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TOWARDS THE IMPROVEMENT OF THE METHODOLOGY FOR ASSESSING DAMAGE FROM SOIL CONTAMINATION CAUSED BY EMERGENCIES AND ARMED AGGRESSION

Purposes. Analyze research on improving the methodology for determining the amount of damage from soil contamination due to emergencies and armed aggression.

Results. Based on a analysis of the current regulatory framework, domestic and foreign scientific reserths, significant shortcomings of the current Methodology are outlined, in particular, limited consideration of soil degradation types, insufficient scientific validity of coefficients, and the absence of a comprehensive cost approach.Taking into account the potential impacts of hostilities on land resources and soil degradation, an attempt made to substantiate key proposals for improving the current methods for determining damage and losses caused to soil as a result of armed aggression.

Conclusions. The need to include the costs of research, monitoring and analysis of pollution in the total amount of damage is argued. The proposed clarifications are aimed at increasing the accuracy of environmental accounting and forming sustainable principles of public management in the field of environmental restoration.

KEYWORDS: *damage assessment methodology, soil degradation, armed aggression, environmental damage, soil restoration, martial law*

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Introduction

The armed aggression against Ukraine has led to large-scale soil contamination with explosives, heavy metals, petroleum products and other toxicants. This poses a threat to environmental safety, food security and public health. Accordingly, there is a need to improve damage assessment methods, which will allow for effective response, recovery and international legal protection.

Today, one of the key and extremely urgent tasks is the economic assessment of the environmental consequences of the war for the territory of Ukraine, which requires an appropriate methodology. If the Ukrainian government began to deal with the recording and assessment of direct economic losses caused by the full-scale invasion of the Russian Federation almost immediately, then the situation with the assessment of environmental losses was initially somewhat more complicated, which is associated with certain problems of both a methodological nature and other reasons.

To solve these problems, an Operational Headquarters was created under the State Ecological Inspectorate of Ukraine, the main task of which is to form a list of all violations in the field

of environmental protection and to hold Russia accountable.

In addition, the Ministry of Environmental Protection and Natural Resources of Ukraine (hereinafter referred to as the Ministry of Environment) is using various tools to record environmental crimes and damage caused by the occupiers to the Ukrainian environment [1]. In connection with the full-scale Russian armed aggression, the issues of assessing the damage and losses caused to the land and soils of Ukraine as a result of emergency situations and/or armed aggression and hostilities during martial law have become extremely urgent, which has led to an urgent need to develop a methodology for determining these losses. The problem of assessing the damage caused to soil resources as a component of the natural resource potential and a component of land capital as a result of armed aggression is new and significant for both science and practice.

In this study, an analysis of existing national and international methodologies for determining the extent of damage caused by soil contamination resulting from emergencies and armed aggression was conducted.

Results and discussion

The relevance of the topic is evidenced by a significant number of publications. The problematic issues of determining the amount of damage due to pollution of land resources [2], modern legal problems of land restoration [3], foreign experience of legal regulation of public administration in conditions of emergency situations and martial law [4], legal issues of determining damage caused to land as a result of armed aggression and hostilities [5], global approaches to assessment, monitoring, mapping and elimination of soil pollution [6] and assessment of soil pollution and sustainable restoration strategies are studied. The imperfection of the methodology for determining the amount of damage caused by pollution and contamination of land resources due to violations of environmental legislation is also noted, namely, the insufficient validity of the criteria by which the levels of land pollution are established.

At the global level, these issues are addressed by such authoritative institutions as the World Economic Forum (WEF) [7; 8], the Royal Institute of Defense Studies (RUSI) [9; 10], the European Bank for Reconstruction and Develop-ment (EBRD) [11], the Organization for Econo-mic Cooperation and Development (OECD) [12], etc. In their analytical materials, they focus on the deep challenges that arise in crisis conditions: ensuring national security and defense, main-taining economic stability, adapting to rapid technological changes, countering hybrid threats, etc. Researchers emphasize the need to develop flexible and adaptive management models capable of quickly responding to dynamic changes in the security environment.

