



## Ecosystem Service Valuation of Natural Healing Assets: A Sustainability-Corrected Gross Ecosystem Product (GEP) Capitalization Model

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**Abstract:** Natural healing resources (NHR) are presented as ecosystem resources that have a dual nature of ecosystem services and economic significance for the country, and the result of their sustainable use should provide a reserve for the provision of rehabilitation and health services to the population. Currently, international scientists' achievements in accounting for natural capital include the System of Ecological-Economic Accounting (SEEA) and the Gross Ecosystem Product (GEP), which have become widely adopted. In contrast, the economic and social functions of healing natural assets that are not included in the system of ecological and economic accounts are not reflected at all. This situation creates institutional collapse within the sectoral economy, which is focused on the development of resort areas, and within the social contribution – rehabilitation, and health. The study is devoted to developing a hybrid methodological framework for capitalizing on natural healing assets by adapting the GEP approach to healing ecosystems. The hybrid methodology proposed by the authors involves conducting an assessment across three areas: ecological, medical-biological, and financial-economic (based on replacement cost, willingness to pay, and market approaches consistent with the principles of ecological-economic accounting).

**Keywords:** natural healing assets, Gross Ecosystem Product (GEP), System of Environmental-Economic Accounting (SEEA), natural capital, resort economy, ecosystem services

### 1. Natural Healing Assets in the Global Transition Beyond GDP

A natural resource is the totality of living and nonliving components of an ecosystem that generate flows of ecosystem services that contribute to human well-being and economic activity. Modern assessment systems, such as the System of Environmental-Economic Accounting (SEEA), the Economics of Ecosystems and Biodiversity (TEEB), and the Gross Ecosystem Product (GEP) approach, quantify natural resources in both physical and monetary terms. One modern tool for assessing natural resources in the economy at the national and regional levels is the GEP concept, developed and tested in China and used in European statistics and World Bank programs.

Despite the growing international adoption of the gross ecosystem product concept in environmental-economic accounting, natural healing resources are virtually unrepresented in existing methodological approaches, which impacts public decision-making. This hinders balanced investment decisions for strategic planning in the development of resort areas to meet the population's rehabilitation and health needs. Unlike traditional gross domestic product (GDP), which reflects only market production, gross ecosystem product (GEP) reflects the total monetary value of ecosystem services, including recreation, climate regulation, and health-related ecosystem benefits. Growing recognition of GEP reflects a broader global shift toward economic assessment frameworks that go beyond GDP and seek to incorporate natural capital into macroeco-



conomic policy assessment and development planning (Beyond GDP: Including Nature in Economic Policy Assessment, 2024).

However, in Ukraine, institutional conditions significantly limit the practical implementation of such approaches. National legislation lacks a uniform definition of the term "natural asset," and the concept of ecosystem product is not formally included in economic or environmental regulatory frameworks. This institutional gap hinders the reflection of natural healing resources in economic statistics, national accounts, and public investment programs. As a result, mineral waters, therapeutic muds, and climate-dependent resources remain largely invisible in budget planning, restoration programs, and financing mechanisms. Systematic undervaluation of these resources contributes to their inefficient use, environmental degradation, and missed opportunities for regional economic development.

The importance of ecosystem services and natural capital accounting has become particularly strategic in the context of Ukraine's post-war reconstruction. Restoring human capital, rehabilitating affected populations, and revitalizing the regional economy require new development tools that integrate environmental, social, and economic factors. Spa economies based on natural healing resources represent a potential mechanism for achieving these goals; however, their economic contribution remains insufficiently quantified within existing policy frameworks.

Addressing this methodological and institutional gap, this study aims to develop a GEP-based methodology for the assessment and management of aquatic natural healing resources (NHR). The proposed approach allows for the simultaneous assessment of economic capitalization and socioeconomic effects generated by ecosystem services derived from mineral waters and therapeutic muds, which is particularly important for territorial development and post-conflict reconstruction strategies. Based on this objective, the study formulates the following research hypotheses:

H1. Natural healing assets generate measurable socio-economic value within resort ecosystem systems.

H2. Natural healing assets, combining ecosystem services (health improvement, recreation, and climate regulation) with ecosystem products (mineral waters and therapeutic muds), can be integrated into a unified Gross Ecosystem Product indicator reflecting their capitalization potential.

The proposed framework applies a hybrid methodological approach that integrates resource inventory, ecological condition assessment, monetary valuation of ecosystem services, and strategic planning for sustainable use. Although Ukraine has adopted the State Environmental Policy Strategy until 2030, natural healing assets are still absent from national statistical accounting and financial planning systems. This institutional invisibility restricts their inclusion in reconstruction policies, investment strategies, and economic incentive mechanisms targeting affected resort territories.

The expected outcomes of the study include the methodological integration of NHAs into the SEEA framework, the development of a natural resource cadaster, and the formulation of economic incentive mechanisms, such as green financing instruments, compensatory payments, and investment support schemes. These measures allow natural healing assets to be treated as components of national capital, enhancing the investment attractiveness of resort regions and strengthening ecosystem services as drivers of post-war recovery and societal well-being.

The contribution of this research lies in extending the international discourse on natural capital monetization by adapting the GEP concept to healing ecosystem resources. The proposed accounting framework consolidates ecosystem products and services derived from natural healing assets into a unified monetary indicator, enabling their capitalization as economic assets. By linking environmental indicators with economic accounting units, the methodology facilitates the inclusion of NHAs within environmental-economic accounting systems and reveals their public value as previously hidden assets. Implementation of this approach in policy and management decisions can stimulate investment flows and enhance regional financial resilience during reconstruction.

The remainder of this paper is structured as follows. Section 2 describes the literature review and theoretical background; section 3 presents the materials and methods; section 4 presents the proposed results; section 5 provides a discussion of the findings; and section 6 presents the conclusions.

## **2. Literature Review and Theoretical Background**

### **2.1. Evolution of Natural Asset and Ecosystem Service Concepts**

The development of approaches and institutional frameworks for managing natural assets and ecosystem services reflects a clear evolution, from establishing conceptual foundations to creating practical methods for economic assessment and integrating these approaches into management and decision-making systems. For the first time, ecosystem services were reflected in 2005 within the framework of the Millennium Ecosystem

Assessment (MEA) project (Percy & Lubchenco, 2005), in which for the first time at the global level the concept of ecosystem services (ES) was systematized, their classification was carried out and the need to integrate these services into economic planning and management decisions was substantiated, taking into account both their monetary and non-monetary value. The priority of the MEA approach is the development of a holistic global approach to ecosystem services. However, the concept includes tools for cost-effective integration. Therefore, the MEA concept itself has become the basis for seeking an economically sustainable relationship with the availability of natural resources.

The idea was further developed in the concept of Natural Capital Accounting (NCA) (García-López & Pérez-Hernández, 2024), which is considered a key tool for businesses and governments, enabling the avoidance of so-called "intangible liabilities" arising from the underestimation or omission of environmental aspects in corporate reporting. The biosphere and natural ecosystems should be considered both economic assets and productive capital (Koval et al., 2025; Shmygol, 2025).

It was proposed to revise GDP as the leading indicator of a state's economic situation and transition to welfare indices, taking into account the state of the ecosystems within the natural environment. Thus, the above approaches prove the economic significance of ecosystem services not only for the general well-being of the population but also for the economic growth of the economy as a whole. The introduction of these approaches into the Ukrainian economic system is critical; however, their practical implementation is complicated by institutional gaps. However, a contemporary review reveals that, despite the existence of various concepts, none offers a comprehensive methodology for assessing and capitalizing on natural health assets, which encompass both tangible products (such as mineral waters and therapeutic mud) and intangible therapeutic services. This creates a research objective: no methodology integrates NHA ecosystem services and products into a single economic indicator for policy and planning.

## **2.2. Gross Ecosystem Product (GEP) as an Environmental-economic Indicator**

Over the last decade, the Gross Ecosystem Product (GEP) tool has gained increasing importance, enabling the monetary valuation of all ecosystem goods and services. Daily and Ruckelshaus actively promote this approach in their research on integrating environmental policy and financing into regional economies (Daily & Ruckelshaus, 2024; Mikhno et al., 2020), namely, valuing natural capital on par with human and physical capital. Using the Gross Ecosystem Product methodology, which measures the economic value of ecosystem goods and services, the authors demonstrate how to value, monetize, and integrate ecosystem services and natural capital into public policy, investment decisions, spatial planning, and conservation activities. Zheng et al. (2023) also focus on the Gross Ecosystem Product (GEP), using China as an example. They apply GEP to budget planning, local development assessment, spatial planning, environmental compensation, and sustainable decision-making assessment by regional managers, thereby establishing a basis for environmental indicators of well-being. Another work, devoted to methodological recommendations for calculating gross ecosystem product (Ouyang et al., 2020), in which the authors propose a comprehensive monetary valuation of ecosystem services adapted to public administration, namely GEP as a formal system for measuring natural capital that can be integrated into national and regional administration to better inform decisions in the field of sustainable development, environmental protection, and budget planning.

The novelty of the GEP approach lies in its provision of an aggregate monetary indicator, adapted for informing political decisions and investment opportunities. However, such a general indicator of the economic assessment of natural assets and ecosystem services may undermine the overall assessment and lead to double-counting. The practical contribution is to establish a basic concept for incorporating ecosystem services into the strategic planning of territorial development and the formulation of environmental investment policies in sectoral management. The proposed GEP concept should become a tool of budget policy. At the state level, this allows integrating capitalized ecosystem services into budget planning. For Ukraine, implementing GEP is feasible as part of a hybrid methodology (in conjunction with SEEA and environmental sustainability adjustments). Despite its versatility, GEP does not account for the specifics of natural health assets and fails to distinguish between therapeutic effects, recreational benefits, and material products. This exacerbates the research purpose, as no methodology allows GEP to be explicitly adapted to NHA.

## **2.3. International Applications of Ecosystem Accounting: Comparative Perspective**

It should be noted that the assessment of ecosystem services depends on the region of application, its institutional framework, and economic and legal objectives. A comparative analysis of approaches to accounting for natural capital in China, the EU, and Africa has been carried out. It should be noted that, in each specific case, integrating accounting for ecosystem services into the national economy and accounting for the diversity of influences on management decision-making are important.

An analysis of international experience allows us to identify economic tools for assessing natural assets and ecosystem services, but it also highlights the imperfections of methodological approaches to assessing natural healing assets.

