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EARTH OBSERVATION FOR ASSESSING ENVIRONMENTAL IMPACTS OF WAR IN UKRAINE: TRANSBOUNDARY RISKS AND MONITORING APPROACHES

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The full-scale war in Ukraine caused significant environmental damage affecting atmospheric systems, water resources, soils, ecosystems, biodiversity, and environmental safety at both national and transboundary levels. Military operations, destruction of industrial infrastructure, fires, fuel combustion, chemical contamination, and damage to hydraulic structures created complex environmental risks extending beyond national borders. Under wartime conditions, traditional environmental monitoring systems often face serious limitations due to restricted territorial access, damaged infrastructure, safety constraints, and interruptions in field observations. In this context, Earth Observation technologies become critically important instruments for environmental assessment, monitoring, and evidence generation.

The article examines the role of satellite Earth Observation technologies in assessing war-related environmental impacts in Ukraine. Particular attention is devoted to transboundary environmental risks associated with atmospheric pollution transport, contamination of international river basins, marine pollution in the Black Sea region, and ecosystem degradation affecting neighbouring countries. The study analyses the potential of modern remote sensing instruments and environmental monitoring platforms, including Sentinel-5P, Copernicus services, NASA atmospheric products, and geospatial environmental intelligence tools for detecting environmental anomalies and supporting environmental assessment under conflict conditions.

The research highlights the importance of integrating Earth Observation data into environmental governance, environmental security frameworks, post-war recovery planning, and sustainable development strategies. The article also demonstrates that satellite monitoring technologies provide opportunities for objective, large-scale, and continuous environmental observations in inaccessible or high-risk territories. The proposed conceptual framework emphasises the growing importance of remote sensing technologies for documenting environmental consequences of war, supporting environmental accountability, and strengthening international environmental cooperation. The study contributes to the development of interdisciplinary approaches combining environmental science, geospatial technologies, environmental security, and sustainable recovery planning under conditions of armed conflict. *Key words:* Earth Observation, environmental impacts of war, Ukraine, transboundary pollution, remote sensing, environmental monitoring, environmental security, sustainable recovery, Sentinel-5P, Copernicus, war-related pollution.

Earth observation for assessing environmental impacts of war in Ukraine: transboundary risks and monitoring approaches.
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Повномасштабна війна в Україні завдала значних екологічних збитків, негативно вплинувши на атмосферне повітря, водні ресурси, ґрунти, екосистеми, біорізноманіття та екологічну безпеку як на національному, так і на транскордонному рівнях. Воєнні дії, руйнування промислової інфраструктури, пожежі, спалювання пального, хімічне забруднення та пошкодження гідротехнічних об'єктів формують комплексні екологічні ризики, наслідки яких виходять за межі території України. В умовах війни традиційні системи екологічного моніторингу часто функціонують із суттєвими обмеженнями через обмежений доступ до територій, руйнування інфраструктури, безпекові ризики та неможливість проведення польових досліджень. У такому контексті технології Earth Observation стають критично важливими інструментами екологічної оцінки, моніторингу та формування доказової бази.

Окреслено значення супутникових технологій Earth Observation у вивченні та оцінці воєнно-обумовлених екологічних впливів в Україні. Особливу увагу приділено транскордонним екологічним ризикам, пов'язаними із забрудненням та перенесенням атмосферного повітря, негативним станом міжнародних річкових басейнів, морським забрудненням у басейні Чорного моря та деградацією екосистем, що впливають на сусідні держави. Проаналізовано потенціал сучасних інструментів дистанційного зондування Землі та платформ екологічного моніторингу, зокрема Sentinel-5P, сервісів Copernicus, атмосферних продуктів NASA та геоінформаційних систем екологічного аналізу для виявлення екологічних аномалій, здійснення екологічної оцінки в умовах збройного конфлікту.

У праці означена важливість інтеграції даних Earth Observation у системи екологічного управління, екологічної безпеки, планування післявоєнного відновлення та забезпечення сталого розвитку. Наголошено, що супутниковий моніторинг забезпечує можливість здійснення об'єктивних, масштабних та безперервних екологічних спостережень на територіях з обмеженим доступом або підвищеним рівнем небезпеки. Запропонований концептуальний підхід акцентує увагу на зростаючій ролі



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технологій дистанційного зондування у документуванні екологічних наслідків війни, підтримці екологічної відповідальності та розвитку міжнародного екологічного співробітництва. Стаття робить внесок у розвиток міждисциплінарних підходів, що поєднують екологічну науку, геоінформаційні технології, екологічну безпеку та підходи до сталого післявоєнного відновлення в умовах збройного конфлікту. *Ключові слова:* Earth Observation, екологічні наслідки війни, Україна, транскордонне забруднення, дистанційне зондування Землі, екологічний моніторинг, екологічна безпека, стале відновлення, Sentinel-5P, Copernicus, воєнно-обумовлене забруднення.

