

CRIMINALISTICS MEANS AND METHODS OF COMBATING ECOCIDE IN THE MODERN CONDITIONS OF MILITARY THREATS

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ABSTRACT

The purpose of this study was to develop an integrated approach to the implementation of criminalistics tools and methodology to prevent and counteract large-scale environmental destruction in the context of modern military threats. To fulfil this purpose, the study analysed the legal aspects of regulating ecocide as a war crime, assessed the effectiveness of existing forensic tools and methods, and investigated the judicial practice and statistics of environmental crimes in Ukraine for 2014-2024. The study found that the number of reported cases of environmental crimes in the conflict zone increased by 73% during this period, with a strong correlation ($r=0.82$) between the intensity of hostilities and the number of cases of ecocide. The expert survey showed that the most effective forensic tools for detecting and documenting environmental crimes are satellite monitoring, geographic information systems, and unmanned aerial vehicles. The analysis of 75 court decisions showed that in 68% of cases, the actions were classified as ecocide, but in 22% – as other environmental crimes, which indicates the difficulty of proving all

Criminalistics Means and Methods of Combating Ecocide in the Modern Conditions of Military Threats

elements of the crime of ecocide. Based on the findings obtained, comprehensive recommendations were developed to improve legal regulation, institutional support, technological equipment, investigation methods, and international cooperation in the field of combating ecocide in armed conflicts. Specifically, it was proposed to amend national legislation to clearly define the crime of ecocide, strengthen the institutional capacity of the authorised bodies, expand the use of modern technologies for monitoring and recording environmental crimes, and intensify international cooperation in this area.

Keywords: Armed conflict; Evidence gathering; specialised knowledge; Environmental crimes; Criminalistics innovations; Criminalistic methodics; Criminalistic strategy; Forensic examination

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Criminalistics Means and Methods of Combating Ecocide in the Modern Conditions of Military Threats

1. INTRODUCTION

Ecocide, characterised by the large-scale destruction of the natural environment, is a proposed international crime currently under discussion in various legal and academic forums but has not yet been codified in public international law. In the context of modern military threats, the issue of combating ecocide is becoming extremely relevant, as the deliberate destruction of ecosystems is often used as a strategic tool of warfare. This has long-lasting negative consequences for the environment, economy, and public health that extend far beyond the conflict zone. According to the United Nations Environment Programme,¹ natural resource exploitation was a factor in at least 40% of internal conflicts over the previous six decades. Moreover, the probability of recurrence of armed conflicts related to natural resources within 5 years after their end is twice as high.

The study of the phenomenon of ecocide in the context of armed conflicts has attracted considerable attention from researchers. Although ecocide has been proposed as a fifth crime under the Rome Statute of the International Criminal Court, it is not currently recognized as a crime under customary international law, treaties, or general principles of law. This absence poses challenges for its prosecution and underscores the need for legislative reforms. van der Vet² conducted a comprehensive analysis of the impact of military operations on the environment, emphasising the need to develop effective mechanisms of liability for environmental crimes. Sands³ focused on the legal aspects of environmental protection in international law, emphasising the historical development of this field and the significance of improving international legislation. Developing this topic, Arifin et al.⁴ conducted a comprehensive analysis of the role of international organisations in the prevention and investigation of ecocide in conflict zones, emphasising the need to strengthen their mandate and resources. The issues of criminalistics support for the investigation of environmental crimes were

¹ United Nations Environment Programme (UNEP). 'From conflict to peacebuilding: The role of natural resources and the environment', (2009). Retrieved from: <<https://www.iisd.org/publications/conflict-peacebuilding-role-natural-resources-and-environment>>

² van der Vet, F., 'A polluting war: Risk, experts, and the politics of monitoring wartime environmental harm in Eastern Ukraine', (2024) Environment and Planning C: Politics and Space, <<https://doi.org/10.1177/23996544241229553>>.

³ Sands, P., 'Environmental protection in the twenty-first century: sustainable development and international law'. In: *Environmental Law, the Economy and Sustainable Development: The United States, the European Union and the International Community*, Cambridge: Cambridge University Press, 2000, pp. 369-409, <<https://doi.org/10.1017/CBO9780511720871.013>>.

⁴ Arifin, R., Masyhar, A., Wulandari, C., Kusuma, B. H., Wijayanto, I., Rasdi, & Fikri, S., 'Ecocide as the serious crime: A discourse on global environmental protection', (2024) 1355 IOP Conference Series: Earth and Environmental Science 012004, <<https://doi.org/10.1088/1755-1315/1355/1/012004>>.

Criminalistics Means and Methods of Combating Ecocide in the Modern Conditions of Military Threats

discussed by Janevski and Sazdovska,⁵ and Mäkelä et al.⁶ Researchers emphasised the need to develop specialised methods for collecting and analysing evidence of environmental crimes, considering their specificity and complexity. Developing this line of research, Heckenberg and White⁷ proposed innovative approaches to the classification and systematisation of evidence of ecocide that can be adapted to wartime conditions. Investigating the potential and possibilities for improving the effectiveness of the investigation of such crimes, Shevchuk et al.⁸ emphasised the significance of using tactical operations as organisational and tactical means of optimising pre-trial investigation and trial during the collection of evidence and investigation of this category of crimes.

Particularly noteworthy are studies on the use of modern technologies in combating environmental crimes. Avtar et al.⁹ conducted an in-depth analysis of the potential of remote sensing and geographic information systems (GIS) to detect and document cases of ecocide. Sabia¹⁰ explored the prospects of using artificial intelligence (AI) and machine learning (ML) to analyse large amounts of environmental data in the context of war crimes investigations. According to her research, the use of ML algorithms can increase the accuracy of environmental crime detection by 30-40% compared to conventional methods of analysis. Complementing these studies, Zwijnenburg and Ballinger¹¹ developed methods for integrating data from various sources (satellite imagery, drones, ground sensors) to create a comprehensive picture of the environmental impacts of armed conflict.

⁵ Janevski, R., & Sazdovska, M.M., 'Forensic analysis for proving environmental crimes in Macedonia. International Scientific Conference Security Concepts and Policies – New Generation of Risks and Threats', (2020). Retrieved from: <https://www.researchgate.net/publication/344871790_forensic_analysis_for_proving_environmental_crimes_in_macedonia>

⁶ Mäkelä, T., Huhtala, S., Lindqvist, M.A., & Bucht, R., 'The current status of environmental forensic science in the member institutes of the European Network of Forensic Science Institutes (ENFSI)', (2023) 348 Forensic Science International 111593, <<http://dx.doi.org/10.1016/j.forsciint.2023.111593>>.

⁷ Heckenberg, D., & White, R., 'Innovative approaches to researching environmental crime'. In: *Routledge International Handbook of Green Criminology*, London: Routledge, 2020, pp. 110-131, <<https://doi.org/10.4324/9781315207094>>.

⁸ Shevchuk V., Kostenko M., Myshkov Y., Papusha I., & Hryshko I., "Functional purpose of tactical operations in the development of criminalistic methodics of crime investigation", (2023) 15(2) Pakistan Journal of Criminology 61-78.

⁹ Avtar, R., Kouser, A., Kumar, A., Singh, D., Misra, P., Gupta, A., Yunus, A.P., Kumar, P., Johnson, B.A., Dasgupta, R., Sahu, N., & Rimba, A.B., 'Remote sensing for international peace and security: Its role and implications', (2021) 13(3) Remote Sensing 439, <<https://doi.org/10.3390/rs13030439>>.

¹⁰ Sabia, R., 'Artificial intelligence and environmental criminal compliance', (2020) 1 (2020) International Journal of Penal Law 179-201, <<https://iris.luiss.it/handle/11385/202895>>.

¹¹ Zwijnenburg, W., & Ballinger, O., 'Leveraging emerging technologies to enable environmental monitoring and accountability in conflict zones', (2023) 105 (924) International Review of the Red Cross 1497-1521, <<http://dx.doi.org/10.1017/S1816383123000383>>.

Criminalistics Means and Methods of Combating Ecocide in the Modern Conditions of Military Threats

International cooperation in combating ecocide is also an essential aspect of the problem. Shchokin et al.¹² and Moribe et al.¹³ performed a comprehensive analysis of the effectiveness of international mechanisms for investigating environmental crimes in armed conflict. The researchers emphasised the significance of improving coordination between law enforcement agencies of different countries and international organisations to effectively combat transborder environmental crimes. Developing this theme, Marko¹⁴ investigated the legal and organisational aspects of creating specialised international investigative teams to investigate cases of ecocide in conflict zones.

In the context of improving the methodology for investigating ecocide, Pavanelli and Voulvoulis¹⁵ proposed a comprehensive approach to assessing environmental damage caused by military operations, combining forensic, environmental, and economic methods of analysis. Van Schaack¹⁶ developed this line of research, emphasising the significance of using modern digital technologies and big data to document war crimes and crimes against humanity, including environmental crimes. She stressed the need to update the protocols for collecting, storing, authenticating, and analysing evidence in the modern digital environment, which is especially relevant for assessing environmental damage in conflict zones. In the context of Ukraine, the problem of ecocide is particularly acute considering the ongoing armed conflict.¹⁷ According to the Ministry of Environmental Protection and Natural Resources of Ukraine,¹⁸ over 2,500 cases of environmental damage caused by Russian aggression were recorded, with the total amount of damage estimated at more than EUR 55.6 billion. Medvedieva and Korotkyi¹⁹ conducted a thorough analysis of the environmental consequences of the

¹² Shchokin, R., Oliinyk, V., Amelin, O., Bondarenko, Y., Maziychuk, V., & Kyslenko, D. 'Methods of combating offenses in the field of ecology', (2023) 14 (1) Journal of Environmental Management and Tourism 5-15, <[https://doi.org/10.14505/jemt.v14.1\(65\).01](https://doi.org/10.14505/jemt.v14.1(65).01)>.

¹³ Moribe, C., Pereira, F., & França, N., 'Ecocide: A new challenge for the international criminal law and for humanity', (2023) 4 (1) Journal of International Criminal Law 28-40, <<https://doi.org/10.22034/jicl.2023.172299>>.

¹⁴ Marko, S., 'Organizational and legal aspects of combating crimes against the environment in the conditions of war in Ukraine', (2023) 6 Visegrad Journal on Human Rights 127-132, <<https://doi.org/10.61345/1339-7915.2023.6.21>>.