The main impacts of military operations are soil resources. According to DSTU 7874:2015 "Soil protection. Soil degradation. Basic provisions", soil degradation is a natural and anthropogenic process of deterioration of natural properties and soil regimes, which cause persistent negative changes in their functions, reduce stability and reduce fertility. This DSTU identifies the following types (a group of types of soil degradation, united by the similarity of the causes and mechanisms of the development of negative phenomena) of soil degradation [13]:

- mechanical degradation – deformation and/or destruction of genetic horizons or the entire soil profile, associated with mechanical movement and spatial redistribution of soil mass;
- physical degradation – persistent deterioration of physical and water-physical properties of soil, granulometric and aggregate composition, negative changes in water and temperature regimes;
- chemical degradation – deterioration of the chemical properties of the soil, negative changes in the content of macro-, meso- and microelements, contamination with toxicants;
- physicochemical degradation – deterioration of the physicochemical properties of the soil (acid-base, colloidal and buffer), negative changes in the ratio of components of the absorption complex;
- biological degradation – a persistent deterioration of the biological properties of the soil, which leads to a decrease in the productivity of the soil biocenosis;
- radiation degradation – deterioration of the radiation state of soils due to contami-nation with radioactive elements.

Each of these types includes a set of specific types of soil degradation (deterioration of soil properties and/or regimes, which can be described by one or more degradation assessment indicators that have related mechanisms of impact on soils and similar forms of degradation manifestation).

Due to the full-scale aggression of the Russian Federation, soil resources of Ukraine

are undergoing large-scale destruction, deterioration of quality, and intensification of degradation processes. Scientists of the NSC "IGA named after O. N. Sokolovsky" introduce a new type of soil degradation – degradation caused by armed aggression.

It should be noted the importance of developing a unified classification of types of soil degradation as a result of military actions. This is a new area of research and it is included in the plans of scientific research and work programs of the specified institute. At the current stage of scientific research, based on the specified standard [13] and research by scientists of the NSC "IGA named after O. N. Sokolovsky", the following are included in the main areas of negative impact of armed aggression on soils:

- mechanical degradation – disruption of the morphological structure of the soil profile; mixing of genetic horizons; increased soil heterogeneity; appearance of unusual inclusions in the soil – foreign bodies (fragments, shells, mines, rockets, cartridges, etc.), disruption of the soil cover due to the rupture of mines, ammunition and the formation of craters, ditches, pits, trenches, trenches; provoking the development of erosion, landslides, destruction of the soil cover, flooding, etc.);
- physical degradation – intensive soil compaction due to the movement of heavy military equipment; destructuring due to a decrease in the content of agronomically valuable fractions, etc.;
- chemical degradation – accumulation of heavy metals, petroleum products and other hazardous pollutants due to munitions explosions, destruction of heavy equipment or its movement from the zone of radioactive contamination; loss of organic carbon, change in its quality, loss of nutrients, movement to the surface of soil horizons in which water-soluble salts accumu-lated – soil salinization, etc.;
- physicochemical degradation – acidification, alkalization of the soil, loss of buffer functions, etc.;
- biological degradation – changes in the structure or loss of soil biota of agronomically useful communities, a decrease in soil biological activity, a decrease in biodiversity, etc.;
- other areas of impact on soils and land plots – loss of ecosystem services; land contamination (presence of foreign objects, materials, waste and/or other substances on the land plot without appropriate permits); burning of fields, burning of vegetation and/or its remains, etc.

The above types of negative impact of armed aggression on soils are closely interrelated. All aspects of soil degradation must be taken into account in the methods of determining damage and losses caused to lands and soils as a result of armed aggression of the Russian Federation.

