CHAPTER 5

Sustainable development policy for post-conflict recovery in Ukraine: the role of environmental indicators in decision-making

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Abstract

This study explores the role of environmental indicators in guiding managerial decision-making for the sustainable recovery of de-occupied territories in Ukraine. The research is grounded in a large-scale survey conducted across 42 territorial communities in southern Ukraine that experienced severe destruction due to the full-scale invasion. The methodological framework is based on sociological data from over 16,000 residents, used to calculate five key environmental indicators: Technogenic Pollution from Military Activity (TPMA), Degradation of Natural Ecosystems and Soil (DNES), Infrastructure and Household War Impacts (IHWI), Access to Natural Resources (ANR), Biosecurity and Public Health Protection (BPHP). The results were visualized using a heat map to identify ecological "hotspots" and prioritize zones requiring urgent intervention.

Particular attention is given to the development of a structural decision-making model that illustrates the progression from problem identification to the implementation of recovery strategies at the local level. The paper proposes actionable directions for response, including environmental monitoring, land reclamation, waste management, and ecological awareness initiatives. It also discusses potential funding sources for environmental initiatives, ranging from international donor programs and national funds to public-private partnerships and innovative financial instruments.

The findings offer practical value for evidence-based environmental policymaking in post-conflict settings, the formulation of localized sustainable development strategies, and the strengthening of institutional capacity at the community level.

Keywords

Sustainable development, environmental indicators, de-occupied territories, post-conflict recovery, decision-making, survey research, environmental policy, project financing, circular economy.

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5.1 Introduction

The issue of sustainable development becomes particularly relevant in the context of post-conflict recovery in territories severely affected by war. Armed conflicts not only result in human casualties and economic losses but also inflict significant environmental damage, exacerbate the vulnerability of social systems, and undermine institutional governance structures. Under such conditions, the achievement of the Sustainable Development Goals (SDGs) – including environmental security, social equity, and economic resilience – requires a rethinking of traditional recovery approaches.

Post-war reconstruction efforts cannot be limited to rebuilding infrastructure or restoring economic functionality. Recovery policies must address interdisciplinary challenges that integrate environmental, social, and governance dimensions. Key priorities include ecosystem restoration, access to clean water, waste management, soil rehabilitation, and the prevention of further environmental degradation. These challenges are not merely humanitarian; they are strategic in terms of national security, stability, and long-term development.

In the Ukrainian context, particularly in de-occupied territories of the southern regions, there is a critical need for an environmentally oriented recovery policy grounded in evidence – namely, environmental indicators, risk assessment, and public engagement. The role of local communities, municipal authorities, and international partners is decisive in this process. Therefore, investigating how environmental factors are incorporated into sustainable development decision-making processes is essential for both scholarly inquiry and practical application.

Integrating environmental considerations into territorial development governance is a prerequisite for achieving long-term sustainability in post-conflict recovery. Policy development and implementation at both the local and national levels must account not only for economic and social factors but also for an objective evaluation of environmental conditions. Environmental quality directly affects public health, agricultural productivity, access to natural resources, and the overall investment attractiveness of a region.

Environmental concerns must be an integral component of local socio-economic development programs. Neglecting them risks creating new sources of social tension and increasing ecological vulnerabilities. In the aftermath of war, ecosystems are profoundly altered – from water contamination to soil degradation and deforestation. These changes disrupt natural balances and complicate reintegration and development processes.

Environmental indicators – such as air and water quality, soil contamination levels, and waste accumulation – serve as critical reference points for decision-making in infrastructure planning, public health, agriculture, and land management. Systematic monitoring and incorporation of these indicators into planning processes help prevent environmentally unsound decisions, increase governance transparency, and lay the groundwork for effective environmental policy.

In post-conflict settings, environmental data becomes even more crucial as a tool for building trust between citizens and authorities, and as a foundation for attracting international aid and investment. Therefore, the environmental dimension must be viewed not as a secondary consideration, but as a foundational element of strategic governance for community recovery in the post-war period.

Despite widespread recognition of the importance of environmental components in local sustainable development strategies, research focusing specifically on the role of environmental indicators in post-conflict recovery remains fragmented and insufficiently systematized. The academic discourse is predominantly oriented toward infrastructure and economic reconstruction [1–5], while environmental concerns are often treated as secondary or disconnected from the broader governance framework.

This gap is particularly pronounced in the Ukrainian context [6–12], where armed aggression has resulted not only in a humanitarian crisis but also in unprecedented environmental degradation. However, existing studies rarely examine how environmental indicators are utilized to inform decision-making at the local level – from resource allocation to regional development priorities. Most recovery programs lack a unified methodology for environmental monitoring or sustainability-oriented impact assessments [13, 14].

Moreover, there is no comprehensive database enabling the analysis of ecological dynamics in de-occupied areas. The potential for engaging citizens in the collection and interpretation of environmental data through civic science approaches remains underexplored, despite its critical importance for transparent decision-making and enhancing trust in local governance.