Problem Statement. The full-scale war in Ukraine caused significant environmental impacts affecting atmospheric systems, water resources, soils, ecosystems, biodiversity, and environmental safety at both national and transboundary levels. Military operations are accompanied by industrial fires, destruction of energy infrastructure, contamination of river basins, emissions of hazardous substances, ecosystem degradation, and the generation of large volumes of demolition waste. Many of these impacts have long-term and transboundary consequences, creating environmental risks not only for Ukraine but also for neighbouring countries and shared regional ecosystems, including the Black Sea basin.

Under wartime conditions, traditional environmental monitoring approaches face serious limitations due to restricted territorial access, safety risks, damaged monitoring infrastructure, and the impossibility of conducting systematic field observations. This creates the need for alternative environmental assessment tools capable of providing operational, large-scale, and objective environmental information. In this context, Earth Observation technologies and satellite remote sensing become increasingly important instruments for assessing environmental impacts under armed conflict conditions.

Relevance of the Study. The relevance of the study is determined by the growing need to develop modern approaches for assessing war-related environmental impacts and establishing scientifically grounded environmental monitoring frameworks under conditions of armed conflict. The war in Ukraine demonstrated that environmental consequences of military activities may extend far beyond local territories and affect regional environmental security, public health, water quality, food systems, biodiversity, and sustainable development processes.

At the same time, Earth Observation technologies have significantly expanded the possibilities for environmental monitoring by enabling continuous and independent observations of inaccessible or high-risk territories. Satellite monitoring systems provide opportunities for detecting atmospheric pollution, monitoring fires and industrial accidents, assessing ecosystem degradation, analysing water contamination, and identifying environmental anomalies at regional and transboundary scales. The integration of geospatial technologies into environmental assessment processes therefore becomes increasingly important for environmental governance, environmental accountability, and post-war recovery planning.

Connection of the Author's Work with Important Scientific and Practical Tasks. The author's work is

connected with current scientific and practical tasks related to environmental security, environmental impact assessment, sustainable recovery, and the application of Earth Observation technologies for environmental monitoring under wartime conditions. The study contributes to the development of interdisciplinary approaches combining environmental science, remote sensing, geospatial analysis, and environmental governance.

The research also addresses practical challenges associated with documenting environmental damage, supporting environmental monitoring in inaccessible territories, strengthening transboundary environmental assessment, and improving the scientific basis for sustainable post-war recovery strategies. The proposed conceptual framework may support decision-making processes in the fields of environmental policy, environmental monitoring, ecological restoration, and international environmental cooperation.

Analysis of Recent Research and Publications. Recent scientific studies increasingly focus on the environmental consequences of armed conflicts and the growing role of remote sensing technologies in environmental assessment. International organisations, including UNEP, the European Environment Agency, NASA, ESA, and Copernicus services, emphasise the importance of satellite monitoring for detecting pollution events, assessing ecosystem degradation, and monitoring atmospheric changes under crisis conditions [1–4].

Several studies demonstrate the potential of Sentinel-5P TROPOMI data for monitoring atmospheric pollutants such as nitrogen dioxide (NO₂), sulfur dioxide (SO₂), carbon monoxide (CO), aerosols, and methane emissions [5–7]. Other researchers highlight the importance of geospatial intelligence and Earth Observation technologies for assessing environmental risks associated with industrial accidents, wildfires, infrastructure destruction, and water contamination during military conflicts [8–10].

At the same time, current literature mainly focuses on individual environmental components or specific technical applications of remote sensing technologies. Comprehensive interdisciplinary approaches integrating transboundary environmental risks, Earth Observation technologies, and sustainable recovery perspectives remain insufficiently developed.

Identification of Previously Unresolved Aspects of the Overall Problem. Despite the growing number of studies dedicated to environmental impacts of war and satellite environmental monitoring, several important

aspects remain insufficiently addressed. Existing research often concentrates on isolated environmental components, such as atmospheric pollution or infrastructure damage, without considering the systemic and interconnected nature of wartime environmental impacts.

Limited attention is also devoted to the transboundary dimension of environmental risks associated with military activities and to the integration of Earth Observation technologies into broader environmental governance and sustainable recovery frameworks. Furthermore, there is still a lack of conceptual approaches combining environmental assessment, transboundary environmental security, remote sensing technologies, and post-war environmental recovery within a unified analytical framework.

Novelty. The scientific novelty of the study lies in the development of an integrated conceptual framework for assessing war-related environmental impacts through the application of Earth Observation technologies and transboundary environmental analysis. The article systematises the main categories of environmental impacts caused by war in Ukraine and demonstrates the role of satellite monitoring technologies in supporting environmental assessment under conditions of restricted territorial access and environmental uncertainty.

