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ECOLOGICAL AND ECONOMIC ASSESSMENT OF THE STATE OF FOREST ECOSYSTEMS IN THE CONDITIONS OF MARITAL STATE IN UKRAINE

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Formulation of the problem. In the Ukrainian economy, the forest sector plays an important role in the socio-economic development of many regions and forms the export potential of Ukraine on the world market. The combination of the two main functions of forestry – socio-economic and ecological – forms the forestry potential of Ukraine. However, the mechanisms for maximizing the efficiency of the use of forest resources in a balanced system of forestry land use have not yet been created. Therefore, it is important to determine the current state and main trends in the development of forestry from the point of view of balanced forest use and reforestation [2].

Today, forestry plays an important role in the socio-economic life of society. At the same time, forest ecosystems perform the function of environmental protection, and are also designed to meet the ecological needs of humans. To date, the scientific and applied understanding of the forest ecosystem as a unit of land, forest vegetation, animal life, and other components of the natural environment has ecological, social, and economic significance [5].

Ecological assessment of forest ecosystems is a process of studying, analyzing and evaluating the impact of human activity on the ecological state of natural ecosystems. It includes the assessment of the impact of various factors such as pollution, land use changes, climate change and other human activities on biodiversity, functioning of ecosystems, as well as on the health of people and other organisms. The process of ecological assessment of ecosystems includes a detailed study of the physical, chemical and biological aspects of the ecosystem. It is based on the collection and analysis of data on various aspects of ecosystems, such as the structure and functioning of biological communities, the presence of threats to biodiversity, the quality of soil and water resources, the level of pollution, risks to the health of people and other organisms [13]. After data collection, their analysis is carried out, during which the main problems affecting the state of the ecosystem are determined. As a result of the assessment, recommendations and strategies are formed for the preservation, restoration and maintenance of ecological sustainability of the ecosystem. Ecological assessment of ecosystems is important for understanding the impact of human activities on the environment and for developing effective strategies for managing and conserving natural resources. It is also a key tool for decision-making in the field of environmental protection and sustainable development [12].

Today, the balanced use of forests depends on a number of requirements and standards that should ensure uninterrupted use of forest resources and protect the ecological and social role of forests. In connection with a significant increase in anthropogenic load and the dominance of the economic nature of forest resources over other equally important ecological and social components, there is a need to develop a balanced development strategy. The main requirement of balanced use of forest resources is further rational use and preservation of ecological, economic and social functions of forest resources [4]. A balanced model of forest use should provide the most effective combination of these components. During this, the emphasis is placed on the forest ecosystem itself, its condition is generally a reflection of the influence of external factors, in particular economic user [8].

The state of forest ecosystems is assessed using various criteria and indicators. Biodiversity and the condition of forest plant ecosystem components are key assessment factors. Currently, the existing methods and recommendations for assessing and monitoring forests (ICP-Forests, FHM, "Sanitary rules in the forests of Ukraine") do not have a clear definition of criteria for assessing the state of forest ecosystems. A large number of indicators, which are included in most methods, complicates the assessment of the state of forest ecosystems and makes it difficult to identify clear trends in their development [6].

Research of the state of forest ecosystems with the help of existing methods often does not allow establishing a cause-and-effect relationship between forest degradation. It should be noted that the degradation of plantations can be caused by changes in other components of the environment, besides afforestation. In such cases, it is almost impossible to determine the causes of degradation. In particular, significant degradation of plantations can occur as a result of a decrease in forest coverage of the watershed or violations of the hydrological regime occurring outside the forest ecosystem [9].

In this context, the state of forest ecosystems should be assessed at two levels: at the catchment level and at the forest ecosystem level. The assessment at these two levels should include an assessment of the state of the catchment components and an assessment of the degree of anthropogenic disturbance of the catchment components (change in forests). It should include an assessment of the state of the catchment components, an assessment of the degree of anthropogenic disturbance (change in forest cover, soil cover disturbance, change in the hydrological regime) and a direct assessment of the forest ecosystem. It is also necessary to conduct a direct assessment of forest ecosystems [14].