These shortcomings underscore the need for interdisciplinary research that combines environmental analytics, public administration tools, and sociological data collection methods. Only through such an integrated approach can effective, environmentally sound recovery policies be developed – policies that address real community needs while contributing to the revitalization of local ecosystems.

Given the current challenges posed by military aggression and the urgent need for territorial recovery, this study aims to identify the potential and actual use of environmental indicators in the formulation and implementation of sustainable development policies in Ukraine's de-occupied regions. Considering the scale of ecological loss, objective assessment of environmental conditions must form the basis for decisions that combine short-term stabilization with long-term development goals.

The research focuses on the extent to which environmental indicators – such as air and water quality, soil conditions, access to natural resources, pollution levels, and the availability of waste processing infrastructure – are integrated into local and regional strategic planning. Special attention is given to empirical data from a population survey conducted in de-occupied communities in southern Ukraine, particularly in Kherson and Mykolaiv regions. This allows for the evaluation of public perceptions of the environmental situation and levels of trust in environmental policies implemented by public authorities.

Given the strategic importance of sustainable development for post-conflict recovery, the study seeks not only to assess the current state of affairs but also to outline pathways for improving institutional mechanisms for evidence-based decision-making. The search for a balanced approach – one that integrates environmental, social, and economic dimensions to ensure effective resource management, ecosystem restoration, and risk mitigation – is at the core of this research.

5.2 Research methodology

This study was conducted as part of the project "Stimulating the Development of De-Occupied Territories through Investment and Innovation Tools within the European Union Framework", supported by the EURIZON – Grants for Remote Research program. The project aims to develop evidence-based strategic recommendations for local authorities, investors, and international partners regarding the sustainable and environmentally oriented recovery of Ukraine's de-occupied territories.

Data collection was carried out through an online survey administered via a custom-designed questionnaire in Google Forms between June and September 2024. The target respondents included residents and internally displaced persons (IDPs) who either currently reside or have lived in the de-occupied areas of Mykolaiv and Kherson regions. Participation was voluntary, anonymous, and open-access, ensuring compliance with ethical standards in research. Invitations were disseminated via social media, partner NGOs, community chats, educational institutions, and email distribution lists.

The sampling frame encompassed 42 territorial communities that were liberated in the Mykolaiv and Kherson regions. A total of 16,000 respondents participated in the survey, averaging approximately 380 participants per community. The sample included adult residents who lived in the liberated territories at the time of the survey. The socio-demographic composition was diverse, including individuals of different genders, age groups, and professional backgrounds. Initial analysis confirms that both residents who remained during the occupation and those who returned post-liberation were represented, allowing for a wide spectrum of perspectives on environmental issues. The selection of 42 communities was driven by the project's geographic scope, which focused on the areas most severely affected by the armed conflict in southern Ukraine. Consequently, the sample is reflective of public perceptions regarding the environmental situation and challenges within these communities.

The main research instrument was a structured questionnaire developed by the authors, consisting of eight thematic sections. Section 4, titled "Environmental Situation", was of particular relevance to the study. It included questions aimed at assessing the post-liberation environmental conditions and quality of life in the respective communities. The survey instrument focused on five core thematic areas aligned with key environmental indicators:

1) technogenic pollution resulting from military operations;
2) degradation of natural ecosystems and soil;
3) infrastructural and domestic consequences of war;
4) access to natural resources;
5) biosecurity and public health protection. Each thematic area was represented by one or more questions.

Respondents were asked to assess the presence and severity of issues in these domains (e.g., chemical contamination of soil or water, scale of forest damage, condition of transport and housing infrastructure, access to clean water, health risks, etc.).

Most questions employed a numerical scale ranging from 1 to 10 to capture the subjective assessment of environmental conditions. While similar to a Likert-type scale, the expanded 10-point range increases the sensitivity and granularity of responses. Respondents independently selected a score reflecting their evaluation of each specific issue in their community.

To standardize interpretation, guidance was provided: a score of 1 indicated the absence of a problem or optimal condition (minimal negative impact), while a score of 10 denoted a critical state or severe issue. For example, in evaluating technogenic pollution, a score of 1 indicated no visible signs of contamination, whereas a 10 reflected extreme environmental burden involving multiple instances of air, water, or soil pollution. Similarly, for ecosystem condition, a score of 1 implied negligible damage, while 10 denoted complete destruction or irreversible loss of ecosystems and soil fertility. This approach enabled the generation of quantitative data on respondents' environmental perceptions, allowing for the calculation of relative indicators and comparison across communities.