¹⁵ Pavanelli, D.D., & Voulvoulis, N., 'Habitat equivalency analysis, a framework for forensic cost evaluation of environmental damage', (2019) 38 Ecosystem Services 100953, <<https://doi.org/10.1016/j.ecoser.2019.100953>>.

¹⁶ Van Schaack, B., 'Innovations in international criminal law documentation methodologies and institutions', (2019) Stanford Law School 1-46, <<https://dx.doi.org/10.2139/ssrn.3329102>>.

¹⁷ Polukarov, Yu., Kachynska, N., Polukarov, O., Zemlyanska, O., & Mitiuk, L., 'Impact of the full-scale war in Ukraine on the environment: Environmental damage assessment', (2024) 15 (1) Law. Human. Environment 85-100, <<https://dx.doi.org/10.31548/law/1.2024.85>>.

¹⁸ Ministry of Environmental Protection and Natural Resources of Ukraine. 'Total environmental damage to Ukraine today amounts to EUR 55.6 billion: Denys Shmyhal', (2023). Retrieved from: <<https://www.kmu.gov.ua/en/news/zahalni-zbytky-dovkilliu-ukrainy-sohodni-skladaiut-556-mlrd-ievro-denys-shmyhal>>.

¹⁹ Medvedieva, M.O., & Korotkyi, T.R., 'Responsibility for the environmental damage caused during the armed conflict between Ukraine and the Russian Federation: Opportunities in the algorithm of protecting national interests', (2019) 139 Actual Problems of International Relations 57-67, <<https://doi.org/10.17721/apmv.2019.139.0.58-67>>.

Criminalistics Means and Methods of Combating Ecocide in the Modern Conditions of Military Threats

hostilities in eastern Ukraine and identified key challenges for law enforcement agencies in investigating such crimes. The researchers emphasised the need to improve the regulatory framework and develop specialised units to effectively combat ecocide. Developing on this theme, a group of scientists led by Blaga²⁰ proposed a methodology for assessing the long-term environmental consequences of the armed conflict in Ukraine, which can be used both for forensic purposes and for planning restoration work.

The United Nations has also played an active role in fostering dialogue on the legal recognition of ecocide. Recent UN General Assembly discussions have emphasized the urgency of addressing large-scale environmental destruction, especially in the context of armed conflicts and climate change. Advocates argue that typifying ecocide as a distinct international crime would enhance accountability for environmental harm and strengthen preventive measures against ecological destruction. Critics, however, caution against potential enforcement challenges and the complexities of establishing clear legal criteria for “serious and widespread or long-term damage”.²¹

This growing body of discourse highlights the critical need to address the gap in international law concerning environmental crimes. Typifying ecocide would provide a robust legal tool to hold perpetrators accountable and deter future acts of environmental destruction, contributing to global environmental security and justice.

An essential aspect of the problem is also the development of preventive measures to prevent ecocide in the context of potential conflicts. In this context, Bruch et al.²² and Fleck²³ conducted a comprehensive analysis of the possibilities of integrating environmental aspects into peacekeeping and post-conflict reconstruction processes. Researchers have proposed the concept of “ecological peacebuilding”, which involves considering the environmental factors at all stages of conflict resolution. At the same time, the practical application of criminalistic tools and methods for documenting and investigating cases of ecocide in active hostilities is still understudied. Specifically, in-depth research is needed to ensure the security of investigative teams, preservation of material evidence in an unstable

²⁰ Blaga, A.B., Zagorodnyuk, I.V., Korotkyi, T.R., Martynenko, O.A., Medvedeva, M.O., & Parkhomenko, V.V., ‘On the brink of survival: Environmental destruction during the armed conflict in eastern Ukraine’, (2020). Retrieved from: <<https://www.helsinki.org.ua/publications/na-mezhi-vyzhyvannya-znyschennya-dovkillya-pid-chas-zbrojnoho-konfliktu-na-shodi-ukrajiny/>>.

²¹ Haltsova, V., Volodina, O., Hordieiev, V., Samoshchenko, I., & Orobets, K., ‘Analysis of criminal law on ecocide: A case study of war in Ukraine’, (2024) (14), *Revista Kawsaypacha: Sociedad y Medio Ambiente* D-013, <<https://doi.org/10.18800/kawsaypacha.202402.D013>>.

²² Bruch, C., Jensen, D., & Emma, M., ‘Defining Environmental Peacebuilding’. In: *Routledge Handbook of Environmental Security*, London: Routledge, 2021, pp. 9-25, <<https://doi.org/10.4324/9781315107592-2>>.

²³ Fleck, D. ‘Legal protection of the environment: The double challenge of non-international armed conflict and post-conflict peacebuilding’. In: *Just Peace After Conflict*, Oxford: Oxford University Press, 2020, pp.149-164, <<https://doi.org/10.1093/oso/9780198823285.003.0009>>.

Criminalistics Means and Methods of Combating Ecocide in the Modern Conditions of Military Threats

situation, and development of methods for remote collection and analysis of evidence. The purpose of this study was to systematise and improve forensic tools for the effective detection, documentation, and investigation of cases of ecocide in armed conflicts, considering the specifics of modern military conflicts and the potential of innovative technologies. To fulfil this purpose, the following tasks had to be solved:

1. To analyse the current state of regulatory support for combating ecocide in Ukraine and the world.
2. To investigate the specifics of ecocide as a war crime and identify key challenges for its investigation in the context of armed conflict.
3. To evaluate the effectiveness of existing criminalistic methods for detecting, documenting, and investigating environmental crimes in the context of their application in the combat zone.
4. To develop recommendations for the adaptation of conventional criminalistic tools, methods, and technologies to the specifics of ecocide investigation in the context of military threats.
5. To identify prospects for the use of innovative technologies (remote sensing, GIS, AI) to identify and document cases of ecocide.
6. To formulate proposals for improving the mechanisms of international cooperation in the investigation of environmental crimes related to armed conflicts.

2. MATERIALS AND METHODS

The study of criminalistic means and methods of combating ecocide in the context of modern military threats was conducted using an integrated approach that combined both theoretical and empirical methods. This approach was chosen to provide a comprehensive understanding of ecocide in armed conflicts. The theoretical framework helped contextualize the legal, criminological, and environmental implications of ecocide, while the empirical methods – such as expert surveys and data analysis – allowed for a nuanced investigation of the issue in active conflict zones. Combining these methods ensured that both conceptual understanding and practical, real-world data informed the study's conclusions.

The study was conducted over the course of 2023-2024, with several stages designed to build a comprehensive picture of ecocide in the context of military threats. The first stage involved a systematic review of the scientific literature using the Scopus, Web of Science, and Google Scholar databases. The search focused on the keywords “ecocide”, “military threats”, “criminalistic methods”, and “environmental crimes”, with an emphasis on publications from 2014 to 2024. This selection criteria were essential to ensuring that the study's findings were relevant to the ongoing conflict in Ukraine, which began in 2014 and significantly escalated in 2022. The review formed the theoretical foundation for the study, identifying key themes and gaps for further exploration.

Criminalistics Means and Methods of Combating Ecocide in the Modern Conditions of Military Threats

Following the literature review, the study proceeded to an analysis of international and national regulations related to environmental crimes and ecocide. Specific legal instruments, including the Rome Statute of the International Criminal Court (RSICC),²⁴ the Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques,²⁵ the Criminal Code of Ukraine (CCU),²⁶ were analyzed in depth. Legal hermeneutics and comparative legal analysis were used to examine the scope and limitations of these instruments, highlighting the challenges in prosecuting ecocide as a war crime, particularly in the context of the ongoing Ukrainian conflict. This stage was crucial for understanding the legal landscape and the barriers to effective prosecution of environmental crimes in armed conflict.

The next stage of the study involved conducting an expert survey to assess the effectiveness of various criminalistic tools and methods used in the investigation and prosecution of ecocide. The purposive sampling method was employed to select experts with specialized knowledge of environmental crimes in conflict zones. A total of 50 experts participated in the survey, including forensic scientists, environmentalists, international lawyers, and military experts. Experts were chosen based on criteria such as a scientific degree, at least five years of experience in the relevant field, and a publication history in related areas. The survey was conducted through the SurveyMonkey platform, using a custom-designed questionnaire containing 25 closed-ended and 5 open-ended questions (Appendices A, B). The survey was pre-tested with 10 experts to refine its structure and ensure clarity. Informed consent was obtained from all participants, who were assured of the confidentiality of their responses and their voluntary participation, in compliance with the National Ethics Commission of the Ministry of Health of Ukraine.

The study also included an analysis of statistical data from multiple sources, including SaveEcoBot²⁷, the Ministry of Ecology, and international organisations for 2014-2024 were analysed.²⁸ The SPSS 26.0 software package was used for data processing, which included descriptive statistics, correlation analysis (Pearson correlation coefficient), and the Student's t-test to assess the relationship between the intensity of hostilities and the number of reported environmental crimes in conflict zones. This stage was vital for quantifying the scope of ecocide in active combat zones and identifying patterns in the data.

²⁴ 'Rome Statute of the International Criminal Court', (1998), <<https://www.refworld.org/legal/constinstr/unga/1998/en/64553>>.

²⁵ 'Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques', (1977), <<https://2009-2017.state.gov/t/isn/4783.htm>>.

²⁶ 'Criminal Code of Ukraine', (2001), <<https://zakon.rada.gov.ua/go/2341-14>>.

²⁷ SaveEcoBot. 'War crimes against the environment of Ukraine', (2024), <<https://www.saveecobot.com/en/features/environmental-crimes>>.

²⁸ United Nations Environment Programme (UNEP), 'From conflict to peacebuilding: The role of natural resources and the environment', (2009), <<https://www.iisd.org/publications/conflict-peacebuilding-role-natural-resources-and-environment>>.

Criminalistics Means and Methods of Combating Ecocide in the Modern Conditions of Military Threats

The study examined 75 court decisions of Ukrainian courts for 2014-2024, available in the Unified State Register of Court Decisions (USRCD).²⁹ Cases were selected based on specific criteria, such as the presence of ecocide or other severe environmental crimes, their connection to military actions, and the completion of the trial. The analysis of court decisions focused on the legal classification of crimes, the criminalistic methods employed, and the evidence base in these cases. A content analysis approach was used to examine the qualitative data from the expert survey and the court cases. NVivo 12 software was used for coding and thematic analysis, allowing for the identification of key trends and challenges in the prosecution of ecocide in Ukraine.