The system for assessing the state of forest ecosystems is divided into two levels:

1 – assessment of the state of biotic and abiotic of these components as a result of anthropogenic disturbances at the catchment level;

2 – assessment of the state of the vegetation composition of the ecosystem at the level of forest ecosystems [3].

The importance of environmental assessment during the pre-war period is that it pays tribute to all the possible consequences of military actions on the environment, which in turn makes it possible to develop effective strategies for the restoration and protection of natural resources after the war [6].

The environmental assessment process includes collecting data on the state of ecosystems before, during, and after a military conflict, assessing the impact of military actions on the natural environment, identifying potential threats to biodiversity and human health, and developing strategies and recommendations for ecosystem restoration and preservation [11].

Due to the fact that military conflicts can have long-term effects on ecosystems and human health, pre-war ecological assessment is critical to ensure sustainable restoration of the natural environment and ensure the viability of ecosystems for future generations [4].

Analysis of recent research and publications. Ecological assessment of forest ecosystems during martial law is an important tool for determining the impact of military operations on natural resources, ecosystems, and people. It allows to assess the changes occurring in the natural environment during the conflict and to determine the consequences for biodiversity, pollution, land use, water resources and other elements of the ecosystem [1].

Russia's full-scale invasion of Ukraine since February 24, 2022 has led to and continues to lead to serious damage to people and infrastructure in settlements where active hostilities continue. However, it is important to emphasize that war also has a serious impact on the natural environment and wildlife.

Events of military conflict, such as the movement of heavy equipment, the construction of fortifications and combat operations, lead to significant damage to the soil cover. This causes the degradation of vegetation and increases the impact of wind and water erosion [3].

According to the data of the Ministry of Environmental Protection and Natural Resources, it is possible to calculate that the aggressor is conducting combat operations on the territory of the nature reserve fund with an area of 12.4 thousand square meters km, which is a third of the entire nature reserve fund of Ukraine.

In Ukraine, to date, about 200 territories of the Emerald Network, which together make up an area of about 2.9 million hectares, are under threat of destruction. The Emerald Network includes protected areas created to preserve species and habitats that require protection at the pan-European level, but are located in countries that are not members of the European Union [4].

These areas act as habitats for thousands of plant and animal species, and play an important role in preserving biodiversity and climate. However, due to active hostilities, some of these protected natural areas, such as virgin unplowed steppes, chalk slopes in Donetsk region, coastal settlements in the southern regions, and swamps in the north, are threatened with destruction. This poses a serious threat to the existence and preservation of rare and endemic species that are part of these unique ecosystems (Fig. 1) [6].

Under the influence of the war, in addition to the direct consequences, cascading processes occur, which may appear only after a few years and lead to serious negative consequences for the environment. For example, fires during military operations not only lead to the destruction of forest ecosystems, but also contribute to the mass emergence of adventive species, some of which can be dangerous to human health. Historical data also testify to the connection of many adventitious species with military actions, in particular from the period of the Second World War. The general synergistic effect of military action, climate change and anthropogenic activity can intensify and accelerate negative processes. Calculations show that if the trend of climate change continues with an increase in average annual temperatures by 2°C, there may be a loss of about 25% of rare plant populations and more than 30% of habitats of Ukrainian biotopes. The strengthening of these processes caused by military actions can in some cases have catastrophic consequences [8].

According to data, among the most affected regions as a result of the military conflict in Ukraine are Chernihiv region, where approximately 400 thousand hectares of land were damaged, Sumy region with losses of about 290 thousand hectares, Luhansk region with damage of 200 thousand hectares, as well as Kyiv region, Zhytomyr region and Kharkiv region with damage of 120-160 thousand hectares of land each. It should be noted that these numbers are only indicative and may not reflect the full picture of the real situation, since during a military conflict, the exact determination of losses and damages can be difficult due to limited access to data and resources in the combat zone [5].