For the first time, China introduced the methodology for calculating gross ecosystem product, on the basis of which economic management tools are used. GEP was first introduced by Ouyang et al. (2020) and measures the total monetary value of ecosystem goods and services produced within a given territory, similar to GDP but reflecting the contribution of nature to economic well-being. The author (Ouyang, 2024) calculated the GDP for the Guizhou Province pilot project for ecosystem services at US\$280 billion at 3 levels: service provision (water, biomass), service regulation (climate, water purification), and cultural services (tourism, recreation). However, this method does not clearly separate health and therapeutic ecosystem effects, which creates methodological gaps for resort economies.

European countries apply ecosystem valuation mainly through the System of Environmental-Economic Accounting (SEEA EA) – a UN statistical standard linked directly to national accounts (Hein et al., 2020). Statistics Netherlands (CBS) developed national ecosystem accounts, including ecosystem extent accounts, ecosystem condition accounts, monetary ecosystem service accounts, and natural capital asset accounts (Berkel et al., 2024), and follows Eurostat and UN SEEA standards. Ecosystem accounts include: forest, urban, and coastal ecosystem indicators; biodiversity condition metrics; and ecosystem service valuation per province. Monetary valuation covers 10 ecosystem services at the national scale and, in the SNA, is treated as a satellite. It connects environmental stocks and flows with macroeconomic indicators used in national statistics. But also has some limitations, such as a focus on statistical monitoring, weak investment and capitalization functions, and limited integration of human health effects.

African implementation follows a governance-oriented pathway through the World Bank WAVES (Wealth Accounting and Valuation of Ecosystem Services) initiative. Natural capital accounting is used for: water resource planning, fiscal sustainability, mining and land-use policy, and long-term wealth measurement. These systems treat ecosystems as national assets supporting economic resilience. However, implementation remains constrained by limited datasets, institutional capacity, and the absence of sectoral valuation models (Central Statistics Office, 2025).

The GEP framework represents one of the most advanced attempts to express ecosystem contributions through a single monetary indicator comparable to Gross Domestic Product. Its primary advantage lies in creating a clear, aggregated value that can be directly used in public governance and regional policy evaluation. GEP has been integrated into administrative decision-making processes and supports ecological compensation mechanisms and territorial development planning. However, the aggregation principle underlying GEP also creates methodological challenges. The use of a unified monetary indicator increases the risk of double-counting ecosystem services, while high levels of aggregation tend to obscure sectoral specificities.

The SEEA ecosystem accounting framework provides a statistically standardized methodology aligned with the System of National Accounts. Its main strength is full compatibility with national accounting systems, ensuring methodological consistency, international comparability, and high statistical reliability. SEEA enables long-term monitoring of ecosystem extent, condition, and service flows, thereby supporting evidence-based environmental governance. Nevertheless, its direct usefulness for economic valuation is to attract investment or develop sector-specific markets. As a result, the framework provides strong measurement capacity but relatively weak mechanisms for transforming ecosystem value into economic capital.

In African countries, natural capital accounting has been introduced to support sustainable development strategies, enabling management decisions based on the state's macroeconomic plans for the development of a specific territory. This approach allows for fiscal control, taking into account the value of natural assets as national wealth. However, the approach's disadvantage is its institutional framework, which does not distinguish between the capitalization of natural resources being assessed. A comparative analysis of the methods is presented in Table 1.

**Table 1.** Comparative implementation of ecosystem valuation frameworks and calculation indicators

Criterion	China (GEP Accounting)	European Union / Netherlands (SEEA EA)	Africa (Natural Capital Accounting)
Example territory	Qinghai Province	Netherlands national accounts	Rwanda, Botswana
Estimated ecosystem value	GEP USD 46.7 billion/year (Qinghai)	Ecosystem services €15–20 billion/year (Netherlands estimates)	Natural capital 30–40% of national wealth (Rwanda WB estimate)
Share relative to GDP	GEP 70–90% of regional GDP	Environmental assets integrated as satellite accounts	Natural capital contributes 25–45% of total wealth

Table 1. cont.

Criterion	China (GEP Accounting)	European Union / Netherlands (SEEA EA)	Africa (Natural Capital Accounting)
Calculation components	Provisioning + regulating + cultural services	Ecosystem extent, condition, service flows	Forest, water, and land asset valuation
Integration into national accounts	Policy indicator parallel to GDP	Fully aligned with SNA (UN standard)	Linked to wealth accounting frameworks
Sources	Ouyang et al., 2020; Zheng et al., 2023	UN SEEA EA 2021; CBS Netherlands	World Bank WAVES Reports

In general, a comparative analysis shows that existing international approaches assess ecosystem services and natural resources at different levels. GEP is focused on monetization, primarily political decision-making; SEEA focuses only on statistical integration into national accounts; and the African Natural Capital Accounting prioritizes sustainable development planning. At the same time, none of these frameworks fully accounts for the multidimensional value of natural healing assets, including the interplay among environmental, economic, and health-related impacts, which justifies the development of valuation methodologies adapted to the sector.

#### 2.4. Natural Capital Indicator Framework and Ecosystem Monitoring Approaches

A key direction is the development of indicator systems to monitor the state of natural capital and ecosystem services (Fairbrass et al., 2020; Xu et al., 2025), which use indicators of natural capital assets and flows. The Natural Capital Indicator Framework (NCIF) was proposed as a methodological framework for national reporting on natural capital, enabling a systematic and comparative assessment of changes in natural resources and ecosystems over time. Such a toolkit will facilitate the integration of natural capital into economic policy and national accounting systems (the System of Environmental-Economic Accounting), enabling managers to make sustainable decisions about the management of the natural environment. The proposed NCIF approach is a qualitative tool for monitoring and comparing systems over time periods. However, it is not acceptable for economic assessment, since it does not provide a monetary value. The central contradiction between NCIF and GEP is that one methodological approach is focused on qualitative indicators, while the other is too “monetary” and too “qualitative” in monetary terms. These approaches focus on providing constantly updated information on indicators for the systematic assessment of the state of natural resources and ecosystems.

These indicators cannot be used to value natural capital, but can be used over time to monitor the state of natural healing assets and their use in economic activities. In Ukraine, a combination of both tools is needed.

#### 2.5. Economic Valuation Methods for Ecosystem Services

Regarding methods for the economic valuation of ecosystem services, various approaches are common in scientific practice: direct market pricing, willingness-to-pay analysis (Contingent Valuation Method, WTP), Hedonic pricing (assessment of the impact of ecosystems on the market value, for example, of real estate), and Value Transfer, the application of valuation results from one territory to another with similar characteristics. The study examines the use of value transfer methods, where the estimated value of ecosystem services from one study (the donor site) is applied to assess similar services in a new area (the policy site) when direct data are unavailable, and can subsequently support ecosystem accounting, including assessments within the SEEA EA framework (Grammatikopoulou et al., 2023). An example of the practical use of WTP is a study conducted in Sardinia, which focused on the conservation (La Riccia et al., 2023) forest ecosystems and management decisions for their conservation and spatial planning, using the conditional valuation method (CVM) to estimate the willingness to pay (WTP) of residents and tourists.

It was proposed using WTP as a predictive planning tool, particularly for determining management priorities, investments, and environmental policies. The project to study the combination of natural infrastructure for stabilizing the US coast (Beasley & Dundas, 2021) aims to determine the monetary value of ecosystem services, which are often devoid of market prices, to support planning and budgeting decisions. Using the analytical approach of Hedonic pricing (real estate analysis), the authors estimate the willingness to pay for coastal protection through changes in the price of housing near protective ecosystems. This approach enables them to determine the optimal location of natural infrastructure to maximize NPV (present value of services) through dynamic bio-economic modeling. These methods show their effectiveness only in their interaction. Therefore, Ukraine needs to integrate them to consider both the population's demand and the actual market

value of services. In Ukraine, such methods have not yet been integrated, and this article proposes their unification, followed by further testing to assess their feasibility in practice.

Using market methods (replacement cost, market price, restoration costs) allowed us to provide a real monetary valuation of ecosystem functions (Cherchyk, 2022; Kostetska, 2025). Ukrainian methods primarily focus on environmental control, damage assessment, and regulation (OVD, SEO, loss methods). International methodological approaches are intended for the value creation and natural capitalization. Such a contradiction highlights why natural healing assets (NHA) are not yet fully integrated into the national economy.

Methodologies for assessing damage and restoration costs following resource exploitation or degradation (Didukh et al., 2025) consider biophysical parameters, environmental standards, and regulations. They can serve as a basis for determining appropriate compensation. Summarizing the diversity of approaches to accounting and assessing natural resources and ecosystem services, we note that they are an integral part of the national economy and should be included in the system of state ecological and economic accounting. This will enable them to overcome gaps in institutional support for their capitalization and monitoring, and to further integrate into management decision-making. This creates another research gap: the lack of a tool that combines capitalization indicators (GEP) and qualitative indicators of the state of healing natural resources for comprehensive NHA management.

## 2.6. Institutional and Regulatory Frameworks (EIA, SEA, and Policy Integration)

The regulatory and legislative methodologies of EIA and SEA (On Strategic Environmental Assessment, 2018) are designed to assess the environmental and public health impacts of projects, plans, and programs. While the previous section focused on valuation methods, this section addresses regulatory and institutional mechanisms. This enables integration into the legal framework of obligations for projects that utilize natural resources. Market-based methods for valuing natural resources (Methodological recommendations for assessing the value of ecosystem services, 2023) examine approaches to monetizing natural assets, including market price, cost, and opportunity cost methods, which are useful for financial planning and support informed decision-making by investors. An interdisciplinary rethinking of key concepts emphasizes that «natural assets» (Martinez-Harms et al., 2018) integrate biophysical, cultural, and economic values, providing a unifying framework that aligns ecological, economic, legal, and ethnocultural approaches to nature management.

The article is devoted to research at the regional level (Mizgajski & Stępniewska, 2012), in which the authors review the current situation regarding the development of ecosystem services (ES) assessment in Poland, identify the main problems in implementing this approach, and propose solutions for integrating ecosystem services into policy and planning for effective natural resource management.