In addition to the numerical scale, several dichotomous (yes/no) questions were included to establish the factual presence of certain conditions. For instance, questions on access to critical resources or exposure to specific threats (e.g., availability of drinking water or presence of landmine hazards) were binary in nature. These items were used to confirm the existence of issues, while subsequent scaled questions captured their severity. Accordingly, the survey combined metric scales (to measure intensity) with nominal variables (to register the occurrence of specific phenomena). All scales were pre-tested for clarity: several respondents completed a trial version of the questionnaire to ensure correct understanding of the 1–10 scale and other question formats.

Several limitations should be taken into account when interpreting the results and formulating recommendations. First, the representativeness of the sample is relative. Although 16,000 participants from 42 communities were surveyed, the sample was based on voluntary online participation. This introduces the potential for selection bias – those more active, with internet access and interest in the topic, may have been more likely to respond. Conversely, groups with limited internet access, such as elderly individuals or residents in remote villages, may be underrepresented. This limitation is common to online surveys and suggests that the results should not be directly generalized to the entire population without adjustments.

Second, all indicators are based on self-reported perceptions rather than objective instrumental measurements of environmental conditions. Thus, findings reflect respondents' subjective experiences, which may be influenced by their awareness, personal encounters, or emotional states following traumatic events. For instance, technogenic pollution may be underestimated in communities where the damage is not visually apparent, or overestimated in areas where anxiety levels are high. To mitigate this limitation, the questionnaire included specific follow-up items (e.g., whether respondents observed smoke, chemical odors, mass fish mortality, etc.). Nevertheless, subjective bias cannot be fully eliminated; therefore, the indicators should be interpreted as indices of public perception rather than precise physical metrics.

Third, due to security constraints, data collection was conducted remotely. This precluded controlled fieldwork, such as randomized household interviews in areas facing landmine threats or infrastructure destruction. Technical disruptions (e.g., power outages or unstable internet connections) may have further limited participation in some communities.

Moreover, the indicators derived from the survey do not account for temporal dynamics. The study employed a one-time data collection effort, capturing conditions at a single point in time. Given the dynamic nature of de-occupied areas – where demining, reconstruction, and seasonal environmental changes (e.g., floods or wildfires) are ongoing – longitudinal measurements are desirable. Repeated assessments would help identify trends, such as improvements resulting from interventions or the emergence of new challenges.

Despite these limitations, the findings provide a valuable data foundation. They address a critical gap in environmental data for de-occupied communities and can inform managerial decisions related to ecological restoration and infrastructure rebuilding. The combination of a large-scale sample and a clear methodology for calculating indicators ensures a sufficient level of reliability for community-level analysis.

Based on the collected data, five core environmental indicators were computed to reflect the environmental damage incurred by each community due to the full-scale invasion of Ukraine. These indicators were calculated by aggregating individual responses within each community and determining the proportion of respondents who reported significant problems in each thematic area. Each community-level indicator is expressed as a fractional value (ranging from 0 to 1.0), representing the perceived intensity of the issue. The formal formula used to calculate the indicator is provided below

$$I_{k,i} = \frac{n_{k,i}}{N_i},$$

where N_i – denotes the total number of respondents in community *i*, and $n_{k,i}$ – represents the number of respondents in the same community who reported a significant issue *k*. Depending on the question type, was defined as follows:

a) for items measured on a 1–10 scale: the number of respondents who selected values in the 8–10 range, which were interpreted as indicating a high intensity of the respective problem;

b) for dichotomous (yes/no) items: the number of respondents who answered "Yes", thereby confirming the presence of the problem.

Accordingly, the indicator reflects the proportion of surveyed residents in a given community who perceive a particular issue as severe.

Table 5.1 presents the computational logic underlying each of the five environmental sustainability indicators, capturing residents' perceptions of the environmental situation in their respective communities following de-occupation.

All indicators are measured on a scale from 0 to 1, where values closer to 1 indicate that the issue is more widely acknowledged and perceived as severe by residents of the respective community. These metrics allow for comparative analysis across communities and help identify territories that require priority interventions in specific environmental domains. They also serve as an empirical foundation for managerial decisions informed by adverse indicator outcomes.

Table 5.1 System of environmental sustainability indicators in de-occupied communities