As a result of hostilities, the tranquility of wild animals is disturbed, which either die or are forced to flee from hot spots. There are three main migration routes of birds within the borders of Ukraine: the Azov-Black Sea latitude (southern corridor) with the highest concentration of migratory birds; Polissia latitudinal (northern corridor) along the Polissya forest strip and in the north of the Forest Steppe; and the Dnieper Meridian Migration Path, which stretches along the Dnieper River and its tributary the Desna. Waterfowl and shorebirds such as *Ansers, Anas platyrhynchos, Gavias, Calidris alpina, Larus* and *Sternas* especially use the latter route. These migration corridors now pass through a zone of active hostilities, which can cause the birds to become anxious, exhausted by changing routes or not being able to rest, as well as putting them at risk of coming under fire [14].

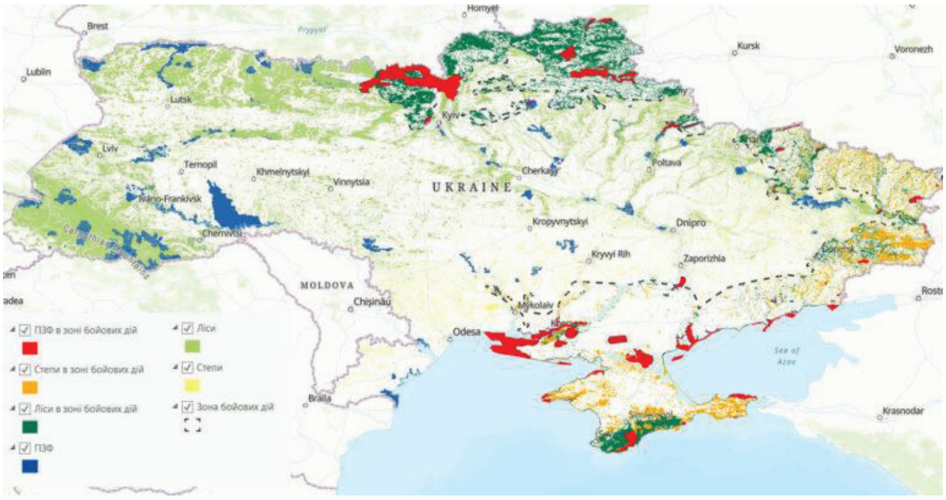

Fig. 1. Visualization of the affected natural territories as a result of the military invasion according to the data of the NGO "Ukrainian Nature Conservation Group"

As a result of the movement and damage of ground military equipment, soil is contaminated with fuel and lubricants and other petroleum products. In polluted soils, water permeability decreases, oxygen is displaced, biochemical and microbiological processes are disturbed. This, in turn, leads to deterioration of water and air regimes, as well as disruption of the circulation of nutrients. The result is inhibition of plant root nutrition, a threat to their growth and development, which can cause their death [13].

In summary, war has serious consequences for ecosystems that can be manifested both directly and indirectly. The movement of heavy equipment, military operations, attacks on infrastructure, damage to natural habitats, as well as chemical pollution and other consequences lead to the degradation of biodiversity, the reduction of populations of rare species of plants and animals, changes in climate and ecological systems in general. Fires, soil pollution with oil products, uncontrolled spread of alien species, disruption of the water and air regime, as well as changes in biochemical and microbiological processes – all this can have serious long-term consequences for ecosystems and biological diversity. Additionally, hostilities can also lead to increased biological pollution of marine ecosystems due to uncontrolled vessel movements and changes in shipping patterns. Understanding these consequences is important for the development of strategies to reduce the impact of conflicts on ecological systems, as well as for the implementation of measures for ecological rehabilitation and recovery after military operations [15].

The purpose to investigate the current ecological state of forest ecosystems on the example of the Vinnytsia Forestry branch of the State Enterprise Forests of Ukraine under the conditions of martial law in Ukraine.

Research materials and methods. Our research was conducted on the example of the State Enterprise "Vinnytsia Forestry", which is a branch of the State Enterprise "Forests of Ukraine" and is responsible for the protection, use and reproduction of forests in the Vinnytsia region. Most of the forest ecosystems include mixed forests with a predominance of *Quercus* and *Fraxinus* with a minor admixture of *Tilia, Acer platanoides L., Carpinus betulus L.* and other species. Pure and mixed forests of *Pinus L., Alnus Mill., Bétula, Populus tremula L., Tilia* were naturally formed in small areas with certain soil and climatic conditions and relief.