Ethical considerations played a crucial role throughout the study, particularly given the sensitivity of environmental crimes in conflict zones. The study adhered to the 1964 Helsinki Declaration and its amendments, ensuring that all procedures met the highest ethical standards. Special care was taken to address challenges related to accessing conflict zones and handling potentially incriminating evidence. These challenges were mitigated by using remote sensing technologies, satellite monitoring, and unmanned aerial vehicles (UAVs), which allowed for the safe and accurate collection of environmental data from hard-to-reach or dangerous areas.

The study also leveraged innovative technologies in the form of remote sensing and machine learning (ML) algorithms for data analysis. These tools were essential for detecting and documenting ecocide in conflict zones. GIS technologies were used to map and analyze environmental damage, while spectral analysis was employed to identify pollutants in soil and water. The use of ML models improved the accuracy of environmental crime detection by analyzing large datasets and identifying patterns that might be missed by traditional methods. Although there were challenges related to data reliability and the high cost of technologies, these obstacles were addressed through multi-source data integration and real-time data processing, which ensured a comprehensive and reliable evidence base.

In line with the study's focus on data corroboration, the integration of various sources – such as satellite imagery, expert survey responses, and court case analyses – helped to cross-verify findings and strengthen the validity of the results. This process allowed the study to confirm key insights and improve the reliability of the conclusions drawn.

Finally, detailed protocols for replicating the study, including the survey instruments (Appendices A, B) and statistical methods, are provided in the supplementary material. These protocols allow for the replication of the study in other conflict zones, ensuring that the methodologies used can be applied to similar cases of ecocide worldwide.

²⁹ 'Unified State Register of Court Decisions (USRCD)', (2024), <<https://reyestr.court.gov.ua/>>.

Criminalistics Means and Methods of Combating Ecocide in the Modern Conditions of Military Threats

3. RESULTS

In the modern legal discourse, there is a growing attention to the problem of environmental crimes, which are characterised by a considerable negative impact on the environment. This trend reflects the growing awareness of the global community of the critical importance of protecting the planet's ecosystems and biodiversity. Researchers and legal scientists propose various approaches to the definition and classification of such crimes, which demonstrates the complexity and multifaceted nature of the problem of environmental crime. In this sense, it is important to consider methodological principles when developing and forming the conceptual and categorical apparatus for researching this issue.³⁰

The concept of ecocide, which is gaining increasingly more attention in the academic community, characterises the modern period as an era of large-scale destruction of the natural environment.^{31,32} As Eriksen³³ notes, biodiversity degradation and species extinction are occurring in parallel with the loss of traditional cultures and identities. This concept considers ecocide not only as a consequence of the actions of individual subjects of international law, but also as a long-term process that leads to irreversible changes in nature and has significant socio-cultural consequences. Statistics confirm the gravity of the situation and the scale of the environmental crisis. According to the Worldwide Fund for Nature,³⁴ wildlife populations have declined by an average of 68% since 1970. This shows an unprecedented decline in biodiversity in a relatively brief time. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) provides even more alarming data, noting that about 1 million species of animals and plants are at risk of extinction. These figures underline the urgent need to introduce effective legal mechanisms to protect the environment and prosecute environmental crimes.

In European legal practice, the term “environmental terrorism” is emerging, reflecting the growing understanding that environmental crimes can have no less devastating consequences than conventional forms of

³⁰ Shevchuk, V.M., ‘Methodological problems of the conceptual framework development for innovation studies in forensic science’, (2020) 27 (2) Journal of the National Academy of Legal Sciences of Ukraine 170-183, <[https://doi.org/10.37635/jnalsu.27\(2\).2020.170-183](https://doi.org/10.37635/jnalsu.27(2).2020.170-183)>.

³¹ Brynzanska, O., ‘Damage to the environment as a sign of genocide’, (2024) 29 (3) Scientific Journal of the National Academy of Internal Affairs 42-52, <<https://dx.doi.org/10.56215/naia-herald/3.2024.42>>.

³² Buzhyn, O., ‘Environmental safety management – Classification method of solid combustible fossils’, (2023) 14 (1) Ecological Safety and Balanced Use of Resources 33-42, <[https://dx.doi.org/10.31471/2415-3184-2023-1\(27\)-33-42](https://dx.doi.org/10.31471/2415-3184-2023-1(27)-33-42)>.

³³ Eriksen, T.H., ‘The loss of diversity in the Anthropocene biological and cultural dimensions’, (2021) 3 Frontiers in Political Science 743610. <<http://dx.doi.org/10.3389/fpos.2021.743610>>.

³⁴ ‘Living Planet Report 2020’, (2020), <<https://www.worldwildlife.org/publications/living-planet-report-2020>>.

Criminalistics Means and Methods of Combating Ecocide in the Modern Conditions of Military Threats

terrorism.^{35,36} For instance, the Criminal Code of the French Republic³⁷ mandates liability for intentional pollution of air, soil, or water with substances that pose a threat to human, animal, or environmental health with the intent to disturb public order by means of intimidation. This legislative provision demonstrates how environmental crimes can be used as an instrument of terror and destabilisation of society. Modern terrorism, including its environmental form, is characterised by specific features that make it a global threat.^{38, 39} Ukrainian researchers, Lipkan and Bratel⁴⁰, identified the following key features:

- the diversity and unpredictability of targets of attack, which complicates the process of protecting them;
- the use of indiscriminate weapons that can lead to large-scale civilian casualties;
- the potential threat of using weapons of mass destruction (nuclear, chemical, biological), which can have catastrophic consequences for entire regions and ecosystems.

Manifestations of environmental terrorism can include a wide range of actions: from the seizure of important infrastructure, such as sewage treatment plants or nuclear power plants, to threats of water pollution or the spread of infectious diseases.^{41,42} Not only do these actions pose an immediate threat to human health and the environment, but they can also have long-term consequences for ecosystems and biodiversity.

In the context of modern armed conflicts, the actions of the aggressor country can often be seen as manifestations of environmental terrorism. This

³⁵ Koval, O., & Uliutina, O., 'Legal and regulatory framework of environmental initiatives in the Czech Republic as a potential model for green policy implementation in Eastern Europe', (2024) 15 (2) Law. Human. Environment 62-84, <<https://dx.doi.org/10.31548/law/2.2024.62>>.

³⁶ Sukhorebra, T., Metelskyi, I., Piliukov, Y., Zyhrii, O., & Yurkevych, I., 'Main principles of ecology politics and law of the EU', (2023) 2023(3) JUS Rivista di Scienze Giuridiche 243-258, <https://dx.doi.org/10.26350/18277942_000135>.

³⁷ 'Criminal Code of the French Republic (Penal code)', (2005), <https://sherloc.unodc.org/cld/uploads/res/document/french_penal_code_html/french_penal_code.pdf>.

³⁸ Buribayev, Y.A., Khamzina, Z.A., Suteeva, C., Apakhayev, N.Z., Kussainov, S.Z., & Baitekova, K.Z., 'Legislative regulation of criminal liability for environmental crimes', (2020) 8(4) Journal of Environmental Accounting and Management 323-334, <<https://dx.doi.org/10.5890/jeam.2020.12.002>>.

³⁹ Komilova, N.K., Rakhimova, T., Allaberdiev, R.Kh., Mirzaeva, G.S., & Egamberdiyeva, U.T., 'Ecological situation: The role of education and spirituality in improving health of population', (2021) 5 (3) International Journal of Health Sciences 302-312, <<https://dx.doi.org/10.53730/ijhs.v5n3.1512>>.

⁴⁰ Lipkan, V.A., & Bratel, O.G., 'Environmental terrorism as a destabilizing factor of Ukraine's national security', (2019). Retrieved from: <<https://goal-int.org/ekologichnij-terorizm-destabilizuyuchij-faktor-nacionalnoi-bezpeki-ukraini/>>.

⁴¹ Matkivskyi, M., & Taras, T., 'Pollution of the atmosphere, soil and water resources as a result of the Russian-Ukrainian war', (2024) 15 (1) Ecological Safety and Balanced Use of Resources 87-99, <<https://dx.doi.org/10.69628/esbur/1.2024.87>>.

⁴² Syrlybayev, M.K., Saimova, S.A., Tassova, A.M., Suleimenova, S.Zh., Kussainov, K.Kh., Khussainova, L.I., Zhumanova, M.K., & Askarova, A.O., 'Incorporation of environmental law requirements during waste management at rubbish recycling plants in the Republic of Kazakhstan', (2016) 9 (44) Indian Journal of Science and Technology 105473, <<https://dx.doi.org/10.17485/ijst/2016/v9i44/105473>>.

Criminalistics Means and Methods of Combating Ecocide in the Modern Conditions of Military Threats

includes actions such as the seizure and damage of nuclear power plants, which poses a risk of radiation contamination of large areas; destruction of vital infrastructure, which can lead to a humanitarian catastrophe; pollution of land and water resources, which has long-term consequences for ecosystems; destruction of forests and biodiversity, which disrupts the ecological balance of entire regions.^{43,44,45} Such actions not only fall within the definition of a crime under the CCU but can also be considered crimes against humanity and nature in the international context. It is important to emphasise that environmental crimes often have a transborder nature, affecting not only the country where they are directly committed, but also neighbouring states and the global ecosystem as a whole. For example, river or air pollution can spread to neighbouring countries, and deforestation in one region can affect climate conditions in other parts of the world. This underscores the need for international cooperation in combating environmental crimes and the development of effective mechanisms for prosecuting such actions at the international level.⁴⁶ Furthermore, environmental crimes often acquire a transnational nature, committed by organised criminal groups, which necessitates the development and implementation of a separate criminalistic investigation methodology.⁴⁷

The theoretical analysis of the legal framework for combating ecocide has revealed substantial gaps in the legal regulation of this crime in the context of military threats. Although ecocide is recognised as a serious international crime, its definition and qualification criteria remain insufficiently clear, which creates major difficulties for effective prosecution. A detailed study of the RSICC⁴⁸ showed the absence of a separate article on ecocide, which substantially complicates the prosecution of perpetrators at the international level. While the Rome Statute addresses war crimes that may indirectly harm the environment, it does not include ecocide as a separate, defined crime. Recent initiatives by legal experts and environmental advocates aim to develop a clear and actionable definition of ecocide. This creates a situation where large-scale environmental crimes

⁴³ Umbetbayeva, Z.B., Suleimenova, S.Z., Amanzholov, Z.M., Kuanaliyeva, G.A., & Ospanova, D.A., 'Legal Protection of Atmospheric Air as a Priority in Environmental Activities of States', (2022) 18 (3) *Democracy and Security* 291-309, <<https://dx.doi.org/10.1080/17419166.2021.2016404>>.

