UDC 504.062:330.15:528.9

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IDENTIFICATION, ASSESSMENT AND MAPPING OF ECOSYSTEM SERVICES IN THE CONTEXT OF SUSTAINABLE NATURAL RESOURCE MANAGEMENT

Summary. The growing "polycrisis", characterised by environmental degradation, climate change and resource scarcity, further exacerbated by the war in Ukraine, highlights the urgent need for sustainable natural resource management. Despite the extensive development of the ecosystem services concept, a significant gap remains between scientific knowledge and its integration into decision-making processes. This study aims to develop a theoretical and methodological approach to integrating ecosystem service values into decision-making by identifying, assessing, and spatially mapping them. The proposed approach combines economic valuation and GIS-based analysis to generate spatially explicit outputs and support evidence-based environmental policy and sustainable post-war recovery.
Keywords: ecosystem services, economic valuation, GIS mapping, decision-making, sustainable natural resource management

Analyzing global risks for society and the economy, experts from the World Economic Forum in Davos (WEF, 2023) pointed out the emergence of a "polycrisis", which is the intertwining and mutual reinforcement of destructive processes such as geopolitical, social, economic, and technological crises, with the loss of environmental quality, the limited capacity of natural ecosystems, and their ability to recover under climate change being at the center of these issues. Ecological risks have become more intense and frequent in recent years, and this trend, according to experts' assessments (WEF, 2025), will continue in the coming decades. Specifically, this refers to the intensification of extreme weather events, biodiversity loss, ecosystem collapse, critical changes in Earth's systems, and natural resource shortages. These global trends are particularly exacerbated by the war in Ukraine, which leads to significant human suffering and has far-reaching geopolitical, ecological, and economic consequences (Balbaa et al., 2022). It negatively impacts food (Abay et al., 2023; Pörtner et al., 2022), energy (Kuzemko et al., 2022), and financial systems (UN, 2022) in Ukraine and globally. Preventing these threats can only be achieved by recognising the importance of preserving ecosystems and the ecosystem services (ES) they provide, by integrating their values/price into decision-making processes in both theory and practice.

The concept of ES emerged in the 1970s (Schumpeter, 1973), and by the 2000s, it had become central in interdisciplinary and national contexts. Works by Westman (1977), R. Costanza et al. (1997), and others sparked deep interest in assessing the value of these services, showing the importance of natural capital. The Millennium Ecosystem Assessment (2005) report, along with numerous publications from the "The Economics of Ecosystems and Biodiversity" (2010) project, provided a significant boost to scientific research and a range of international and national programs and reports. Much of the literature on this subject focuses on the classification and quantitative assessment of services to operationalise this concept and integrate it into decision-making processes (de Groot et al., 2012; Braat et al., 2012; Spash, 2016; Schomers, 2013; Pelyukh et al., 2021; Pelyukh & Zahvoyska, 2026). In recent years, there has been an increase in publications on the methodology of identifying and assessing the benefits society derives from natural ecosystems (TEEB, 2010; Spangenberg & Settele, 2016, etc.), especially in the context of developing plans for "green" post-war economic recovery (European Green Deal, 2019; Recovery Plan for Europe, 2020).

In many countries, activities are intensifying on a wide range of issues related to ES, including their assessment, identifying potential sellers and buyers, compensation mechanisms, and forming markets for these services. There have already been significant achievements in this direction, including

the publication of fundamental international research results on the economics of ES (such as "Ecosystem Services at the Millennium's Threshold" 2003, 2005; "The Economics of Ecosystems and Biodiversity" (TEEB, 2008); the World Bank's work in this area, etc.). Along with theoretical developments, several countries have successful examples of economic assessment and compensation of ES within international and national economic mechanisms to counteract the negative impacts of climate change. Identifying and assessing ES and subsequently forming economic and institutional mechanisms to integrate these assessments into decision-making processes are crucial in this context.

The State Environmental Policy Strategy of Ukraine for the period until 2030, the European Green Deal (2019), and the Green Recovery Policy (2020) aim to create favorable conditions for the transformation of policies and practices in natural resource management. However, in Ukraine, the issue of ES is insufficiently addressed in both scientific literature and political, legal, and directive documents. Currently, in state regulation, the concept of "ES" is virtually absent. They are not adequately assessed and, therefore, not considered in decision-making processes.

The identification and assessment of ES aim to better combine the rational use of the environment, its preservation and restoration, with permanent economic development and ensuring a decent standard of living for people. However, even 60 years after the inception of the ES concept, a persistent gap persists between the generation of scientific knowledge about ES and its use to support policy and management in these areas (Bitoun et al., 2022).

In recent years, projects aimed at evaluating ES have become increasingly active, and platforms have been created to support decision-making (e.g., the Ecosystem Services Tool Selection Portal in the USA). As an example, the "ARIES" project (Artificial Intelligence for Ecosystem Services), carried out by the University of Vermont (USA), aimed to create "intelligent" databases of landscape spatial structure as a foundation for assessing ES with practical applications. In Eastern Europe, with the support of WWF, similar projects have been implemented in Bulgaria and Romania to integrate forest ecosystem services into management decisions. However, gathering, assessing, and applying ES data in decision-making processes is difficult due to factors like scale, decision uncertainty, and stakeholder interests. There is a clear need to refine the theory and methodology of ES assessment (TEEB, 2010; Spangenberg & Settele, 2016), particularly within the context of decision-making (de Groot et al., 2012; Braat et al., 2012; Spash, 2016; Schomers, 2013; Pelyukh et al., 2021; Kyrylenko et al., 2024; Pelyukh & Zahvoyska, 2026).

The aim of this study is to develop a theoretical and methodological approach for integrating ES values into decision-making processes by identifying them, assessing their value/price, and mapping them, with the goal of preventing socio-ecological-economic threats.

To achieve this, the research applies an integrated methodological approach that combines several interrelated components. First, it includes the systematisation and critical analysis of existing conceptual and methodological frameworks for ecosystem service assessment. Second, it involves identifying and classifying provisioning, regulating, supporting, and cultural ecosystem services relevant to the study context. Third, it applies economic valuation methods, including both market-based approaches and non-market techniques, such as stated and revealed preference methods, to capture the value of ecosystem services. Finally, the approach incorporates GIS-based spatial analysis in QGIS to map the distribution of ecosystem services, accounting for ecological characteristics and spatial heterogeneity.

The proposed methodological approach illustrates the logical sequence and interconnections between all stages, from input data (ecological, spatial, and socio-economic) to the generation of spatially explicit outputs, including maps of key ecosystem services such as carbon storage, water regulation, erosion control, recreation, and habitat provision. The approach also includes an integration block, ensuring the application of results in decision-making processes for natural resource management, land-use planning, and environmental policy.

The expected contribution of the study lies in bridging the gap between theoretical developments in ecosystem service research and their practical application in environmental governance. The developed framework is intended to support evidence-based decision-making in natural resource

management, land-use planning, and environmental policy. Its relevance is particularly significant in the context of sustainable development and post-war recovery in Ukraine, where the integration of ecosystem services into policy and planning processes can contribute to more resilient and adaptive socio-ecological systems.

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