The soil in the forests of Vinnytsia Forest Farm is very diverse. According to the classification, there are such types of soils as chernozem, gray forest, gray forest-steppe, podzolic, swamp and mountain soils. Precisely for the determination of ecotoxicological indicators in forest ecosystems, soil samples were taken in the Hnivansky and Voronovytskyi forestry, where the consequences of military actions were reflected, namely, over the territory of the Hnivaansky and Voronovytskyi forestry, an enemy X-59 missile of the terrorist country was shot down, the fragment of which exploded on the territory of the forestry, where soil samples were taken, at the place of the rocket rupture, and the control sample was a soil sample at a distance of 1000 m from the rupture site. In the territory we studied, we took soil samples using the envelope method. With the help of this method, representative soil samples can be obtained for further analysis, necessary for elucidating the physical and chemical characteristics of the soil cover.

Ecotoxicological indicators in the form of the content of heavy metals in the studied soil were determined in the Scientific and Measuring Agrochemical Laboratory of the Department of Ecology and Environmental Protection of the National Institute of Agricultural Technologies and Nature Management using the atomic absorption method, which is an important process that allows us to obtain accurate and reliable results.

To assess the degree of danger of a pollutant element, we used the hazard ratio of the pollutant element – the ratio between the concentration of the pollutant in the soil and their maximum permissible concentration. It is used to assess the degree of danger of a polluting element. Under normal conditions, the hazard ratio should be less than or equal to 1. It is determined by the formula:

$$HR = C/MPC \geq 1 \qquad (1)$$

where C – is the concentration of the ith pollutant, mg/kg; MPC is the maximum permissible concentration of the pollutant, mg/kg.

Research results. Currently, a difficult situation has developed in Ukraine, when the state of the forest ecosystem does not meet the ecological and economic requirements, including as a result of military operations. The reason for this situation is the difficulty of making management decisions in the forest sector due to the long period of afforestation and the difficulty of forecasting future development options, both economic and ecological. However, the balanced use of forest resources is ensured not only by the process of consumption, but also by the process of reproduction, which together form the basis of the development of forest potential. Therefore, the task of ensuring not only an effective, but also an ecologically balanced system of forest management has become urgent [20].

When considering the issue of improving forestry management mechanisms and tools, it is necessary to research and analyze the country's forestry activities to determine the most effective directions of use. Economic transformations in the state, which were carried out for almost three decades in forestry, were accompanied by significant changes in the structure of national forestry, and also affected the level of economic and ecological efficiency of forest use.

The total area of forest plots belonging to the forest fund of Ukraine is 10.4 million hectares, including 9.6 million hectares covered with forest vegetation. At the same time, compared to many European countries, the territory of Ukraine is characterized by low forest cover (15.9%), which is calculated as the percentage of forest vegetation covered by forest in relation to the planted area.

SE "Vinnytsia Forestry" is a state enterprise of the State Service of Forest Resources of Ukraine, Vinnytsia Regional Department of Forestry and Hunting, located on the territory of five administrative districts of the north-west of Vinnytsia Oblast: Vinnytsia, Tyvrivskyi, Kalynivskyi, Orativskyi and Nemyrivskyi. It includes 23 forestry companies. An important indicator of forestry activity is monitoring of the ecological state of forest ecosystems of the Vinnytsia region (Table 1).

The main ecological indicators of the condition of forests include the area of forest lands affected by forest fires, the presence of areas of concentration of forest pests and their appearance, the elimination of forest pest foci by means of control measures, the death of plantations due to adverse weather conditions and forest regeneration (Table 1).

The volume of wood damaged by forest fires in 2023 reached 131 m^3. Since the beginning of the current year, forest diseases and pests have developed on an area of 7,625 hectares, which is 2.2% of the total area of forests in the region.

The area of pest nests has significantly decreased, 7,075 hectares of pest and disease nests have been identified, but all of them have been destroyed by medical measures or natural destruction. Adverse weather conditions destroyed 10% of forests in the region.

