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WAR IMPACT ON SOIL AND AGRICULTURAL LAND: BIBLIOMETRIC LANDSCAPE AND IMPROVING METHODS OF ASSESSING DAMAGE

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The article provides a thorough analysis of the latest scientific research and publications presented in the Web of Science (WoS) database, which concerns the impact of military operations on the condition of soils and agricultural lands. The author draw attention to the fact that the number of scientific works in this area is relatively small compared to other areas of environmental and agricultural research. This situation may be a consequence of the lack of attention of the scientific community to this issue, the objective difficulties associated with the complexity of research in a combat zone, limited access to resources, and the risks that arise in the context of active military conflicts. Particular attention is paid to the growth dynamics in the number of publications observed since 2022. This growth can be explained by the activation of Ukrainian scientists who were forced to respond to the challenges that arose as a result of a full-scale invasion. Military operations have led to significant soil degradation, disruption of agroecosystems, and loss of agricultural land productivity, which has created an urgent need for relevant research. Ukrainian scientists in the conditions of martial law have faced new threats, which prompted them to develop innovative methods for assessing environmental damage caused by military operations. The article also critically evaluates the existing methodology for determining damage caused to soils and agricultural lands as a result of emergencies, armed aggression, and other military operations. Several shortcomings have been identified, including insufficient accuracy, limited adaptation to the specific conditions of martial law, and the lack of an integrated approach that takes into account both environmental and economic aspects. The author emphasizes the importance of improving existing methodologies and developing new approaches to assessing the impact of military operations on the environment.

Keywords: *agricultural lands, soils, economic assessment, losses, scientometric analysis, military operations.*

INTRODUCTION

One of the most important and at the same time extremely urgent tasks of modern science is the economic assessment of the environmental consequences of the ongoing war on the territory of Ukraine. The military actions that unfolded as a result of the full-scale invasion of Russia caused serious damage to both the country's economy and its natural environment. In this context, the development of a scientifically sound methodology that will allow for a comprehensive assessment of the damage caused to the environment and, based on this assessment, to form a recovery strategy is of particular importance.

From the moment the invasion began, the Ukrainian government immediately began work on accounting and assessing direct economic losses. This includes damage to infrastructure, industrial facilities, housing stock, and other sectors of the economy. However, when it came to assessing environmental losses, in particular those related to land and soils, significant difficulties arose. These difficulties were associated with several methodological and organizational problems, as well as the lack of sufficiently developed tools for conducting such assessments.

Against the backdrop of full-scale Russian military aggression, the issue of assessing damage and losses caused to Ukrainian lands and lands as a result of hostilities has become even more urgent. In this regard, the need to create special methods that would allow us to accurately determine the scale of environmental damage has increased. It is important to emphasize that the problem of assessing damage to soil resources is new to the scientific community. This is important not only for scientific research but also for practical activities since the effectiveness of restoration measures and the future ecological state of the country depend on the correct understanding and assessment of these damages.

Damage caused to soils and other natural resources of Ukraine directly affects its natural resource potential and land capital, which, in turn,

are important components of the state's economic development. The environmental consequences of war can have long-term consequences for agriculture, biodiversity, water resources, and the overall health of the ecosystem. Therefore, the development of methods for accurate assessment of these damages is not only a scientific but also a national necessity, requiring the consolidation of the efforts of scientists, the government, and the international community. Accordingly, the creation of comprehensive and reliable tools for assessing environmental damage will not only allow us to determine the extent of the damage but will also contribute to the international recognition of these damages, which can become the basis for receiving compensation and assistance in the framework of the country's recovery. This will also help to form a more sustainable environmental policy that will take into account both current challenges and future threats to the environment of Ukraine.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

Research on the impact of war on soils is a relatively new but important topic that is actively developing in Ukraine and abroad. In recent years, the number of scientific publications that analyze both the immediate and long-term consequences of military operations on soil resources has been increasing.

During military operations, soils are contaminated with heavy metals, toxic substances (in particular, explosive residues), and radioactive elements. V. Kolodezhna examines the accumulation of heavy metals (lead, copper) in soils, which occurs due to ammunition residues. This disrupts the chemical balance of soils and poses a threat to vegetation [1]. In their publication, R. Geris et al. consider the use of fungi for bioremediation of soils contaminated with heavy metals and explosives as a result of military operations [2].

Explosions, trenching, and heavy machinery cause mechanical compaction of soils, destruction of the topsoil, and erosion. G. Certini, R. Scalenghe, and W.I. Woods. describe how military activities disrupt the structure of the soil, reducing its ability to allow water and air exchange [3].

War causes significant destruction of vegetation cover, which increases the risk of water and wind erosion of soils. M. Solokha et al. found that military actions in eastern Ukraine led to an increased risk of erosion processes in the region [4]. Pollution and mechanical damage to soils negatively affect microbiological activity, which reduces fertility. P. Broomandi et al. consider the reduction of populations of beneficial microorganisms due to contamination with toxic substances [5]. Soil degradation affects agricultural production, which complicates food security and the economic development of regions. The publication "The Impact of the Russian War on Ukraine on the State of Ukrainian Soils" highlights how soil damage makes effective agriculture impossible in significant areas [6].

M.J. Lawrence et al. analyze the impact of modern wars and military activities on biodiversity and soils, including habitat degradation and soil erosion [7]. A collective monograph edited by T.O. Chaika analyzes methods for restoring the physical properties of soils after their degradation due to hostilities [8]. A study by O.H. Williams and N.L.J. Rintoul-Hynes analyzes the long-term impact of World War I on soil formation and heavy metal contamination of soils in trenches [9]. R.A. Wuana and F.E. Okieimen analyze the sources, risks, and best strategies for cleaning up soils contaminated with heavy metals, including those that may arise from military operations [10].