Regulatory and legal framework for assessing damage and losses caused to lands and soils. The current main regulatory and legal framework for assessing damage and losses caused to lands and soils of Ukraine as a result of Russian aggression includes the following key documents:

- Procedure for determining damage and losses caused to Ukraine as a result of the armed aggression of the Russian Federation (approved by Resolution of the Cabinet of Ministers of Ukraine dated March 20, 2022 No. 326) [14];
- Methodology for determining the amount of damage caused to land and soils as a result of emergency situations and/or armed aggression and hostilities during martial law (approved by order of the Ministry of Environmental Protection and Natural Resources of Ukraine dated April 4, 2022 No. 167) [15];
- Methodology for determining damage and losses caused to the land fund of Ukraine as a result of the armed aggression of the Russian Federation (approved by order of the Ministry of Agrarian Policy and Food of Ukraine dated May 18, 2022 No. 295) [16].

The main weaknesses of the current 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:

- Insufficient consideration of international experience in assessing damages as an evidentiary basis in the context of holding the aggressor accountable and limited opportunities to do so due to the lack of such generally recognized methods in the world.
- Failure to take into account the impact of hostilities on the mechanical degradation of soil resources.
- Failure to take into account the impact of hostilities on the physical degradation of soil resources.
- Incomplete consideration of the impact of hostilities on the chemical degradation of soil resources, in particular, the loss of organic carbon, changes in its quality, and the loss of nutrients are ignored.
- Failure to take into account the impact of hostilities on the physicochemical degradation of soil resources.

− Failure to take into account the impact of hostilities on the biological degradation of soil resources.

− Failure to take into account the impact of hostilities on other types of soil resource degrada-tion, in particular, the loss or reduction in the value and value of soil ecosystem services, field burning, and burning of vegetation and/or its remains.

− Insufficient justification of individual coefficients. For example, when determining the amount of damage from soil contamination, the specific costs for eliminating the consequences of soil contamination of the relevant land plot (A) were taken at 1.5, that is, they were actually equated to one and a half times the normative monetary value of the land plot whose soils were contaminated. Experts from the Professional Association of Ecologists of Ukraine propose to apply a value of 10 for indicator A, taking into account the special status of land as a major national asset, the danger of pollutants (heavy metals), the duration and significant cost of soil restoration measures. When determining the amount of damage due to land contamination, the specific costs for eliminating the consequences of land contamina-tion, including cleaning (A), are taken at 1, that is, they are actually equated to the regulatory monetary valuation of the land that has been contaminated. The conversion factor for contami-nation of a land plot with foreign objects, materials, waste and/or other substances without appropriate permits (B) is 15, and for hazardous waste and/or other hazardous substances – 300. Experts from the Professional Association of Ecologists of Ukraine propose to apply a value of 10 for indicator A, and 300 for indicator B. The arguments regarding the latter indicator are related, in particular, to the fact that in accordance with Article 34 of the Law of Ukraine "On Waste", all hazardous waste is divided into four classes according to the degree of their harmful impact on the environment and on human life and health and is subject to accounting. That is, all waste is hazardous. In addition, there is currently no valid regulatory document in the field of waste management, approved in the established manner, which regulates the procedure for determining the class, category of waste hazard. There is every reason to agree with the proposals regarding the advisability of applying one coefficient for all waste, however, determining the value of the considered coefficients requires additional scien-tific justification.

− Insufficient consideration of the cost-effective methodological approach to restoring soils affected by armed aggression and hostilities, i.e. by determining the cost of restoring soil quality. The latter, in turn, is determined by the cost of measures that must be applied to restore soil parameters to their initial (pre-war) level.

− Failure to take into account the costs of assessing the extent of damage and losses (conducting research, sampling, analyses, remote sensing, collecting economic data and performing calculations, etc.).

Main proposals for improving the current Methodology for determining the amount of damage caused to land and soils as a result of emergency situations and/or armed aggression and hostilities during martial law.

Given the weaknesses outlined, the following main additions and/or suggestions are proposed to improve the specified Methodology:

1. Determining the amount of damage due to mechanical soil degradation (MSD). The amount of damage due to mechanical soil degradation is determined based on the amount of costs for measures to recultivate soils disturbed as a result of hostilities.

2. Determining the amount of damage due to physical soil degradation (PSD). The amount of damage due to physical soil degradation is determined based on the amount of costs for measures to decongest soils disturbed as a result of hostilities.