Comparing the studied indicators, we can see that the current state of forest ecology in 2023 has improved. In particular, the amount of fire-damaged wood, the area of pest nests, and the area of forest plantations killed by adverse weather conditions decreased. However, forest regeneration has slowed to 19%, including 14% artificial and 43.1% natural.

The research we conducted made it possible to determine the content of heavy metals in the soils of the SE "Vinnytsia Forestry" in the territory of the Vinnytsia district within the forest ecosystems that are part of the forests of the SE "Vinnytsia Forestry", namely the Hnivansky and Voronovytskyi Forestry, where the X-59, part of which ammunition detonated when it fell (Table 2). For

Table 1

Dynamics of indicators of the ecological state of forests in the Vinnytsia region for 2023–2024

Indicator	2023 year	2024 year	% from 2023 to 2024
The area of forest lands covered by fires:			
- number of illegal fellings, units;	213	108	-39.6
- volumes of destroyed or damaged wood, m^3;	546	131	-127,2
- damage caused, hryvnias	1319214	381972	-110
The presence of foci of forest pests and diseases (area), ha:			
- at the beginning of the year;	7345	7625	3,8
- at the end of the year.	7584	4305	-43.3
They require immediate action	6249	3026	-51.6
Occurrence of foci of forest pests and diseases, their elimination by control measures (area), ha:			
– arose;	9536	7075	-35.8
– eliminated as a result of measures and disappeared under the influence of natural factors Death of forest plantations as a result of adverse weather conditions.	9297	7075	-18.8
Death of forest plantations due to adverse weather conditions,%	14	10	-4
Reproduction of forests – everything, hec.	2613	2134	-19
Among them: – planting and seeding of forest;	2225	1913	-14
- natural renewal	388	221	-43.1

comparison, soil samples were taken at 2 points: the first – at the point of fall and detonation of the missile fragment, and the second – at a distance of 1000 m from the first.

According to the results of our research, it was found that the content of heavy metals in sample №1 in the territory of the forest ecosystems of the Hnivan Forestry at the point of explosion of the rocket fragment, namely, the content of Pb, Cd, Zn and Cu was higher than the MPC by 4.11, 2.48, 1.23 and 1.08 times, respectively. The highest content of heavy metals in sample №1 was Cu, it was higher compared to Pb, Cd, and Zn by 2.41, 34.1, and 2.09 times, respectively. In the territory of the forest ecosystems of the Hnivan Forestry at the point of soil sampling at a distance of 1000 m from the point of explosion of the fragment, there were no exceedances of the MPC, although the concentration was close to the MPC. Thus, the concentration of Pb, Cd, Zn, and Cu was lower than the MPC by 1.03, 1.07, 1.18, and 1.86 times, respectively. The highest content of heavy metals in point №2 was Cu, and it was higher than Pb, Cd, and Zn by 5.06, 45.33, and 1.51 times, respectively.

Table 2

The content of heavy metals in SE "Vinnytsia Forestry"mg/kg

Selection points	Pb	MPC	Cd	MPC	Zn	MPC	Cu	MPC
Gnivan forestry								
№1 (explosion point)	24.71	6.0	1.74	0.7	28.44	23.0	59.45	55.0
№2 (1000 m from the first)	5.82	6.0	0.65	0.7	19.41	23.0	29.47	55.0
Voronivtsi forestry								
№1 (explosion point)	18.91	6.0	2.47	0.7	29.55	23.0	57.38	55.0
№2 (1000 m from the first)	4.58	6.0	0.47	0.7	16.33	23.0	21.13	55.0

In the territory of forest ecosystems of the Voronovytskyi Forestry, where soil sample №1 was taken at the point of explosion of the rocket fragment, an excess of all heavy metals was also observed, namely, the concentration of Pb, Cd, Zn, and Cu was higher than the MPC in 3.15, 3.52, 1.28 and 1.04 times respectively. The highest content of heavy metals at the point of explosion was Cu, compared with Pb, Cd, and Zn in 3.03, 23.23, and 1.94 times, respectively. In soil sample №2, no exceedance of the MPC of heavy metals was observed, the total content of Pb, Cd, Zn, and Cu was lower than the MPC by 1.31, 1.48, 1.4 and 2.6 times, respectively. At that time, the highest content of heavy metals in sample №2 was Cu, which was higher compared to Pb, Cd, and Zn by 4.61, 44.9 and 1.29 times, respectively.