Indicator Name		Definition	Formula
Techno-genic Pollution from Military Activity	TPMA	Proportion of community residents who reported significant environmental contamination due to military operations (e.g., chemical pollution, toxic remnants of munitions). A higher value (closer to 1) indicates that most respondents observed substantial pollution	$I_{\mathrm{TPMA},\,i} = \dfrac{n_{\mathrm{TPMA},\,i}}{N_i}$, where $n_{\mathrm{TPMA},\,i}$ – the number of respondents in community *i* who rated the pollution level as high (8–10 out of 10) or confirmed the presence of such incidents
Degradation of Natural Ecosystems and Soil	DNES	Reflects the extent of ecosystem degradation (forests, meadows, protected areas) and loss of soil fertility as perceived by residents. A higher score indicates greater ecological damage as perceived by respondents	$I_{\mathrm{DNES},\,i} = \dfrac{n_{\mathrm{DNES},\,i}}{N_i}$, where $n_{\mathrm{DNES},\,i}$ – the number of respondents who reported severe damage to ecosystems and soil, including signs such as burned or deforested areas, polluted land, or craters in agricultural fields
Infrastructure and Household War Impacts	IHWI	Share of respondents who reported serious infrastructure-related problems (housing, roads, water or electricity supply), or rated at least one key facility as critically damaged (8–10 on the scale)	$I_{\mathrm{IHWI},\,i} = \dfrac{n_{\mathrm{IHWI},\,i}}{N_i}$, where $n_{\mathrm{IHWI},\,i}$ – the number of respondents in community *i* who reported severe infrastructure or household issues (e.g., rated infrastructure condition as 8–10 or selected critical issues from listed options)
Access to Natural Resources	ANR	Indicates the prevalence of problems related to access and safety of natural resources (e.g., drinking water, forests, farmland, water bodies). Higher values reflect widespread concerns about safety or shortages of resources	$I_{\mathrm{ANR},\,i} = \dfrac{n_{\mathrm{ANR},\,i}}{N_i}$, where $n_{\mathrm{ANR},\,i}$ – the number of respondents who reported significant issues with resource access. This includes those who answered "Yes" to questions about safety concerns (e.g., mined forests or contaminated water bodies) or rated water availability/quality at a critical level
Biosecurity and Public Health Protection	BPHP	Proportion of respondents who expressed serious concerns about sanitation, epidemic risks, or access to healthcare. A higher value signals population-level concern about health-related threats	$I_{\mathrm{BPHP},\,i} = \dfrac{n_{\mathrm{BPHP},\,i}}{N_i}$, where $n_{\mathrm{BPHP},\,i}$ – the number of respondents who rated biosecurity or health threats as severe (8–10), or reported serious concerns about related risks

Source: compiled by the authors based on [5, 10, 15, 16]

For instance, a community with a technogenic pollution index of 0.80 (80%) has a significantly higher proportion of residents reporting contamination compared to a community with an index of 0.20 (20%). This disparity underscores the need for urgent environmental remediation efforts in the former.

5.3 Theoretical foundations of sustainable development and environmental security in post-conflict recovery

The concept of sustainable development is based on the integration of three fundamental dimensions – environmental, social, and economic – with the goal of achieving balanced progress across all three spheres [6, 17]. In its classical formulation by the Brundtland Commission, sustainable development is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [18]. In this sense, society must pursue economic growth and social progress without depleting natural resources or causing irreversible environmental harm. The emergence of this paradigm in the late 20th century was a response to the realization of the limitations inherent in the traditional, economically focused development model, which often neglected environmental and social consequences. By the early 1990s, the global community officially recognized sustainable development as the guiding ideology for human progress in the 21st century, which was reflected in numerous international agreements and initiatives.

Each of the three pillars of sustainable development has its own objectives and metrics. The environmental dimension focuses on preserving ecosystems and ensuring the rational use of natural resources. The social dimension addresses poverty reduction, access to quality education and healthcare, gender equality, and broader social justice [7, 8, 17]. The economic dimension emphasizes stable growth, innovation, sustainable industry, and infrastructure, while promoting efficient use of financial and material resources. Crucially, these three elements are treated holistically: sustainable development is conceived as a complex process of harmonizing social, economic, and environmental objectives to ensure effective use, protection, and regeneration of natural systems, alongside quality of life for both current and future generations [7, 8, 17]. The integrated approach assumes that progress in one area must not come at the expense of another. Consequently, sustainable development has become a global strategic policy direction, as evidenced by the adoption of the United Nations Sustainable Development Goals (SDGs) in 2015 – a global framework encompassing all three dimensions of sustainability.

Indicator-based governance is a central tool in international practice for implementing the SDGs and guiding environmental policy. In 2015, the United Nations adopted 17 Sustainable Development Goals and 169 associated targets, which progress is tracked using a comprehensive system of quantitative indicators [1, 3, 17, 19]. To monitor implementation of the 2030 Agenda, an official global indicator framework was introduced, originally comprising 232 indicators covering a broad range of issues – from poverty, hunger, health, and education to environmental quality, climate change, and institutional capacity. Countries regularly collect and report data on these indicators within the UN framework, enabling both national performance assessment and international comparisons. Each SDG is linked to specific indicators with target thresholds to be achieved by 2030. For example, Goal 6 "Clean Water and Sanitation" includes indicators on access to safe drinking water and wastewater treatment, while Goal 13 "Climate Action" includes indicators on greenhouse gas emissions, climate adaptation policies, and climate finance. The entire SDG framework is based on the principle that "what gets measured gets managed", directing government efforts toward indicators falling short of targets.