The study also proposes an interdisciplinary approach combining environmental science, geospatial technologies, environmental security, and sustainable recovery perspectives for analysing environmental consequences of armed conflicts.

Methodological or General Scientific Significance. The methodological significance of the study lies in the development of an interdisciplinary analytical approach integrating Earth Observation technologies, environmental assessment, transboundary environmental analysis, and sustainable recovery perspectives within the context of armed conflict. The proposed framework demonstrates the potential of satellite monitoring technologies for supporting environmental assessment under conditions where conventional monitoring systems become limited or partially inaccessible.

The study also contributes to the broader scientific discussion regarding the role of remote sensing technologies in environmental governance, environmental security, and post-conflict environmental management. The integration of geospatial environmental intelligence into environmental assessment processes may strengthen scientific decision-making, improve environmental accountability mechanisms, and support evidence-based recovery planning. Furthermore, the research highlights the growing importance of Earth Observation technologies for assessing complex environmental interactions across atmospheric, hydrological, terrestrial, and ecosystem components at regional and transboundary scales.

Presentation of the Main Material

Environmental Impacts of War in Ukraine

The environmental consequences of the war in Ukraine represent a complex and multidimensional environmental crisis affecting atmospheric systems, water resources, soils, ecosystems, biodiversity, and environmental security at both national and transboundary scales. Military activities generate interconnected environmental pressures associated with industrial destruction, hazardous emissions, ecosystem degradation, infrastructure damage, and long-term environmental contamination [11–13].

One of the most significant environmental challenges relates to atmospheric pollution caused by industrial fires, explosions, fuel combustion, and damage to energy infrastructure. Large-scale fires release particulate matter, greenhouse gases, toxic compounds, nitrogen oxides, sulfur compounds, and combustion-related pollutants capable of affecting both environmental quality and public health. Environmental risks further increase in regions characterised by dense industrial infrastructure and hazardous industrial facilities.

Water contamination also represents a major environmental challenge under wartime conditions. Damage to wastewater treatment systems, industrial sites, hydraulic infrastructure, and river ecosystems may contribute to deterioration of water quality and increased ecological risks for aquatic systems. In addition, contamination of river basins connected to transboundary water systems creates broader regional environmental threats affecting neighbouring territories and marine ecosystems [14].

Military activities additionally contribute to soil degradation and ecosystem disturbance. Heavy metal contamination, explosive residues, landmine pollution, destruction of vegetation cover, habitat fragmentation, and biodiversity loss significantly reduce ecological resilience and complicate future environmental restoration processes.

The environmental consequences of war should therefore be understood not as isolated environmental incidents but as interconnected systemic impacts generating cumulative long-term environmental risks affecting environmental security, public health, sustainable development, food systems, and ecological resilience [15].

Military activities in Ukraine generated significant environmental pressures affecting atmospheric systems, water resources, soils, ecosystems, and biodiversity. According to the Joint Research Centre report on the status of environment and climate in Ukraine (Belis et al., 2025), war-related military operations generated approximately 77 MtCO₂-eq during the first eighteen months of the full-scale invasion [16]. Simultaneously, large-scale destruction of industrial facilities, energy infrastructure, oil depots, and military operations contributed to substantial atmospheric pollution and environmental degradation across multiple regions of Ukraine.

Particular concern is associated with large-scale land and soil degradation caused by military activities. Recent environmental assessments indicate that approximately 10.5 million hectares of Ukrainian land, representing nearly 40% of the country's territory, are vulnerable to degradation processes intensified by warfare, including soil contamination, crater formation, fires, heavy metal accumulation, and explosive remnants of war [17, 18]. Such environmental degradation creates long-term risks for agricultural productivity, ecosystem recovery, food security, and sustainable land management in post-war Ukraine.

The environmental consequences additionally extend beyond national borders. Pollutants released during industrial fires, explosions, fuel combustion, and infrastructure destruction may spread through atmospheric transport pathways and river basin systems, creating transboundary environmental risks for neighbouring countries and the Black Sea region [19].

Transboundary Environmental Risks

The transboundary nature of environmental pollution represents one of the most significant characteristics of war-related environmental impacts. Atmospheric pollutants generated by industrial fires, explosions, and combustion processes may spread across extensive geographical distances depending on meteorological conditions and atmospheric circulation dynamics [20, 21].

Environmental consequences generated within conflict zones may therefore affect neighbouring countries and regional ecosystems beyond national territorial boundaries. Such transboundary risks are particularly relevant in regions characterised by

interconnected atmospheric circulation systems, shared river basins, and marine ecosystems.