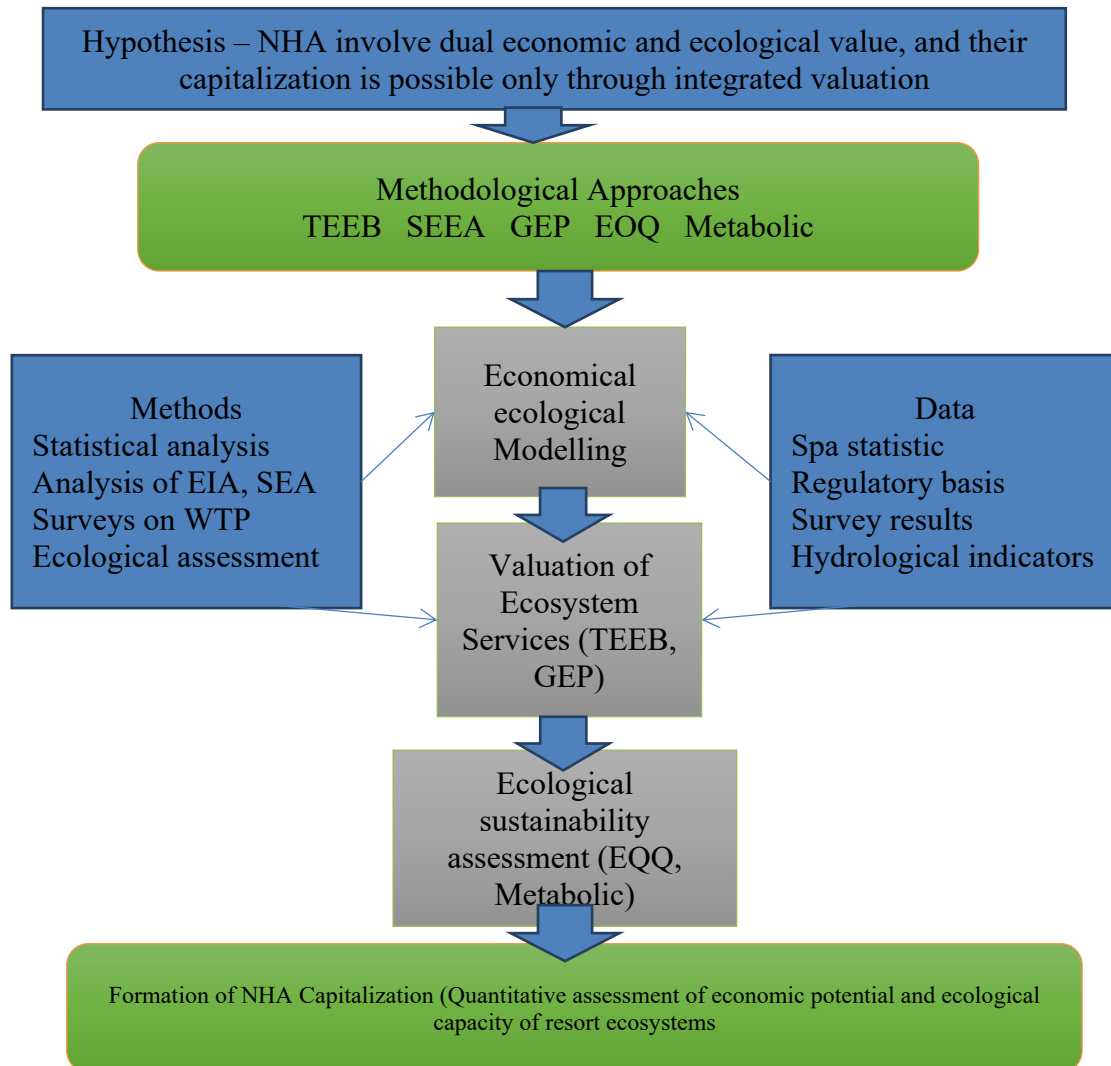
Additionally, research (Maczka et al., 2016), based on a systematic empirical analysis of key strategic and policy documents, is dedicated to developing the concept of ecosystem services (ES) for its further integration into Poland's national environmental policy. Generalizing international methodological support, namely approaches (TEEB, SEEA) in which the initial unit for assessing natural capital is determined by the ecosystem of the territory, in which resources and services are an integrated system. This proves that NHA cannot be analyzed separately; their added value arises from their interactions with the functions provided by the territory. Thus, the hypothesis that Natural healing assets contribute to the socio-economic value of the resort area's ecosystem is confirmed. Thus, it is relevant for Ukraine to transition from a control-based assessment of damage and restoration to a system focused on creating economic value from natural assets. A hybrid approach is optimal: GEP as an aggregate, SEEA as an accounting base, and local methods for specific services. This will enable natural healing assets to be included in national accounts and increase their investment attractiveness.

## 2.7. Research Gap and Conceptual Positioning of Natural Healing Assets

This study fills the gaps identified, as it proposes for the first time: the adaptation of the GEP concept to natural healing assets; the integration of products (mineral waters, therapeutic muds) and services (health, climate, recreational, therapeutic) into a single capitalized indicator; and combines material approaches to valuation (GEP, SEEA) with intangible ones (NCIF) into a single hybrid methodology, which makes it possible to create a basis for including NHA in the national natural capital accounting and budget planning system as a capitalization tool that can be used in recovery policy, resort area management, and investment planning.

It is assumed that Natural Healing Assets (NHA) used in the sanatorium and resort sector have dual economic and ecological value, and that their capitalization is possible only under an integrated approach that combines the assessment of economic benefits and the risks of degradation. The rational use of natural healing assets, based on a hybrid economic-ecological assessment system (TEEB–SEEA–GEP–EOQ–Metabolic),

increases the level of capitalization in resort areas, ensuring a sustainable socio-economic effect and reducing environmental risks (Fig. 1). A hybrid approach was chosen because no single methodology can fully capture the multidimensional value of natural healing assets, which simultaneously generate benefits in medical, environmental, social, and economic domains. By integrating several complementary structures, the hybrid system enables a more accurate representation of both market and non-market values, internationalizing ecosystem services, rehabilitation effects, long-term regenerative capacity, and environmental limitations. This provides a balanced assessment that prevents resource overexploitation while maximizing the socio-economic contribution of resort areas.



**Fig. 1.** Conceptual Framework of the Study

To substantiate the author's methodological approach for use in international research, a comparison was made of the existing methodological support for ecosystem accounting currently used in practice worldwide and the author's methodology for capitalizing natural healing assets. The comparative analysis highlights the conceptual differences, analytical capabilities, and practical applicability of existing approaches to sectoral economic assessment and policy implementation.

**Table 2.** Comparative assessment of international ecosystem accounting approaches and the author's natural healing assets capitalization methodology

Criterion	GEP	SEEA	Natural Capital Accounting	Author's Methodology (Natural Healing Assets, Resort Economy)
Primary objective	Monetary valuation of ecosystem services	Integration of natural capital into national statistics	Sustainable development and wealth accounting	Economic capitalization of natural healing assets and development of a resort economy
Object of assessment	Ecosystem services	Ecosystems and natural capital stocks	Natural resources at the macro level	Natural healing assets (mineral waters, muds, climate resources)
Type of asset	Environmental asset	Environmental asset	Natural resource capital	Hybrid asset (economic + ecological + medical-biological)
Sector specificity	Low (aggregated indicator)	Low (statistical framework)	Medium (resource sectors)	High (sector-oriented: rehabilitation and wellness market)
Integration with health effects	Not included	Partially included (cultural services)	Absent	Core evaluation component (therapeutic and rehabilitation effects)
Economic capitalization logic	Indirect	Weak	Limited	Direct capitalization mechanism and investment valuation
Compatibility with national accounts (SNA)	Parallel indicator to GDP	Fully compatible (satellite accounts)	Partial compatibility	Designed for future integration into the national economic structure
Investment applicability	Moderate	Low	Moderate	High (PPP models, investment planning, regional development)
Policy usability	Strong regional governance tool	Statistical policy support	Development policy support	Strategic economic and recovery policy instrument
Consideration of anthropogenic pressure	Yes	Yes	Partial	Yes + impact on medical effectiveness and sustainability
Data requirements	High ecological data demand	Complex statistical datasets	Limited data availability	Adapted to incomplete data environments (post-conflict conditions)
Ability to measure intangible benefits	Limited	Partial	Weak	Explicit valuation of intangible therapeutic services
Market orientation	Environmental policy focused	Accounting focused	Development planning focused	Market-oriented (resort and rehabilitation services market)
Practical application level	Regional ecological management	National statistics	Macro planning	Regional, sectoral, and national economic management
Risk of double-counting	High	Low	Medium	Reduced via sector-based valuation structure
Innovation contribution	Ecosystem monetization	Environmental accounting standardization	Natural wealth recognition	Resource - Asset - Capitalized healing asset transformation model
Relevance for post-war recovery	Limited	Indirect	Moderate	High (rehabilitation economy and human capital recovery)

## 2.8. Methodological Gap: Limitations of Existing Approaches

The analysis of international achievements in methodological approaches to accounting for ecosystem services and natural resources showed that, currently, there is no methodological support for assessing ecosystem services, capitalizing on natural healing assets, and economic assessment of rehabilitation services.

The author's methodology offers a new interdisciplinary model that integrates ecological, economic, and medical-biological dimensions into a single assessment system, allowing the transformation of natural resources into capitalized healing assets and expanding the role of ecosystem accounting in the development of the resort economy within the structure of the national economy.

### 3. Materials and Methods

#### 3.1. Data Sources and Approaches

Methodological approaches include economic valuation of natural assets in the following directions: economic valuation of natural assets TEEB (The Economics of Ecosystems and Biodiversity), ecological and economic balance, namely integrating environmental indicators into the system of national accounts SEEA (System of Environmental-Economic Accounting), macroeconomic integration – formation of an aggregate indicator of the economic contribution of natural assets to regional GDP is GEP (Gross Ecosystem Product), Determining the optimal level of NHA use without exceeding the limit of environmental sustainability – EOQ-model (Ecological-Economic Optimization), determination of the exchange of substances between the natural system and economic processes, assessment of energy intensity and losses (arXiv-based), determining public willingness to pay for sanatorium and resort services as a reflection of the intangible value of SPA – WTP (Willingness to Pay). Thus, TEEB and WTP form the basis of market and social value, while SEEA and GEP are integrated into national accounts. EOQ and Metabolic monitor the sustainability and optimization of use. Their combination creates a hybrid system that simultaneously shows economic benefits, social impacts, and environmental limits.

The observational framework for these methodological approaches spans the period from 2010 to 2023, corresponding to the availability of official statistical, environmental, and health-related data in Ukraine and in international databases. Geographically, the analysis spans national-level assessments and regional case studies, with a particular emphasis on resort territories of the Odesa region (Ukraine), where natural healing assets have significant socio-economic importance.

At the same time, the empirical component is subject to several data limitations that must be acknowledged:

- seasonality of NHA use, which affects demand, pricing, ecological pressure, and medical outcomes;
- incomplete temporal continuity of environmental monitoring (irregular observations of water quality, mud deposits, mineralization levels);
- restricted access to geological data due to regulatory constraints and security considerations;
- war-related disruptions after 2022, which influenced reporting, damaged resort infrastructure, and altered migration flows and rehabilitation needs;
- regional unevenness of statistical coverage and differences in classification systems of natural healing resources.

