, root system, surface runoff, erosion processes

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Introduction

Scientists of the world increasingly note the dominant role of human activity in terms of adverse impact on vegetation in general and park stands in particular [1; 2]. Tourist activity affects the reduction of adaptation of vegetation to anthropogenic loads and increases its vulnerability [3]. An increase in degraded zones is observed in areas adjacent to tourist hiking tests [4]. S.V. Halla-Bobik [5] notes the negative impact of the functioning of recreational and tourist complexes on the state of water in the Syniavka River in the National Natural Park (NNP) “Zacharovanyi Krai”.

The risk of soil erosion is increasing on a global scale. It is related to the type of soil, topography, slope, frequency, and intensity of extreme precipitation, the state of vegetation cover, etc. [6]. Since urban park areas in complex terrain are affected by water erosion, tree and shrub vegetation plays an extraordinary role in protecting and preventing the development of landslides and soil degradation [7; 8]. The conditions of the crossed relief are most vulnerable to the destructive action of water erosion, the development of which is influenced by the steepness, length, exposure, and shape of the slope. Specifically, soil is washed out more intensively on convex slopes than on concave ones. In turn, the water-physical properties of the soil, including density and moisture, directly determine its anti-erosion resistance. At the same time, vegetation is an essential factor that prevents the development of erosion processes or reduces them. The destruction of vegetation, including by recreational exercise, increases the danger.

Therefore, park plantations suffer from excessive trampling, damage to vegetation by burning, especially in places where spontaneous recreation areas are arranged, erosion processes, clogging, etc. This leads to a weakening of their biological stability, liquefaction, aesthetics, and

Suggested Citation:
Maliuha, V., Minder, V., & Sovakov, O. (2022). The influence of recreational load on the anti-erosion properties of the soils of park stands. *Ukrainian Journal of Forest and Wood Science*, 13(3), 41-49.

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death. Preservation and reproduction of plant cover, the main producer of organic matter for trophic chains, is the key to the normal development of the natural environment in general and parks and forest parks in particular. In this context, it is important to be aware of the recreational value of vegetation. As for green spaces, recreation should be understood as the restoration of a healthy person's strength as a result of direct communication with nature.

Studies of the recreational load on park plantings stay relevant, as they can be used to regulate and limit anthropogenic impact. They were aimed at the manifestation of erosion processes, which occur mainly on test networks, especially in conditions of complex terrain. The purpose of these studies was to find out the anti-erosion and runoff-regulating effects of urban parks. The main task included determining the condition and basic water-physical properties of the soils of the test network of the park territories. The originality of this study lies in the use of runoff sprinklers on the test network to protect against water erosion. To fulfil the purpose of the study and complete the main task, the application of a complex approach is provided.

It is equally important to identify the causes of erosion processes. Soil washout on tests occurs due to the concentration of surface runoff, which is formed in liquefied vegetation on slopes, or comes in transit from the carriageway of highways or paved roads. Asphalted roads bordered by curbs contribute to the concentration of surface runoff. The improper condition of hydrotechnical structures, e.g., high-speed channels, is the reason for the development of erosion processes [7]. In this paper, attention is focused on test networks with a soft ground surface, which are common on the slopes of parks on difficult terrain: M.T. Rylsky Holosiivskyi Park of Culture and Recreation (PCR) and NNP "Holosiivskyi". Compared to forest stands of natural and especially artificial origin, which require considerable time for the formation of the forest environment in countering the manifestation of erosion, hydraulic structures operate relatively quickly from the moment of their construction. However, stands that have an established forest environment are much more efficient than hydraulic structures. The latter require constant maintenance and repairs, and the anthropogenic factor plays a crucial role.

Literature Review

The deterioration of the ecological state of the natural environment inevitably affected people's health (burnout, stress, etc.). Recently, the need for recreational forest use in general and forest park and park use in particular has increased substantially. The known positive and comprehensive impact of forest stands on the human body encourages it to communicate more often with the natural environment. In this regard, systems of green spaces can provide architectural and planning, recreational and health and aesthetic functions.