If we compare the soil samples taken on the territory of the forest ecosystems between the Hnivansky and Voronovytskyi forestry, the content of Pb and Cu in sample №1 was higher in the territory of the Hnivansky forestry compared to the content of Pb and Cu on the territory of the Voronovytskyi forestry by 1.3 and 1.03 times, respectively, then, as the content of Cd and Zn, on the contrary, was higher in sample №1, selected in the territory of Voronovytskyi Forestry, by 1.41 and 1.03 times compared to the content of Cd and Zn in the sample taken on the territory of Voronovytskyi Forestry. In sample №2, the content of Pb, Cd, Zn, and Cu was higher in that sample taken in the territory of Hnivan Forestry, compared to the sample taken in the territory of Voronovytskyi Forestry by 1.27, 1.38, 1.18, and 1.39 times, respectively.

We also calculated the indicator of the danger coefficient (Fig. 2), if this indicator reaches more than 1, it means that the soils of these areas are dangerous for the collection of forest plant raw materials and the breeding of forest species on these areas and the conduct of any other economic activity.

From Fig. 2 shows that the studied indicators of the hazard ratio exceed the numerical value of 1 in the selected samples №1, both in the territory of Hnivanskyi and in the territory of Voronovetski forestry. In sample №1, selected on the territory of the forest ecosystems of the Hnivan forestry, the hazard ratio was the highest for Pb, compared to Cd, Zn, and Cu by 1.65, 3.33, and 3.79 times, respectively. In sample №1, selected in the territory of the forest ecosystems of the Voronovytskyi forestry, the hazard ratio was the highest for Cd, compared to Pb, Zn, and Cu by 1.11, 2.73, and 3.36 times, respectively. In samples №2, the hazard ratio did not exceed the numerical value of 1 on the territory of both forestry companies. Thus, the indicator of the hazard ratio in sample №2, selected on the territory of Hnivan forestry, was the highest for Pb, compared to Cd, Zn, and Cu by 1.04, 1.14, and 1.81 times, respectively. In sample №2, selected on the territory of the Voronovytskyi forestry, the indicator of the hazard ratio was also the highest for Pb, compared to Cd, Zn, and Cu by 1.13, 1.07, and 2.0 times, respectively.

If we compare the indicators of the coefficient between the samples taken on the territory of Hnivan forestry, the hazard ratio in sample №1 was higher for Pb, Cd, Zn Cu by 4.27, 2.69, 1.46, and 2.03 times, respectively, compared to sample №2. Similarly, when comparing the indicators of the hazard ratio between the samples taken on the territory of the Voronovytskyi forestry, the hazard ratio in sample №1 was higher for Pb, Cd, Zn, and Cu by 4.14, 5.22, 1.8, and 2.73 times, respectively, compared to sample №2.

Conclusions. The content of heavy metals in the soils of the SE "Vinnytsia Forestry" on the territory of the Hnivansky and Voronovytskyi forests exceeded the maximum permissible concentrations in the samples taken on the territory of forest ecosystems at the explosion points of fragments of downed missiles. The content of Pb, Cd, Zn and Cu was higher than the MPC by 4.11, 2.48, 1.23 and 1.08 times, respectively, in samples from Hnivan Forestry. In the territory of forest ecosystems of the Voronovytskyi