These limitations do not diminish the conceptual value of the hybrid approach, but highlight the need for cautious interpretation and future expansion of empirical datasets to ensure more precise calibration of the TEEB – SEEA – GEP – EOQ – Metabolic – WTP valuation framework.

The integration of natural healing asset methods into the system of environmental, economic, and social aspects is presented in Table 3.

Primary statistical data from the clinical sanatorium named after Pirogov (Kuyalnik) in Ukraine were used for calculations, including: the average cost of a sanatorium voucher; the number of medical procedures performed; the cost of mud- and water-based procedures; and the estimated number of annual visitors.

These data were used to calculate the real volume of ecosystem services delivered by the spa and to determine their monetary value. For WTP (Willingness to Pay) analysis, respondents were selected among sanatorium visitors and potential consumers of SPA services. The survey aimed to capture their willingness to pay for specific procedures (balneotherapy, mud therapy, climatotherapy). The WTP data were later averaged and incorporated into the economic valuation model.

To complement these sources, an ecological assessment of hydrological parameters was also conducted. The study conducted an ecological assessment of hydrological parameters using indicators such as mineral water flow, temperature, mineralization level, biota status, and the ecological sustainability coefficient, which was defined as the ratio of the volume of extraction to the natural increase of the resource per year. This allows for the potential restoration of the SPA to be taken into account.

**Table 3.** Integration of assessing natural healing assets methods into the system of environmental, economic and social aspects

Method / Approach	Ecological Aspect	Economic Aspect	Social Aspect	Place in the Calculation System	Interaction with other Methods
TEEB (Total Economic Value)	Considers ecosystem services and the ecological value of natural assets	Forms the baseline structure of NHA economic value (market and non-market benefits)	Includes intangible benefits such as health, recreation, and aesthetic enjoyment	Initial level – establishes the general valuation framework	Provides input data for SEEA (accounting) and GEP (aggregated result)
SEEA (System of Environmental–Economic Accounting)	Defines ecological limits of resource use; develops eco-economic balance	Integrates natural capital into national accounts; calculates environmentally adjusted GDP	Assesses environmental impacts on population well-being through environmental costs	Second level – standardization of natural capital accounting	Receives data from TEEB; supplies structured accounts for GEP
GEP (Gross Ecosystem Product)	Demonstrates the contribution of natural assets to maintaining ecosystem functions	Aggregates the economic value of ecosystem services into a single GDP-analog indicator	Implicitly captures public health improvements via ecosystem benefits	Macro level – integrated result of NHA assessment	Synthesizes SEEA accounts; adjusted by sustainability factors derived from EOQ and Metabolic models
EOQ-modelling (Ecological–Economic Optimization)	Identifies optimal resource use levels without exceeding natural regeneration	Minimizes economic losses and costs from ecological overload	Creates conditions for sustainable employment linked to the NHA sectors	Optimization level – calculates permissible ecological load	Interacts with Metabolic modelling to refine sustainability coefficients; uses SEEA data for cost calculations
Metabolic Modelling (Metabolic Flow Analysis)	Analyzes material and energy flows between nature and the economy; defines sustainability coefficients	Evaluates resource efficiency, energy intensity, and production cycle losses	Assesses environmental safety for the population under anthropogenic pressure	Control level – verifies ecological balance of the system	Provides feedback to EOQ; reconciles sustainability metrics for SEEA and GEP
WTP (Willingness to Pay)	Indirectly promotes conservation via consumer preferences	Captures real market and intangible value of ecosystem-based services (e.g., recreation, rehabilitation)	Reveals social readiness to pay for high-quality, environmentally sound services	Social level – evaluates intangible benefits and behavioral motivations	Adjusts TEEB and GEP through social multipliers, confirming the social importance of NHA

### 3.2. Calculation Framework

The proposed system of indicators and formulas is based on the concept of hybrid valuation of Natural Healing Assets (NHA), which integrates ecological, economic, and social dimensions. Each group of parameters—ecological, economic, and integrative—corresponds to one of the functional subsystems within the NHA capitalization model. The methodological foundation of the framework draws on TEEB, SEEA, GEP,

EOQ modelling, and metabolic modelling, which collectively enable the transition from biophysical indicators to their monetary and policy-relevant representations. Importantly, the methods are not applied independently—the framework is hierarchically interconnected, and indicators from one methodological block serve as inputs to another. TEEB and WTP generate primary market and non-market values. SEEA transforms ecological parameters ( $Q$ ,  $H'$ ) into environmental-economic accounts. GEP aggregates outputs from SEEA and TEEB to form the overall ecosystem product. EOQ and Metabolic models check sustainability constraints and correct the final GEP value.  $K_{eco}$  serves as an ecological correction coefficient, constraining GEP to the ecosystem's regenerative capacity.

Thus, ecological indicators guide economic valuation, economic indicators enrich ecosystem accounting, and sustainability coefficients ensure that the final valuation does not exceed regeneration thresholds. The formulas presented below operationalize this transition by linking ecological processes with economic valuation and aggregate ecosystem accounting:

- Ecological indicators (Formulas 1–2) characterize the state, functioning, and productivity of the ecosystem.
- Economic indicators (Formulas 3–6) capture use and non-use values of natural resources.
- Ecosystem product indicators (Formulas 5–9) integrate these ecological and economic dimensions into a consolidated Gross Ecosystem Product (GEP) metric, adjusted by the ecological sustainability coefficient ( $K_{eco}$ ).

### Ecological Parameters

Ecological indicators serve as the foundation of the assessment because they quantify the physical and biological conditions that determine the carrying capacity, regenerative potential, and long-term sustainability of NHA, forming the basis for all subsequent economic and social valuation, including the calculation of water flow rate ( $Q$ ) (Formula 1).

$$Q = A \times v, \quad (1)$$

where:

$A$  – cross-sectional area of the flow ( $m^2$ )

$v$  – average flow velocity ( $m/s$ )

Formula 2 provides the physical basis for estimating the total stock and the annual recharge of mineral waters. The indicator is later used in the GEP calculation (Formula 6) to determine the potential economic yield of hydrological resources.

$$H' = -\sum(p_i \times \ln p_i), \quad (2)$$

where  $p_i$  is the proportion of the  $i$ -th species in the ecosystem.

A higher biodiversity index indicates greater ecosystem resilience to anthropogenic pressure. In the model,  $H'$  is incorporated indirectly into the ecological sustainability coefficient ( $K_{eco}$ ) in Formula (9), which adjusts economic outputs to account for ecological degradation risks.

### Economic Parameters

Economic indicators translate the ecological state into monetary expressions, capturing both replacement costs and society's willingness to pay for ecosystem benefits, including the replacement cost (Formula 3).

$$Cep = \sum(Calt), \quad (3)$$

The Willingness to Pay (WTP) parameter (Formula 4) is crucial for internalizing environmental costs into investment and policy decisions.

$$WTP = \sum \frac{P_i}{N}, \quad (4)$$

where  $P_i$  is respondents' willingness to pay, and  $N$  is the number of respondents.

This indicator captures non-market values such as health improvement, comfort, and perceived quality, and later complements the GEP estimation to reflect societal benefits beyond direct revenues.

$$EP_{H_2O} = S_{H_2O} \times V_{H_2O}, \quad (5)$$

where:

$S_{H_2O}$  – annual number of mineral-water procedures,

$V_{H_2O}$  – average price per procedure.

$$EP_{Mud} = S_{Mud} \times V_{Mud} + A_{Mud} + V_{App}, \quad (6)$$

where:

$S_{Mud}$  – annual number of mud procedures,

$V_{Mud}$  – price per mud procedure,

$A_{Mud}$  – number of mud applications,

$V_{App}$  – unit price of application.

These formulas ensure that only annual flows of services are included in economic valuation. At the same time, geological “stock” estimates (total mud reserves) are excluded from annual GEP to prevent structural double-counting.

Ecosystem product indicators

The ecosystem service values for mineral waters and therapeutic muds ( $EP_{H_2O}$  and  $EP_{Mud}$ ) serve as the primary inputs for constructing the Gross Ecosystem Product (GEP).

They represent the annual economic flows generated by NHA-based services and replace earlier stock-based estimates, ensuring methodological compatibility with SEEA and GEP frameworks. The Gross Ecosystem Product (GEP) framework (Formulas 7–11) integrates ecological and economic outcomes to provide a comprehensive valuation of the ecosystem services provided by NHA. It serves as an analogue of GDP but includes contributions from natural capital and ecological corrections. Calculate the gross ecosystem product (GEP) for the area (formula 5).

$$GEP = \sum_{i=1}^n V_i * P_i, \quad (7)$$

where:

$V_i$  – volume of services,

$P_i$  – market price of the service.

For mineral waters, the (formula 6) should include both direct production and sale of water and the cost of services (baths, inhalations, etc.).

$$GEP_{H_2O} = (Q_{H_2O} \times P_{H_2O}) + (S_{H_2O} \times V_{H_2O}), \quad (8)$$

where:  $EP_{H_2O}$  – ecosystem product of mineral waters (in monetary terms),  $Q_{H_2O}$  – volume of extracted/used mineral waters ( $m^3$ ),  $P_{H_2O}$  – average market price per  $1/m^3$  of mineral water (UAH),  $S_{H_2O}$  – number of procedures using mineral waters (units),  $V_{H_2O}$  – average cost of one procedure (UAH).

For therapeutic muds, taking into account the sale of mud as raw material and mud therapy procedures (Formula 7).

$$EP_{Mud} = (Q_{Mud} \times P_{Mud}) + (S_{Mud} \times V_{Mud}) \quad (9)$$

where:

$EP_{Mud}$  – ecosystem product of therapeutic muds (in money),

$Q_{Mud}$  – volume of extracted therapeutic muds (tons),

$P_{Mud}$  – average market price for 1 ton of mud (UAH),

$S_{Mud}$  – number of procedures using muds (units),

$V_{Mud}$  – average cost of one procedure (UAH).

General formula for the entire NHA system (Formula 8).

$$GEP_{NHA} = EP_{H_2O} + EP_{Mud} + EP_{otherNHA}, \quad (10)$$

where:

$GEP_{NHA}$  – gross ecosystem product of NHAs (UAH),

$EP_{H_2O}$  – ecosystem product of mineral waters,

$EP_{Mud}$  – ecosystem product of therapeutic muds,

$EP_{otherNHA}$  – ecosystem product of other NHAs (e.g., climatotherapy, balneotherapy, ozokerite).