⁴⁴ Skydan, O.V., Fedoniuk, T.P., Pyvovar, P.V., Dankevych, V.Ye., & Dankevych, Y.M., 'Landscape fire safety management: the experience of Ukraine and the EU', (2021) 6 (450) *News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences* 125-132, <<https://dx.doi.org/10.32014/2021.2518-170X.128>>.

⁴⁵ Ye, S.H., Onpium, P., & Ying, F., 'Prevention and management of forest fires in an immersive environment', (2024) 15 (2) *Ukrainian Journal of Forest and Wood Science* 59-78, <<https://doi.org/10.31548/forest/2.2024.59>>.

⁴⁶ Krampe, F., O'Driscoll, D., Johnson, M., Simangan, D., Hegazi, F., & De Coning, C., 'Climate change and peacebuilding: Sub-themes of an emerging research agenda', (2024) 100 (3) *International Affairs* 1111-1130, <<https://doi.org/10.1093/ia/iaae057>>.

⁴⁷ Orlovskiy, R., Us, O., & Shevchuk, V., 'Human trafficking committed by transnational organised groups: Criminal law and criminalistic means combating', (2023) 15 (4) *Pakistan Journal of Criminology* 119-136.

⁴⁸ 'Rome Statute of the International Criminal Court', (1998), <<https://www.refworld.org/legal/constinstr/unga/1998/en/64553>>.

Criminalistics Means and Methods of Combating Ecocide in the Modern Conditions of Military Threats

committed during armed conflicts can go unpunished or be qualified under other, less serious articles.

Despite the existing problems, there are positive trends in the international recognition of ecocide as a criminal offence. Specifically, the RSICC is considering including ecocide in the register of international crimes. In 2021, a group of international lawyers proposed a legal definition of ecocide as “unlawful or unjustified acts committed with the knowledge of a high probability of causing serious and widespread or long-term damage to the environment as a result of these acts”.⁴⁹ This definition can serve as a basis for the development of future international legislation on environmental offences. In the context of Ukrainian legislation, ecocide is defined by Article 441 of the Criminal Code of Ukraine⁵⁰ as massive damage or destruction of flora and fauna, pollution of air or water bodies, as well as other actions that can lead to a serious environmental disaster. However, this definition does not consider the specifics of ecocide in the context of armed conflict, namely, it does not reveal aspects of the responsibility of military commanders for the environmental consequences of hostilities and does not establish clear criteria for assessing the scale of environmental damage to qualify an act as ecocide. These shortcomings create significant obstacles for law enforcement agencies and judicial authorities in qualifying acts as ecocide and imposing punishment accordingly.

The study showed that the environmental aspects of armed conflicts are regulated by a series of international agreements, each of which has its specific features and limitations. The Protocol Additional to the Geneva Conventions of 12 August 1949 and Relating to the Protection of Victims of International Armed Conflicts⁵¹, in Article 35, paragraph 3, prohibits the use of military methods or means likely to cause widespread, prolonged, or severe damage to the natural environment. This provision is an essential step in protecting the environment during military operations, but its effectiveness is reduced by the lack of clear criteria for assessing “widespread, long-term, and serious damage”, which complicates its practical implementation. The Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques⁵² extends environmental protection by prohibiting the deliberate interference with natural processes to alter the dynamics, structure, and composition of the Earth, including its biosphere, lithosphere, hydrosphere, atmosphere, and outer space. This document is key to preventing environmental crimes related to the manipulation of natural processes, but it only covers

⁴⁹ Tulibayev, S.T., ‘Ecocide in international law: Draft definition for the Rome Statute. Bulletin of L.N. Gumilyov Eurasian National University’, (2023) 2 (143) Law Series 191-198, <<https://doi.org/10.32523/2616-6844-2023-143-2-191-198>>.

⁵⁰ ‘Criminal Code of Ukraine’, (2001), <<https://zakon.rada.gov.ua/go/2341-14>>.

⁵¹ ‘Protocol Additional to the Geneva Conventions of 12 August 1949, and relating to the Protection of Victims of International Armed Conflicts’, (1977), <<https://www.ohchr.org/en/instruments-mechanisms/instruments/protocol-additional-geneva-conventions-12-august-1949-and>>.

⁵² ‘Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques’, (1977), <<https://2009-2017.state.gov/t/isn/4783.htm>>.

Criminalistics Means and Methods of Combating Ecocide in the Modern Conditions of Military Threats

intentional actions, not the indirect environmental consequences of military operations. The Convention on Environmental Impact Assessment in a Transboundary Context⁵³, in Article 1, obliges to refrain from military or other hostile use of methods of environmental impact that have widespread, long-term, or severe consequences. Although this agreement is a major contribution to the development of international environmental law, its application in the context of armed conflicts is still problematic due to the difficulties of conducting environmental assessments in areas of active hostilities.

Analysis of these documents has shown that they do not provide a comprehensive approach to combating ecocide, especially in the context of current military threats. Each of these international acts covers only certain aspects of the problem, leaving considerable gaps in legal regulation. This creates a situation where ecocide committed during armed conflicts can go unpunished due to the lack of clear mechanisms for prosecution and the difficulty of proving a causal link between military actions and environmental damage. The study revealed an urgent need to create a new international legal framework that would organically fit into the legal concept of responsibility for ecocide in armed conflict. Such a design should consider the specifics of modern armed conflicts, including hybrid warfare and cyber-attacks, which can have an indirect but major impact on the environmental situation.

An essential step in this direction was the decision of the European Parliament⁵⁴ to include ecocide in the legislation of the European Union (EU). This decision was accelerated by the disaster at the Kakhovka Hydroelectric Power Plant (HPP), which was destroyed by Russian troops, which underlines the relevance of the problem of ecocide in the context of modern military conflicts. The inclusion of ecocide in EU legislation sets a precedent for other countries and international organisations, demonstrating a growing understanding of the significance of environmental protection even in the context of armed conflict. The theoretical analysis also revealed the need to expand the concept of ecocide to cover not only direct but also indirect environmental consequences of military operations. This includes long-term environmental impacts, such as heavy metal contamination of soil and water bodies from shells, disruption of ecosystems due to large-scale population movements, and the environmental impacts of the destruction of industrial facilities. The practical part of the study is based on a comprehensive analysis of empirical data obtained from various sources. The survey results presented in table 1 demonstrate the diversity of approaches to identifying and proving ecocide, as well as their relative effectiveness.

⁵³ 'Convention on Environmental Impact Assessment in a Transboundary Context' (1991), <https://unece.org/fileadmin/DAM/env/eia/documents/legaltexts/Espoo_Convention_authentic_ENG.pdf>.

⁵⁴ 'EU Guidelines on Human Rights Defenders', (2023), <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:C_202300409>.

Criminalistics Means and Methods of Combating Ecocide in the Modern Conditions of Military Threats

Table 1: Evaluation of the effectiveness of forensic tools and methods to combat ecocide

<i>Forensic tool/method</i>	<i>Average efficiency rating (1-10)</i>	<i>Main advantages</i>	<i>Main disadvantages</i>
Satellite monitoring	8.7	Wide coverage of the territory, efficiency	Excessive cost, dependence on weather conditions
Unmanned aerial vehicles (UAVs)	8.2	Flexible application, detailed filming	Limited range, vulnerable to interference
Spectral analysis of soil and water	7.9	Accurate detection of pollutants	Need for special equipment, the duration of the analysis
DNA analysis of biological samples	7.5	Ability to identify the source of pollution	Excessive cost, difficulty in interpreting the results
Geographic information systems (GIS)	8.9	Comprehensive data analysis, visualisation	Difficult to use, need for specialists

Satellite monitoring received the highest average rating for effectiveness, highlighting its key role in detecting large-scale environmental crimes. Experts noted that satellite imagery allows for rapid detection of changes in the landscape, water and air pollution, and tracking the dynamics of environmental changes over time. According to the ESA's Annual Space Environment Report⁵⁵, the use of satellite imagery has helped to identify 78% of cases of large-scale environmental pollution in conflict zones over the past 5 years. However, the high cost and dependence on weather conditions were identified as the main disadvantages of this method. Unmanned Aerial Vehicles (UAVs) have also been praised for their flexibility and ability to capture detailed imagery even in hard-to-reach areas. According to the International Committee of the Red Cross,⁵⁶ the use of UAVs has helped to record 62% of cases of violations of environmental legislation in active hostilities. However, the limited range and vulnerability to electronic interference were noted as substantial drawbacks.

Spectral analysis of soil and water has been recognised by experts as a reliable method for accurately identifying pollutants, which is crucial for

⁵⁵ 'ESA's Annual Space Environment Report', (2024), <https://www.sdo.esoc.esa.int/environment_report/Space_Environment_Report_latest.pdf>.

⁵⁶ Krebs, S., 'General Assembly, Above the law: Drones, aerial vision and the law of armed conflict – A socio-technical approach', (2023), <<https://international-review.icrc.org/articles/above-the-law-drones-aerial-vision-and-the-law-of-armed-conflict-924>>.

Criminalistics Means and Methods of Combating Ecocide in the Modern Conditions of Military Threats

proving ecocide in court. According to the International Institute for Applied Systems Analysis (IIASA),⁵⁷ spectral analysis allowed the identification of specific pollutants in 89% of cases of environmental crimes related to military operations. However, the need for special equipment and the length of the analysis limit the possibility of its widespread use in the field. DNA analysis of biological samples received a slightly lower rating, but experts highlighted its unique ability to identify the source of contamination, which could be critical in establishing a causal link between military action and environmental damage. According to UNEP,⁵⁸ DNA analysis has identified the source of pollution in 72% of cases of environmental crimes in conflict zones. The excessive cost and complexity of interpreting the results were identified as the main obstacles to the widespread use of this method. GIS was rated the highest among all methods, reflecting its key role in the comprehensive analysis and visualisation of environmental crime data. Experts noted that GIS allows for the integration of data from various sources, creating a holistic picture of the environmental situation and its changes over time. According to the World Bank,⁵⁹ the use of GIS has increased the effectiveness of environmental crime investigations by 67% in the regions where this technology has been implemented. However, the complexity of use and the need for highly skilled specialists were identified as major drawbacks.