3. Determining the amount of damage due to chemical soil degradation (SCD). In this case, it is proposed to supplement the calculation of damage due to soil contamination with damage from the loss of organic carbon and loss of nutrients.

4. Determination of the extent of damage caused by physical and chemical degradation of soils (PCD). The extent of damage caused by physical and chemical degradation of soils is determined based on the total cost of measures to neutralize the acidity of soils affected by hostilities.

5. Determination of the amount of damage due to biological degradation of soils (RBD). The amount of damage due to biological degradation of soils is determined based on the amount of costs for measures to restore soil biota and biodiversity of the soil affected by hostilities. If these costs are included in other items (for example, costs for eliminating the consequences of soil contamination - remediation measures - may

include the cost of phyto-amelioration and soil remediation using biological products that allow restoring the state of microbial coenoses in soils), then they are not determined separately. When determining the amount of damage due to physical, chemical and physico-chemical degradation of soils, it is worth relying on the methodological developments of the NSC "IGA named after O. N. Sokolovsky" [17].

6. Determination of the amount of damage due to other types of soil degradation (RSHD). In this case, it is proposed to supplement the calculation of damage due to land contamination with damage from the loss or reduction of soil ecosystem services, field burning, burning of vegetation and/or its residues [18]. For the economic assessment of damage from burning of plant residues, it is worth taking as a basis the methodology developed under the leadership of S. Yu. Bulygin [19], according to which all damage caused to the environment is grouped into five categories:

(1) damage from the destruction and/or transformation of soil organic matter under the influence of high temperatures during burning of residues;

(2) losses from increased erosion and deflationary risks;

(3) losses from the destruction of plant residues as an organic fertilizer and a source of soil organic matter renewal;

(4) damage from the destruction of natural soil fauna and soil microbiological fauna; (5) damage from air pollution by products of burning plant residues and oxygen consumption.

The first three items are direct (internal) damages, which are calculated according to the relevant formulas and standards, the last two items are indirect (external) damages, which are equal to the sum of the first three (since it is very difficult, and sometimes impossible, to quantify them, it is assumed that external environmental damages are no less in size than direct ones).

The amount of damage resulting from other types of soil degradation caused by armed aggression and hostilities is determined based on the amount of costs for measures to restore soil quality to its initial (pre-war) level.

7. Determination of costs for assessing the extent of damage and losses (D&L). The amount of costs for assessing the extent of damage and losses caused to land and soil as a result of emergencies and/or armed aggression and hostilities during martial law is determined based on the costs of conducting research, sampling, analysis, remote sensing, collecting economic data and performing calculations, etc.

8. Determination of the total amount of damage for the simultaneous manifestation of all types of soil degradation (TED). The total amount of compensation for the simultaneous manifestation of all types of soil degradation as a result of emergency situations and/or armed aggression and hostilities during martial law is determined by the formula:

$$TED = MSD + PSD + SCD + PCD + RBD + RSHD$$

9. It is recommended to expand the range of entities that establish the facts of soil degradation caused by armed aggression, as well as their scale. In particular, the number of specified entities should include all entities that exercise state control over the use and protection of lands of all categories and forms of ownership in accordance with the Law of Ukraine "On State Control over the Use and Protection of Lands" (central executive body that implements state policy in the field of land relations; central executive body on agrarian policy; central executive body that ensures the implementation of state policy on state supervision (control) in the field of environmental protection, rational use, reproduction and protection of natural resources; executive bodies of village, settlement, city councils within the powers defined by law), as well as scientific institutions of NASU, NAAS, land owners and land users, enterprises, institutions and organizations whose land plots were damaged and lost as a result of armed aggression.

Technologies for monitoring and assessing the condition of land resources.

Also, one of the most important state problems today is the monitoring and protection of lands for the post-war restoration and development of the economy of Ukraine, the solution of which is largely associated with a comprehensive system of observations, assessment and forecasting of the state of changes in land resources and the restoration of soil fertility under the influence of natural and anthropogenic factors. It should be noted that monitoring refers to the functions of state administration, where the content, features and procedure for conducting land monitoring are regulated by the Land Code of Ukraine, the laws of Ukraine "On Land Protection", "On Environmental Protection", "On Land Management", "On State Control over the Use and Protection of

Lands", "Regulations on Land Monitoring" and other subordinate legislation.