The Black Sea region represents a particularly vulnerable environmental system due to the interconnected nature of river basins, marine systems, and atmospheric transport pathways. Pollution transported through the Dnipro, Dniester, and Danube river systems may contribute to regional ecological degradation and increased environmental risks for coastal and marine ecosystems.

In addition to atmospheric and hydrological impacts, transboundary environmental consequences may affect biodiversity corridors, migratory species, protected ecosystems, and regional ecological connectivity. Such environmental interactions demonstrate that wartime environmental impacts require coordinated international monitoring approaches and strengthened transboundary environmental governance mechanisms [22–25].

Monitoring Challenges under Wartime Conditions

Environmental monitoring during armed conflicts faces substantial operational, technical, and methodological limitations. Active military operations, restricted territorial access, damaged infrastructure, occupation of territories, and safety risks significantly limit the possibility of conducting field observations and conventional environmental assessments [16, 26].

In many affected regions, environmental monitoring stations may be damaged, destroyed, or temporarily unavailable, resulting in fragmented environmental datasets and reduced monitoring continuity. Additional challenges emerge due to the dynamic nature of wartime environmental impacts, including industrial fires, explosions, flooding events, infrastructure destruction,

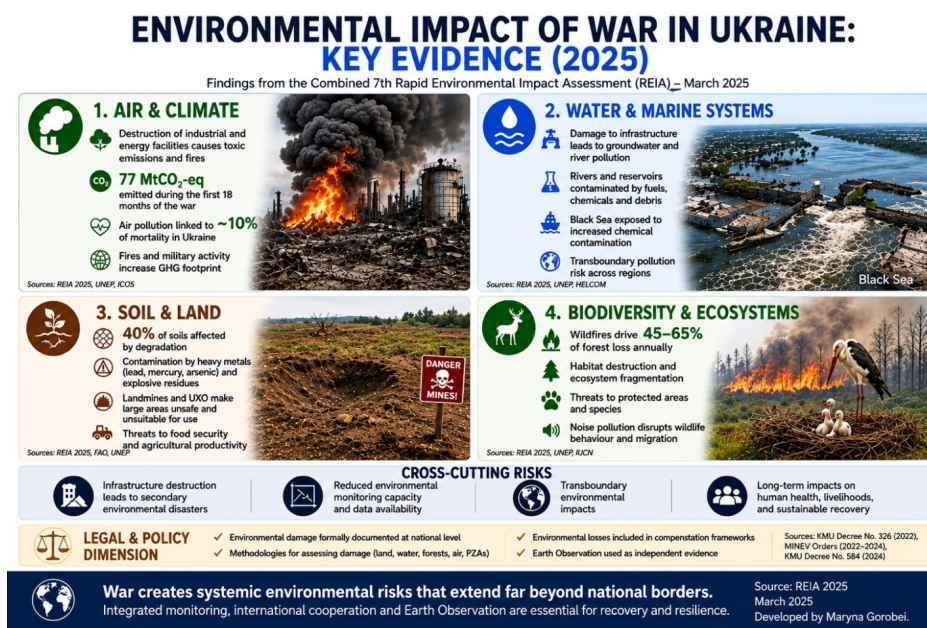


Fig. 1. Environmental impacts of war in Ukraine: key environmental dimensions and systemic risks (developed by author based on Belis et al., 2025; UNEP, 2022; FAO; IUCN and environmental assessment materials)

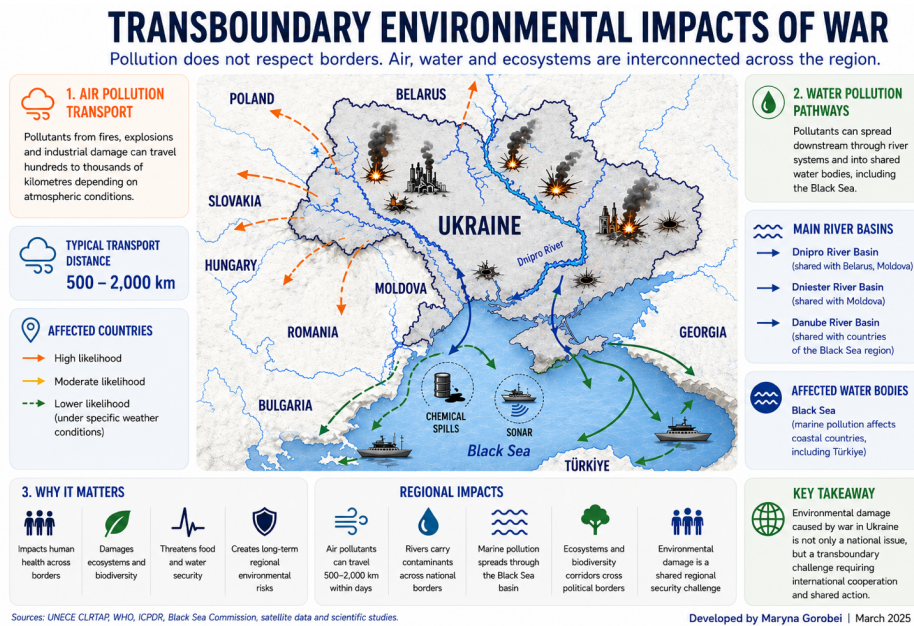


Fig. 2. Transboundary environmental impacts of war: atmospheric transport pathways, shared river basins, and regional environmental risks (developed by author based on UNECE, WHO, ICPDR, Black Sea Commission and scientific sources)