The application of indicators is also well established at the national level. Many countries have adapted the global SDGs to their local contexts by setting national targets and indicators. Ukraine, for instance, has developed its own monitoring system, which includes 86 national targets and corresponding indicators, with defined benchmarks to be achieved by 2030 [12, 14, 17]. These indicators are integrated into national planning and statistical reporting systems, and their monitoring supports assessment of strategic implementation (e.g., the national report "Sustainable Development Goals: Ukraine" presents progress across key indicators) [17]. The Ukrainian government annually publishes updates on SDG performance and, in 2020, presented its first Voluntary National Review (VNR), which identified areas of strength and weakness and outlined priorities for future action [17, 20]. This international experience illustrates the utility of quantitative indicators in guiding development: they serve as the foundation for decision-making, policy adjustments, and resource allocation in underperforming areas.

Another example of an indicator-based approach is the European Green Deal – an ambitious political initiative launched by the European Union in late 2019, aimed at transforming the EU economy to achieve climate neutrality by 2050 [19]. The Green Deal encompasses a wide array of interconnected policy areas, including climate and energy, biodiversity, agriculture, transport, industry, and finance [10, 14, 19]. Progress in implementing this strategy is monitored using numerous indicators and benchmarks. The European Commission established a system to track key parameters (e.g., GHG emissions and their reduction relative to 1990 levels, share of renewables in the energy mix, energy efficiency, air and water quality indices, circular economy indicators, waste recycling rates, forest health, and ecosystem condition) [6, 19]. These data are used to assess progress toward both the intermediate targets for 2030 and the long-term goal for 2050.

In addition to official EU monitoring, independent research institutions and academics have also developed methodologies to assess the performance of the Green Deal. One such study proposed a rating system using a set of 26 key indicators from Eurostat, grouped into three thematic clusters [6, 19]. These indicators represent the core dimensions of the Green Deal: climate-energy (e.g., CO_2 emissions, share of renewables, energy efficiency); environmental (e.g., air and water quality, waste management, pollution, resource efficiency); and socio-economic (e.g., investment in green technologies, employment in the green sector, environmental innovation index). Based on the indicator values, composite scores were calculated to evaluate the degree of progress achieved by each EU member state. This approach allows for identification of strengths and weaknesses: some countries may lead in reducing emissions but lag in biodiversity conservation or waste management, while others exhibit the opposite pattern. By analyzing these gaps, the EU and national governments can recalibrate policies and intensify efforts in areas where targets are not being met. Overall, international experience underscores the central role of indicator systems in managing sustainable development. They ensure transparency, accountability, and evidence-based decision-making, promote best practices, and help coordinate the actions of different countries toward shared development goals.

Armed conflicts have devastating consequences not only for human lives and economic stability but also for the environment, creating unique challenges for post-conflict recovery from the perspective of environmental security. The war in Ukraine, launched by the Russian Federation in 2022, is a telling example: environmental damage has been estimated at over 56 billion USD, with widespread chemical pollution of air, water, and soil, and approximately 30% of the country's territory contaminated by mines and unexploded ordnance [20]. Around 30% of protected natural areas have suffered from military activities, including fires, explosions, and ecosystem destruction [20]. Certain war-related technogenic incidents have created long-term threats – for instance, the seizure of the Zaporizhzhia Nuclear Power Plant and the destruction of the Kakhovka Dam pose risks of regional-scale environmental catastrophe [20, 21]. Many of these impacts directly or indirectly endanger human health and safety, exacerbating the humanitarian crisis [14, 20]. Therefore, environmental considerations must be integrated into recovery planning. A just and lasting peace is impossible without restoring the natural environment alongside rebuilding damaged infrastructure.

One of the most complex issues in the post-conflict period is the management of vast amounts of debris and waste generated by destruction. In Ukraine, large-scale hostilities have produced unprecedented quantities of construction and mixed rubble – so-called "conflict-related waste". As of 2023, the destruction of thousands of buildings has resulted in millions of tons of debris (concrete, brick, metal, wood, glass, plastic, electronics), often including hazardous materials such as unexploded ordnance, explosives, toxic chemicals, asbestos, and e-waste [20, 22]. These wartime residues pose significant risks to both the environment and public health. Poorly managed waste threatens secondary contamination (e.g., soil poisoning by heavy metals, groundwater pollution), increases health hazards due to exposure to toxic substances, and can hinder reconstruction due to inaccessible or obstructed land [8, 22]. Unfortunately, Ukraine lacked a formal system for managing such waste at the onset of recovery; only in September 2022 was the first regulatory document on construction debris adopted [7, 22], and local communities still lack financial and technical capacity for safe collection, sorting, and processing [22]. This situation highlights the urgent need for specialized policy solutions and investment in environmentally sound waste management systems.