Taking into account the correlation and the coefficient of ecological sustainability/recovery (Formula 9).

$$GEP_{NHA}^{corr} = [(EP_{H_2O} + EP_{Mud} + EP_{otherNHA})] \times K_{eco} \quad (11)$$

where:

$K_{eco}$  – coefficient of ecological sustainability/recovery of NHA (0.7–1.0).

This correction ensures that the monetary output cannot exceed the ecosystem's regenerative capacity, making the model compatible with sustainability accounting standards (SEEA, GEP, and OECD Green Growth Indicators).

According to environmental assessments (EAs) that account for anthropogenic pressures,  $K_{eco} = 0.7-0.9$ . The coefficient  $K_{eco}$ , ranging from 0.7 to 0.9, reflects the actual ratio of exploitation to natural restoration of resources in resort ecosystems in Ukraine. Its range is based on the data from environmental assessments (EIA, SEA), which show the load on most natural healing assets in Ukraine, and is not critical, but exceeds safe limits. The practice of applying SEEA for resort areas, where exploitation accounts for 70–90% of the natural increase, is also considered.

The algorithm of the hybrid model of capitalization of natural healing assets proposed by the authors combines ecological diagnostics, monetary valuation, ecological sustainability adjustment, and result interpretation, and yields seven interrelated results.

The first stage involves inventorying natural healing assets based on their ecological and physical indicators, which subsequently form the basis for their inclusion in the SEEA ecological and economic accounts for further assessment.

The second stage involves the assessment of natural healing assets according to hydrological, chemical, and biological indicators, and provides data on anthropogenic load to determine the ecological sustainability coefficient:

The third stage is designed for the implementation of natural healing assets as ecosystem services and products using the market approach, the replacement cost method, and willingness-to-pay (WTP). The TEEB approach takes into account market and non-market benefits, and WTP allows reflecting the social and rehabilitation value of healing services.

The fourth stage is dedicated to avoiding double-counting between resource extraction and services derived from it, and provides for a separate determination of annual economic indicators for activities using natural healing assets.

At the fifth stage, according to formula 10, the aggregation into the gross ecosystem product of natural healing assets is carried out.

At the sixth stage, the adjustment of GEP by the ecological sustainability indicator is included, providing a capitalized assessment of natural healing assets that does not exceed the ecological and regenerative capacities of ecosystems.

The seventh stage provides a connection between ecosystem accounting, investment planning, post-war recovery policy, and the development of a rehabilitation-oriented resort economy, and demonstrates, through the adjusted GEP value, the indicators of the contribution of natural healing assets to natural capital, rehabilitation potential, and regional development.

In addition to formula-based calculations, practical valuation methods were applied to cross-check the results. The application of the WTP (Willingness to Pay) method enabled us to assess the demand and subjective value of SPA procedures from the consumer's perspective. To ensure the reliability of the Willingness to Pay (WTP) estimates and the validity of the consumer demand analysis, the study employed a stratified sampling design based on key socio-demographic variables: gender, age, income level, and visitor type (tourists and locals).

Sensitivity of GEP to  $K_{eco}$ : if  $K_{eco}$  decreases from 0.9 to 0.7, the corrected GEP significantly drops, reflecting rising ecological pressure on NHA.

1. Sensitivity of GEP to service prices. In the GEP model, prices for sanatorium services act as direct multipliers of the economic component. A change in prices automatically changes the monetary equivalent of the ecosystem product, as the price determines the cost of both the water itself and the procedures based on it, and, for mud therapy, the price of procedures accounts for a significant share of the added value. Thus, a change in service prices leads to a proportional change in GEP in those segments where prices are the key parameter of value formation. Therefore, price parameters are one of the most sensitive elements of the GEP model, as they directly affect the economic component of the ecosystem product.
2. Sensitivity of GEP to extraction and use volumes. The volume of use of natural healing assets affects the GEP model in two ways: as a direct economic effect, namely an increase in the volume of extraction or the number of procedures, which increases the gross ecosystem product, and as an indirect environmental effect through the impact on  $K_{eco}$ ; more intensive use can reduce environmental sustainability, so the environmental correction factor tends to decrease.
3. Sensitivity of WTP. The WTP indicator is a central element of the socio-economic assessment within the TEEB framework, as it adjusts the social component of GEP. The survey included 200 respondents of the Pirogov Sanatorium (Kuyalnik, Ukraine) in the summer of 2022, a period corresponding to the annual attendance peak. Data were collected through direct interviews, online reviews, and the sanatorium's feedback system.

Representativeness was verified by comparing the obtained sample with the official visitor statistics published on the Kuyalnik Resort website for the same year. Stratification was applied by region of residence, type of medical package used, and frequency of resort visits (Table 4). At the same time, the stratification method was used to reduce variability among the selected groups of health-improving individuals by regional distribution and the use of the rehabilitation and health-improving package of services at the Kuyalnik resort. Representativeness was ensured through statistical information posted on the official resort website.

**Table 4.** Socio-Demographic Characteristics of the Respondents (n = 200)

Parameter	Categories	Number of respondents	Share (%)	Relevance to WTP
Gender	Female	118	59%	Higher share among rehabilitation clients
	Male	82	41%	Slightly lower WTP but higher use of physical therapy
Age	18–30 years	22	11%	Preventive procedures, moderate WTP
	31–45 years	54	27%	Family tourists, medium income, stable WTP
	46–60 years	73	36%	Main rehabilitation users, highest WTP
	61+ years	51	26%	Pensioners, lower WTP but higher visit frequency
Income level	Below average	46	23%	Price-sensitive, rely on social packages
	Average	97	49%	Typical target group of spa services
	Above average	57	28%	Seek premium services, high WTP elasticity
Visitor type	Tourists (non-local)	126	63%	Higher total expenditures per stay
	Local residents	74	37%	Frequent users, smaller per-visit WTP

### 3.3. Interpretation and Representativeness Check

The gender and age balance of the sample reflects the actual medical statistics of the sanatorium's clientele, with a predominance of women and middle-aged visitors. Income stratification matches regional averages in Odesa oblast, ensuring that all affordability segments are represented. The tourist-to-local ratio (63% / 37%) is consistent with the resort's official attendance distribution, confirming proportional representativeness.

Pearson's Chi-square test for homogeneity ( $p > 0.05$ ) indicated no significant deviation from the population structure, validating the sample's adequacy for WTP modeling.

Despite the sample's representativeness, the WTP method has disadvantages: respondents in the survey process agree to pay more for additional services, whereas in reality their actual behavior may differ. In addition, WTP assessment indicators depend on respondents' perceptions of the value of health and rehabilitation services, as well as on seasonality and income level. Therefore, in the article, the authors used the stratification method to select respondents, assess response consistency, and average estimates across consumer groups. Thus, the WTP method was used not as a single pricing indicator, but as a corrective social parameter in the GEP assessment structure.

Market pricing was the primary method for determining the cost of medical procedures, as well as mud and water, based on current prices. The method for calculating the gross ecosystem product was employed, with subsequent adjustments for ecological sustainability, enabling us to confirm the feasibility of making informed management decisions regarding the implementation of a methodological approach in program and strategic documents.

The validation procedures included cross-checking hydrological and ecological data (discharges, salinity, and biota), comparing estimated costs with actual sanatorium prices for market validation, and analyzing willingness-to-pay data through consistency checks and averaging across respondent groups.

### 3.4. Limitations

Despite the comprehensiveness of the approach, there are several limitations, namely:

- Statistical data from sanatoriums is quite fragmentary and not always publicly available. The calculation of the GE directly depends on the volumes of services, extraction, and procedures recorded by sanatorium-resort institutions. Since many institutions do not publish complete reports or use heterogeneous accounting

systems, the indicators obtained are primarily predictive and illustrative. This limits their direct use in strategic territorial planning and complicates cross-regional comparisons.

- Calculation of the willingness to pay indicator depends on the income level and the structure of the survey, which leads to possible distortions of the final data. The final value strongly depends on who exactly participated in the survey (tourists, locals, high-income groups, socially vulnerable groups). Therefore, WTP may overestimate or underestimate the real purchasing capacity of the population in need of rehabilitation. This raises methodological limitations in using WTP as a basis for setting prices for services involving NHA.
- Volatility of market prices for mud and water treatments varies depending on the season and region. Since the economic activity of providing balneological services is strongly seasonal, the valuation of NHA may vary substantially throughout the year. As a result, market-based valuation requires seasonal adjustment, without which price-induced distortions may appear.
- Risk of double counting in relation to mud therapy: duplication of direct products (e.g., sale of mud) and services (mud therapy) can lead to overestimation of the results. Suppose both the sale of mud as a natural resource and mud therapy procedures are included simultaneously without separating primary and secondary value streams. In that case, this may lead to overestimated GEP values. Therefore, valuation must clearly distinguish between resource value (raw materials) and service value (procedures), ensuring the mutual exclusivity of the calculations.
- Determination of the environmental coefficient (Keco) is based on expert assessments and environmental monitoring, which may not be standardized. Keco plays a decisive role in correcting GEP, but differences in monitoring methodologies across regions create uncertainty. Although the indicator is used in licensing procedures, it still lacks methodological unification and may introduce expert bias into final calculations.

The main gap in institutional support is the lack of established methods for ecological and economic accounting of natural resources, such as SEEA, which prevents them from being reflected in statistical information. Because Ukraine has not yet fully implemented SEEA principles in its national statistics, natural capital assets (NHA) cannot be formally recorded in national accounts, GEP cannot be integrated into budget planning, and ecosystem services lack official statistical indicators. Regional and national authorities lack a unified mechanism for reporting on natural capital.

This institutional gap leads to contradictions in decision-making when GEP results are used, as there is currently no official statistical framework into which they can be incorporated.

Seasonality, data fragmentation, expert-based corrections, and the lack of unified institutional records collectively limit the model's robustness. This demonstrates the need for standardized ecological monitoring of NHA, unified reporting procedures for sanatorium-resort institutions, harmonization of valuation methods with SEEA standards, and the development of national guidelines for ecological-economic accounting of NHA.

In summary, the adaptation of the methodological approach to the Ukrainian context is limited by existing institutional gaps, the absence of unified natural capital accounting, seasonality of resort activities, fragmented statistical reporting, and the need for methodological harmonization with SEEA. These constraints limit the direct integration of the results into national strategic documents, underscoring the need for further institutional development and standardization.

## 4. Results

### 4.1. Theoretical Foundations of Natural Healing Assets Use as the Basis of Gross Ecosystem Product Formation

In the international field, the term “natural asset” refers to the living and non-living components of an ecosystem, specifically natural resource funds, which ensure the flow of ecosystem services. Further, it was divided into two components: natural ecosystem assets and modified ecosystem assets, such as farms (Zheng et al., 2023). Thus, in combination, natural assets can be defined as basic elements that form the potential for ecosystem services (Khumarova & Vernihorova, 2024; Manyuk et al., 2025).