and hazardous emissions occurring across extensive geographical territories [27, 28].

Under such conditions, timely access to reliable environmental information becomes critically important for environmental risk assessment, emergency response, environmental governance, and sustainable recovery planning. These limitations significantly increase the importance of alternative monitoring approaches capable of providing large-scale environmental observations independent of local infrastructure conditions.

Earth Observation technologies therefore become essential tools for environmental assessment under wartime conditions. Satellite monitoring systems provide opportunities for detecting environmental anomalies, monitoring ecosystem changes, identifying pollution events, and supporting evidence-based environmental analysis in inaccessible or high-risk territories [3, 4].

Role of Earth Observation Technologies

Earth Observation technologies play an increasingly important role in environmental monitoring and environmental assessment under conditions of armed conflict and environmental instability. Unlike conventional monitoring systems, satellite-based observations provide continuous, objective, and spatially extensive environmental information regardless of accessibility limitations or damaged infrastructure [4, 5, 21].

Modern Earth Observation systems support the monitoring of atmospheric pollution, wildfire activity, water contamination, vegetation degradation, land-use changes, infrastructure destruction, and ecosystem disturbances. Satellite platforms such as Sentinel-5P,

Sentinel-2, Landsat, MODIS, and Copernicus services provide environmental datasets that may be integrated into environmental monitoring and decision-making processes.

Particular significance is associated with the capability of remote sensing technologies to identify environmental anomalies resulting from military activities. Atmospheric monitoring instruments enable the observation of pollution transport pathways, combustion-related emissions, and aerosol distribution, while optical and radar imagery support the assessment of damaged infrastructure, flooded territories, and ecosystem fragmentation.

The integration of Earth Observation technologies into environmental assessment processes significantly improves environmental situational awareness and strengthens evidence-based environmental governance. Satellite monitoring additionally supports long-term environmental assessment and contributes to the development of sustainable recovery strategies for conflict-affected regions.

To better systematise the role of Earth Observation technologies in wartime environmental assessment, Table 1 presents the relationship between major categories of environmental impacts, monitoring challenges under conflict conditions, and applicable satellite and airborne monitoring approaches. The proposed framework demonstrates how different Earth Observation technologies may support operational environmental monitoring, rapid environmental assessment, and long-term environmental recovery planning in conflict-affected territories.

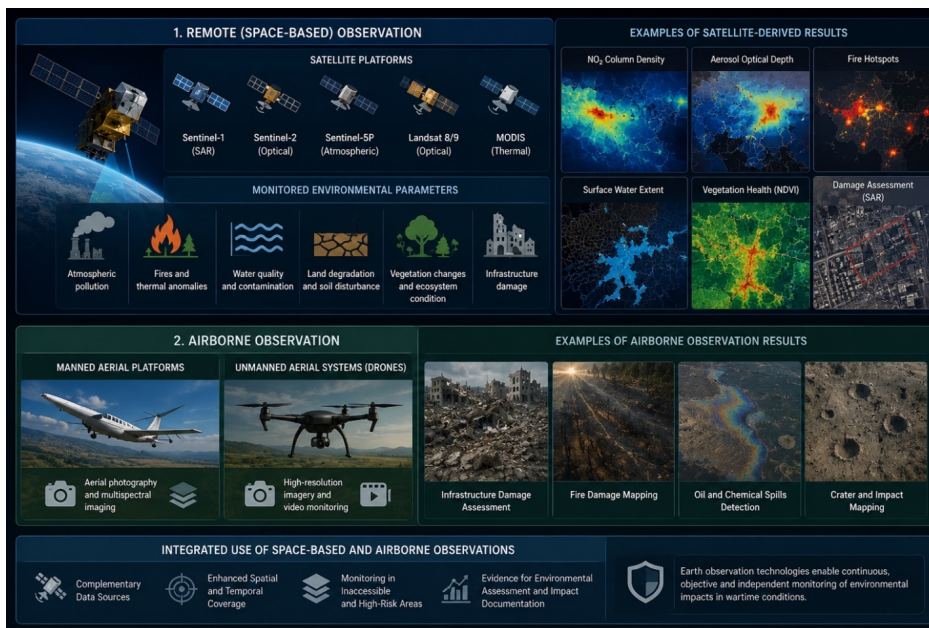


Fig. 3. Earth Observation technologies for environmental monitoring and assessment under wartime conditions (developed by author based on Copernicus, NASA Earth Observatory, ESA and environmental monitoring frameworks)