MATERIALS AND METHODS

The purpose of this work is a bibliometric analysis of studies of the impact of military actions on soils and agricultural lands as a basis for identifying problems and substantiating ways to improve methods for assessing damage caused to land resources and soils of Ukraine as a result of armed aggression. The study used a set of basic methods, such as *bibliometric and graphical analyses* (for a detailed study of methods for assessing damage and losses from aggression and developing proposals for their improvement); *abstract-logical method* (for theoretical generalization and concluding). Bibliometric analysis was carried out using VOSviewer software. This tool is designed to create and visualize bibliometric networks. Such networks can include journals, scientists or individual publications and be built based on citation, bibliographical references, joint citation or co-authorship. In addition, VOSviewer also provides text analysis capabilities that can be used to build and visualize co-occurrence networks of key terms taken from the scientific literature [11]. The information base is publications indexed in the Web of Science and containing the terms "impact of war on soil" and "impact of war on agricultural land" (Fig. 1). This revealed 409 publications published between 1990 and 2024 (as of March 2024). This period was chosen to cover a wide range of research and assess its development over more than three decades.

RESULTS AND DISCUSSION

The results of the analysis of research and publications indicate that the issue of assessing damage and losses caused to land and soils as a

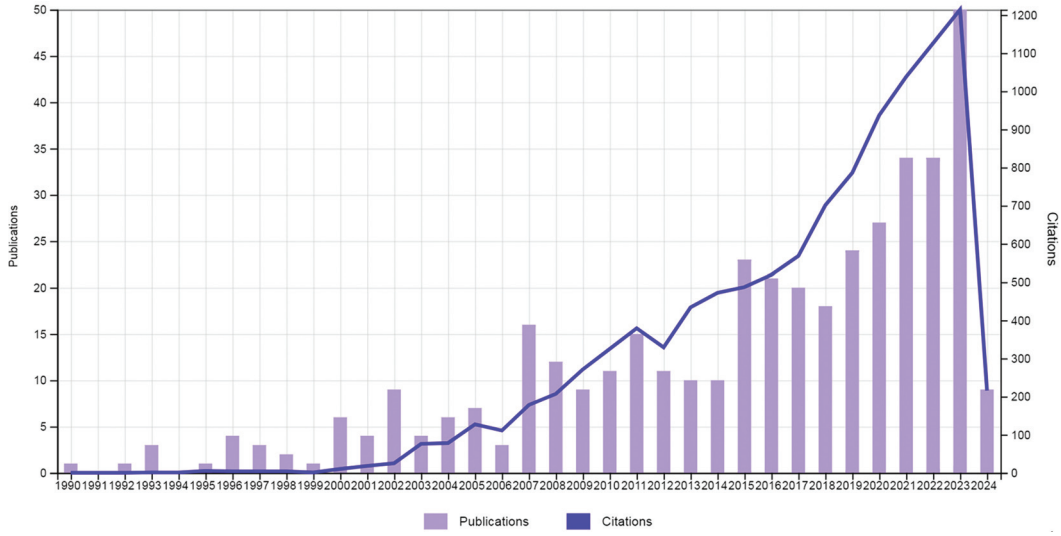

Fig. 1. Trends in publications on the impact of military actions on soils and agricultural lands in the world

Source: the diagram was created by the author based on data from the Web of Science database using VOSviewer software.

result of the war has not been given due attention in the scientific literature. This is evidenced, for example, by the analysis of the dynamics of the number of publications (*Fig. 1*). Until 1999, there was low activity in publications in this area, but since then the number of documents has begun to increase. From a certain point, there has been a noticeable increase in the volume of publications, reaching a peak in 2021 and 2022 with 34 publications per year.

In 2023, this trend continued, and the number of scientific papers increased even more, reaching a record 50 publications. Even at the beginning of 2024, although the year has just begun, nine articles on this topic have already been published, which indicates continued activity in the study of the impact of military actions on soils and agricultural lands. The results of the analysis show that the predominant form of publication is scientific articles, which account for almost 86% of all documents. In addition, most of these articles were published in peer-reviewed journals, which confirms their seriousness and scientific contribution. In addition, it is important to note that the most common field of research in the topic under consideration is environmental sciences — 33.9%, earth sciences, interdisciplinary works — 11.2%, ecological studies — 10.5%, water resources — 6.8%, ecology — 6.6%, physical geography — 6.6%, geography — 6.3%, soil science — 6.1%. This indicates the relevance of problems related to the impact of military actions on natural resources and ecosystems, as well as the growing interest in these issues in the scientific community, but none of them relate to economic sciences and do not touch on the issue of assessing damage and losses caused to soils or agricultural lands. The results of a study of the 15 most productive institutions (organizations) dealing with the impact of military actions on soils and agricultural lands are interesting. These topics attract the attention of researchers from different countries of the world, in particular Belgium, Germany, Ukraine, France, the USA, Poland, Denmark, China and Spain. The most productive in this regard are the Humboldt University of Berlin (Germany), Ghent University (Belgium), the National Center for Scientific Research (France), and the Ministry of Education and Science of Ukraine (Ukraine). It is worth noting that, despite this, institutions in the USA (6) and Spain (2) are successfully working on this topic. This indicates a wide international interest and cooperation in this field of research. Thanks to the visualization of bibliometric data (*Fig. 2*), it can be seen that the largest number of publications was written in the USA.

Also, a fairly large number of publications were created in Germany, Great Britain, Italy, France, Spain, and Ukraine. Much less activity is observed in Norway, China, Finland, Sweden, and Iraq. Even fewer publications come from scientists from Vietnam and Georgia. Most countries actively cooperated. Such data make it possible to understand the level of scientific activity in different countries and identify potential areas of cooperation and research development.

Web of Science distinguishes two types of keywords, if present: author keywords (selected by the author and included in the article when it is submitted to the journal) and KeyWords Plus

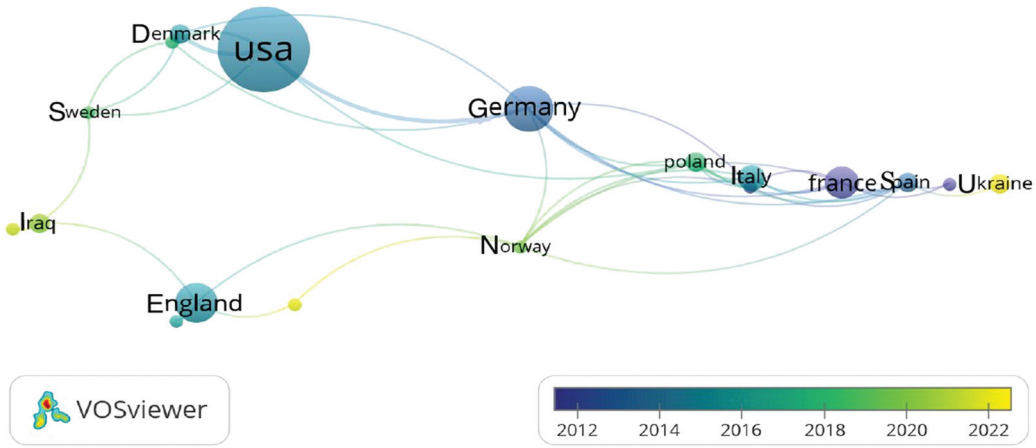

Fig. 2. Countries where publications on the selected topic were written (co-authorship, countries, minimum number of documents per country: 2).
Source: the map was created by the author based on data from the Web of Science database using VOSviewer software.