The definition of land monitoring is given and legally enshrined in Art. 191 of the Land Code of Ukraine [20], according to which land monitoring is a system of observations of the state of land, which aims to timely detect changes in the state of land, assess them, prevent and eliminate the consequences of negative processes. The Land Code of Ukraine and the Regulations on Land Monitoring establish the structure, tasks and content of monitoring. The task of land monitoring is to collect information necessary for maintaining the state land cadastre, organizing land use and land management, exercising state control over the use and protection of land in order to prevent negative processes. Thus, monitoring becomes particularly relevant, allows you to clearly determine the quantitative and qualitative characteristics of land resources and, if necessary, take timely measures adequate to the background state of the land. It is also designed to initiate an environmentally friendly, resource-saving and regenerative, that is, rational, nature of their use, providing for the preservation of soils and limiting the negative impact on them [21].

Land monitoring is carried out at the local (on the territory of individual land tenures, land uses, landscape areas), regional (within administrative-territorial units, on the territories of economic and natural regions), national (covers the entire territory of Ukraine) and global levels (connected with international scientific and technical 16 programs). At each level, it is advisable to determine the impact of anthropogenic load. This requires various integral indicators of the action of anthropogenic load of all subspecies and the use of integral assessment indices. This encourages rational planning of territories and placement of national economic objects on them, taking into account the rules and norms of environmental protection [22].

Land monitoring is regulated by Law of Ukraine "On Environmental Protection: Art. 22 In order to ensure the collection, processing, preservation and analysis of information on the state of the environment, forecasting its changes and developing scientifically based recommendations for making effective management decisions in Ukraine, a system of state environmental monitoring is being created. Monitoring of the state of the environment and the level of its pollution is carried out by the central executive body that implements state policy in the field of environmental protection, other specially authorized state bodies, as well as enterprises, institutions and organizations whose activities lead or may lead to a deterioration in the state of the environment. The specified enterprises, institutions and organizations are obliged to transfer analytical materials of their observations to the relevant state bodies free of charge.

The procedure for conducting state environmental monitoring is determined by the Cabinet of Ministers of Ukraine.

State bodies, together with relevant scientific institutions, ensure the organization of short-term and long-term forecasting of environmental changes, which must be taken into account when developing and implementing programs and measures for the economic and social development of Ukraine, including environmental protection, use and reproduction of natural resources, and ensuring ecological safety [23];

Land monitoring is also regulated by Law of Ukraine "On State Control over the Use and Protection of Lands" (regarding monitoring of agricultural land soils). Art. 5: Bodies exercising state control over the use and protection of lands, compliance with the requirements of the legislation of Ukraine on land protection, monitoring of soil fertility.

State control over the use and protection of land of all categories and forms of ownership is carried out by the central executive body that implements state policy in the field of land relations. State control over the use and protection of land is also carried out by executive bodies of village, settlement, and city councils within the limits of their powers determined by law, if the relevant council adopts a decision to exercise such control.

State control over compliance with the requirements of the legislation of Ukraine on and protection is carried out by the central exeecutive body, which ensures the implementation of state policy on state supervision (control) in the field of environmental protection, rational use, reproduction and protection of natural resources.

Monitoring of soil fertility of agricultural lands and agrochemical certification of agricultural lands is carried out by the central executive body for agrarian policy.

Article 8: Powers of the central executive body implementing state policy in the field of land relations when monitoring soil fertility

Article 9: Organization and implementation of state control over the use and protection of lands, compliance with the requirements of the legislation of Ukraine on land protection and soil monitoring.