International post-conflict recovery experiences emphasize the critical importance of integrating environmental priorities into rebuilding efforts. Reports by the United Nations Environment Programme (UNEP) and joint studies by the World Bank, EU, and UNDP highlight the enormous volumes of debris in war-affected cities and stress the need to remove toxic and explosive residues to prevent long-term contamination [22]. Countries in the Middle East that have experienced major conflicts (e.g., Syria, Iraq, Lebanon, Gaza) have developed practices such as establishing temporary sites for rubble storage and sorting, deploying mobile recycling units, and coordinating between military and civil institutions to clear debris efficiently [7, 8, 22]. One of the core strategies has been the application of circular economy principles – maximizing reuse of materials, recycling concrete and metal as aggregate for construction, and repurposing suitable debris in road building. For Ukraine, these approaches are highly relevant: recycling construction waste and reusing materials can reduce pressure on landfills, conserve resources, and lower reconstruction costs. Moreover, international experts recommend involving local communities in waste management planning as early as possible, improving transparency and public access to environmental data on war-related damage [22]. Legal frameworks must also be updated: Ukrainian scholars advocate for defining "war waste" in legislation, streamlining environmental impact assessment procedures for demolition activities, and developing standards for safe dismantling and disposal [22].

In conclusion, post-conflict recovery requires an ecosystem-based approach with a strong emphasis on environmental security. Reconstruction must include: clearance of explosive remnants (demining of agricultural land and residential areas is critical for recovery and resettlement); remediation of technogenic disasters (monitoring water systems after dam explosions, restoring water supply, mitigating radiological risks); sustainable management of natural resources (avoiding overexploitation of forests and minerals); and modern waste management practices. Integrating environmental indicators into recovery planning can serve as a practical tool – for example, tracking water quality, soil conditions, and air pollution levels in de-occupied areas can help identify high-risk zones and prioritize intervention. All these measures align with the "build back better" principle – rebuilding infrastructure in ways that enhance sustainability and resilience. According to international law and expert consensus, lasting peace is impossible without ecological restoration. Ensuring environmental safety – through clean ecosystems, healthy landscapes, and minimized technogenic risks is essential for long-term recovery and population well-being.

5.4 Results of environmental indicator calculations and managerial implications for the sustainable recovery of post-conflict territories

Based on the responses collected through the survey, five environmental indicators were calculated, allowing for a quantitative assessment of the scale and nature of the war's environmental consequences in de-occupied communities in southern Ukraine. To ensure clarity and enable deeper analysis, the values of these indicators were visualized using a heat map.

The heat map provides a spatial overview of environmental stress across the studied communities, highlighting areas with critical values and indicating where the environmental impact of military actions is most extensive and multifaceted. This approach not only illustrates the current ecological condition of each community but also serves as a foundation for evidence-based decision-making in the context of recovery and sustainable development in post-conflict areas (**Fig. 5.1**).

In **Fig. 5.1**, the computed values for the five indicators – TPMA, DNES, IHWI, ANR, and BPHP – are displayed across 42 de-occupied communities in southern Ukraine. The indicator values vary widely. Most communities demonstrate moderate levels of environmental burden, with indicator scores falling within the mid-range (0.3 to 0.7 on a normalized 0–1 scale), represented in the map by orange tones. At the same time, a distinct group of communities exhibits elevated values across all five indicators (rows shaded in red tones on the heat map), signaling a high cumulative level of environmental stress at the community level.

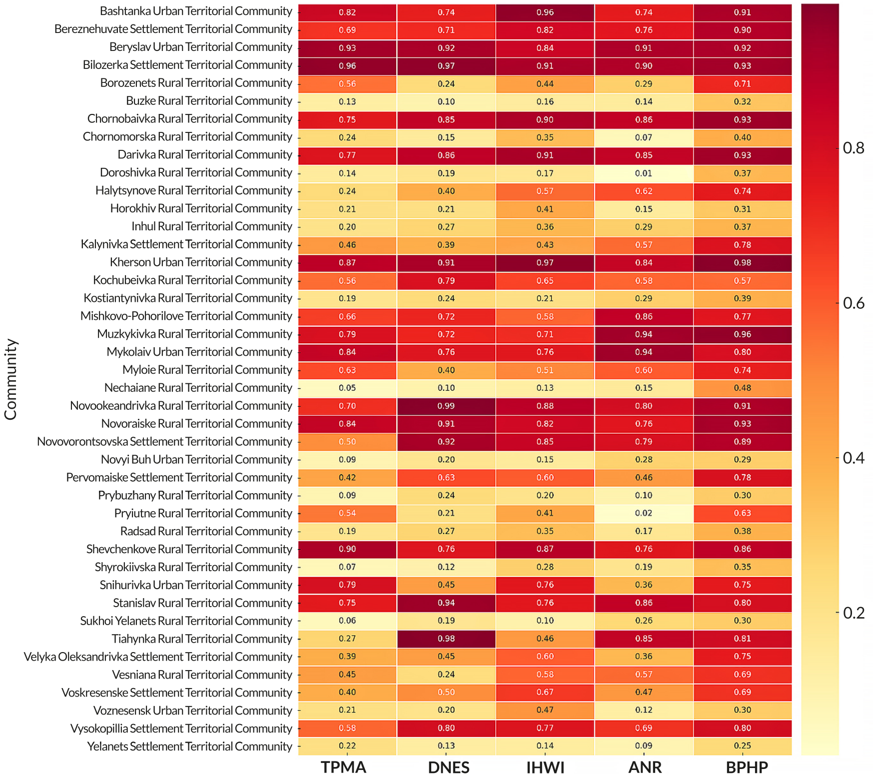

Fig. 5.1 Heat map of environmental indicators
in de-occupied territorial communities of Southern Ukraine
Source: visualized by the authors