(selected by Web of Science). Both types have their advantages: author keywords help to understand how researchers describe their field and can be used as search terms in other databases. However, these keywords are usually considered unstructured because there is no control over their use — no organization checks for accuracy or combines similar terms into one. In turn, KeyWords Plus is a controlled dictionary from the Web of Science. They can be thought of as a thesaurus of terms selected by Web of Science based on the titles in the document's reference list [12].

The *Figure 3* shows the most frequently used keywords by the authors in publications related to the selected topic. According to these authors, these key terms can become effective search queries in other databases. Among these keywords, "soil erosion", "land-use change" and "agriculture" stand out.

The *Figure 4* shows the keywords selected by Web of Science in scientific publications related to the selected topic. Among these terms, "management", "model", "dynamics", "impacts" and "armed conflict" stand out. At this stage, we see that the keywords defined by the authors do not match with KeyWords Plus. In both cases, only "armed conflict" matched.

The developed bibliometric map (*Fig. 5*) shows that the most used terms are "management", "model", "dynamics", "impacts" and "armed conflict".

Next, the author reviewed the most cited articles related to the impact of the war on the soils and agricultural lands of Ukraine. To do this, the search engine analyzed the results of the search for "war impact on soil" (All Fields) "war impact on agricultural land" (All Fields), and "Ukraine" (All Fields). The articles were selected from the "Highly Cited Papers" category. *Table 1* shows the most cited articles on the selected topic. However, not all articles are suitable for theoretical study and analysis of the topic. Some articles

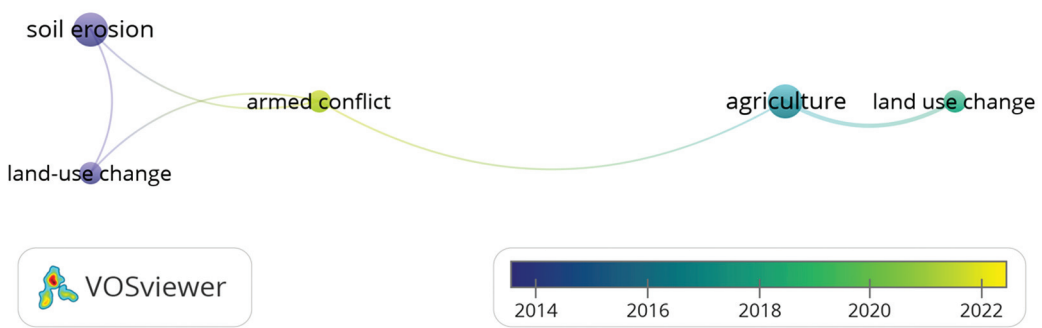

Fig. 3. Visualization of the use of author keywords in publications on the selected topic (co-occurrence, author keywords, minimum number of keyword occurrences: 5)
Source: the map was created by the author based on data from the Web of Science database using VOSviewer software.

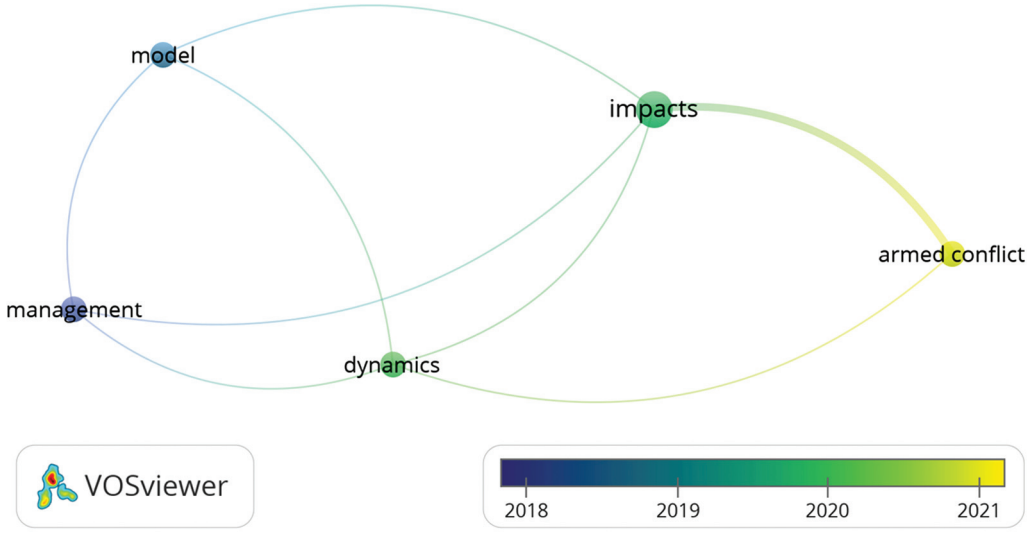

Fig. 4. Visualization of the use of KeyWords Plus in publications on the selected topic (co-occurrence, KeyWords Plus, minimum number of keyword occurrences: 5)

Source: the map was created by the author based on data from the Web of Science database using VOSviewer software.

consider the impact on agricultural lands from the point of view of economic losses, while others are devoted to a broader study of the impact of the war, where the impact on soil and land is only part of the article.