State control over the use and protection of lands, compliance with the requirements of the legislation of Ukraine on land protection and soil monitoring is carried out by:

- conducting inspections;
- consideration of applications from legal entities and individuals;
- participation in the commissioning of land reclamation systems and reclaimed lands, protec-tive forest plantations, anti-erosion hydraulic structures and other facilities that are being constructed to increase soil fertility and ensure land protection;
- review of land management documentation related to land use and protection;
- conducting soil monitoring and agrochemical certification of agricultural lands [24];
– Resolution of the Cabinet of Ministers of Ukraine “On Approval of the Regulation on Land Monitoring” [25];
–"Regulations on the State Environmental Monitoring System" dated March 30, 1998, No. 391 [26].

Land monitoring should be understood not as separate one-time measures, but as a holistic, dynamic and continuous observation system that combines large-scale technical activities and in-depth information and analytical work. Its main task is to form a complete, objective and timely picture of the state of the country's land resources. This complex system is implemented through the active use of specialized technical means of control and careful, systematic tracking of the qualitative characteristics of the land. The monitoring process is multi-stage and includes a number of key operations, including:

Field surveys and sampling: Conducting route surveys, establishing test sites, taking soil and groundwater samples for further laboratory analysis to identify anthropogenic pollution, soil fatigue, or natural anomalies.

Comprehensive studies: Organization and conduct of soil-geobotanical, agrochemical, land reclamation, ecological-toxicological and other necessary surveys that allow for a comprehensive assessment of land, taking into account all interrelationships in the natural environment.

Laboratory and analytical work: Performing accurate laboratory analyses, measurements and tests to determine the chemical composition (content of heavy metals, pesticides, radionuclides, pH), biological properties (microbiological activity, humus content) and physical condition (density, structure, moisture) of soils.

However, the functions of land monitoring are not limited to the collection of empirical data. The next, no less important stage is their in-depth analysis, interpretation and systematization. Based on the mass of information received, specialists conduct a comprehensive assessment of the state of the land, develop scientifically based forecasts for the development of the main negative processes. Such processes include, in particular, water and wind erosion, man-made pollution, secondary salinization, drainage, flooding, acidification, loss of the fertile humus layer, as well as land degradation due to improper management. Based on these forecasts, specific preventive and restoration measures are developed aimed at preventing, localizing and completely eliminating negative phenomena.

Another critically important aspect of monitoring is the systematic observation of actual and targeted land use. This process involves identifying, recording, and documenting cases of inappropriate use of land plots, unauthorized land grabbing, and violations of good agricultural practices, which often lead to irreversible deterioration of soil quality, a decrease in soil fertility, and a general deterioration of the environmental situation in the region [27].

Land monitoring rightfully occupies a central, basic place in the general system of all other types of monitoring and state cadastres of natural resources. The information accumulated, systematized and updated as a result of its implementation serves as the main information foundation and a single geospatial framework for:

Conducting industry monitoring: Effective monitoring of the natural environment, water, forest, mineral and raw materials, and other resources is impossible without accurate and up-to-date information about land, since all natural objects are located on the land surface and are closely interconnected.

Formation and maintenance of state cadastres: Land monitoring data is the primary source for the formation and maintenance of the State Land Cadastre (SLC), and is also actively used in the State Cadastre of Natural Resources, the Cadastre of Flora and Fauna, which ensures the unity and consistency of the entire cadastral system of the country.

Land monitoring in Ukraine is organizationally and functionally assigned to the State Service of Ukraine for Geodesy, Cartography and Cadastre (State Geocadastre). However, due to the complex and interdisciplinary nature of the tasks, this work is not carried out in isolation, but with the mandatory participation and

close interaction with other specialized central executive bodies and scientific institutions, among which the following play a key role:

- Ministry of Environmental Protection: Responsible for general environmental policy, environmental quality regulation, and pollution monitoring.
- Ministry of Agrarian Policy and Food: Ensures the connection of monitoring with the needs of agricultural production, develops recommendations for increasing soil fertility.
- Ukrainian Academy of Agrarian Sciences: Provides scientific support, conducts fundamental and applied research in the field of soil science, agrochemistry, and agriculture.