Table 1

Application of Earth Observation technologies for wartime environmental monitoring

Environmental impact category	Monitoring challenges under wartime conditions	Applicable Earth Observation technologies	Potential monitoring outputs
Atmospheric pollution	Restricted field access, damaged monitoring stations	Sentinel-5P, TROPOMI, CAMS	NO ₂ , SO ₂ , aerosol and fire-related atmospheric anomalies
Industrial and infrastructure damage	Inaccessible territories, active combat zones	Sentinel-2, SAR, drone imagery	Damage mapping, thermal anomalies, burned areas
Water contamination	Limited sampling possibilities, destroyed infrastructure	Sentinel-2, Landsat, SAR	Flood mapping, turbidity, oil spills, water quality changes
Soil and land degradation	Landmine contamination, unsafe territories	NDVI analysis, multispectral imagery	Vegetation stress, degraded land, ecosystem fragmentation
Ecosystem disturbance	Restricted biodiversity monitoring	MODIS, Sentinel-2	Forest loss, habitat fragmentation, wildfire assessment

The presented classification demonstrates that Earth Observation technologies provide significant advantages for environmental assessment under wartime conditions, particularly in territories with restricted physical accessibility and damaged monitoring infrastructure. Satellite observations, airborne monitoring systems, and geospatial analytical tools enable continuous large-scale environmental monitoring and support rapid identification of environmental anomalies, pollution hotspots, ecosystem disturbances, and infrastructure-related environmental risks. Consequently, Earth Observation technologies become essential instruments for operational environmental assessment and evidence-based environmental governance during armed conflicts.

Applications of Earth Observation for Environmental Assessment

The practical applications of Earth Observation technologies for wartime environmental assessment continue to expand due to advances in satellite monitoring capabilities and geospatial analytical methods. One of the most important applications involves atmospheric pollution monitoring and assessment of pollutant transport processes. Satellite observations enable identification of large-scale atmospheric anomalies associated with industrial fires, explosions, and combustion-related emissions.

Remote sensing technologies are also widely applied for wildfire detection and burned area assessment.

Thermal anomaly monitoring and multispectral satellite imagery support rapid identification of fire locations, estimation of burned territories, and evaluation of ecosystem damage.

Another important application concerns water resource monitoring and contamination assessment. Satellite observations support identification of flooded areas, sediment transport, water quality changes, and environmental impacts associated with damaged hydraulic infrastructure. Earth Observation technologies additionally provide opportunities for monitoring coastal ecosystems and marine environmental conditions within the Black Sea region.

Land degradation assessment represents another significant application area. Remote sensing technologies enable monitoring of vegetation stress, soil degradation, land cover changes, and ecosystem fragmentation caused by military activities. Geospatial analysis additionally supports identification of environmentally vulnerable territories requiring ecological restoration and environmental remediation.

The integration of multiple environmental datasets significantly improves the analytical capabilities of Earth Observation systems and contributes to the development of environmental intelligence approaches supporting sustainable environmental management and post-war recovery planning.

Earth Observation for Environmental Recovery and Sustainable Development

Earth Observation technologies may significantly contribute to environmental recovery processes and sustainable reconstruction strategies in post-war Ukraine. Reliable environmental information is essential for identifying priority recovery areas, assessing environmental damage, supporting ecological restoration, and strengthening environmental resilience.

Satellite monitoring systems provide opportunities for long-term environmental assessment and evaluation of ecosystem recovery dynamics over time. Continuous environmental observations support monitoring of vegetation restoration, water quality improvement, land rehabilitation, and effectiveness of environmental remediation measures.

Earth Observation data may additionally support climate adaptation planning and sustainable land-use management by identifying environmentally vulnerable territories and assessing environmental risks associated with future development scenarios.

Another important aspect concerns environmental governance and international environmental cooperation. Satellite observations provide transparent and scientifically grounded environmental information supporting environmental accountability mechanisms, international reporting processes, and transboundary environmental cooperation initiatives.

Consequently, Earth Observation technologies should be considered not only as monitoring instruments but also as strategic tools supporting sustainable development,

environmental resilience, evidence-based environmental governance, and environmentally responsible post-war recovery planning.

Main Conclusions. The conducted study demonstrates that the environmental impacts of war in Ukraine represent a complex and interconnected system of atmospheric, hydrological, terrestrial, and ecological disturbances with significant long-term and transboundary consequences. Military activities generate environmental risks extending beyond directly affected territories and influencing regional environmental security, ecosystem stability, and sustainable development processes.