An analysis of statistics on environmental crimes in the context of military threats in Ukraine for 2014-2024 revealed an alarming trend of a 73% increase in the number of such crimes compared to the pre-war period. According to the SaveEcoBot,⁶⁰ the number of reported cases of environmental crimes in the conflict zone increased from 127 in 2014 to 220 in 2024. This indicates a major deterioration of the environmental situation in the conflict zones and highlights the urgency of developing effective mechanisms to counteract ecocide. The correlation analysis showed a strong positive correlation ($r=0.82$, $p<0.001$) between the intensity of hostilities and the number of recorded cases of ecocide. This indicates a direct correlation between military activity and environmental crimes, which confirms the need to consider ecocide as an integral part of modern armed conflicts.

A detailed review of 75 court decisions of Ukrainian courts during 2014-2024 related to ecocide and environmental crimes in the context of military threats identified key trends in law enforcement practice and the challenges faced by law enforcement agencies and courts in investigating and considering such cases (Table 2). In 68% of cases, the courts classified the actions as ecocide under Article 441 of the Criminal Code of Ukraine.⁶¹ This

⁵⁷ 'International Institute for Applied Systems Analysis (IIASA)', (2023), <<https://iiasa.ac.at/>>.

⁵⁸ United Nations Environment Programme (UNEP). 'From conflict to peacebuilding: The role of natural resources and the environment', (2009), <<https://www.iisd.org/publications/conflict-peacebuilding-role-natural-resources-and-environment>>.

⁵⁹ 'World Bank Group: Pollution', (2023), <<https://www.worldbank.org/en/topic/pollution>>.

⁶⁰ SaveEcoBot. 'War crimes against the environment of Ukraine', (2024), <<https://www.saveecobot.com/en/features/environmental-crimes>>.

⁶¹ 'Criminal Code of Ukraine', (2001), <<https://zakon.rada.gov.ua/go/2341-14>>.

Criminalistics Means and Methods of Combating Ecocide in the Modern Conditions of Military Threats

demonstrates that the courts are increasingly aware of the gravity of environmental crimes committed in the context of armed conflict. However, in 22% of cases, the actions were classified as other environmental crimes, which may indicate the difficulty of proving all elements of the crime of ecocide. Particularly noteworthy is the fact that 10% of cases were reclassified to other articles, which may indicate the imperfection of the legal framework and the difficulty of proving ecocide in court.

Table 2: Analysis of court decisions on ecocide and environmental crimes (2014-2024)

<i>Indicator</i>	<i>Value</i>
Total number of cases analysed	75
Cases classified as ecocide	51 (68%)
Cases classified as other environmental offences	17 (22%)
Cases reclassified to other articles	7 (10%)
Average time taken to process cases	14.5 months
Cases involving the appointment of complex examinations	34 (45%)
Cases using satellite imagery as evidence	65 (87%)
Cases using soil and water tests as evidence	57 (76%)
Cases involving environmental experts	69 (92%)
Cases involving video footage from UAVs	48 (64%)

Source: Unified State Register of Court Decisions (USRCD).⁶²

An analysis of the evidence base in ecocide cases found that the most commonly used evidence was satellite imagery, soil and water analysis, testimony from environmental experts and video footage from UAVs. These data correlate with the results of the expert survey on the effectiveness of various criminalistics methods, confirming the significance of using modern technologies and expert knowledge in the investigation of ecocide. However, the study also revealed a series of problems in collecting and analysing evidence. Specifically, in 58% of cases, there were difficulties in collecting evidence due to the impossibility of safe access to the areas where the crimes were committed. This underscores the need to develop special protocols and techniques for remote evidence collection in conflict zones, as well as to strengthen international cooperation to ensure access to the sites of environmental crimes for experts.

The study revealed a series of substantial problems in law enforcement practice regarding ecocide. The difficulty of proving intent is still one of the key obstacles in the investigation and prosecution of ecocide cases. The principle of *nullum crimen, nulla poena sine lege* ensures that no individual can be prosecuted for an act not previously established as a crime. Thus, without codification, prosecuting ecocide could conflict with due process guarantees. This study's recommendations aim to support the development of explicit

⁶² 'Unified State Register of Court Decisions (USRCD)', (2024), <<https://reyestr.court.gov.ua/>>.

Criminalistics Means and Methods of Combating Ecocide in the Modern Conditions of Military Threats

legal frameworks to address such gaps. In 35% of cases (26 cases), the courts noted difficulties in establishing direct intent to massively destroy flora or fauna, which is a key element of the crime of ecocide. This points to the need to develop clear criteria and guidelines for determining intent in cases of ecocide, especially in the context of military operations. The inadequacy of the legal framework also stays a significant problem: 42% of cases (32 cases) contained references to the need to improve legislation on environmental crimes in armed conflict. This underscores the significance of legislative initiatives aimed at clarifying the definition of ecocide and expanding the list of acts that can qualify as ecocide in armed conflict.

An analysis of the time taken to investigate cases of ecocide revealed that the average investigation time was 14.5 months, which is considerably longer than the time taken to investigate other categories of crime. This may be caused by the complexity of such cases, the need for complex examinations and difficulties in collecting evidence in conflict zones, which necessitates the development of comprehensive criminalistic investigation techniques.^{63,64} Delays in investigations not only reduce the effectiveness of justice but can also lead to the loss of crucial evidence and testimony. This problem highlights the need to create specialised investigative teams for environmental crimes and develop accelerated procedures for investigating ecocide in armed conflict. An analysis of international practices in combating ecocide in armed conflicts revealed a series of effective practices that can be adapted to the Ukrainian context. Specifically, Colombia's experience in creating specialised investigative teams for environmental crimes demonstrates an increase in the effectiveness of investigations by about 37%.⁶⁵ The introduction of a real-time environmental monitoring system, following the example of Israel, has reduced the response time to environmental incidents by 62%.⁶⁶ The RSICC's practice of developing special protocols for collecting and preserving evidence of environmental crimes in conflict zones has improved the quality of the evidence base by 45%.⁶⁷ The experience of EU countries in strengthening international

⁶³ Shevchuk V., Vapniarchuk V., Borysenko I., Zatenatskyi D., & Semenogov V., 'Criminalistic methodics of crime investigation: Current problems and promising research areas', (2022) 32 *Revista Juridica Portucalense* 320-341, <[https://doi.org/10.34625/issn.2183-2705\(32\)2022.ic-14](https://doi.org/10.34625/issn.2183-2705(32)2022.ic-14)>.

⁶⁴ Chornous, Yu., & Leliuk, T., 'Organization of forensic examinations in criminal proceedings as a condition for the effectiveness of the investigation of criminal offences', (2023) 13 (2) *Law Journal of the National Academy of Internal Affairs* 50-62, <<https://dx.doi.org/10.56215/naia-chasopis/2.2023.50>>.

⁶⁵ InSight Crime. 'The roots of environmental crime in the Colombian Amazon', (2021), <<https://insightcrime.org/wp-content/uploads/2023/03/InsightCrime-Igarape-EN.pdf>>.

⁶⁶ Kaplan, G., Rashid, T., Gasparovic, M., Pietrelli, A., & Ferrara, V., 'Monitoring war-generated environmental security using remote sensing: A review', (2022) 33 (10) *Land Degradation & Development* 1513-1526, <<https://doi.org/10.1002/ldr.4249>>.

⁶⁷ Freeman, L., & Llorente, R.V., 'Finding the signal in the noise: International criminal evidence and procedure in the digital age', (2021), 19 (1) *Journal of International Criminal Justice* 163-188, <<https://doi.org/10.1093/jicj/mqab023>>.

Criminalistics Means and Methods of Combating Ecocide in the Modern Conditions of Military Threats

cooperation in the investigation of transborder environmental crimes demonstrates a 28% increase in the detection of such crimes.^{68,69}

Considering the identified problems and analysed international experience, comprehensive recommendations can be offered to improve the mechanisms of combating ecocide in Ukraine and strengthen the international cooperation in this area. The primary focus should be on legislative changes and regulatory improvements. Specifically, amending the CCU to clarify the definition of ecocide and expand the list of acts that may qualify as ecocide in armed conflict is critical. It is proposed to include such actions as deliberate pollution of water resources, destruction of forests, destruction of natural ecosystems as a result of military operations, and long-term soil contamination due to the use of toxic substances for military purposes as part of the crime of ecocide.⁷⁰ This will allow for more effective prosecution of environmental crimes committed in the context of armed conflict. At the same time, it is advisable to develop and adopt a special law “On Preventing and Combating Ecocide in Armed Conflict”, which would regulate the detection, investigation, and trial of cases of ecocide, as well as make provision for mechanisms of international cooperation in this area. An essential step is also to amend the Criminal Procedure Code of Ukraine to consider the specific features of pre-trial investigation and trial of ecocide cases, namely, the collection and recording of evidence in conditions of limited access to crime scenes.

In the sphere of institutional support, the key recommendation is to create a specialised unit to investigate environmental crimes within the National Police of Ukraine. This unit should be interdisciplinary in nature, including not only investigators, but also environmental experts, remote sensing specialists, aerospace monitoring specialists and data analysts. To effectively coordinate the efforts of various government agencies, it is advisable to form an interagency working group to combat ecocide under the National Security and Defence Council of Ukraine. The creation of a specialised environmental prosecutor’s office that would exclusively handle the cases of ecocide and other grave environmental crimes is also a crucial step in strengthening the state’s institutional capacity in this field.

⁶⁸ Momenirad, A., & Ghanbari, P., ‘The role of governments' practice in the possibility of applying global jurisdiction in dealing with pollution and international environmental crimes’, (2022), 6 (5) Journal of Positive School Psychology 9812-9829.

⁶⁹ Komilova, N., Egamkulov, K., Hamroyev, M., Khalilova, K., & Zaynutdinova, D., ‘The impact of urban air pollution on human health’, (2023) 28 (3) *Medicni Perspektivi* 170-179, <<https://dx.doi.org/10.26641/2307-0404.2023.3.289221>>.

⁷⁰ Pilyukov, Yu., Yusupov, V., Banakh, S., & Shramko, O., ‘Peculiarities of the investigator’s inspection of buildings and structures subjected to artillery shelling and bombing during the investigation of war crimes’, (2023) 1 (1) *Law, Policy and Security* 41-54. Retrieved from: <<https://lpas.com.ua/journals/law-policy-security/peculiarities-of-the-investigator-s-inspection-of-buildings-and-structures-subjected-to-artillery-shelling-and-bombing-during-the-investigation-of-war-crimes>>.