At the international level, one of the most important and developed methodologies is the FAO Damage and Loss Assessment Methodology [19]. It is used to identify, analyze, and assess the impact of disasters on agriculture, including crops, forestry, livestock, aquaculture, and fisheries. The main focus of this methodology is on assessing the impact of natural disasters on agricultural assets and production flows, while land and soil

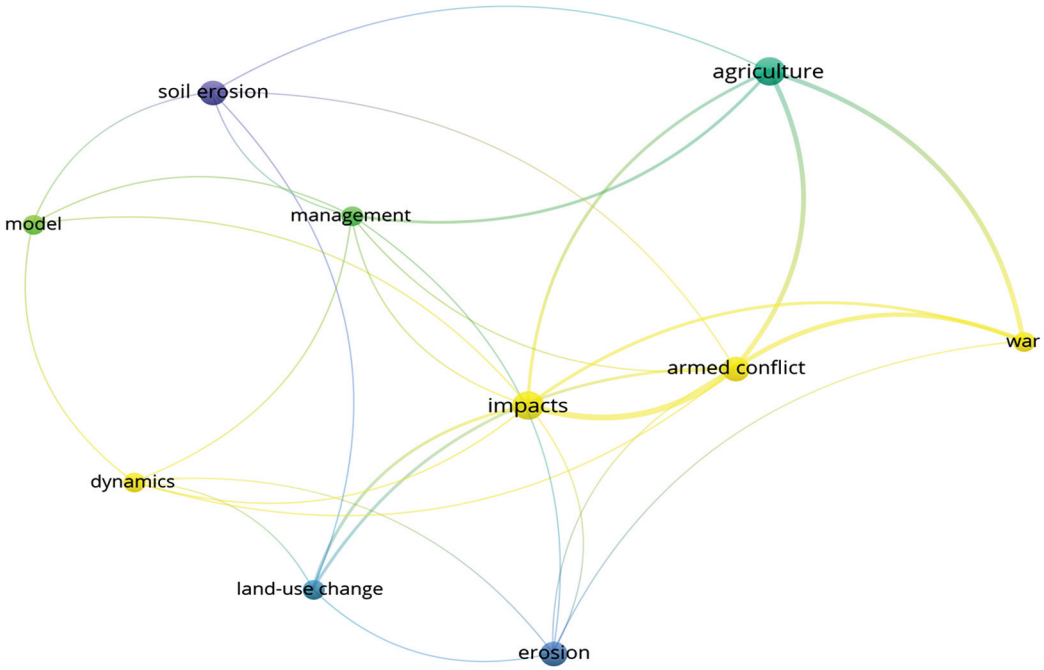

Fig. 5. Visualization of the use of all keywords in publications on the selected topic (co-occurrence, all keywords, minimum number of keyword occurrences: 5)

Source: the map was created by the author based on data from the Web of Science database using VOSviewer software.

Table 1

The most cited articles on the impact of the Russian-Ukrainian war on soils and agriculture according to the Web of Science database

No.	Title of the article	Authors	Year of publication	Number of citations	Journal
1	Russian-Ukrainian war impacts the total environment	Pereira, P., Basic, F., Bogunovic, I., Barcelo, D.	2022	144	Science of the Total Environment
	The text of the article claims that the Russian-Ukrainian war has already led to serious air pollution, greenhouse gas emissions, and the threat of radiation leakage due to the battles near the Zaporizhia NPP and Chornobyl. Significant impacts are observed on soils, particularly through bombing, which causes land degradation, especially black soil, one of the most fertile in the world. This can lead to reduced food production, degraded water quality, and significant damage to ecosystems and biodiversity [13].				
2	The impact of Russia-Ukraine conflict on global food security	Lin, F.Q., Li, X.C., Jia, N.Y., Feng, F., Huang, H., Huang, J.X., Fan, S.G., Ciais, P., Song, X.P.	2023	101	Global Food Security-Agriculture Policy Economics and Environment
	Satellite data showed a decrease in wheat production in Ukraine in 2021–2022. In three scenarios, depending on the duration of the war, a significant drop in trade (up to 60%), an increase in wheat prices (up to 50%) and a decrease in purchasing power of more than 30% are predicted. Countries that depend on wheat imports from Ukraine will suffer the most, including Egypt, Turkey, Mongolia, Georgia and Azerbaijan [14].				
3	Environmental damages due to war in Ukraine: a perspective	Rawtani, D., Gupta, G., Khatri, N., Rao, P.K., Hussain, C.M.	2022	101	Science of the Total Environment
	The article covers many aspects of the environment that are negatively affected by the Russian-Ukrainian war, particularly because changes in physical, chemical, and biological characteristics due to shelling have worsened serious losses in agriculture. Water pollution, air quality degradation, and the threat of radiation flow create safety for human health and ecosystems. The war also causes large-scale deforestation, loss of biodiversity, and worsening global environmental problem [15].				
4	High energy and fertilizer prices are more damaging than food export curtailment from Ukraine and Russia for food prices, health and the environment	Alexander, P., Arneth, A., Henry, R., Maire, J., Rabin, S., Rounsevell, M.D.A.	2023	58	Nature Food
	The authors show that agricultural input costs and export restrictions could increase commodity prices by 60 to 100 percent in 2023, leading to 61 to 107 million undernourished people and 416,000 to 1.01 million additional deaths. Reduced intensification of land use due to high costs will cause expansion of agricultural land, loss of carbon, and biodiversity. The influence of resource costs on prices reached the consequences of the reduction of exports from Russia and Ukraine [16].				
5	Telecoupled impacts of the Russia-Ukraine war on global cropland expansion and biodiversity	Chai, L., Liu, A., Li, X.C., Guo, Z.S., He, W.R., Huang, J.X., Bai, T.C., Liu, J.G.	2024	11	Nature Sustainability
	To quantify such impacts on biodiversity, the global expansion of arable land, triggered by the reformatting of international flows of virtual arable land under different war scenarios, was simulated and biodiversity impacts were assessed. The results show that in the baseline situation (reduction of Ukraine's exports by 33.57%), the war will lead to an additional expansion of cultivated areas by 8.48 million hectares compared to the "no war" scenario [17].				

End of Table 1

No.	Title of the article	Authors	Year of publication	Number of citations	Journal
6	Disrupted harvests: how Ukraine-Russia war influences global food systems — a systematic review	El Bilali, H., Ben Hassen, T.	2024	5	Policy Studies
	The findings highlight that the war affected all aspects of food security, with the most severe impact on access to food through reduced domestic production, damage to assets, increased costs of production, impacts on soils and agricultural land, and labor shortages. This has led to reduced food supply, higher prices, and disruption of trade, especially among vulnerable population groups. Food consumption was affected by a decline in the quality of the diet, while stability was threatened by price volatility. The war also affected the environmental, social, economic, and political aspects of food system sustainability, particularly by exacerbating food insecurity, poverty, and displacement [18].				