The research confirms that conventional environmental monitoring approaches are often insufficient under wartime conditions due to restricted physical access to territories, damaged monitoring infrastructure, and security limitations. In this context, Earth Observation technologies provide substantial scientific and practical advantages for operational environmental assessment and long-term environmental monitoring.

The study additionally demonstrates that satellite observations, airborne monitoring systems, and geospatial analytical approaches may support the detection of atmospheric anomalies, pollution transport pathways, ecosystem degradation, land disturbance, water contamination, and infrastructure-related environmental risks. Earth Observation technologies therefore become essential instruments for evidence-based environmental governance and environmental damage assessment during armed conflicts.

Particular importance is associated with the capability of Earth Observation systems to support monitoring in inaccessible or high-risk territories where traditional field investigations remain limited or impossible. Satellite monitoring enables continuous large-scale environmental observations and contributes to transparent environmental assessment and international environmental cooperation.

Overall, the study confirms that Earth Observation technologies should be considered strategic tools for environmental security, post-war environmental recovery, sustainable development planning, and strengthening environmental resilience in Ukraine.

Prospects for the Application of the Study Results. The presented research may serve as a conceptual and methodological foundation for further investigations dedicated to wartime environmental monitoring, environmental security assessment, and post-war ecological recovery in Ukraine.

Future studies may focus on the integration of satellite observations with atmospheric transport modelling, geographic information systems (GIS), field-based environmental measurements, and environmental risk assessment methodologies for the development of comprehensive environmental monitoring frameworks under conflict conditions.

A particularly promising direction remains the application of high-resolution Earth Observation data for detailed assessment of atmospheric pollution dynamics, wildfire impacts, land degradation, water contamination, biodiversity disturbances, and infrastructure-related environmental risks in war-affected territories.

The obtained results may additionally support the development of national environmental monitoring systems, post-war environmental recovery programmes,

climate adaptation strategies, environmental governance mechanisms, and international environmental cooperation initiatives.

The methodological approaches presented in the study may also be adapted for environmental assessment in other regions affected by military conflicts, technological disasters, or large-scale environmental emergencies where traditional environmental monitoring remains limited due to accessibility and security constraints.