An important stage in the development and consolidation of the state control system was the adoption of the Resolution of the Cabinet of Ministers of Ukraine dated 30.11.2016 No. 910-r "Issues of the State Service for Geodesy, Cartography and Cadastre". With this strategic document, the Government centralized and assigned to the State Geocadastre the full range of functions and powers for state supervision (control) in the agro-industrial complex. This concerns strict compliance with land legislation, rational use and protection of lands of all categories and forms of ownership, as well as ensuring the preservation and restoration of soil fertility. It is important to note that these critically important powers previously belonged to the State Inspectorate of Agriculture, which was liquidated as part of the administrative reform [28, 29].

Information on the condition of lands collected during field, laboratory and remote observations is subject to careful systematization and spatial generalization at various levels:

- By administrative-territorial units: (districts, cities, regions) for the needs of local self-government.
- By individual natural complexes and watersheds: (e.g., forest-steppe zone, Dnipro River basin) for ecological planning.
- By land categories and types of land: (agricultural land, forest land, etc.).

Further processing, storage, and analysis of these large data sets (Big Data) takes place in modern automated information systems (AIS) of regional land resources departments and the central office of the State Geocadastre.

The final product of analytical work is the preparation of detailed annual and periodic reports, scientifically based forecasts for the medium and long term, as well as packages of specific practical recommendations. These documents are sent in accordance with the established procedure to local executive authorities, local governments and the central office of the State Geocadastre for further implementation of operational, tactical and strategic measures. These measures are aimed at timely prevention, localization and complete elimination of the consequences of negative processes, as well as at stimulating rational land use.

Modern challenges and high requirements for land resource management in the context of global changes necessitate the widespread use of advanced, innovative approaches to collecting, storing, analyzing, modeling, and predicting the state of the environment. Solving these complex tasks is ensured solely through the implementation of a comprehensive geoinformation approach that integrates various data sources into a single digital space. The key technologies that dramatically increase the efficiency of land use and the quality of management decisions today are:

Modern geographic information systems (GIS): They are the core of the entire monitoring system. They provide a powerful platform for operational processing, deep spatial analysis, visual visualization in the form of maps and diagrams, secure storage and rapid transmission of information about the state of the land. It is GIS technologies that transform raw data into knowledge, which is critically important for making informed public management decisions at different levels [30].

Global positioning satellite systems (GPS, GLONASS, Galileo): Revolutionary opportunities have been opened for fast, accurate and cost-effective geodetic surveys and inventories of large areas. When conducting surveying work using GNSS equipment, the difficulties inherent in traditional methods (the need for direct visibility between points, the influence of weather conditions, low speed) largely disappear.

Remote sensing of the Earth (RS): It is a set of the most modern methods for studying the Earth's surface, lithosphere and atmosphere with subsequent decoding and interpretation of the obtained images. Aerospace means, in particular observations from artificial satellites of high and ultra-high spatial resolution (satellites of the Sentinel, Landsat, SPOT, Planet series), allow obtaining high-quality, objective, multispectral information in a mode close to real time. This provides a unique opportunity to quickly and with high accuracy assess the state of land resources and crops, monitor the dynamics of the state of forest lands, control unauthorized changes in the purpose of land, as well as promptly detect the occurrence and develop-

ment of dangerous natural phenomena (fires, floods) and man-made emergencies.

Thus, the information support of the land monitoring system is based on the integration of data from various sources:

Remote sensing data (space-based imaging and observation; Aerial photography and research from unmanned aerial vehicles (UAVs);Ground survey and observation: Includes route patrols, use of mobile laboratories, installation of stationary sensors and gauges; Stock (archival) data: Cartographic materials, materials of previous surveys, data from state cadastres, allowing analysis of the dynamics of changes.

The large-scale implementation of geoinformation technologies, global positioning systems, and advanced remote sensing methods of the Earth transforms them from simple tools into key drivers and infrastructure factors for increasing the efficiency of land resource management, thereby ensuring a new qualitative level of land monitoring in Ukraine and its integration into the European and global data space.