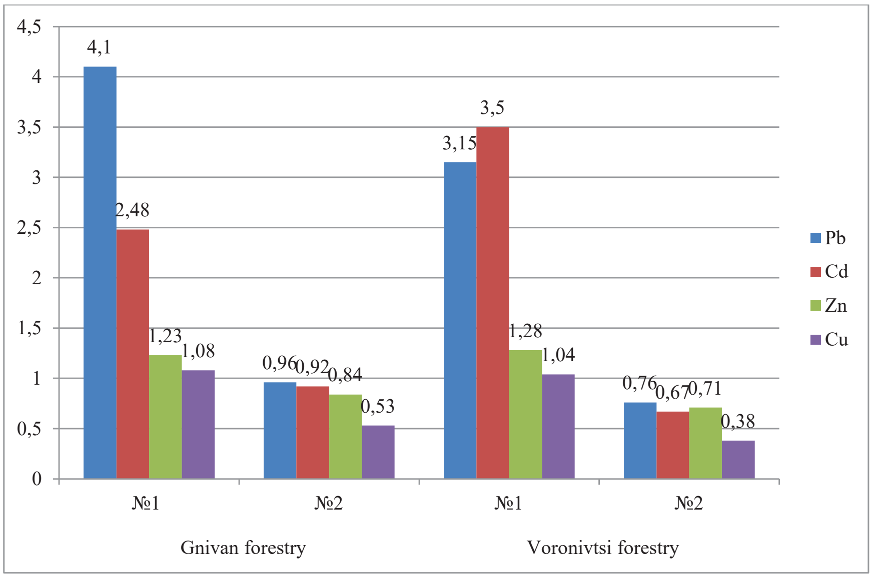

Fig. 2. The coefficient of danger of heavy metals of the studied areas of SE "Vinnytsia Forestry"

Forestry the concentration of Pb, Cd, Zn, and Cu was higher than the MPC in 3.15, 3.52, 1.28 and 1.04 times respectively. The studied indicators of the hazard ratio exceed the numerical value of 1 in the selected samples in the zone of the rupture of the missile fragment, both in the territory of Hnivanskyi and in the territory of Voronovetski forestry, which indicates that this territory is dangerous for harvesting non-wood forestry products and breeding of forest species.

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Vradii O.I., Alieksieiev O.O. Ecological and economic assessment of the state of forest ecosystems in the conditions of marital state in Ukraine

The purpose of the article to investigate the current ecological state of forest ecosystems on the example of the Vinnytsia Forestry branch of the State Enterprise Forests of Ukraine under the conditions of martial law in Ukraine. **Methods.** The methodological basis of this research is: empirical (field experiments and observations; measurement of indicators of the research object; theoretical (putting forward a hypothesis and forming conclusions based on research results; statistical; mathematical. **Results.** In the territory of the forest ecosystems of the Hnivan Forestry at the point of soil sampling at a distance of 1000 m from the point of explosion of the fragment, there were no exceedances of the MPC, although the concentration was close to the MPC. Thus, the concentration of Pb, Cd, Zn, and Cu was lower than the MPC by 1.03, 1.07, 1.18, and 1.86 times, respectively. The highest content of heavy metals in point №2 was Cu, and it was higher than Pb, Cd, and Zn by 5.06, 45.33, and 1.51 times, respectively. The highest content of heavy metals in Voronovetski forestry at the point of explosion was Cu, compared with Pb, Cd, and Zn in 3.03, 23.23, and 1.94 times, respectively. In soil sample №2, no exceedance of the MPC of heavy metals was observed, the total content of Pb, Cd, Zn, and Cu was lower than the MPC by 1.31, 1.48, 1.4 and 2.6 times, respectively. At that time, the highest content of heavy metals in sample №2 was Cu, which was higher compared to Pb, Cd, and Zn by

4.61, 44.9 and 1.29 times, respectively. The hazard ratio in sample №1 of Hnivan forestry was higher for Pb, Cd, Zn Cu by 4.27, 2.69, 1.46, and 2.03 times, respectively, compared to sample №2. Similarly, when comparing the indicators of the hazard ratio between the samples taken on the territory of the Voronovytskyi forestry, the hazard ratio in sample №1 was higher for Pb, Cd, Zn, and Cu by 4.14, 5.22, 1.8, and 2.73 times, respectively, compared to sample №2. **Conclusions.** The content of heavy metals in the soils of the SE "Vinnytsia Forestry" on the territory of the Hnivansky and Voronovytskyi forests exceeded the maximum permissible concentrations in the samples taken on the territory of forest ecosystems at the explosion points of fragments of downed missiles. The content of Pb, Cd, Zn and Cu was higher than the MPC by 4.11, 2.48, 1.23 and 1.08 times, respectively, in samples from Hnivan Forestry. In the territory of forest ecosystems of the Voronovytskyi Forestry the concentration of Pb, Cd, Zn, and Cu was higher than the MPC in 3.15, 3.52, 1.28 and 1.04 times respectively. The studied indicators of the hazard ratio exceed the numerical value of 1 in the selected samples in the zone of the rupture of the missile fragment, both in the territory of Hnivanskyi and in the territory of Voronovetski forestry, which indicates that this territory is dangerous for harvesting non-wood forestry products and breeding of forest species.