References

1. United Nations Environment Programme (UNEP). The Environmental Impact of the Conflict in Ukraine: A Preliminary Review. Nairobi: UN Environment Programme, 2022. URL: <https://www.unep.org/resources/report/environmental-impact-conflict-ukraine-preliminary-review>.
2. European Environment Agency (EEA). Air Quality and Environmental Monitoring in Europe. Copenhagen: EEA, 2023. URL: <https://www.eea.europa.eu>.
3. European Space Agency (ESA). Sentinel-5P Mission Overview. URL: <https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-5p>.
4. Copernicus Atmosphere Monitoring Service (CAMS). Atmospheric Composition Monitoring and Forecasting Products. URL: <https://atmosphere.copernicus.eu/>.
5. Veefkind J.P., Aben I., McMullan K., Förster H., de Vries J., Otter G., Claas J., Eskes H.J., de Haan J.F., Kleipool Q. et al. TROPOMI on the ESA Sentinel-5 Precursor: A GMES mission for global observations of the atmospheric composition for climate, air quality and ozone layer applications. *Remote Sensing of Environment*. 2012. Vol. 120. P. 70–83. DOI: <https://doi.org/10.1016/j.rse.2011.09.027>.
6. Turos O.I., Petrosian A.A., Maremukha T.P., Morhulova V.V., Brezitska N.V., Kobzarenko I.V., Tsarenok T.V. Assessment of Ambient Air Pollution by Particulate Matter (PM₁₀, PM_{2.5}) and Risk for Human Health Caused by War Actions. *Wiadości Lekarskie*. 2023. Vol. 76, No. 4. P. 738–744. DOI: <https://doi.org/10.36740/WLek202304106>.
7. Turos O.I., Petrosian A.A., Maremukha T.P., Morhulova V.V., Grabovets D.M., Brezitska N.V., Tsarenok T.V. Long-term trends (compared to the pre-war period) and public health impact of surface ozone in Ukraine. *Wiadości Lekarskie*. 2024. Vol. 77, No. 4. P. 703–709. DOI: <https://doi.org/10.36740/WLek202404114>.
8. Pereira P., Bašić F., Bogunovic I., Barcelo D. Russian–Ukrainian war impacts the total environment. *Science of The Total Environment*. 2022. Vol. 837. Article 155865. DOI: <https://doi.org/10.1016/j.scitotenv.2022.155865>.
9. Rawtani D., Gupta G., Khatri N., Rao P.K., Hussain C.M. Environmental damages due to war in Ukraine: A perspective. *Science of The Total Environment*. 2022. Vol. 850. Article 157932. DOI: <https://doi.org/10.1016/j.scitotenv.2022.157932>.
10. Almeida M., Soviev M., San-Miguel J., Durrant T., Oom D., Branco A., Ferrari D., Boca R. et al. (eds.) Report on the Large Wildfires of 2022 in Europe. Chapter 12: Wildfires in Ukraine in Times of War / Zibtsev S., Goldammer J.G., Myroniuk V., Sydorenko S., Soshenskyi O., Bogomolov V., Borsuk O. Luxembourg: Publications Office of the European Union, 2024. DOI: <https://doi.org/10.2760/19760>, JRC138859.
11. Belis C.A., Petrosian A., Turos O., Maremukha T., Morhulova V., Kona A., Djatkov D., Caudullo G., Ceccherini G., Beck P.S.A., San-Miguel J., Arias Navarro C., Wojda P., Jones A., Hanke G., Mariani G., Carravieri A. Status of Environment and Climate in Ukraine. European Commission: Joint Research Centre. Luxembourg: Publications Office of the European Union, 2025. DOI: <https://doi.org/10.2760/6292177>, JRC141480.
12. World Wide Fund for Nature (WWF). Assessing the Environmental Impacts of the War in Ukraine. 2022. URL: <https://wwfcee.org/our-offices/ukraine/assessing-the-environmental-impacts-of-the-war-in-ukraine>.
13. Harari S., Annesi-Maesano I. The war in Ukraine is an environmental catastrophe. *The International Journal of Tuberculosis and Lung Disease*. 2023. Vol. 27, No. 2. P. 94–95. URL: <https://theunion.org/news/the-war-in-ukraine-is-an-environmental-catastrophe>.
14. Миронюк В., Вайнрайх А., фон Доскі В., Поллі Г., Діс М. Скільки лісових ресурсів у нас в Україні? Дані, методологія та результати інвентаризації лісів на основі дистанційного зондування 2023 року. Центр національної інвентаризації лісів України, 2024.
15. Полякова Л., Абрускаго С. Підтримка відновлення та сталого управління українськими лісами та лісовим сектором України. *Forest Europe*. Бонн, 2023. URL: <https://foresteurope.org/wp-content/uploads/2023/08/Supporting-the-recovery-and-sustainable-management-of-Ukrainian-forests-and-Ukraines-forest-sector-Final-report.pdf>.
16. UNECE Convention on Long-range Transboundary Air Pollution (CLRTAP). Geneva: United Nations Economic Commission for Europe. URL: <https://unece.org/environment-policy/air>.
17. Copernicus Atmosphere Monitoring Service (CAMS). Atmospheric Composition Monitoring and Forecasting Products. URL: <https://atmosphere.copernicus.eu/>.
18. NASA Earth Observatory. Remote Sensing Applications for Environmental Monitoring and Atmospheric Pollution Assessment. URL: <https://earthobservatory.nasa.gov>.
19. Black Sea Commission (Commission on the Protection of the Black Sea Against Pollution). State of the Environment of the Black Sea (2009–2014/5) / ed. Krutov A. Istanbul: BSC, 2019. ISBN: 978-605-84837-0-5.
20. International Commission for the Protection of the Danube River (ICPDR). Danube River Basin Management Plan. Vienna: ICPDR, 2021.

21. World Health Organization (WHO). Ambient Air Quality and Health. Fact sheet. Geneva: WHO, 2022. URL: [https://www.who.int/news-room/fact-sheets/detail/ambient-\(outdoor\)-air-quality-and-health](https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health).
22. Скок А., Хрутьба В., Рак О., Хлобістов С. Якість повітря в Україні до та під час повномасштабного вторгнення. SaveDnipro. Київ, 2023. URL: <https://www.savednipro.org/wp->
23. Сорока М., Трелевський О., Черноцова М. Запоріжжя: Якість повітря в умовах воєнного стану (Аналітична записка). Прага–Київ, 2022. URL: <https://cleanair.org.ua/wp-content/uploads/2023/01/cleanair.org.ua-2022-zaporizhzhia-air-war-report-final.pdf>.
24. World Bank; Government of Ukraine; European Commission; United Nations. Ukraine – Third Rapid Damage and Needs Assessment (RDNA3): February 2022–December 2023. Washington DC: World Bank Group, 2024. URL: <https://documents.worldbank.org/en/publication/documents-reports/documentdetail/099021324115085807>.
25. IPCC. Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the IPCC / Lee H., Romero J. (eds.). Geneva: IPCC, 2023. DOI: <https://doi.org/10.59327/IPCC/AR6-9789291691647>.

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