In Ukrainian legislation (Parliament of Ukraine, 2024), ecosystem services are defined as the direct or indirect contributions of ecosystems to human well-being. The State Environmental Policy Strategy (Parliament of Ukraine, 2019) emphasizes that the development of ecosystem services enables sustainable progress not only for ecosystems themselves but also for the well-being of the population. According to the SEEA Experimental Ecosystem Accounting, ecosystem services are defined as the contributions of ecosystems to the benefits utilized in economic and other human activities.

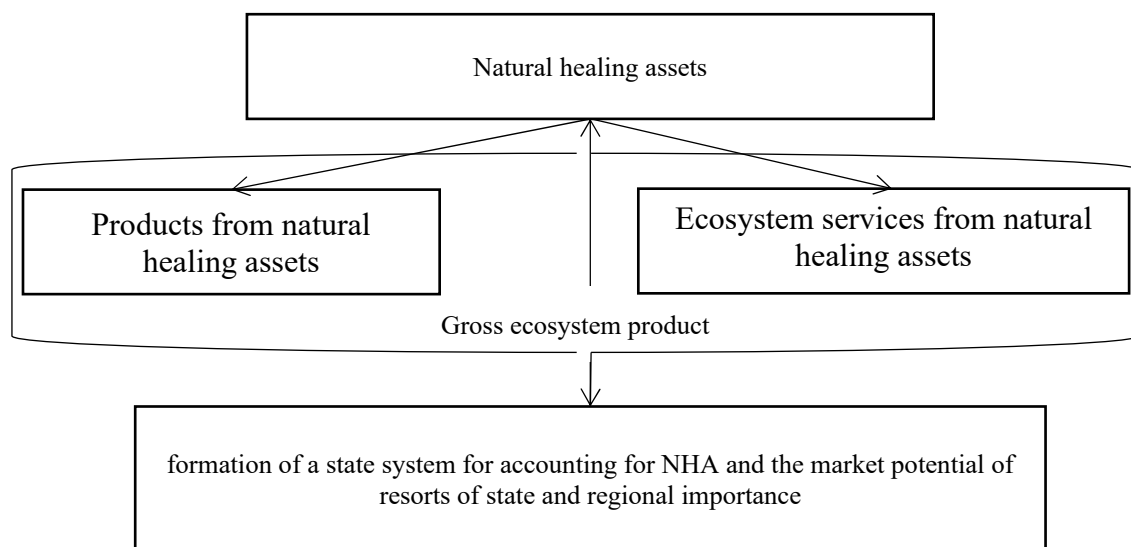
In international practice (Parliament of Ukraine, 2024; Rokicki et al., 2024), the concept of “ecosystem product” is also used as a tool for monetary valuation of all ecosystem services produced by a territory over a certain period, which is calculated as the volume of ecosystem services provided multiplied by their monetary valuation.

The concept of “ecosystem product” is not used; however, it is mentioned in the Methodological Recommendations for the Development of Environmental Protection Programs (Parliament of Ukraine, 2023). Direction 5: Preservation and Restoration of Biodiversity and Natural Ecosystems, Development of Protected Areas and Objects, considers components that can be indirectly considered ecosystem products, in connection with the assessment of the costs of cleaning, recreation, and damage. The main topics and their essence are given in Table 5.

**Table 5.** Main research concepts and their differences (international/domestic)

Term	International	Ukrainian
Natural asset	Takes into account the integrity of ecosystems and their multifunctionality	Focused on ownership and use rights of NHA
Ecosystem services	Has a complete institutional systematized classification by type	Has a fragmentary interpretation focused on assessing losses from the activities of business entities

GEP enables the capitalization of Natural Healing Assets, which is crucial not only for recognizing them as a strategic state resource but also as a key basis for management decisions, including investment planning for regional economic development and ecosystem restoration (Fig. 2).



**Fig. 2.** Schematic representation of GEP NHA

Since the ecosystem product can be represented within the NHA (therapeutic mud, mineral waters, etc.) and indicates the monetary result of the ecosystem's activities, the ecosystem service is represented by a set of resources and services that form the overall economy of the resort, namely, showing the intangible benefit provided by the ecosystem. At the same time, the price of the ecosystem product is determined by reserves and the market price per unit. The ecosystem service (for example, balneotherapy, clamatotherapy) is assessed on a per-service or per-session basis, depending on demand, duration, and effect.

The research was based on the hypothesis that the ecosystem within the context of resort territories can be conceptualized as an integrated spatial and functional system, where Natural Healing Assets, such as mineral waters, therapeutic muds, climatic and landscape factors, act as ecosystem services and ecosystem products that possess both ecological and economic value.

According to this hypothesis, the ecosystem product of NHA represents the material outcome of natural processes occurring within the resort ecosystem, which have therapeutic, rehabilitation, health, or recreational value and can be utilized directly or following specific technological preparation. The research results

confirmed that NHA generates a dual value system: ecological value, determined by the regenerative and sustainable potential of natural resources; and economic value, derived from the monetization of therapeutic and health-related services provided by these assets. Therefore, the capitalization of natural healing assets is feasible only through integrated valuation, which combines material (mineral waters, therapeutic muds) and intangible (health, recreational, climate-regulating) components into a single indicator of the natural potential value.

This validates the hypothesis that the economic value of NHA enhances the total value of the resort ecosystem, as their market utilization (the sale of therapeutic resources and provision of rehabilitation services) simultaneously promotes ecological preservation and social welfare, thereby forming the foundation for sustainable resort ecosystem development.

Thus, the gross ecosystem product (Gross Ecosystem Product, GEP) of natural healing assets is defined as a monetary measure of the total economic value of all ecosystem services and NHA products in a given territory.

This indicator reflects the generalized value of natural healing resources that arise from their use in health, rehabilitation, recreational, and tourism activities.

At the macro level, the gross ecosystem product of a country with NHA can be considered an aggregate indicator obtained by summing the monetary value of all ecosystem services and NHA products in the state's resort territories.

#### **4.2. Overview of Existing Methodological Approaches of Natural Healing Assets in the Resort Economy Ecosystem**

Given the value the state can derive from NHA's gross ecosystem product, it is advisable to analyze methodological approaches for calculating it. In the work (Rosano-Peña et al., 2021), existing approaches to assessing the use of natural resources and ecosystem services are considered, such as the rent approach to the economic assessment of medical resources, the method for assessing the cost of restoration, and tools that take into account the type of resource or ecosystem service and the industry in which it is used.

Ouyang et al. (2020) provided a protocol for the inventory of sources, including data templates and methods for assessing the condition of sources. An algorithm for calculating indicators of the ecosystem of sources was provided, including: determining the geographical location, performing physicochemical measurements, conducting biological assessment, assessing anthropogenic threats, and integrating all components.

An algorithm was developed to standardize and assess NHA by classifying source systems based on their chemical composition (Nisa & Umar, 2024).

Having analyzed these two methods, we summarized the primary approaches, both of which consider quantitative indicators: flow rate, water quality, and geomorphology. At the same time, the Appendix A methodology (Springs Stewardship Institute, 2013) assesses ecosystem sources for sustainable natural resource management. It takes into account biota, recreational aspects, and anthropogenic load, which can be used for the assessment and inventory of NHA. In contrast, the second methodology (Spring systems classification) is more suitable for hydrogeological and chemical assessment.

In the pilot project in the city of Saxatun (Green Municipal Fund, 2020), an inventory of natural assets and the monetization of their ecosystem services were carried out, and the total cost of ecosystem services was determined to be 48.2 million US dollars per year. This methodology differs from previous ones in the way it calculates the financial value of ecosystem services for their integration into the budget. However, the Green Municipal Fund methodology is a purely economic assessment (cost of providing services) without a deep ecosystem analysis, and can be used to calculate the financial value of medical services (hydrotherapy, tourism, and the ecosystem as a medical factor).

The Economics of Ecosystems and Biodiversity (TEEB) (Kettunen et al., 2012) is a classic methodology for natural and cultural inventory and assessment, as well as the standardization of "Natural Capital," dedicated to integrating the economic value of ecosystems and biodiversity into decision-making processes, monetizing services, and accounting for natural capital.

The Gross Ecosystem Product (GEP) Accounting methodology in wetland systems (Mainstreaming Nature in Policy and Investment Decisions, 2024) focuses on determining the economic value of ecosystem services (tangible, regulatory, and intangible) for integration into public policy and investment decisions, creating a system of incentives for environmental conservation and compensatory payments to communities for ecosystem services.

The Environmental Accounting for Ecosystem Conservation: Linking Societal and Ecosystem Metabolisms (ArXiv, 2007) methodology is a theoretical model of environmental accounting based on ecosystem metabolism that uses conceptual models of "metabolism" to represent energy and matter flows through eco-

systems and human systems. The methodology's concept is based on the "negentropic cost" indicator, which quantifies the degree of degradation or natural integrity of the system. This indicator quantitatively characterizes the degree of anthropogenic intervention by assessing changes in biome states.

A sustainable inventory model with pollution costs is an economic inventory model that considers the environmental impact (Medina-Santana & Cárdenas-Barrón, 2020). The authors of this methodology include an exponential component in the emission function to reflect the increase in emissions when the order batch is reduced. This methodology can be used to calculate optimal volumes of NHA use, accounting for both economic and environmental factors. Table 6 can be characterized in terms of the implementation of methodological approaches in Ukraine. Using the Appendix A (Springs Inventory) methodology, it is possible to detect degradation or anthropogenic impact on SPAs. This approach is advisable to use for monitoring and further management, as it justifies the feasibility of investments.