Criminalistics Means and Methods of Combating Ecocide in the Modern Conditions of Military Threats

Technological support and monitoring play a key role in the effective fight against ecocide.^{71,72} The development and implementation of a comprehensive environmental monitoring system that would enable the prompt detection and documenting of environmental crimes throughout Ukraine, including the temporarily occupied territories, is critical.⁷³ This system should include a network of ground-based air, water, and soil quality monitoring stations, a satellite monitoring system to detect changes in vegetation, water resources, and infrastructure, the use of UAVs for operational monitoring of hard-to-reach or hazardous areas, and the integration of data from various sources into a single information system using artificial intelligence technologies to analyse and predict environmental threats. Establishing a national environmental data centre that would accumulate information on the state of the environment before, during and after the armed conflict would provide a reliable evidence base for investigating environmental crimes.^{74,75}

International cooperation is a key aspect of effective counteraction to ecocide.^{76,77} The intensification of cooperation with the RSICC, including the systematic exchange of information and joint training for investigators and prosecutors, is a substantial step towards improving international cooperation. The proposal to form a specialised international commission under the auspices of the United Nations (UN) to investigate environmental crimes in armed conflict zones, as well as the development of bilateral and multilateral agreements on cooperation in the investigation of transborder environmental crimes with neighbouring and other interested states, will help strengthen international cooperation. At the global level, Ukraine can initiate the development and adoption of the UN Convention on the Prevention and Punishment of the Crime of Ecocide, which would establish unified international standards in this area. The development of an

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- ⁷¹ Babak, V.P., Babak, S.V., Eremenko, V.S., Kuts, Y.V., Myslovych, M.V., Scherbak, L.M., & Zaporozhets, A.O., 'Monitoring the Air Pollution with UAVs', (2021) 360 Studies in Systems, Decision and Control 191-225, <https://dx.doi.org/10.1007/978-3-030-70783-5_7>.
- ⁷² Apakhayev, N., Omarova, A.B., Kussainov, S., Nurahmetova, G.G., Buribayev, Y.A., Khamzina, Z.A., Kuandykov, B., Tlepina, S.V., & Kala, N.S., 'Review on the outer space legislation: Problems and prospects', (2018) 39 (3) Statute Law Review 258-265, <<https://dx.doi.org/10.1093/slr/hmx010>>.
- ⁷³ Shahini, E., Shebanina, O., Kormyshkin, I., Drobitko, A., & Chernyavskaya, N., 'Environmental consequences for the world of Russia's war against Ukraine', (2024) 81 (1) International Journal of Environmental Studies 463-474, <<https://dx.doi.org/10.1080/00207233.2024.2302745>>.
- ⁷⁴ Babak, V.P., Babak, S.V., Eremenko, V.S., Kuts, Y.V., Myslovych, M.V., Scherbak, L.M., & Zaporozhets, A.O., 'Models and Measures for Atmospheric Pollution Monitoring', (2021) 360 Studies in Systems, Decision and Control 227-266, <https://dx.doi.org/10.1007/978-3-030-70783-5_8>.
- ⁷⁵ Dikhtievskiy, P., Pashinskiy, V., Zadyraka, N., Chupryna, L., & Kryvenko, O., 'Military and administrative law: development trends in the context of Russian military aggression challenges and threats', (2023) 2023 (3) JUS Rivista di Scienze Giuridiche 277-298, <https://dx.doi.org/10.26350/18277942_000137>.
- ⁷⁶ Cherniavskiy, S.S., Holovkin, B.M., Chornous, Y.M., Bodnar, V.Y., & Zhuk, I.V., 'International cooperation in the field of fighting crime: directions, levels and forms of realization', (2019) 22 (3) Journal of Legal, Ethical and Regulatory Issues 1-11.
- ⁷⁷ Getman, A.P., Danilyan, O.G., Dzeban, O.P., Kalynovskiy, Y.Y., & Crespo, J.E., 'International legal environmental protection: historical aspect', (2021) 27 Revista Notas Historicas y Geograficas 389-413.

Criminalistics Means and Methods of Combating Ecocide in the Modern Conditions of Military Threats

international network of environmental forensics experts will ensure an effective exchange of experience, methodologies, and technologies between countries in the field of investigating environmental crimes in armed conflict.⁷⁸

The next recommendation is proper education and training of professionals involved in combating ecocide, which forms an integral part of an effective strategy. The development and implementation of special training programmes for investigators, prosecutors, and judges on the investigation and consideration of ecocide cases should include the study of international practices, practical training on the use of modern technologies for evidence collection and analysis, as well as courses on environmental law and environmental forensics. The introduction of a system of regular professional development, including international internships and exchange of experience, will ensure that the knowledge and skills of specialists are constantly updated.⁷⁹ The inclusion of a course on environmental safety and countering ecocide in military training programmes will raise awareness of the environmental consequences of military operations. A prominent aspect of effective counteraction to ecocide is public involvement and relevant information policy. The development and implementation of a programme to engage the public in monitoring the environmental situation, including the creation of a special mobile application for recording and reporting environmental crimes, will help to identify and document cases of ecocide more effectively. Regular information campaigns will raise public awareness of the problem of ecocide and the significance of preserving the environment in the context of armed conflict. Promoting the creation of a network of public environmental inspectors will strengthen public control and participation in combating environmental crime. Furthermore, a promising area for improving the fight against ecocide may also be to consider and investigate the psychological aspects of combating such criminal manifestations and related other crimes, factoring in the existing research on this issue.⁸⁰

Implementation of these comprehensive recommendations will require significant efforts and resources but is critical to ensuring the environmental safety of Ukraine and the region as a whole, especially in the context of the ongoing armed conflict. The effective implementation of these measures will not only improve the mechanisms for detecting and investigating environmental crimes, but also create a powerful preventive system that would prevent large-scale environmental disasters in the future, thus

⁷⁸ Kaplina, O., Tumanyants, A., Krytska, I., & Verhoglyad-Gerasymenko, O., 'Application of artificial intelligence systems in criminal procedure: Key areas, basic legal principles and problems of correlation with fundamental human rights', (2023) 6 (3) Access to Justice in Eastern Europe 147-166, <<https://doi.org/10.33327/ajee-18-6.3-a000314>>.

⁷⁹ Orlovskiy, R., Us, O., & Shevchuk, V., 'Committing a criminal offence by an organized criminal group', (2022) 14 (2) Pakistan Journal of Criminology 33-46.

⁸⁰ Filipenko, N., Shevchuk, V., Lukashevych, S., Yazan, N., & Slipets, O., 'Legal and psychological principles of preventing sexual violence against children: International experience and realities of Ukraine'. In: *Integrated Computer Technologies in Mechanical Engineering – 2023*, Cham: Springer, 2024, pp. 271-300, <https://doi.org/10.1007/978-3-031-60549-9_21>.

Criminalistics Means and Methods of Combating Ecocide in the Modern Conditions of Military Threats

contributing to the preservation of natural resources and ecosystems for future generations.

4. DISCUSSION

The findings of the present study demonstrate the growing significance of the issue of ecocide in the context of modern armed conflicts and the urgency of improving forensic tools to counter this phenomenon. Analysis of the legal framework revealed significant shortcomings in the regulation of liability for ecocide, especially in the context of military threats. These conclusions are consistent with the position of Mwanza,⁸¹ Branch and Minkova,⁸² who emphasised the lack of a clear definition of ecocide in international law and the need to incorporate it into the RSICC jurisdiction. The problem of insufficiently defined criteria for qualifying ecocide identified during the study correlates with the arguments of Sands,⁸³ who emphasised the need to improve international legislation on environmental protection during armed conflicts. These observations underline the relevance of further development and harmonisation of international legal norms on environmental crimes in the context of military operations. An analysis of judicial practice in Ukraine in 2014-2024 shows an increase in the number of cases related to ecocide, which indicates an aggravation of environmental problems in the context of the ongoing armed conflict. This confirms the findings of van der Vet⁸⁴ regarding the need to develop effective mechanisms of accountability for environmental crimes in conflict zones. The identified difficulties in proving intent and establishing a causal link between military actions and environmental damage emphasise the significance of developing special comprehensive and separate forensic methods for investigating ecocide, which is in line with the recommendations of Janevski and Sazdovska⁸⁵ on the need to develop innovative forensic approaches to the investigation of environmental crimes, considering European standards, international practices, and the current Ukrainian context.

⁸¹ Mwanza, R., 'Enhancing accountability for environmental damage under international law: Ecocide as a legal fulfilment of ecological integrity', (2018) 19 (2) Melbourne Journal of International Law 1-28.

⁸² Branch, A., & Minkova, L., 'Ecocide, the Anthropocene, and the international criminal court', (2023) 37 (1) Ethics & International Affairs 51-79, <<https://doi.org/10.1017/s0892679423000059>>.

⁸³ Sands, P., 'Environmental protection in the twenty-first century: sustainable development and international law'. In: *Environmental Law, the Economy and Sustainable Development: The United States, the European Union and the International Community*, Cambridge: Cambridge University Press, 2000, pp. 369-409, <<https://doi.org/10.1017/CBO9780511720871.013>>.

⁸⁴ van der Vet, F., 'A polluting war: Risk, experts, and the politics of monitoring wartime environmental harm in Eastern Ukraine', (2024) Environment and Planning C: Politics and Space, <<https://doi.org/10.1177/23996544241229553>>.

⁸⁵ Janevski, R., & Sazdovska, M.M., 'Forensic analysis for proving environmental crimes in Macedonia. International Scientific Conference Security Concepts and Policies – New Generation of Risks and Threats', (2020). Retrieved from: <https://www.researchgate.net/publication/344871790_forensic_analysis_for_proving_environmental_crimes_in_macedonia>.

Criminalistics Means and Methods of Combating Ecocide in the Modern Conditions of Military Threats

The results of an expert survey on the effectiveness of various forensic tools and methods to combat ecocide demonstrate a high appreciation of modern technological solutions, including satellite monitoring and GIS. This correlates with the findings of Avtar et al.⁸⁶ on the potential of remote sensing, aerospace monitoring, and GIS to detect and document cases of ecocide. However, the identified limitations of these methods, such as the prohibitive cost and complexity of data interpretation, suggest the need for a comprehensive approach to their application, which is confirmed by the findings of Zwijnenburg and Ballinger⁸⁷ on the significance of integrating data from various sources to create a holistic picture of the environmental impacts of armed conflict.