Source: author's own elaboration using the WoS database.

issues are not sufficiently addressed. In general, it can be noted that there is no internationally recognized methodology for assessing damage to land and soils as a result of armed aggression and hostilities [20]. More general methodologies can also be used. They are proposed to be detailed for individual components and adapted taking into account the assessment of ecosystem losses. For example, according to Didukh et al. the use of a habitat assessment system facilitates the process of collecting and quantifying data. In particular, a 9-criteria damage assessment system for natural systems was proposed by Didukh et al. each of which is rated on a scale from 1 to 4 points. According to the total damage score, 5 categories are distinguished [21]:

1) category A (over 80% of points) — complete destruction, ecosystems will not be able to recover;

2) category B (60–79%) — significant damage, for recovery it is necessary to use external targeted activities with the involvement of financing;

3) category B (40–59%) — significant losses, recovery requires monitoring and adjustment of processes;

4) category D (20–39%) — damage is present, but recovery will occur naturally;

5) category D (up to 20%) — minor damage to the ecosystem.

The current regulatory framework for assessing damage and losses caused to the lands and soils of Ukraine as a result of Russian aggression includes three key documents [22–24]. In the "Methodology..." [23], damage and losses caused to lands and soils are determined as a result of soil contamination — the accumulation in soils of substances that negatively affect their fertility and other useful properties, and soil pollution — the presence of foreign objects, materials, waste and/or other substances placed on the land plot without appropriate permits [23]. Weaknesses of the current "Methodology..." [20; 23; 25; 26]:

1. No attention is paid to the mechanical degradation of territories as a result of military operations. This is a violation of the grounded structure due to the use of heavy equipment, artillery fire, explosions, and other combat factors that significantly change the physical characteristics of the base.

2. Physical degradation, such as erosion, compaction, and other changes that reduce the ability of the soil to retain moisture and provide plants with nutrients, are also not properly taken into account. These processes have a long-term negative impact on soil fertility.

3. Biological degradation, i.e. the destruction of microflora and microfauna, which are important for ecosystem support, is not taken into account in the methods. This leads to the loss of natural land functions, such as supporting crops and natural ecosystems.

4. Other forms of justification for degradation, such as the loss of ecosystem services (e.g., justifying the ability to support local ecosystems) or field energy due to shelling and fires, have also not been given due attention. This issue is important because it affects the overall sustainability of ecosystems and agricultural lands.

5. Costs of assessing unaccounted-for losses. Research and sampling are justified, their analysis and the use of modern remote sensing technologies require significant financial and resource costs that are not taken into account in the methods.

6. In addition, existing approaches do not take into account the costs of demining areas affected by military operations. Clearing land

from mines and explosive devices is a key factor in its safe use, but these costs are not taken into account.

7. There is a lack of methodological approaches to restoring the territory after hostilities. It is important not only to assess the damage caused but also to calculate the cost of restoration measures that allow returning to a reasonable state of war. This includes improving the chemical composition, physical characteristics, and biological activity.

Disadvantages of the "Methodology..." [20; 24; 25]:

1. Ignoring losses from a drop in soil productivity. The methodology does not take into account how the deterioration of soil quality affects the potential income that land users could receive if the soils retained their normal fertility. It does not take into account how this decrease affects the overall economic result of the use of land resources.

2. Underestimating budget losses due to a decrease in the value of land. The methodology does not take into account how a decrease in the market price of land affects budget revenues from land tax. This leads to non-accounting of the full amount of financial losses from a drop in the value of land, which harms the state and local budgets.

3. Costs of assessing unaccounted losses. The methodology does not include the costs associated with the process of assessing damage to the land fund. This applies to the costs of conducting research, developing land management projects, sampling, laboratory analyses, remote sensing, collecting economic data, and performing calculations. Because of this, the methodology may underestimate the actual costs required to restore land after armed aggression. There are other shortcomings of modern methods of assessing damage and losses [26; 27; 28], which indicate the need for their improvement.

CONCLUSIONS

The article is devoted to bibliometric analysis of studies examining the impact of military actions on land resources and agricultural lands. It is noted that this topic remains understudied compared to other environmental issues, such as climate change or soil erosion. However, interest in this issue increased after Russia's full-scale invasion of Ukraine in 2022. The intensification of research is due to both the need to assess the damage caused to ecosystems and the search for solutions for the restoration of damaged areas. It was found that existing damage assessment methodologies, such as the Ukrainian Methodology for Determining the Size of Damage, have significant shortcomings. In particular, they do not take into account the complex impact of military actions, including mechanical, chemical, and biological degradation of soils. Insufficient attention is also paid to the economic assessment of losses, which complicates the planning of restoration measures. The author emphasizes the need to improve existing approaches and develop new assessment tools. It is also important to create recovery plans that take into account the consequences of military actions and increase the resilience of agroecosystems. Further research should be aimed at ensuring sustainable recovery of damaged areas.