It is important to consider the age parameters of the city parks being created. Young urban landscapes are less resistant to degradation compared to old ones [9]. Soil and vegetation are interconnected and mutually determined. During soil formation, the main role is played by green plants – creators of organic matter. At the same time, plants depend on the soil on which they grow. Consequently, soil destruction leads to degradation of plant communities [10]. There should be constant monitoring of soil and vegetation properties, as well as the number of visitors and their activity in parks [11; 12]. Grass cover reacts earlier than arboreal plants to the use of precipitation that enters the soil [13]. E.A. Fedoruk [14] notes that the living ground cover is the first link in the forest environment that suffers from an increase in anthropogenic impact on it. Trampling of the soil by recreationists manifests negative properties of the upper layers of the soil and adversely affects the plant cover [15]. The impact of trampling substantially affects the species diversity of ecosystems [16].

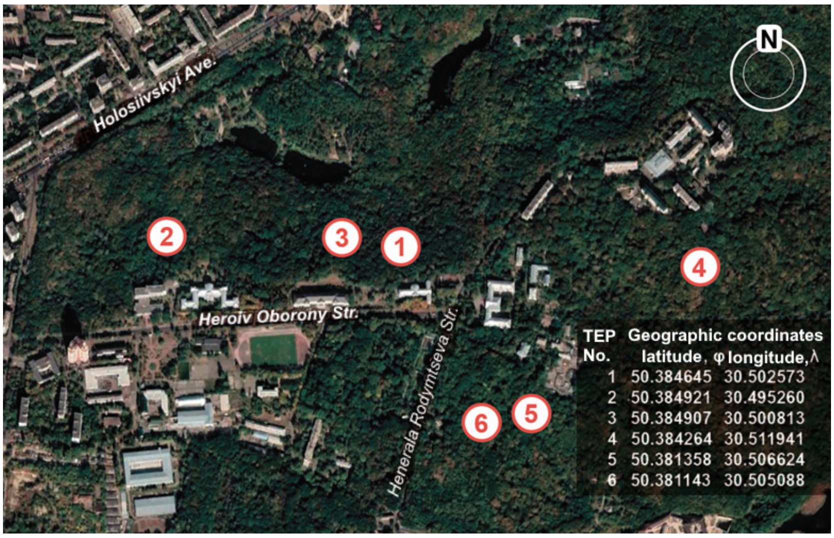
Together with disturbance and compaction of litter, the recreational load leads to compaction of the upper mineral part of the soil to a depth of up to 15 cm, and much deeper on the paths [17]. Typically, the indicator of recreational load per 1 ha of their area is used to assess the impact of visitors on park stands [18; 19]. Recreational load, as an indicator, was calculated by the authors in person-days/ha, which is the most common methodical approach. However, this kind of assessment does not allow establishing the causes and prevent the manifestations of erosion processes in time. These studies are dedicated to solving the issue of preventing the development of erosion processes on the test networks of park plantations with complex terrain.

Modern studies of the recreational load on the plantations of the NNP "Holosiivskyi" highlight the constantly growing urban influence, the consequences of which for the natural components of the forest are increasing degrees of degradation and a decrease in the value of forest ecosystems. The main value of Holosiivskyi forest ecosystems for urban visitors is noted, which lies in protecting soils from erosion, regulating water flow, producing oxygen, absorbing carbon dioxide, preserving biodiversity, recreational, wellness and cultural-historical functions [20]. Therewith, the pine stands of the zone of regulated recreation in the southern part of the "Holosiivskyi" NNP are characterized by a moderate recreational load of 1.2-2.5 people·days/ha, which corresponds to the second stage of recreational digression. The recreation coefficient was 0.05-0.15, i.e., the permissible load is not exceeded [21]. Considering the forecast of a multi-year steady distribution of the daily average annual flow of visitors to sites in Kyiv [22], the "Holosiivskyi" NNP has a 19% share of the city's visitors, being almost at the same level as Podol (18%) and inferior only to Pechersk (28%) and Starokyivska Hora (20%). This testifies to the rather high importance of the territory under study among the city's recreational locations, and the importance of maintaining its aesthetic and ecological potential. Therefore, it is necessary to perform monitoring and, specifically, erosion control of the anthropogenic load on park plantings in the conditions of the complex topography of Kyiv.