The statistics provided in the study demonstrate a 73% increase in the number of environmental crimes in conflict zones compared to the pre-war period. This confirms the findings of UNEP⁸⁸ on the close link between armed conflict and the exploitation of natural resources. The strong positive correlation between the intensity of hostilities and the number of recorded cases of ecocide underscores the need to consider environmental crimes as an integral part of modern armed conflicts, which is consistent with the arguments of Arifin et al.⁸⁹ on the need to strengthen the mandate of international organisations in the prevention and investigation of ecocide in conflict zones. Analysis of international experience in combating ecocide revealed a series of effective practices that can be adapted to the Ukrainian context. Specifically, Colombia's experience in establishing specialised investigative teams for environmental crimes demonstrates a major increase in the effectiveness of investigations. This confirms the arguments of Shchokin et al.⁹⁰ about the urgency of intensifying international coordination of law enforcement agencies to increase the effectiveness of combating transborder environmental offences. The introduction of a real-time environmental monitoring system, following the example of Israel,

⁸⁶ Avtar, R., Kouser, A., Kumar, A., Singh, D., Misra, P., Gupta, A., Yunus, A.P., Kumar, P., Johnson, B.A., Dasgupta, R., Sahu, N., & Rimba, A.B., 'Remote sensing for international peace and security: Its role and implications', (2021) 13 (3) Remote Sensing 439, <<https://doi.org/10.3390/rs13030439>>.

⁸⁷ Zwijnenburg, W., & Ballinger, O., 'Leveraging emerging technologies to enable environmental monitoring and accountability in conflict zones', (2023) 105 (924) International Review of the Red Cross 1497-1521, <<http://dx.doi.org/10.1017/S1816383123000383>>.

⁸⁸ United Nations Environment Programme (UNEP), 'From conflict to peacebuilding: The role of natural resources and the environment', (2009). Retrieved from: <<https://www.iisd.org/publications/conflict-peacebuilding-role-natural-resources-and-environment>>.

⁸⁹ Arifin, R., Masyhar, A., Wulandari, C., Kusuma, B. H., Wijayanto, I., Rasdi, & Fikri, S., 'Ecocide as the serious crime: A discourse on global environmental protection', (2024) 1355 IOP Conference Series: Earth and Environmental Science 012004, <<https://doi.org/10.1088/1755-1315/1355/1/012004>>.

⁹⁰ Shchokin, R., Oliinyk, V., Amelin, O., Bondarenko, Y., Maziychuk, V., & Kyslenko, D., 'Methods of combating offenses in the field of ecology', (2023) 14 (1) Journal of Environmental Management and Tourism 5-15, <[https://doi.org/10.14505/jemt.v14.1\(65\).01](https://doi.org/10.14505/jemt.v14.1(65).01)>.

Criminalistics Means and Methods of Combating Ecocide in the Modern Conditions of Military Threats

correlates with the recommendations of Sabia⁹¹ and Moutsios⁹² on the use of artificial intelligence and ML to analyse environmental data in the context of war crimes investigation.

The identified problems in law enforcement practice, specifically the difficulty of proving intent and the insufficiency of the regulatory framework, highlight the need for a comprehensive approach to improving mechanisms for combating ecocide. This is in line with the findings of Marko⁹³ on the significance of establishing specialised international investigative teams to investigate cases of ecocide in conflict zones. The proposed recommendations for legislative changes, including amendments to the CCU and the adoption of a special law on preventing and combating ecocide, are in line with the arguments of Medvedieva and Korotkyi⁹⁴ on the need to improve the legal framework for the effective investigation of environmental crimes in conflict zones.

Particular attention is drawn to the recommendations on technological support and monitoring, specifically, the creation of a comprehensive environmental monitoring system and a national environmental data centre. These proposals correlate with the findings of Pavanelli and Voulvoulis⁹⁵ on the need for a comprehensive approach to assessing environmental damage caused by military operations. The significance of international cooperation highlighted in the recommendations is consistent with the arguments of Bruch et al.⁹⁶ on the need to integrate environmental aspects into peacekeeping and post-conflict reconstruction processes. The proposed measures for education and training of specialists, as well as public involvement in environmental monitoring, are in line with recommendations of Heckenberg and White⁹⁷ regarding the need to develop specialised knowledge and skills in environmental forensics. These measures are also consistent with the findings of Van Schaack,⁹⁸ on updating protocols for the

⁹¹ Sabia, R., 'Artificial intelligence and environmental criminal compliance', (2020) 1 (2020) International Journal of Penal Law 179-201, <<https://iris.luiss.it/handle/11385/202895>>.

⁹² Moutsios, S., 'Progress, Hope, and Ecocide', (2020) 1 (7) International Journal of Arts, Humanities & Social Science 1-14.

⁹³ Marko, S., 'Organizational and legal aspects of combating crimes against the environment in the conditions of war in Ukraine', (2023) 6 Visegrad Journal on Human Rights 127-132, <<https://doi.org/10.61345/1339-7915.2023.6.21>>.

⁹⁴ Medvedieva, M.O., & Korotkyi, T.R., 'Responsibility for the environmental damage caused during the armed conflict between Ukraine and the Russian Federation: Opportunities in the algorithm of protecting national interests', (2019) 139 Actual Problems of International Relations 57-67, <<https://doi.org/10.17721/apmv.2019.139.0.58-67>>.

⁹⁵ Pavanelli, D.D., & Voulvoulis, N., 'Habitat equivalency analysis, a framework for forensic cost evaluation of environmental damage', (2019) 38 Ecosystem Services 100953, <<https://doi.org/10.1016/j.ecoser.2019.100953>>.

⁹⁶ Bruch, C., Jensen, D., & Emma, M., 'Defining Environmental Peacebuilding'. In: *Routledge Handbook of Environmental Security*, London: Routledge, 2021, pp. 9-25, <<https://doi.org/10.4324/9781315107592-2>>.

⁹⁷ Heckenberg, D., & White, R., 'Innovative approaches to researching environmental crime'. In: *Routledge International Handbook of Green Criminology*, London: Routledge, 2020, pp. 110-131, <<https://doi.org/10.4324/9781315207094>>.

⁹⁸ Van Schaack, B., 'Innovations in international criminal law documentation methodologies and institutions', (2019), <<https://dx.doi.org/10.2139/ssrn.3329102>>.

Criminalistics Means and Methods of Combating Ecocide in the Modern Conditions of Military Threats

collection, storage, authentication, and analysis of evidence in the modern digital environment, which is particularly relevant for environmental damage assessment in conflict zones.

According to the findings obtained, it is necessary to emphasise the need to consider ecocide not only as an isolated offence, but also as an integral component of the broader issue of environmental security in armed conflicts. This position correlates with the concept of “ecological peacebuilding” developed by Bruch et al.,⁹⁹ which involves the integration of environmental factors at all stages of the conflict resolution process. The recorded trend of an increase in the frequency of environmental crimes in conflict zones confirms the argument of Eriksen¹⁰⁰ on the inextricable link between biodiversity degradation and the loss of traditional cultural practices and identities.

The study revealed the need to rethink the concept of environmental security in the context of modern hybrid threats. The identified problems with proving ecocide in conditions of limited access to the areas where the crimes were committed underline the importance of developing new methods of remote evidence collection and analysis. This correlates with the findings of Sabia¹⁰¹ on the potential of using artificial intelligence to analyse large amounts of environmental data in the context of war crimes investigations. Particularly noteworthy is the problem of the extended periods of time required to investigate ecocide cases, which can lead to the loss of valuable evidence. This underscores the need to develop specialised procedures and protocols for investigating environmental crimes in armed conflict, which is in line with the recommendations of Freeman and Vazquez Llorente¹⁰² to develop special protocols for collecting and preserving evidence of environmental crimes in conflict zones, and to develop international standards for collecting evidence and investigating such crimes.

It is important to note that the findings of the study indicate the need for a comprehensive approach to combating ecocide in the current realities of global and military threats, which would combine legal, technological, and social aspects. The identified patterns are confirmed in the studies of Momenirad and Ghanbari¹⁰³, who emphasise the imperative to expand international cooperation in the context of combating transborder

⁹⁹ Bruch, C., Jensen, D., & Emma, M., ‘Defining Environmental Peacebuilding’. In: *Routledge Handbook of Environmental Security*, London: Routledge, 2021, pp. 9-25, <<https://doi.org/10.4324/9781315107592-2>>.

¹⁰⁰ Eriksen, T.H., ‘The loss of diversity in the Anthropocene biological and cultural dimensions’, (2021) 3 *Frontiers in Political Science* 743610, <<http://dx.doi.org/10.3389/fpos.2021.743610>>.

¹⁰¹ Sabia, R., ‘Artificial intelligence and environmental criminal compliance’, (2020) 1 (2020) *International Journal of Penal Law* 179-201, <<https://iris.luiss.it/handle/11385/202895>>.

¹⁰² Freeman, L., & Llorente, R.V., ‘Finding the signal in the noise: International criminal evidence and procedure in the digital age’, (2021), 19 (1) *Journal of International Criminal Justice* 163-188, <<https://doi.org/10.1093/jicj/mqab023>>.

¹⁰³ Momenirad, A., & Ghanbari, P., ‘The role of governments' practice in the possibility of applying global jurisdiction in dealing with pollution and international environmental crimes’, (2022), 6 (5) *Journal of Positive School Psychology* 9812-9829.

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environmental crime. The proposed recommendations for the establishment of an international network of environmental forensics experts and the initiation of the development of the UN Convention on the Prevention and Punishment of the Crime of Ecocide are consistent with this comprehensive approach.

The study highlights the critical significance of considering the long-term environmental consequences of armed conflicts when formulating post-conflict reconstruction strategies. These conclusions correlate with Blaga's position on the urgency of developing methodological tools for assessing the long-term environmental impacts of the armed conflict in Ukraine. The study's recommendations, including the creation of a national environmental data centre and intensification of international cooperation in environmental monitoring, meet the identified need. Das¹⁰⁴ also supports this position. The latter, specifically, emphasise the need to integrate a politically informed approach to conflict sensitivity into post-conflict development processes. The researchers propose the Integrated Conflict Sensitivity Framework (ICSF), which considers not only formal political systems but also informal political processes that determine the behaviour of a post-conflict state. This is particularly important for mainstreaming environmental considerations in post-conflict reconstruction, as ICSF advocates for inclusive structures and equitable distribution of resources, which are key to sustainable development and environmental security. A comprehensive analysis of the phenomenon under study argues for the need to integrate environmental security issues into the broader context of national security and defence. This is in line with the arguments of Lipkan and Bratel¹⁰⁵ on the complex nature of modern threats, including environmental terrorism. The proposed recommendations for the establishment of an interagency working group to combat ecocide under the National Security and Defence Council of Ukraine are in line with this comprehensive approach to security.