Key words: forest ecosystem, heavy metals, excess, concentration, soil, hazard ratio.

Врадій О.І., Алєксєєв О.О. Еколого-економічна оцінка стану лісових екосистем в умовах воєнного стану в Україні

Мета статті – дослідити сучасний екологічний стан лісових екосистем на прикладі філії «Вінницький лісгосп» ДП «Ліси України» в умовах воєнного стану в Україні.. **Методи.** Методологічною основою даного дослідження є: емпіричні (польові експерименти та спостереження; вимірювання показників об'єкту дослідження; теоретичні (висунення гіпотези та формування висновків за результатами досліджень; статистичний; математичний. **Результати.** На території лісових екосистем Гніванського лісництва в місці відбору проб ґрунту на відстані 1000 м від місця вибуху осколка перевищень ГДК не виявлено, хоча концентрація близька до ГДК. Так, концентрація Pb, Cd, Zn та Cu була нижчою за ГДК у 1,03, 1,07, 1,18 та 1,86 рази відповідно. Найбільший вміст важких металів у точці відбору №2 був по Cu, і він перевищував вміст Pb, Cd та Zn відповідно у 5,06, 45,33 та 1,51 рази. Найбільший вміст важких металів у Вороновецькому лісництві на місці вибуху становив по Cu порівняно з Pb, Cd та Zn відповідно у 3,03, 23,23 та 1,94 рази. У зразку ґрунту №2 перевищення ГДК важких металів не спостерігалось, сумарний вміст Pb, Cd, Zn та Cu був нижчим за ГДК у 1,31, 1,48, 1,4 та 2,6 рази відповідно. Тоді у зразку №2 найвищий вміст важких металів був по Cu, який був вищим порівняно з Pb, Cd та Zn відповідно у 4,61, 44,9 та 1,29 рази. Коефіцієнт небезпеки у зразку №1 Гніванського лісництва був вищим за Pb, Cd, Zn Cu у 4,27, 2,69, 1,46 та 2,03 рази відповідно порівняно зі зразком №2. Так само при порівнянні показників коефіцієнта небезпеки між пробами, відібраними на території Вороновицького лісництва, коефіцієнт небезпеки у пробі №1 був вищим по Pb, Cd, Zn та Cu у 4,14, 5,22, 1,8 та 2,73 рази відповідно, порівняно зі зразком №2. **Висновки.** Вміст важких металів у ґрунтах ДП «Вінницьке лісове господарство» на території Гніванського та Вороновицького лісництв перевищував гранично допустимі концентрації у пробах, відібраних на території лісових екосистем у місцях розриву осколків збитих ракет. У пробах Гніванського лісництва вміст Pb, Cd, Zn та Cu перевищував ГДК відповідно в 4,11, 2,48, 1,23 та 1,08 рази. На території лісових екосистем Вороновицького лісництва концентрації Pb, Cd, Zn та Cu перевищували ГДК відповідно у 3,15, 3,52, 1,28 та 1,04 рази. Досліджувані показники коефіцієнта небезпеки перевищують числове значення 1 у відібраних пробах у зоні розриву осколка ракети, як на території Гніванського, так і на території Вороновецького лісництва, що свідчить про небезпеку даної території для заготівля недеревної продукції лісового господарства та розведення лісових порід.

Ключові слова: лісова екосистема, важкі метали, перевищення, концентрація, ґрунт, коефіцієнт небезпеки.