Conclusions

As a result of the research, an analysis of the potential opportunities for the development of methodological principles for determining the amount of damage caused to land and soil as a result of the armed aggression of the Russian Federation and the conduct of active hostilities during martial law was carried out. Taking into account the significant potential impacts of military operations on the state of land resources and the intensification of soil degradation processes, a comprehensive review of scientific publications was conducted and key proposals were substantiated for improving the current methods for determining the amount of damage and losses caused to soil cover as a result of armed aggression.

Based on the identified key weaknesses of the current Methodology for determining the amount of damage caused to land and soils as a result of emergencies and/or armed aggression and hostilities during martial law, a number of main additions and/or proposals have been proposed to significantly improve this Methodology, in particular: the introduction of a mechanism for determining the amount of damage due to mechanical, physical, chemical, physico-chemical, biological and other types of soil degradation based on a cost-based methodological approach, according to which the amount of damage due to soil degradation is determined based on the sum of all necessary costs for a set of measures to fully restore soil quality. As for clarifying the determination of the amount of damage due to other types of soil degradation, it is proposed to significantly supplement the calculation of damage due to land contamination by also including an assessment of damage from the loss or significant reduction of soil ecosystem services, damage from large-scale field burning, burning of vegetation and/or its remains. It is also proposed that the total amount of damage and losses caused to land and soil as a result of emergencies and/or armed aggression and hostilities during martial law must necessarily take into account the full amount of costs for assessing their value, based on the calculation of costs for conducting compre-hensive field research, sampling, laboratory analysis, remote sensing, collecting economic data and performing calculations, etc.

The practical value of this study lies in the fact that its results can be used by the Ministry of Agrarian Policy and Food of Ukraine, the Ministry of Environmental Protection and Natural Resources of Ukraine, the State Ecological Inspectorate of Ukraine and other interested parties to consistently improve the Methodology for determining the amount of damage caused to land and soils as a result of emergency situations and/or armed aggression and hostilities during martial law, as well as for practical assessment of the amount of these losses during the restoration of affected territories.

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the authors fully complied with ethical standards, including plagiarism, data falsification, and double publication.

***Authors Contribution*:** all authors have contributed equally to this work.

The work did not use an artificial intelligence resource.

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ДО ПРОБЛЕМИ УДОСКОНАЛЕННЯ МЕТОДИКИ ВИЗНАЧЕННЯ РОЗМІРУ ШКОДИ ЗА ЗАБРУДНЕННЯ ҐРУНТІВ ВНАСЛІДОК НАДЗВИЧАЙНИХ СИТУАЦІЙ ТА ЗБРОЙНОЇ АГРЕСІЇ

Мета. Проаналізувати дослідження щодо удосконалення методики визначення розміру шкоди за забруднення ґрунтів внаслідок надзвичайних ситуацій та збройної агресії.

Результати. На основі аналізу сучасної нормативно-правової бази, вітчизняних і зарубіжних наукових досліджень окреслено суттєві недоліки чинної Методики, зокрема обмежене врахування типів деградації ґрунтів, недостатню наукову обґрунтованість коефіцієнтів та відсутність комплексного витратного підходу. Ураховуючи потенційні впливи воєнних дій на земельні ресурси та деградацію ґрунтів здійснено спробу обґрунтувати ключові пропозиції щодо вдосконалення чинних методик визначення шкоди та збитків, завданих ґрунтам внаслідок збройної агресії.

Висновки. Аргументовано необхідність включення витрат на дослідження, моніторинг і аналіз забруднень до загального обсягу збитків. Запропоновані уточнення спрямовані на підвищення точності екологічного обліку та формування сталих засад публічного управління у сфері відновлення природного середовища.

КЛЮЧОВІ СЛОВА: *методика оцінки шкоди, деградація ґрунту, збройна агресія, екологічні збитки, відновлення ґрунту, воєнний стан*

Конфлікт інтересів

Автори заявляють, що конфлікту інтересів щодо публікації цього рукопису немає. Крім того, автори повністю дотримувались етичних норм, включаючи плагіат, фальсифікацію даних та подвійну публікацію.

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