The highest aggregate scores across all environmental indicators were recorded in specific communities, particularly in Bilozerka Settlement Territorial Community and Kherson Urban Territorial Community. These communities are represented by the darkest red tones on the heat map, indicating values approaching the upper threshold (0.9–1.0). Such high scores reflect the extreme negative environmental impact of military operations in all evaluated domains – from technogenic pollution and ecosystem degradation to biosecurity challenges.

Also included in the group of most heavily burdened communities are Beryslav Urban and Dariivka Rural Territorial Communities, where the cumulative scores across the five indicators exceed 4.5 out of a possible 5. This highlights the presence of complex environmental challenges and identifies these locations as "hotspots" of ecological risk in de-occupied territories.

Conversely, several territorial communities are characterized by low levels of cumulative environmental stress, as indicated by consistently low values across all indicators (light yellow segments on the heat map). The lowest aggregate scores were observed in Yelanets Settlement, Buzke Rural, and Doroshivka Rural Territorial Communities, where the total indicator values are close to 0.8. In these areas, the indicators of technogenic pollution, ecosystem degradation, infrastructure condition, resource access, and biosecurity are among the lowest recorded across the entire sample. These results suggest a relatively limited environmental impact of hostilities and a faster ecological recovery in these communities compared to high-risk areas such as Bilozerka or Kherson.

To illustrate the relationship between the environmental conditions of de-occupied areas and corresponding managerial responses, a structural model of decision-making was developed. This model is based on the five environmental indicators and outlines the logical progression from problem identification to the implementation of sustainable recovery measures (**Fig. 5.2**).

Fig. 5.2 presents a stepwise structure encompassing:

– environmental indicators (TPMA, DNES, IHWI, BPHP, ANR);

– the typical problems identified through these indicators;

– strategic response proposals;

– specific actions for implementing these strategies;

– the anticipated outcomes of these interventions.

The model enables the integration of empirical analysis results into a framework for informed environmental governance, with a focus on local community needs and sustainable development principles. It not only synthesizes the findings of the study but also serves as a practice-oriented tool for local policy planning. Its application can help improve the effectiveness of decision-making, mitigate environmental risks, and strengthen community resilience for sustainable post-war development.

The implementation of managerial decisions aimed at addressing the environmental consequences of armed conflict requires more than just data and strategic vision – it also depends on well-defined funding sources. In the context of significant budget constraints, especially at the level of de-occupied communities, the mobilization of external resources, cross-sector partnerships, and innovative financing mechanisms becomes a pressing need.