Materials and Methods

The recreational load on the soils of park stands was studied on temporary experimental plots (TEP) in the "Holosiivskyi" NNP (TEP No. 4-6) and the M.T. Rylskyi Holosiivskyi PCR (TEP No. 1-3), which is part of it. Monitoring of the water and physical properties of soils took place in April-August 2022, which accounts for 60% of the flow of visitors to urban park areas. The location of the experimental sites is presented in Figure 1.

The leading factor in the destruction of plant communities is trampling, which primarily affects the ground cover and herbaceous vegetation. According to the intensity of trampling [23] in the territories under study, it was found that up to 20% of the hiking tests are devoid of any vegetation cover that is, they have the stage V of complete trampling; up to 30% of the paths are in the stages III-IV of trampling with the destruction of the grass cover from 15% to 60%; 50% of the total area of the test network is classified as stages I-II of trampling, where up to 15% of the grass cover has been destroyed.



TEP No.	Geographic coordinates latitude, φ	longitude, λ
1	50.384645	30.502573
2	50.384921	30.495260
3	50.384907	30.500813
4	50.384264	30.511941
5	50.381358	30.506624
6	50.381143	30.505088

Figure 1. Geolocation of temporary test areas in park plantations

Source: developed by the authors based on a Google Earth image

Experimental plots of plantations on the TEP were chosen in the middle part of the slopes. All of them are mixed with representatives of deciduous tree species of maple (*Acer platanoides* L.), hornbeam (*Carpinus betulus* L.) and oak (*Quercus robur* L.). The steepness of the slopes is from 7 to 17 degrees of northern, eastern, and southern exposures. The difference in the thickness of the humus horizon is insignificant and ranges from 19 to 21 cm (Table 1).

Table 1. The main forestry and taxation indicators of park stands

Number TEP	Stand composition	Age, years	Average		Density	Slope		Humus horizon, cm
			height, m	diameter, cm		steepness, degree	exposition	
M.T. Rylskyi Holosiivskyi PCR								
1	6Ap4Cb	75	24.5	28.0	0.7	13	N	20
2	6Cb4Ap	80	25.0	29.0	0.6	17	N	19
3	7Cb3Ap	75	25.0	30.0	0.7	15	N	19
NNP “Holosiivskyi”								
4	7Ap3Cb	70	23.5	27.0	0.5	8	E	21
5	5Cb5Ap	80	26.0	31.0	0.6	12	E	20
6	7Ap3Qr	70	24.0	26.0	0.5	7	S	21

Note: Ap – *Acer platanoides* L.; Cb – *Carpinus betulus* L.; Qr – *Quercus robur* L.

Source: compiled by the authors based on the studies conducted

According to the determined forest inventory parameters, the researched plantations grow according to the first (I) site index class, having an age ranging from 70 to 80 years and a stocking of 0.5-0.7 (Fig. 2). According to the method of I.D. Rodichkin [17], they form landscapes of closed (TEP No. 1-3, 5) and semi-open (TEP No. 4, 6) types of spaces.

TEP No. 1 TEP No. 2 TEP No. 3 TEP No. 4 TEP No. 5 TEP No. 6

Figure 2. General view of the test network of park stands on temporary experimental plots
Source: photographs taken by the authors

Soil hardness was measured from the surface with a Golubev hardness tester. The number of measurements is 20 times in the middle of the path of different trampling intensity. Measurements in stands at 20 m from the paths were used as a control and comparison of research results. The water permeability of the soil was determined using steel cylinders with a diameter of 80 mm and a height of 100 mm by sinking them into the soil half the height and filling the above-ground part with water. The time of water penetration into the soil is measured by a stopwatch. The determined absorption time of a 50 mm layer of water corresponds to torrential precipitation. The number of measurements is 10 times. Water permeability is defined as the amount of absorbed water over the time it was absorbed in mm/min [7]. The statistics of measuring soil hardness and water permeability were obtained for ungrouped series based on a small number of observations: N is the number of repetitions, χ is the mean value, σ is the mean square deviation, m is the error of the mean value, υ is the coefficient of variation, p is the precision of the mean value. The significance of the difference between the average values was also estimated [24]. The root mass was collected from monoliths measuring 10×10×10 cm with a total volume of 1,000 cm^3. The density of the soil, as the dry mass of a unit of its volume without disturbing the natural compaction [25] was identified according to the method of a cutting steel ring with a diameter of 50 mm and a height of 30 mm. Soil moisture was determined by the drying method.