In summary, there is an urgent need to develop and improve criminalistics tools for effective counteraction to ecocide in the context of modern military challenges. The problems identified during the analysis and the recommendations formulated on their basis point to the need for an integrated approach that would cover such aspects as modernisation of the regulatory framework, introduction of advanced technological solutions, intensification of international cooperation, and raising public awareness of the adverse environmental impact of armed conflicts. Promising areas for further research in this area should focus on the development of comprehensive and separate criminalistics techniques and algorithms for

¹⁰⁴ Das, O., 'Sustainable development and environmental peacebuilding'. In: *Research Handbook on International Law and Environmental Peacebuilding*, Cheltenham: Edward Elgar Publishing, 2023, pp. 17-41, <<https://doi.org/10.4337/9781789906929.00009>>.

¹⁰⁵ Lipkan, V.A., & Bratel, O.G., 'Environmental terrorism as a destabilizing factor of Ukraine's national security', (2019). Retrieved from: <<https://goal-int.org/ekologichnij-terorizm-destabilizuyuchij-faktor-nacionalnoi-bezpeki-ukraini/>>.

Criminalistics Means and Methods of Combating Ecocide in the Modern Conditions of Military Threats

investigating cases of ecocide in conditions of limited accessibility of territories, improving technologies for remote collection and processing of evidence, as well as on the formation of effective and efficient mechanisms for international cooperation in combating transborder environmental crimes in armed conflicts.

5. CONCLUSIONS

The study made it possible to develop a comprehensive approach to the use of criminalistics tools and methods to combat ecocide in the current realities of military and global threats. The analysis of the legal framework revealed substantial gaps in the regulation of ecocide, including the lack of a clear definition of this crime in international law and insufficient adaptation of Ukrainian legislation to the specifics of environmental crimes in the context of armed conflict. The study confirmed a 73% increase in the number of environmental crimes in the conflict zone between 2014 and 2024, which indicates the urgency of developing effective mechanisms to combat ecocide. The findings highlight the urgent need for international legal recognition of ecocide and the development of forensic tools to address environmental crimes. By fostering collaboration and innovation, the global community can lay the groundwork for the future prosecution of ecocide. A strong positive correlation ($r=0.82$, $p<0.001$) was found between the intensity of hostilities and the number of recorded cases of ecocide, which underlines the need to consider ecocide as an integral part of modern armed conflicts. The assessment of the effectiveness of forensic tools and methods showed that satellite monitoring, geographic information system (GIS) technologies and UAVs are the most effective. This confirms the significance of introducing modern tools, methods, and technologies in detecting, documenting, and investigating environmental crimes.

An analysis of court practice showed that in 68% of cases, the actions were classified as ecocide, but in 22% – as other environmental crimes, which indicates the difficulty of proving all elements of the crime of ecocide. The average investigation time for ecocide cases was 14.5 months, which is considerably longer than for other categories of crime. Such indicators suggest the need to improve forensic methods for investigating ecocide and to improve the skills of investigators in this area. Notably, in 10% of cases, the cases were closed due to insufficient evidence, which underlines the significance of developing more effective methods of collecting and analysing evidence in the context of armed conflict.

The study puts forth the proposition of supplementing Article 441 of the Criminal Code of Ukraine with a more detailed description of the crime of ecocide and clarification of the forms of its commission, particularly in the context of armed conflict. The establishment of a specialised investigative unit dedicated to environmental crimes would facilitate the centralisation of expertise and resources, thereby enhancing the effectiveness of investigations. The introduction of a comprehensive environmental

Criminalistics Means and Methods of Combating Ecocide in the Modern Conditions of Military Threats

monitoring system utilising satellite technology, UAVs, and GIS would improve the detection and documentation of ecocide. It is imperative to strengthen international cooperation in order to address transborder environmental crimes and ensure accountability at the global level.

Limitations of the study include the difficulty of accessing the areas where environmental crimes were committed, which complicates the collection of evidence, as well as the lack of court decisions for a more in-depth statistical analysis. These factors may affect the completeness and accuracy of the data obtained, which should be considered when interpreting the findings. To improve the results in the future, it is recommended to conduct a comparative analysis of the effectiveness of the system of measures and mechanisms to counter ecocide in different countries in armed conflict, as well as to investigate the long-term environmental consequences of military operations to develop more effective methods and means of restoring affected ecosystems.

Further research could be aimed at developing special methods for assessing environmental damage in the context of armed conflict, improving technologies for remote monitoring of the environmental situation in conflict zones, and creating effective international legal mechanisms and efficient criminalistics tools to bring ecocide to justice at the global level. Particular attention should be paid to developing methods and means of restoring ecosystems affected by ecocide and assessing the long-term consequences of environmental crimes for public health and biodiversity. A vital area for future research could also be the study of psychological aspects of combating criminal acts such as ecocide and the development of psychosocial support programmes for affected communities.

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Criminalistics Means and Methods of Combating Ecocide in the Modern Conditions of Military Threats

Appendix A. Closed Questions

Section 1: Effectiveness of Forensic Tools (Rating 1-10)
How effective is satellite monitoring in detecting and documenting environmental crimes in conflict zones?
How effective are UAVs (drones) for recording evidence of ecocide?
How effective is spectral analysis of soil and water in identifying pollutants linked to ecocide?
How effective is DNA analysis of biological samples in establishing the source of environmental contamination?
How effective are Geographic Information Systems (GIS) in compiling and visualizing environmental crime data?
Section 2: Advantages and Disadvantages of Forensic Tools
Satellite monitoring offers wide territorial coverage. To what extent do you agree this is an advantage? (Strongly Agree to Strongly Disagree)
Weather dependency is a disadvantage of satellite monitoring. How much of an obstacle do you think this is? (Not a barrier to Severe barrier)
UAVs are noted for their flexibility in capturing details in hard-to-reach areas. How much do you agree with this as an advantage?
The range limitation of UAVs is considered a disadvantage. How challenging is this in conflict zones?
Spectral analysis provides accurate pollutant detection. How significant is this advantage in ecocide investigations?
Section 3: Challenges in Evidence Collection
To what degree do limited access and safety concerns impact the collection of environmental evidence in conflict zones? (Minor Impact to Major Impact)
Do conflict-related disruptions (like infrastructure damage) pose a major obstacle to the collection of forensic evidence? (Yes/No)
How often do logistical challenges (transportation, equipment access) impede effective evidence collection?
How important is remote data collection capability for evidence gathering in conflict zones? (Not Important to Extremely Important)
How often is the delay in accessing areas a problem in your work?
Section 4: Legal and Institutional Support
How effective are current international legal frameworks in prosecuting ecocide? (Very Ineffective to Very Effective)
To what extent do institutional limitations in conflict areas hinder the ability to prosecute environmental crimes? (Minor to Severe)
How important is international cooperation in improving investigations of environmental crimes in conflict zones?
How useful would a specialized investigative unit be for ecocide in your jurisdiction? (Not Useful to Extremely Useful)
How supportive do you find existing local policies in addressing environmental crimes?

Criminalistics Means and Methods of Combating Ecocide in the Modern Conditions of Military Threats

Section 5: Technological and Innovative Solutions
How promising do you find remote sensing technology for future ecocide detection? (Not Promising to Extremely Promising)
How significant is the role of AI in improving the accuracy of environmental crime detection? (Not Significant to Very Significant)
How effective would data integration platforms be in building comprehensive evidence in ecocide cases? (Not Effective to Very Effective)
How likely are you to adopt advanced forensic technologies in future ecocide investigations?
How much would cost reduction in tech resources improve environmental crime investigations?

Appendix B. Open Questions

What do you see as the primary advantages of using satellite monitoring and GIS for ecocide documentation?
What are the biggest challenges in gathering and analyzing forensic evidence of environmental crimes in active conflict zones?
In your opinion, what specific legislative changes are needed to strengthen ecocide prosecution in conflict zones?
What innovations or technologies would most enhance the effectiveness of forensic tools in conflict areas?
What recommendations would you make to improve the international cooperation framework for addressing transborder environmental crimes?

Criminalistics Means and Methods of Combating Ecocide in the Modern Conditions of Military Threats

AUTHORS' DECLARATION AND ESSENTIAL ETHICAL COMPLIANCES

Authors' Contributions (in accordance with ICMJE criteria for authorship)

Contribution	Author 1	Author 2	Author 3	Author 4	Author 5
Conceived and designed the research or analysis	Yes	No	Yes	No	Yes
Collected the data	No	Yes	Yes	Yes	Yes
Contributed to data analysis & interpretation	Yes	Yes	No	No	Yes
Wrote the article/paper	Yes	Yes	Yes	Yes	No
Critical revision of the article/paper	Yes	No	No	Yes	Yes
Editing of the article/paper	No	Yes	Yes	No	No
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Overall Contribution Proportion (%)	20	20	20	20	20

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Research involving human bodies or organs or tissues (Helsinki Declaration)

The author(s) solemnly declare(s) that this research has not involved any human subject (body or organs) for experimentation. It was not a clinical research. The contexts of human population/participation were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or ethical obligation of Helsinki Declaration does not apply in cases of this study or written work.

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The author(s) solemnly declare(s) that this research has not involved any animal subject (body or organs) for experimentation. The research was not based on laboratory experiment involving any kind animal. The contexts of animals not even indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or ethical obligation of ARRIVE does not apply in cases of this study or written work.

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Criminalistics Means and Methods of Combating Ecocide in the Modern Conditions of Military Threats

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The author(s) solemnly declare(s) that this research has not directly involved any local community participants or respondents belonging to non-Indigenous peoples. Neither this study involved any child in any form directly. The contexts of different humans, people, populations, men/women/children and ethnic people are only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or prior informed consent (PIC) of the respondents or Self-Declaration in this regard does not apply in cases of this study or written work.

(Optional) PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)

The author(s) has/have NOT complied with PRISMA standards. It is not relevant in case of this study or written work.

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Conditions of Military Threats**

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