**Table 6.** Methodological approaches to natural assets (foreign experience)

Criterion	Springs Inventory*	TEEB (Economics of Eco-Services)	GEP (Gross Ecosystem Product)	Metabolism (arXiv)	Eco-EOQ (2020)
Objective	Assessment of the state of springs and ecosystems	Monetization of Ecosystem Services	Monetary valuation of gross eco-product	Analysis of resource flows and funds	Inventory Optimization with CO <sub>2</sub> Costs
Direction	Hydrology, biota, anthropogenic impact	Ecosystem Services and Natural Capital	Eco-services as a product for the economy	Eco-metabolism and scenario modeling	Supply Chains, CO <sub>2</sub> Emissions
Evaluation levels	Local (springs, small objects)	Local, Global	Municipal, regional	Multiscale (landscape, biomes)	Local, Enterprise
Evaluation methods	Scales (1–5), indices, formulas	Direct and Indirect Economic Valuations	Biophysical + economic models	Fund-flow models, negentropic cost	EOQ Models with Discrete Costs
Biota consideration	Yes	Indirect	Partially (through services)	Yes (biome level)	None
CO <sub>2</sub> and climate consideration	Partially (anthropogenic impact)	Yes	Yes	Yes (via eco-metabolism)	Main Focus
Monetary assessment	None	Basic Approach	basic approach	Possible (via scenarios)	for Logistics and Environmental Costs
Difference of application	Low	Medium	High	High	Medium
Suitability for NHA	Spring monitoring	Financial Valuation of PLA	Monetary justification	Theoretical indicator of integrity	Eco-Chain Optimization

The TEEB (Economics of Ecosystem Services) approach is designed to monetize ecosystem services, i.e., calculate the market or potential value of SPAs. Using this methodology, it is advisable to assess the market potential of resorts. The GEP (Gross Ecosystem Product) approach is the most relevant, as it treats ecosystem services and products as a single element, enabling their monetary valuation. This methodology is recommended for establishing a database of the state SPA accounting system and assessing the market potential of national and regional resorts.

Metabolism (arXiv) can be used as a theoretical framework for assessing the sustainable use of SPAs when developing strategic directions for state management of SPAs. Eco-EOQ (2020) is a resource and inventory management model taking into account environmental parameters (CO<sub>2</sub> emissions, disposal, and logistics costs). It can be used to optimize costs and environmental footprint. The considered methods propose a toolkit for their provision, according to specific goals, as outlined in Table 7.

**Table 7.** Tools for implementing the goals of the methodology

Tool	Mechanism	Expected effect
TEEB (Total Economic Value)	Calculation of the full economic value of PLA: direct, indirect, option, legacy, existence	Determining the value of sources to justify investments
InVEST	Spatial modeling of ecosystem services	Determining scenarios for the use and protection of natural resources
Eco-economic EOQ	Optimization of NHA extraction and use taking into account environmental constraints	Reducing the burden on resources while maintaining economic benefits
Environmental accounting (SEEA)	Accounting for NHA as part of the state's natural capital	Creating a national cadastre of natural resources
Financial and economic models (DCF, NPV, ROI)	Evaluation of investment projects using NHA	Calculating efficiency for investors
Green bonds and loans	Attracting funds for the restoration and support of NHA	Financing restoration projects
Subsidies and tax breaks	Stimulating business for the rational use of NHA	Involving entrepreneurs in the field of rehabilitation services
Compensation mechanisms	Restoring the natural balance when using resources	Sustainable management of natural resources
Licensing and eco-certification	Control of access to the use of NHA	Preserving the quality of resources and their intended use

The most significant number of tools is proposed for use by methodologies focused on determining monetized indicators of NHA:

- TEEB includes environmental accounting (SEEA), helps to consider NHA as part of the state's natural capital, and includes financial and economic models for assessing projects related to ecosystems. To stimulate sustainable business management in NHA, it provides for the use of green bonds, subsidies, and benefits.
- GEP is based on approaches to the economic value of services and products. It accounts for tools for spatial modeling of ecosystem impacts, integrates NHA into national accounts (SEEA), and includes financial and economic models, as well as green bonds, to justify investments and attract funds. It suggests the use of subsidies, benefits, a compensation mechanism, and also provides for control over the use of NHA through licensing and certification.

The toolkit defined by the Eco-EOQ methodology is more suitable for managing NHA by economic entities through the use of an ecological-economic model that reflects the optimal volumes of extraction, combined with an assessment of efficiency. Also includes green bonds, benefits, compensation mechanisms, and licensing.

Metabolism (arXiv) focuses on scenario modeling of resource flows and funds using eco-metabolism to conduct systems analysis.

Appendix A focuses on the inventory of sources and ecosystems (data collection and monitoring), including licensing and eco-certification to control the condition of sources and their access.

In the domestic scientific literature and legislative field, methodological approaches to the use of NHA have also been introduced (Table 8), namely, methodological recommendations for assessing the value of ecosystem services provide for the assessment of the monetary value of ecosystem services for integration into budgets and resource management (Cherchyk, 2022; Kostetska, 2025). Didukh et al. (2025) proposed a Methodology for calculating environmental damage to ecosystems (2023–2024) to assess the cost of ecosystem restoration. Methodological recommendations for environmental impact assessment (EIA) and strategic environmental assessment (SEA) (Methodological recommendations for assessing the value of ecosystem services, 2023) for assessing the impact of projects, plans, and programs on the environment. Scientists

(Martienko et al., 2018) consider market methods for the economic valuation of natural resources, including the monetary valuation of natural assets for financial planning.

**Table 8.** Methodological approaches to natural assets (national experience)

Methodology	Objective	Methods	Monetary Assessment	Suitability for NHA
Evaluation of ecosystem services	Monetary valuation of nature's functions	GIS, market methods	Yes	Important for financing medical functions
Evaluation of environmental damage	Determining damage and restoration costs	Biomass assessment, regulatory standards	Yes	For compensation after damage
EIA and SEA (2021–2024)	Assessing the environmental impacts of projects	Analytical methods, EIA, health impact analysis	Partially	Useful for NHA project planning
Market-based methods for resource valuation	Explaining approaches to economic valuation	Market data, cost analysis, alternative methods	Yes	General tools adaptable for NHA
Recreational resources	Determining optimal resource use	Regime classification, environmental limits	No	For regulating tourist and resort pressure

The Ecosystem Services Assessment Methodology incorporates GIS analysis and market-based methods (replacement cost, market price, and restoration costs) to facilitate further monetary valuation of ecosystem services, thereby reflecting their actual value. The Environmental Damage Assessment Methodology combines biophysical approaches with regulatory methods to assess environmental damage and calculate the cost of restoration following exploitation or resource damage.

The Methodology: EIA and SEA (2021–2024) is used at the planning stage of projects using NHA to assess their environmental and public health impacts. The Market Methods for Resource Assessment Methodology encompasses the use of market prices, cost methods, and the opportunity cost method to justify the economic value of natural resources.

The Recreational Resources Methodology involves classifying use modes and determining ecological load limits to identify the optimal use mode for natural areas in tourism and recreation.

To determine the directions and feasibility of forming methodological recommendations for NHA, we conducted a generalization and comparison of Ukrainian and foreign methods for assessing ecosystems (Table 9).

Thus, national methodologies are primarily focused on environmental monitoring and legal regulation (EIA, SEA, damages). In contrast, foreign methodologies concentrate on the economic value of ecosystem services (TEEB, GEP) and their integration into budget planning. The hypothesis that ecosystem services and NHA products are components of economic value, allowing to integrate material (mineral waters, therapeutic mud) and intangible (health, recreational, climate-regulating) components into a single indicator of natural potential capitalization is justified by the fact that the economic value of NHA increases the total value of the resort ecosystem due to the sale of healing assets in interaction with their use in rehabilitation and health procedures in the process of capitalization.

In Ukraine, methodologies are applied within the framework of local and regional programs, particularly through EIA and SEA processes. Foreign approaches are implemented both at the global level (e.g., TEEB, GEP) and in regional or municipal contexts. While Ukrainian methodologies include monetary valuation, it is primarily used to estimate damages and restoration costs. In contrast, in TEEB and GEP, monetary valuation is central, serving as a key element for informed decision-making.

**Table 9.** Comparison of Ukrainian and foreign methods of ecosystem assessment

Criterion	Ukrainian Methods	Foreign Methods
Objective	Determining the cost of ecosystem services for budgets and EIA; regulation of recreational load on NHA	Integration of natural capital into public accounts (TEEB, GEP); monetization of services for nature conservation incentives
Direction	Ecosystems, NHA, damage assessment; optimal modes of recreational resource use	Monetary valuation of services (TEEB, GEP); system analysis of resource flows (metabolism)
Levels of application	Local and regional programs; Environmental Impact Assessment (EIA, SEA)	Global initiatives (TEEB, GEP); regional and municipal cases (Green Municipal Fund, Chinese GEP)
Assessment methods	GIS mapping, assessment scales, biodiversity indices; cost and market methods (replacement cost, WTP)	Monetary monetization: replacement cost, shadow pricing (TEEB); physico-chemical models (classification & methods)
Monetary valuation	Available, but limited—mainly for damage and restoration	Core approach (TEEB, GEP)
Coverage of biota	Included (H' indices, endemic species)	Partial (biota considered as part of ecosystem services or biomes)
CO <sub>2</sub> and climate considerations	Partial (EIA, environmental damage)	Key element (GEP, EOQ-ecology, TEEB)
Complexity of methodology	Medium complexity; adapted for local government use	High complexity; requires analytical models and economic data (TEEB, metabolic modeling)
Suitability for NHA	Directly focused on NHA (use modes, damage assessment, tourism potential)	Suitable for financial justification of NHA, but requires adaptation to the recreational and resort sector

### 4.3. Approbation of Methodical Recommendations for the Gross Ecosystem Product of Natural Healing Assets Calculation

Combining existing international and national practical recommendations, a hybrid methodology for assessing Natural Healing Assets (NHA) has been developed and tested. This approach integrates environmental monitoring, economic valuation, and strategic management and restoration planning, following the principles of TEEB, SEEA, GEP, EOQ, and metabolic modeling. The methodological structure ensures that ecological, economic, and social parameters are considered simultaneously, providing a scientifically grounded basis for capitalizing on natural healing assets.

Applying this integrated framework to the Kuyalnyk estuary enabled the calculation of its Gross Ecosystem Product, which reflects the combined market and non-market economic value generated by mineral waters, therapeutic muds, balneotherapy services, and associated ecosystem functions. Based on verified extraction and recharge volumes, market prices for healing procedures, non-market valuation derived from WTP surveys, correction by ecological sustainability coefficient *Keco*, and integration of direct, indirect, and induced ecosystem services, the estimated GEP of Kuyalnyk constitutes approximately 1,5 billion USD. Thus, its estimate represents an integrated, ecologically adjusted, and socio-economically grounded measure of the total annual ecosystem contribution of the Kuyalnyk NHA system, obtained through the hybrid model compliant with SEEA and GEP valuation principles.

The calculation of the gross ecosystem product for the example of the Kuyalnytskyi estuary of 1.5 billion USD is formed as a set of three components (formula 12):

$$GEP_K = V_p + V_\delta + V_r \quad (12)$$

where:

$V_p$  – the cost of ecosystem products (mineral waters, therapeutic mud);

$V_\delta$  – the cost of ecosystem services (balneological, climatotherapy, recreational);

$V_r$  – the cost of indirect rehabilitation and multiplier effects.