The manifestation of erosion processes was observed in 2018-2022. Research on the types of soil erosion was investigated on the test network of intensive trampling by measuring the depth and length of erosion. The washes were studied by the arrangement of trenches on the flow sprinklers before the dam day for silt retention.

Results and Discussion

The anti-erosion and runoff-regulating effect of park stands is closely related to the hardness and water permeability of the upper soil layer and the spread of root systems in it [7]. In turn, the above-mentioned depends on the state of the stands themselves and their use of living space [26]. The measured indicators of soil hardness (Table 2), in plantations and on paths, have a substantial difference, which can be explained by the trampling intensity.

Table 2. Soil hardness measurement statistics

No.TEP	Stand composition	A, years	N	χ	σ	m	υ	p
1	6Ap4Cb	75	20	9.5	0.88	0.23	4.74	1.22
1a	path	–	20	19.7	1.25	0.29	6.34	1.46
2	6Cb4Ap	80	20	10.8	1.01	0.26	5.67	1.46
2a	path	–	20	30.8	0.66	0.15	2.14	0.40
3	7Cb3Ap	75	20	9.1	0.76	0.20	4.45	1.15
3a	path	–	20	15.4	1.10	0.25	7.15	1.60
4	7Ap3Cb	70	20	9.8	0.84	0.22	4.83	1.25
4a	path	–	20	23.7	0.68	0.15	2.86	0.64
5	5Cb5Ap	80	20	10.5	0.98	0.25	5.52	1.43
5a	path	–	20	29.0	0.63	0.14	2.14	0.84
6	7Ap3Qr	70	20	10.2	0.94	0.24	5.29	1.36
6a	path	–	20	25.8	0.70	0.16	2.70	0.60

Note: in the TEP numbering, “a” indicates that the soil hardness measurements were made in the middle of the path
Source: compiled by the authors based on the studies conducted

In the tree stands, despite the difference in age and composition, the range of hardness indicators was within 9.1 ± 0.76-10.8 ± 1.01 kg/cm^2, which according to M.A. Kaczynski classifies [25] them as loose and medium loose. The assessment of the significance of the difference between the average values of the indicators (Table 3) shows that it is insignificant in the stands on TEP No. 1-3, where the Student's criterion does not exceed 4.34. On the paths, these indicators differ substantially from each other. This is related to the trampling intensity, 15.4 ± 0.25-30.8 ± 0.15 kg/cm^2, as well as the vegetation and changes from a medium loose to a dense state. They revealed a significant difference in the average values of soil properties indicators, where the Student's criterion increases from 8.82 to 13.77.

Table 3. Evaluation of the significance of the difference between the average values of hardness indicators

Difference between average values	Number of degrees of freedom	Criterion Student $t_{0.05}$	Difference between average values	Number of degrees of freedom	Criterion Student $t_{0.05}$
1-2*	36	4.34	1-4	36	1.10
2-3a*	36	13.77	6a-4a*	36	9.62
2a-5a*	36	8.82	1a-3a*	36	11.55

Note: * – significant
Source: compiled by the authors based on the studies conducted

For park stands to effectively perform anti-erosion action, it is important to know not only the indicators of soil hardness, but also their ability to absorb liquid atmospheric precipitation according to indicators of water permeability (Table 4).

Table 4. Statistics of soil water permeability measurement

No. TEP	Stand composition	A, years	N	χ	σ	m	υ	p
1	6Ap4Cb	75	10	19.9	1.42	0.45	13.7	4.32
1a	path	–	10	4.6	0.63	0.20	13.6	4.32
2	6Cb4Ap	80	10	18.6	1.77	0.76	15.3	4.80
2a	path	–	10	1.9	0.20	0.10	10.0	3.18
3	7Cb3Ap	75	10	20.6	1.58	0.66	13.8	4.17
3a	path	–	10	5.7	1.04	0.33	18.2	5.75
4	7Ap3Cb	70	10	20.0	1.45	0.53	13.4	4.39
4a	path	–	10	3.9	0.32	0.11	8.3	2.61
5	5Cb5Ap	80	10	19.0	1.63	0.54	16.1	4.83
5a	path	–	10	2.7	0.16	0.05	5.8	1.83
6	7Ap3Qr	70	10	19.5	1.75	0.53	15.5	4.73
6a	path	–	10	3.4	0.33	0.11	9.6	3.20