REFERENCES

1. Kolodezhna, V. (2023). Gruntovi metamorfozy: Ukrainske doslidzhennia vplyvu viiny na grunty [Soil metamorphoses: Ukrainian study of the impact of war on soils]. Robocha hrupa z vyvchennia ekolohichnykh naslidkiv viiny v Ukraini —Ukraine War Environmental Consequences Work Group (UWEC). URL: https://uwec-workgroup.info/uk/soil-metamorphosis-ukrainian-study-of-war-impacts-on-soils/?utm_source=chatgpt.com [in Ukrainian].
2. Geris, R. et al. (2024). A Review about the Mycoremediation of Soil Impacted by War-like Activities: Challenges and Gaps. *Journal of Fungi, 10 (2)*, 94. DOI: https://doi.org/10.3390/jof10020094 [in English].
3. Certini, G., Scalenghe, R., & Woods, W.I. (2013). The impact of warfare on the soil environment. *Earth-Science Reviews, 127*, 1–15. DOI: https://doi.org/10.1016/j.earscirev.2013.08.009 [in English].
4. Solokha, M. et al. (2024). Soil Degradation and Contamination Due to Armed Conflict in Ukraine. *Land, 13 (10)*, 1614. DOI: https://doi.org/10.3390/land13101614 [in English].
5. Broomandi, P. et al. (2020). Soil Contamination in Areas Impacted by Military Activities: A Critical Review. *Sustainability, 12 (21)*, 9002. DOI: https://doi.org/10.3390/su12219002 [in English].
6. Holubtsov, O., Sorokina, L., Splodytel, A., & Chumachenko, S. (2023). *Vplyv viiny rosii proty Ukrainy na stan ukrainskykh gruntiv. Rezultaty analizu [The impact of the Russian war against Ukraine on the state of Ukrainian soils. Results of the analysis]*. Kyiv: NGO 'Center for Ecological Initiatives "Ecodia"' [in Ukrainian].
7. Lawrence, M.J. et al. (2015). The effects of modern war and military activities on biodiversity and the environment. *Environmental Reviews, 23 (4)*, 443–460. DOI: https://doi.org/10.1139/er-2015-0039 [in English].
8. Chaika, T.O. (Ed.). (2023). *Zakhyst i vidnovlennia ekolohichnoi rivnovahy ta zabezpechennia samovidnovlennia ekosystem: kolektyvna monohrafiia [Protection and restoration of ecological balance and ensuring self-renewal of ecosystems: collective monograph]*. Poltava: Publishing house "Astraia" [in Ukrainian].
9. Williams, O.H., & Rintoul Hynes, N.L.J. (2022). Legacy of war: Pedogenesis divergence and heavy metal con-

tamination on the WWI front line a century after battle. *European Journal of Soil Science, 73 (4)*. DOI: https://doi.org/10.1111/ejss.13297 [in English].
10. Wuana, R.A., & Okieimen, F.E. (2011). Heavy Metals in Contaminated Soils: A Review of Sources, Chemistry, Risks and Best Available Strategies for Remediation. *ISRN Ecology, 2011*, 1–20. DOI: https://doi.org/10.5402/2011/402647 [in English].
11. Van Eck, N.J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics, 84 (2)*, 523–538. DOI: https://doi.org/10.1007/s11192-009-0146-3 [in English].
12. Web of Science. (n.d.). Clarivate. Academia and Government. URL: https://clarivate.com/academia-government/scientific-and-academic-research/research-discovery-and-referencing/web-of-science [in English].
13. Pereira, P. et al. (2022). Russian-Ukrainian war impacts the total environment. *Science of the Total Environment, 837*, 155865. DOI: https://doi.org/10.1016/j.scitotenv.2022.155865 [in English].
14. Lin, F. et al. (2023). The impact of Russia-Ukraine conflict on global food security. *Global Food Security, 36*, 100661. DOI: https://doi.org/10.1016/j.gfs.2022.100661 [in English].
15. Rawtani, D. et al. (2022). Environmental damages due to war in Ukraine: A perspective. *Science of The Total Environment, 850*, 157932. DOI: https://doi.org/10.1016/j.scitotenv.2022.157932 [in English].
16. Alexander, P., Arneth, A., Henry, R. et al. (2023). High energy and fertilizer prices are more damaging than food export curtailment from Ukraine and Russia for food prices, health and the environment. *Nature Food, 4*, 84–95. DOI: https://doi.org/10.1038/s43016-022-00659-9 [in English].
17. Chai, L. et al. (2024). Telecoupled impacts of the Russia–Ukraine war on global cropland expansion and biodiversity. *Nature Sustainability, 7*, 432–441. DOI: https://doi.org/10.1038/s41893-024-01292-z [in English].
18. El Bilali, H., & Ben Hassen, T. (2024). Disrupted harvests: how Ukraine-Russia war influences global food systems — a systematic review. *Policy Studies, 45 (3–4)*, 310–335. DOI: https://doi.org/10.1080/01442872.2024.2329587 [in English].
19. Conforti, P., Markova, G., & Tochkov, D. (2020). FAO's methodology for damage and loss assessment in agriculture. *FAO Statistics Working Paper, 19–17*. Rome: FAO. DOI: https://doi.org/10.4060/ca6990en [in English].
20. Kucher, A. (2022). Metodyka otsiniuvannia zbytkiv, zavdanykh zbroinoiu ahresiieiu zemelnomu fondu ta gruntam: problemy ta napriamy vdoskonalennia [Methodology for assessing damages and losses caused by the armed aggression to the land fund and soils: problems and directions of improvement]. *Journal of Innovations and Sustainability, 6 (2)*, 10. DOI: https://doi.org/10.51599/is.2022.06.02.10 [in Ukrainian].
21. Didukh, Ya.P., Maruniak, Ye.O., Lisovskyi, S.A., Kuzemko, A.A., & Chekhnii, V.M. (2024). Metodolohichni aspekty typizatsii vplyviv na dovkillia, sprychynenykh rosiiskoiu ahresiieiu v Ukraini [Methodological aspects of classification of environmental impacts caused by russian aggression in Ukraine]. *Ukr. heohr. zhurnal. — Ukrainian Geographic Journal, 2*, 3–12. DOI: https://doi.org/10.15407/ugz2024.02.003 [in Ukrainian].
22. Poriadok vyznachennia shkody ta zbytkiv, zavdanykh Ukraini vnaslidok zbroinoi ahresii rosiiskoi federatsii: Postanova Kabinetu Ministriv Ukrainy vid 20 bereznia 2022 r. № 326 [The procedure for determining the damage and losses caused to Ukraine as a result of the armed aggression of the Russian Federation: Resolution of the Cabinet of Ministers of Ukraine dated March 20, 2022, No. 326]. (2022). URL: https://zakon.rada.gov.ua/laws/show/326-2022-%D0%BF#Text [in Ukrainian].
23. Metodyka vyznachennia rozmiru shkody, zavdanoi zemli, gruntam vnaslidok nadzvychainykh sytuatsii ta/abo zbroinoi ahresii ta boiovykh dii pid chas dii voiennoho stanu: Nakaz Ministerstva zakhystu dovkillia ta pryrodnykh resursiv Ukrainy vid 4 kvitnia 2022 r. № 167 [Methodology for determining the amount of damage caused to land and soil as a result of emergency situations and/or armed aggression and hostilities during martial law: Order of the Ministry of Environmental Protection and Natural Resources of Ukraine dated April 4, 2022, No. 167]. (2022). URL: https://zakon.rada.gov.ua/laws/show/z0406-22#Text [in Ukrainian].
24. Metodyka vyznachennia shkody ta zbytkiv, zavdanykh zemelnomu fondu Ukrainy vnaslidok zbroinoi ahresii rosiiskoi federatsii: Nakaz Ministerstva ahrarnoi polityky ta prodovolstva Ukrainy vid 18 travnia 2022 r. № 295. [Methodology for determining damage and losses caused to the land fund of Ukraine as a result of the armed aggression of the Russian Federation: Order of the Ministry of Agrarian Policy and Food of Ukraine dated May 18, 2022, No. 295]. (2022). URL: https://zakon.rada.gov.ua/laws/show/z0586-22#Text [in Ukrainian].
25. Kucher, A., & Kucher, L. (2023). Impact of war on soils: a bibliometric landscape. *Proceedings of 17th International Scientific Conference "Monitoring of Geological Processes and Ecological Condition of the Environment"* (Kyiv, 7–10 November 2023). Kyiv: EAGE, 2023. DOI: https://doi.org/10.3997/2214-4609.2023520212 [in English].
26. Kucher, A., & Kucher, L. (2024). War loss and damage to soil resources: towards sustainable land management. *International Journal of Environmental Studies, 81 (1)*, 18–29. DOI: https://doi.org/10.1080/00207233.2023.2296769 [in English].
27. Baliuk, S.A., Kucher, A.V., & Romashchenko, M.I. (Eds.). (2024). *Gruntovyi pokryv Ukrainy v umovakh voiennykh dii: stan, vyklyky, zakhody z vidnovlennia: monohrafiia [Soil cover of Ukraine in the conditions of hostilities: state, challenges, activities for soil restoration: monograph]*. Kyiv: Ahrarna nauka. DOI: https://doi.org/10.31073/978-966-540-612-9 [in Ukrainian].
28. Ibatullin, S., Dorosh, I., Dorosh, O., Sakal, O., Butenko, Ye., Kharytonenko R., & Shtohryn, H. (2022). Determination of economic losses on agricultural land in connection with hostilities on the example of the territory of Kyivska oblast in Ukraine. *Acta Scientiarum Polonorum. Formatio Circumiectus, 21 (2)*, 49–61. DOI: https://doi.org/10.15576/ASP.FC/2022.21.2.49 [in English].