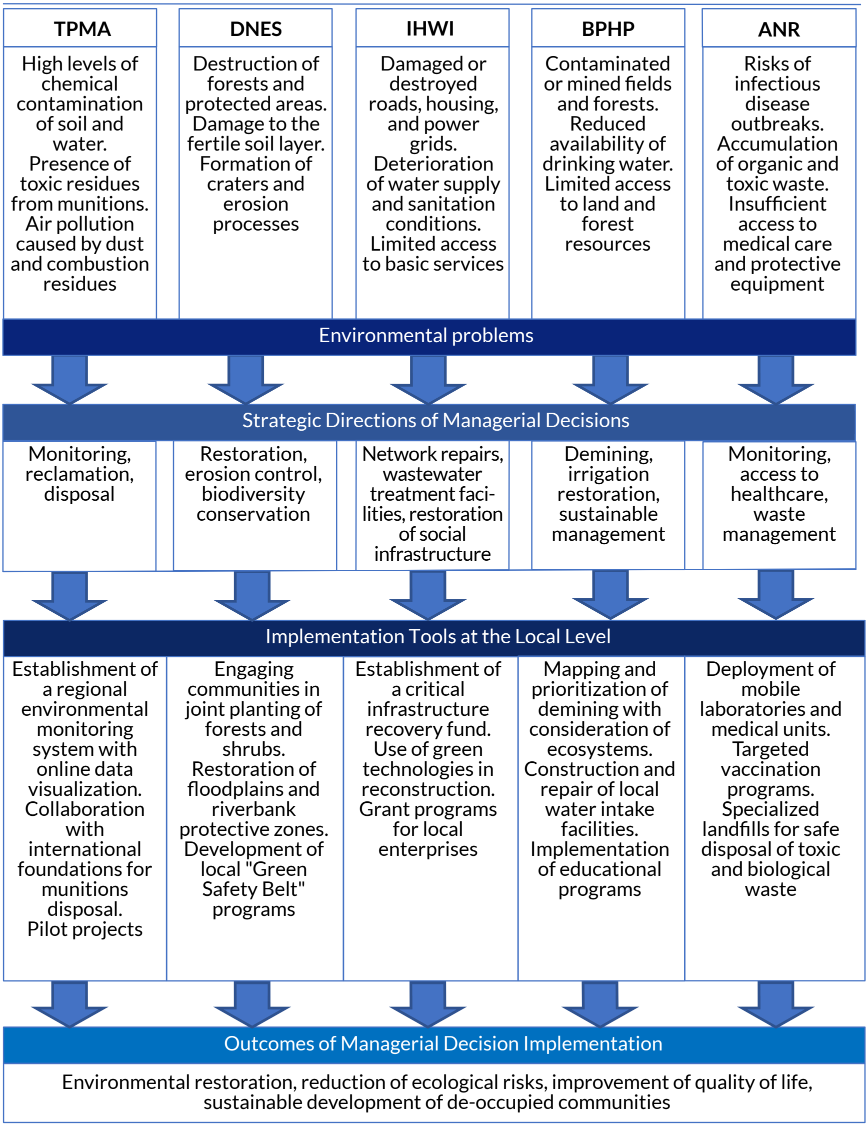

Fig. 5.2 Structural model of managerial decisions for sustainable recovery of de-occupied territories based on environmental indicators
Source: visualized by the authors

International donors play a pivotal role in financing environmental recovery efforts. The European Union, World Bank, UNDP, USAID, NEFCO, and other development partners are already supporting projects in Ukraine focused on demining, waste management, water infrastructure rehabilitation, and the deployment of energy-efficient technologies [23–26]. Several grant and investment programs are specifically tailored to assist war-affected communities, making the integration of environmental components into funding proposals a key factor in increasing their competitiveness and likelihood of approval.

Within Ukraine, both national and regional funds support environmental initiatives, including the State Fund for the Elimination of Consequences of Armed Aggression, the Environmental Protection Fund, and the Regional Development Fund. Through effective inter-municipal coordination, communities may submit joint projects – such as the construction of waste management facilities or the restoration of water resources – that address cross-cutting environmental challenges.

Equally important is the potential of public–private partnerships, particularly the engagement of the private sector in implementing eco-technologies and innovative solutions. Financial instruments such as green bonds, crowdfunding, and community-based investment in infrastructure and environmental protection projects offer additional avenues for mobilizing resources. In this context, it is essential that communities possess not only strategic planning documents, but also clear financial models that enable them to present their initiatives effectively to potential donors and investors.

Given the scale of environmental challenges and the limited availability of resources, the development of a coherent financing roadmap is a critical component of environmentally oriented recovery policy. Systematic planning, transparency, and openness to international cooperation significantly enhance the capacity of local governments and communities not only to address the consequences of war, but also to build long-term ecological resilience.

5.5 Conclusion

The findings of this study demonstrate that the sustainable recovery of Ukraine's de-occupied territories is not feasible without the systematic integration of environmental considerations into decision-making processes. The war has placed a substantial burden on the natural environment, manifested in increased technogenic pollution, ecosystem degradation, limited access to natural resources, compromised biosecurity, and the destruction of critical infrastructure.

Analysis of the sociological survey conducted across 42 de-occupied communities in southern Ukraine enabled the calculation of five core environmental indicators. These indicators not only reveal which territories are facing the most acute ecological challenges but also help identify priority areas for intervention. Visualization through a heat map and a structural decision-making model further underscores the practical value of the indicator-based approach in planning sustainable recovery efforts.

The proposed structural model for managerial decision-making provides a clear framework for transitioning from problem identification to the implementation of targeted strategic and operational actions. Its application at the community level can enhance transparency, legitimacy, and the overall effectiveness of environmental policy within the context of post-conflict reconstruction.

Moreover, the findings highlight the need to institutionalize environmental monitoring systems, foster civic science initiatives, establish open-access ecological data platforms, and promote inclusive decision-making involving local communities.

This study has several limitations, including reliance on self-reported assessments, a voluntary sampling methodology, and the absence of longitudinal data. Future research should aim to triangulate subjective perceptions with objective environmental measurements, conduct follow-up assessments to track dynamic changes, and expand the geographic scope to include other regions of Ukraine. A promising direction for future inquiry is the development of a national index of environmental resilience for post-conflict territories, integrating local-level data, SDG-aligned indicators, and policy performance evaluations. Additionally, regulatory improvements are urgently needed, particularly regarding the management of war-related waste and the environmental assessment of reconstruction projects.

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