Note: in the TEP numbering, "a" indicates that the soil hardness measurements were made in the middle of the path
Source: compiled by the authors based on the studies conducted

The determined water permeability of the soil under the experimental stands ranged within 18.6 ± 0.76-20.6 ± 0.66 mm/min, which has no significant difference between the average values (Table 5). On the test network, the water permeability indicators had a sufficiently large discrepancy from 1.9 ± 0.10 to 5.7 ± 0.33 mm/min, which revealed significant differences between the average values of the indicators both on the tests and compared to the plantations. Therewith, the Student criterion was 2.86-19.88.

Table 5. Evaluation of the significance of the difference between the average values of soil water permeability indicators

Difference between average values	Number of degrees of freedom	Criterion Student $t_{0.05}$	Difference between average values	Number of degrees of freedom	Criterion Student $t_{0.05}$
1-2*	16	1.81	1-4	16	0.16
2-3a*	16	19.88	6a-4a*	16	3.44
2a-5a*	16	9.88	1a-3a*	16	2.86

Note: * – significant
Source: compiled by the authors based on the studies conducted

The absorptive capacity of the soil of park plantations according to the intensity of infiltration during the first hour will be from 1116 to 1236 mm/h. According to M.A. Kaczynskii [25], such results allow estimating the water permeability of the soil as failure. The obtained indicators of water permeability of the soil under the stands testify to their powerful anti-erosion capabilities. On the paths, depending on their trampling during the first hour, the intensity of infiltration can range from 114 to 342 mm/h. Therefore, the researched park plantings contribute to the rapid transfer of surface runoff to ground runoff, which makes it impossible for erosion processes to occur. However, provided the formation of liquefied stands of surface runoff on the sloping sections of the paths or the arrival of its transit part under the tent, the threat of erosion processes increases depending on the intensity of trampling.

Research has confirmed that soil hardness is clearly correlated with water permeability, having inverse correlations (Fig. 3). Both indicators substantially depend on the level of soil moisture. As the level of soil moisture increases, its hardness decreases, which allows plants to build up their root system. But excessive soil moisture also reduces water permeability.

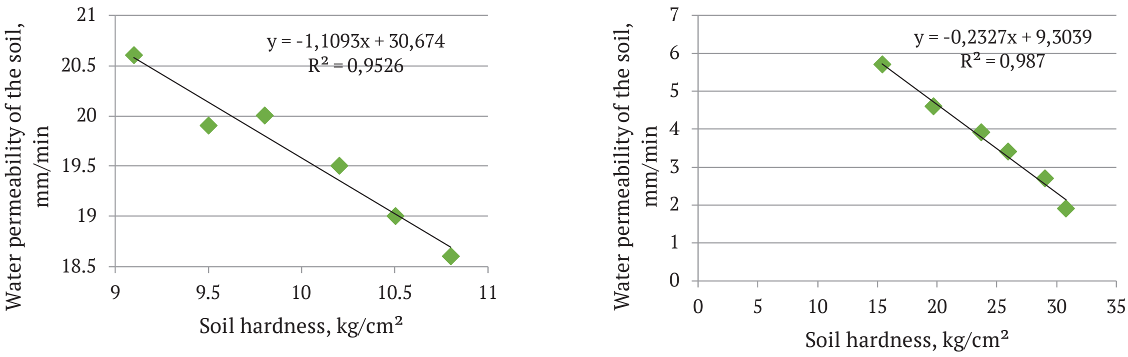


Figure 3. Dependence of soil water permeability on hardness: a – in stands; b – on the paths
Source: compiled by the authors based on the studies conducted

The density of soil composition and its hardness have a proportional relationship. As the folding density increases, the hardness increases. Investigating the physical and mechanical properties of the soil cover (Table 6), it was established that the density of the soil composition in the park stands (1.12-1.20 g/cm^3) and in the middle of the paths (1.34-1.66 g/cm^3) substantially differs due to greater anthropogenic load (trampling). Comparable results were obtained in the parks of Ivano-Frankivsk region [27; 28]. At an elevated level of recreational load, the volumetric mass of the soil increases by 1.5 or more times, and on the paths, the diversion is 2 to 10 times. A soil density level of 0.8-1.0 g/cm^3 allows tree stands to grow and develop normally, and when it increases to 1.12-1.20 g/cm^3, tree species begin to fall from the stand [17]. That is, the established density of the soil is critical for the further normal development of tree stands and can lead to its liquefaction.