ВПЛИВ ВІЙНИ НА ҐРУНТ І СІЛЬСЬКОГОСПОДАРСЬКІ ЗЕМЛІ: БІБЛІОМЕТРИЧНИЙ АНАЛІЗ ТА ВДОСКОНАЛЕННЯ МЕТОДІВ ОЦІНКИ ЗБИТКУ

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У статті здійснено ґрунтовний аналіз останніх наукових досліджень і публікацій, представлених у базі даних Web of Science (WoS), які стосуються впливу воєнних дій на стан ґрунтів і сільськогосподарських угідь. Авторка звертає увагу на те, що кількість наукових робіт у цій сфері є відносно невеликою порівняно з іншими напрямами екологічних та аграрних досліджень. Така ситуація може бути наслідком як недостатньої уваги наукової спільноти до цієї проблематики, так і об'єктивних труднощів, пов'язаних зі складністю досліджень у зоні бойових дій, обмеженістю доступу до ресурсів і ризиками, що виникають у контексті активних воєнних конфліктів. Особливу увагу приділено динаміці зростання кількості публікацій, що спостерігається з 2022 року. Це зростання можна пояснити активізацією українських науковців, які були змушені реагувати на виклики, що виникли внаслідок повномасштабного вторгнення. Воєнні дії призвели до значної деградації ґрунтів, порушення агроекосистем і втрати продуктивності сільськогосподарських угідь, що створило нагальну потребу в проведенні відповідних досліджень. Вітчизняні вчені в умовах воєнного стану стикнулися з новими загрозами, що спонукало їх до розроблення інноваційних методів оцінювання екологічної шкоди, спричиненої бойовими діями. У статті також критично оцінено існуючу методику визначення шкоди, заподіяної ґрунтам і сільськогосподарським землям у результаті надзвичайних ситуацій, збройної агресії та спричинених нею бойових дій. Виявлено низку недоліків, серед яких недостатня точність, обмежена адаптація до специфічних умов воєнного стану та відсутність інтегрованого підходу, що враховує як екологічні, так і економічні аспекти. Авторка наголошує на важливості вдосконалення наявних методологій і розробки нових підходів до оцінки впливу військових дій на довкілля.

Ключові слова: *сільськогосподарські угіддя, ґрунти, економічна оцінка, втрати, наукометричний аналіз, воєнні дії.*