Table 6. Physical and mechanical properties of the soil cover

No. TEP	Stand composition	A, years	Soil characteristics				Root weight, d
			raw weight, g	dry weight, g	density, g/cm^3	humidity, %	
1	6Ap4Cb	75	83	69	1.17	20.3	9.1
1a	path	–	92	82	1.39	12.2	1.9
2	6Cb4Ap	80	82	68	1.15	20.6	6.2
2a	path	–	109	98	1.66	11.2	0.0
3	7Cb3Ap	75	78	66	1.12	18.2	9.8
3a	path	–	91	81	1.37	12.3	2.2
4	7Ap3Cb	70	85	71	1.20	19.7	7.5
4a	path	–	89	79	1.34	12.6	0.7
5	5Cb5Ap	80	83	71	1.20	16.9	8.3
5a	path	–	100	89	1.51	12.3	0.0
6	7Ap3Qr	70	81	69	1.17	17.4	5.8
6a	path	–	88	79	1.34	11.4	0.8

Source: compiled by the authors based on the studies conducted

Soil moisture in plantations (16.9-20.6%) is higher compared to paths (11.2-12.6%), this is explained by the presence of forest litter 2-3 cm thick, which acts as mulch and reduces the load. The presence of active roots (diameter < 2 mm) in a 10-centimetre layer clearly reflects the influence of soil density and moisture. In tree stands, the weight of roots in a volume of 1000 cm^3 is 5.8-9.8 g, and on paths, depending on the intensity of anthropogenic load, from 0.0 to 2.2 g. At soil hardness over 29.0 ± 0.14 kg/cm^2, active roots are absent in the upper active layer. Therefore, the possibilities of binding the soil are minimized, and the probability of its washing out under such conditions, during the passage of concentrated surface runoff, increases. The obtained data confirm earlier studies [7].

The most frequent and largest washouts occur on intensively used tests that are located on the slopes of complex landforms. This applies to the areas where concentrated surface runoff is formed under the canopy of liquefied vegetation, as well as in places where the transit part of the runoff coming from roadways reaches them (Fig. 4a).

Figure 4. Characteristic erosion processes on park paths were identified: a – linear erosion; b – scum on the drain sprayer; c – the thickness of washed soil for 2021-2022

Source: photographs taken by the authors

In 2017, runoff sprinklers were installed at TEP No. 5 to protect the path from erosion and silt retention (Fig. 4b). In 2020, the operation of drain sprinklers was studied. During the three years of operation of one of the sprinklers (2018-2020), it retained 1.5 m^3 of silt. The total thickness of the washed soil layers during this period was 20 cm, and their number was 18 pieces (Fig. 4c). Maintenance work was carried out to remove silt for uninterrupted operation of the drain sprayer. During the next period (2021-2022), the thickness of the washed soil layer was 9 cm (Fig. 4c). Such a difference is related to the number and intensity of downpours in the specified periods. Therefore, for the effective operation of a simple hydraulic structure – a drain sprinkler, it is necessary to carry out constant monitoring and maintenance, and if necessary, in cases of damage by recreationists, to carry out repairs.

The obtained data on the anthropogenic influence on the anti-erosion properties of the soils of the parks of Kyiv confirm the zones [20] where conflict and threats are identified in the areas of the territories under study: unregulated recreational load (dense laying of tourist tests, visits to the most valuable, least developed areas of the forest) and non-target use of forest areas (dumping of household waste, felling, unorganized parking lots), as a result – destruction of the age-old structure of stands.

It is impossible to immediately react to the thinning of the stands through which the test routes pass, where surface runoff is formed during intense torrential rains, or their transit part arrives in the conditions of complex relief on the slopes. However, it is possible to install runoff sprinklers, which can prevent the manifestation of erosion (soil washout or erosion) under conditions of constant monitoring, maintenance, and prompt repairs. The prospect of further research envisages the implementation of studies on the improvement of flow sprinklers.

Conclusions

Park spaces are in a satisfactory condition and fully perform an anti-erosion effect. The threat of erosion processes occurs on paths of intense load. The anti-erosion and runoff-regulating effect of park stands is closely related to the hardness, water permeability of the upper soil layer, and the spread of root systems in it. In park stands, despite the difference in age and composition, the range of hardness indicators was within 9.1 ± 0.76-10.8 ± 1.01 kg/cm^2, which refers them to the loose and medium loose state. On the paths, these indicators differ substantially between each other and between stands and vary from a medium loose to a dense state of 15.4 ± 0.25-30.8 ± 0.15 kg/cm^2, which is explained by the trampling intensity.

The water permeability of the soil under the experimental stands was determined, which ranges within 18.6 ± 0.76-20.6 ± 0.66 mm/min. On the test network, the water permeability indicators had a fairly large discrepancy from 1.9 ± 0.10 to 5.7 ± 0.33 mm/min. Research has confirmed that soil hardness is clearly correlated with water permeability, having an inverse correlation.

It was established: the density of the soil composition in the park stands (1.12-1.20 g/cm^3) and in the middle of the paths (1.34-1.66 g/cm^3); soil moisture in stands (16.9-20.6%) is higher compared to paths (11.2-12.6%); the presence of active roots of a 10-centimetre layer of stands is 5.8-9.8 g, and on paths, depending on the intensity of anthropogenic load, from 0.0 to 2.2 g. With a soil hardness over 29.0 ± 0.14 kg/cm^2, there are no active roots on the paths, which can lead to washout or erosion.

The identified partially adverse impact of the recreational load on the soils of park stands can be used for its regulation, which allows preventing the complete degradation of the investigated ecosystems under constantly growing urbanization. Further studies should continue to monitor the state of anti-erosion properties of park plantings in conditions of complex terrain, as they are valuable for their aesthetic and ecological potential.

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Вплив рекреаційного навантаження на протиерозійні властивості ґрунтів паркових насаджень

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Анотація. Зміни, пов’язані з міською інфраструктурою, безпосередньо впливають на екологічне середовище, у тому числі, на властивості ґрунту. Мета роботи – вивчення протиерозійної та стокорегулюючої дії паркових насаджень у складних умовах рельєфу міста Києва. Лісівничо-таксаційні показники насаджень встановлено за визнаними таксаційними методами. Верхні шари ґрунту вивчено шляхом визначення твердості, водопроникності, щільності та вологості на стежинах і в насадженнях. Твердість ґрунту в насадженнях із 9,1 ± 0,76-10,8 ± 1,01 кг/см^2 зростає до 15,4 ± 0,25-30,8 ± 0,15 кг/см^2, що пов’язано з інтенсивністю їх витоптування. При цьому ґрунти із пухкого стану переходять до середньопухкого та навіть щільного. Визначення водопроникності теж показало значну розбіжність відповідно від 18,6 ± 0,76-20,6 ± 0,66 мм/хв. до 1,9 ± 0,10-5,7 ± 0,33 мм/хв. Дослідженнями підтверджено обернено пропорційні зв’язки між показниками твердості та водопроникності ґрунту. Отримані показники щільності складання ґрунту в насадженнях (1,12-1,20 г/см^3) і на стежинах (1,34-1,66 г/см^3), хоч і мають не дуже різкі відмінності, але в обох випадках вказують на їх критичність для подальшого нормального розвитку насаджень. Зміни даних вологості ґрунту в насадженнях (16,9-20,6 %) мають спадний характер у порівнянні із стежинами (11,2-12,6 %), що теж свідчить про погіршення умов зростання. Наявність активного коріння у верхній товщі ґрунту на контролі виявилась 5,8-9,8 г, а на стежинах, залежно від інтенсивності витоптування, від 0,0 до 2,2 г. Здійснено обстеження досліджуваних територій на виявлення характерних ерозійних процесів. Встановлено, що паркові насадження знаходяться у задовільному стані та повністю виконують протиерозійну дію. Загроза прояву ерозійних процесів має місце на стежках інтенсивного навантаження. Отримані результати можуть використовуватись для моніторингу та регулювання антропогенного навантаження

Ключові слова: складний рельєф, стежкова мережа, коренева система, поверхневий стік, ерозійні процеси