ЛІТЕРАТУРА

1. Колодежна В. Ґрунтові метаморфози: Українське дослідження впливу війни на ґрунти. Робоча група з вивчення екологічних наслідків війни в Україні (Ukraine War Environmental Consequences Work Group, UWEC). 2023. URL: https://uwecworkgroup.info/uk/soil-metamorphosis-ukrainian-study-of-war-impacts-on-soils/?utm_source=chatgpt.com (дата звернення: 13.10.2024).
2. Geris R. et al. A Review about the Mycoremediation of Soil Impacted by War-like Activities: Challenges and Gaps. *Journal of Fungi*. 2024. Vol. 10, No. 2. 94. DOI: https://doi.org/10.3390/jof10020094
3. Certini G., Scalenghe R., Woods W.I. The impact of warfare on the soil environment. Earth-Science Reviews. 2013. Vol. 127. P. 1–15. DOI: https://doi.org/10.1016/j.earscirev.2013.08.009
4. Solokha M. et al. Soil Degradation and Contamination Due to Armed Conflict in Ukraine. *Land*. 2024. Vol. 13, No. 10. 1614. DOI: https://doi.org/10.3390/land13101614
5. Broomandi P. et al. Soil Contamination in Areas Impacted by Military Activities: A Critical Review. *Sustainability*. 2020. Vol. 12, No. 21. 9002. DOI: https://doi.org/10.3390/su12219002.
6. Вплив війни росії проти України на стан українських ґрунтів. Результати аналізу / О. Голубцов, Л. Сорокіна, А. Сплодитель, С. Чумаченко. Київ: ГО "Центр екологічних ініціатив "Екодія"", 2023. 32 с.
7. Lawrence M.J. et al. The effects of modern war and military activities on biodiversity and the environment. *Environmental Reviews*. 2015. Vol. 23, No. 4. P. 443–460. DOI: https://doi.org/10.1139/er-2015-0039
8. Захист і відновлення екологічної рівноваги та забезпечення самовідновлення екосистем: колективна монографія; за заг. ред. Т.О. Чайки. Полтава: Видавництво ПП "Астрая", 2023. 308 с.
9. Williams O.H., Rintoul Hynes N.L.J. Legacy of war: Pedogenesis divergence and heavy metal contamination on the WWI front line a century after battle. *European Journal of Soil Science*. 2022. Vol. 73, No. 4. DOI: https://doi.org/10.1111/ejss.13297
10. Wuana R.A., Okieimen F.E. Heavy Metals in Contaminated Soils: A Review of Sources, Chemistry, Risks and Best Available Strategies for Remediation. *ISRN Ecology*. 2011. Vol. 2011. P. 1–20. DOI: https://doi.org/10.5402/2011/402647
11. Van Eck N.J., Waltman L. Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics*. 2010. Vol. 84. P. 523–538. DOI: https://doi.org/10.1007/s11192-009-0146-3
12. Web of Science. Clarivate. Academia and Government. URL: https://clarivate.com/academia-government/scientific-and-academic-research/research-discovery-and-referencing/web-of-science (accessed: 14.06.2024).
13. Pereira P. et al. Russian-Ukrainian war impacts the total environment. *Science of the Total Environment*. 2022. Vol. 837. 155865. DOI: https://doi.org/10.1016/j.scitotenv.2022.155865
14. Lin F. et al. The impact of Russia-Ukraine conflict on global food security. *Global Food Security*. 2023. Vol. 36.

100661. DOI: https://doi.org/10.1016/j.gfs.2022.100661
15. Rawtani D. et al. Environmental damages due to war in Ukraine: A perspective. *Science of The Total Environment*. 2022. Vol. 850. 157932. DOI: https://doi.org/10.1016/j.scitotenv.2022.157932
16. Alexander P., Arneth A., Henry R. et al. High energy and fertilizer prices are more damaging than food export curtailment from Ukraine and Russia for food prices, health and the environment. *Nature Food*. 2023. No. 4. P. 84–95. DOI: https://doi.org/10.1038/s43016-022-00659-9
17. Chai L. et al. Telecoupled impacts of the Russia-Ukraine war on global cropland expansion and biodiversity. *Nature Sustainability*. 2024. No. 7. P. 432–441. DOI: https://doi.org/10.1038/s41893-024-01292-z
18. El Bilali H., Ben Hassen T. Disrupted harvests: how Ukraine-Russia war influences global food systems — a systematic review. *Policy Studies*. 2024. No. 45 (3–4). P. 310–335. DOI: https://doi.org/10.1080/01442872.2024.2329587
19. Conforti P., Markova G., Tochkov D. FAO's methodology for damage and loss assessment in agriculture. *FAO Statistics Working Paper*. 2020. No. 19–17. Rome: FAO. DOI: https://doi.org/10.4060/ca6990en
20. Кучер А. Методика оцінювання збитків, завданих збройною агресією земельному фонду та ґрунтам: проблеми та напрями вдосконалення. *Journal of Innovations and Sustainability*. 2022. Vol. 6, No. 2. 10. DOI: https://doi.org/10.51599/is.2022.06.02.10
21. Дідух Я.П., Маруняк Є.О., Лісовський С.А., Куземко А.А., Чехній В.М. Методологічні аспекти типізації впливів на довкілля, спричинених російською агресією в Україні. *Укр. геогр. журнал*. 2024. № 1. С. 3–12. DOI: https://doi.org/10.15407/ugz2024.02.003
22. Порядок визначення шкоди та збитків, завданих Україні внаслідок збройної агресії російської федерації: Постанова Кабінету Міністрів України від 20 березня 2022 р. № 326. URL: https://zakon.rada.gov.ua/laws/show/326-2022-%D0%BF#Text (дата звернення: 23.01.2024).
23. Методика визначення розміру шкоди, завданої землі, ґрунтам внаслідок надзвичайних ситуацій та/або збройної агресії та бойових дій під час дії воєнного стану: Наказ Міністерства захисту довкілля та природних ресурсів України від 4 квітня 2022 р. № 167. URL: https://zakon.rada.gov.ua/laws/show/z0406-22#Text (дата звернення: 25.08.2024).
24. Методика визначення шкоди та збитків, завданих земельному фонду України внаслідок збройної агресії російської федерації: Наказ Міністерства аграрної політики та продовольства України від 18 травня 2022 р. № 295. URL: https://zakon.rada.gov.ua/laws/show/z0586-22#Text (дата звернення: 23.04.2024).
25. Kucher A., Kucher L. Impact of war on soils: a bibliometric landscape. Monitoring of Geological Processes and Ecological Condition of the Environment: Proceedings of 17th International Scientific Conference (Kyiv, 7–10 November 2023). Kyiv: EAGE, 2023. DOI: https://doi.org/10.3997/2214-4609.2023520212
26. Kucher A., Kucher L. War loss and damage to soil resources: towards sustainable land management. *International Journal of Environmental Studies*. 2024. Vol. 81. Is. 1. P. 18–29. DOI: https://doi.org/10.1080/00207233.2023.2296769
27. Ґрунтовий покрив України в умовах воєнних дій: стан, виклики, заходи з відновлення: монографія; за ред. С.А. Балюка, А.В. Кучера, М.І. Ромащенка. Київ: Аграрна наука, 2024. 340 с. DOI: https://doi.org/10.31073/978-966-540-612-9
28. Ibatullin S., Dorosh I., Dorosh O., Sakal O., Butenko Ye., Kharytonenko R., Shtohryn H. Determination of economic losses on agricultural land in connection with hostilities on the example of the territory of Kyivska oblast in Ukraine. *Acta Scientiarum Polonorum. Formatio Circumiectus*. 2022. Vol. 21, No. 2. P. 49–61. DOI: https://doi.org/10.15576/ASP.FC/2022.21.2.49

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