These three indicators consist of a direct market indicator, which reflects the assessment of income from procedures, the use of mineral waters, and mud. Non-market indicator, which is selected through a capitalized assessment of WTP and replacement cost. The multiplier indicator reflects the accompanying effects on the economy from rehabilitation, tourism, and investment.

The approach allows us to take into account an integrated capitalization indicator rather than just market valuation when extracting natural healing assets.

### **Stage 1. Inventory and Mapping of NHA**

At this initial stage, in line with the System of Environmental-Economic Accounting (SEEA), an inventory of NHA was conducted. The process included:

- GIS mapping of all assets.
- Classification by type (mineral waters, therapeutic muds, climatic factors).
- Determination of area, volume, and anthropogenic pressure.

This stage establishes the physical and statistical foundation for subsequent assessments and enables the integration of NHA data into national environmental-economic accounts. The inventory is updated every five years, providing a baseline for resource and reserve balances, ensuring comparability across reporting periods, and supporting adaptive management decisions.

### **Stage 2. Ecological Assessment of NHA**

The ecological assessment evaluates the current state of NHA and its capacity for sustainable use. Key steps include:

- Hydrological and chemical measurements: flow rate (Q), total dissolved solids (TDS), pH, and water temperature.
- Biodiversity assessment using Shannon-Wiener indices (H').
- Analysis of anthropogenic threats, including pollution and recreational load.

These data inform the calculation of ecological sustainability coefficients (Keco), which in turn determine allowable extraction rates and the potential for regeneration.

### **Stage 3. Economic Assessment of NHA**

The economic valuation phase integrates TEEB, GEP, and WTP frameworks, clearly distinguishing the value of ecosystem services from resort operational revenue. The process involves:

1. Identification of ecosystem services:
  - Water purification.
  - Microclimate regulation.
  - Recreational and cultural functions.
2. Application of monetary valuation methods:
  - Replacement Cost Method – estimates the hypothetical cost society would incur if the ecosystem service were lost.
  - Market Pricing Method – identifies comparable market analogues for resources.
  - Willingness to Pay (WTP) – captures the social and emotional value of NHA services.

WTP was obtained from a stratified survey of 200 respondents at the Pirogov Sanatorium (Kuyalnik) during summer 2022. Respondents were grouped by gender, age, income, and origin (tourist/local), reflecting the real socio-demographic composition of resort visitors. Representativeness was confirmed using Pearson's Chi-square test for homogeneity ( $p > 0.05$ ).

#### 3. Calculation of the Gross Ecosystem Product (GEP):

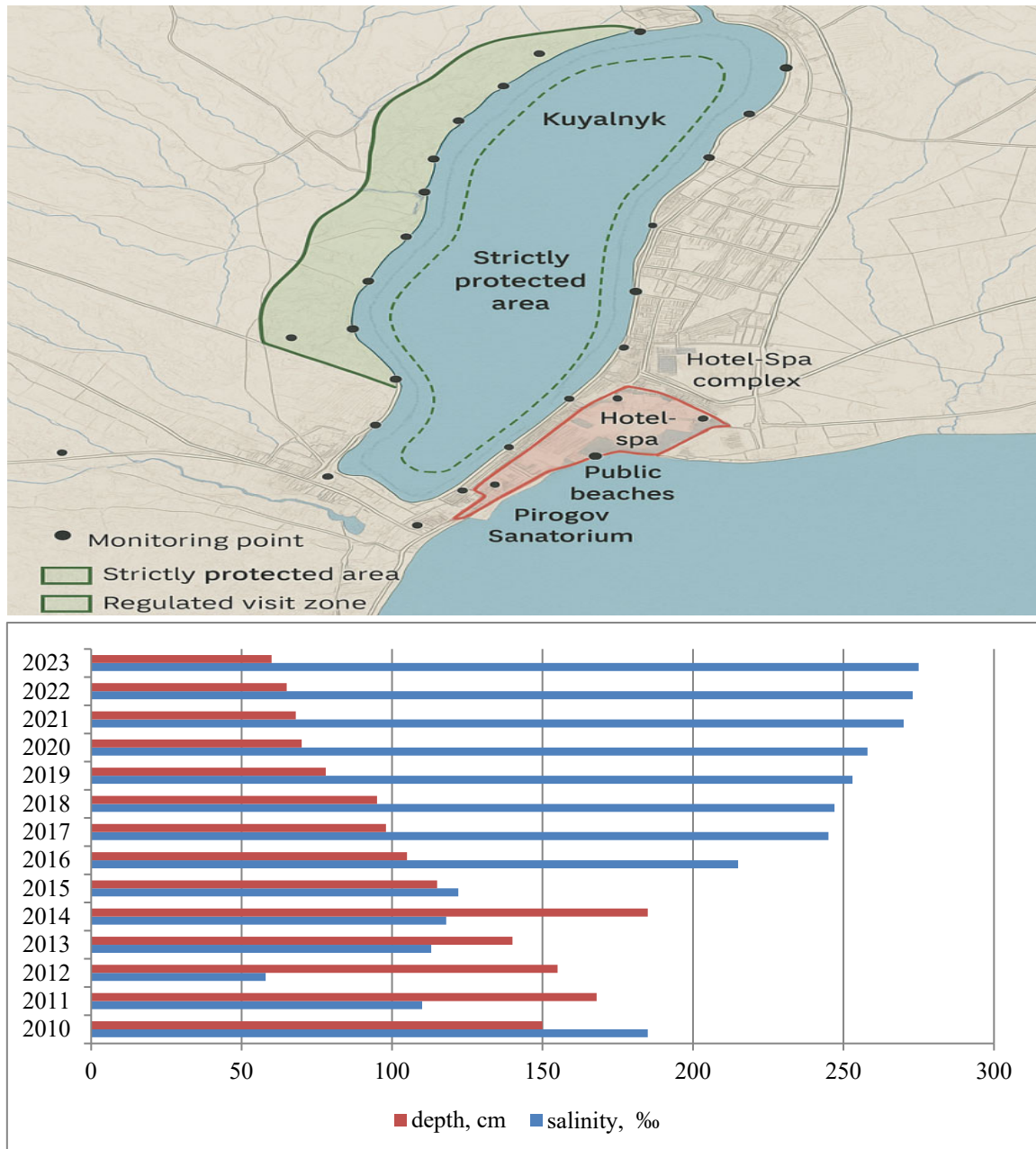
- For mineral waters, GEP includes the direct production and sale of water, as well as the cost of services (such as baths and inhalations).
- For therapeutic muds: GEP accounts for the sale of raw material and mud therapy procedures.
- GEPcorr represents the monetized value of nature itself, corrected for sustainability, regeneration, and social utility.

The hybrid methodology ensures consistency between ecological diagnostics, economic valuation, and social validation. The ecological module (Q, H', Keco) determines carrying capacity, the economic module (GEP, Replacement Cost) translates ecosystem functionality into monetary terms, and the social module (WTP) validates the human-centered significance. This integration establishes a robust ecosystem-based economic framework for decision-making and sustainable development in the resort sector.

#### Stage 4. Management and Strategic Planning

1. Develop NHA use regimes that include regulated visits, strictly protected areas, and recreational zones.
2. Integrate data into EIA and SEA for restoration and sustainable management planning.
3. Design eco-compensation mechanisms to finance the preservation of NHA.

The methodology was tested using medicinal waters and muds from the Kuyalnyk resort, with a map showing monitoring points, recreational zones, and salinity and water volume dynamics (Fig. 3), demonstrating its practical applicability and potential to support informed management and policy decisions.



**Fig. 3.** The Map-scheme of Kuyalnyk with marked monitoring points and recreation zones, and the salinity and water volume dynamics graph

In Fig. 3, the monitoring points on the map indicate locations where long-term hydrological and ecological measurements were collected in the Kuyalnyk Estuary. These points capture water depth, salinity, seasonal water exchange, and the state of strictly protected and regulated-use zones.

Their spatial distribution enables tracking changes across the entire water body, including the most vulnerable northern part (characterized by reduced water exchange) and the southern part adjacent to the recreational infrastructure.

The graph illustrates the dynamics of salinity and water depth between 2010 and 2023. The data show a clear trend of increasing salinity in most years, indicating accelerated evaporation and limited fresh water inflow. Periodic decreases in water depth, especially in 2013–2015 and 2020–2022, reflect hydroclimatic stress and anthropogenic pressure.

Overall, the graph indicates that the estuary is experiencing long-term ecological stress, as evidenced by the increasing mineral concentrations and intermittent water loss. These monitoring data directly informed the calculation of the ecological sustainability coefficient ( $K_{eco}$ ) and its application in the corrected ecosystem product ( $GEP_{corr}$ ):

**Influence on  $K_{eco}$ :** increasing salinity, together with reduced depth, indicates a decline in regenerative capacity, requiring lowering  $K_{eco}$  toward the lower boundary of the sustainable range (0.7–0.9). Years with excessive mineralization (>240‰) and reduced water volume were treated as ecological warning conditions, and a more conservative  $K_{eco}$  value was applied. Thus,  $K_{eco}$  was not assumed arbitrarily; it was data-driven and reflected the hydrological state documented by the monitoring points.

**Influence on  $GEP_{corr}$ :** Years with high salinity and low depth reduced the corrected ecosystem value. This adjustment prevents overestimating the economic output of mineral water and mud therapies under conditions of ecological degradation. High-salinity peaks prompted a stronger correction, lowering  $GEP_{corr}$  to align with the SEEA sustainability criteria.

Thus, the monitoring points and temporal dynamics of salinity and water depth provide an empirical basis for assessing ecological stress, which directly influences  $K_{eco}$  and, consequently, the sustainability-adjusted ecosystem valuation  $GEP_{corr}$ . Without these monitoring data, the correction factor would not reflect real environmental conditions, rendering the economic valuation ecologically invalid.

According to Martienko et al. (2018), the daily flow of mineral waters at Kuyalnik is approximately 1,385 m<sup>3</sup>/day, while the total volume of the reservoir-estuary is about 52 million m<sup>3</sup>, reflecting the scale of the resource. The regional report on the state of the natural environment (Environmental Report, 2021) indicates that the estuary contains approximately 23.8 million m<sup>3</sup> of hydrogen sulfide therapeutic mud, with annual volumes calculated based on the extraction schedule.

Researchers estimated that the mineral concentration in the brine was 234 g/L in 2015, increasing to 324 g/L by 2020 (Gushcha et al., 2021). The hypersaline estuarine spring covers an area of 56 km<sup>2</sup>, with an average depth of 1 m and summer water temperatures of 28–30°C (Wikimedia, 2010).

The economic value of sulfide mud reserves is preliminarily estimated at around 7 billion USD (Shikhaleeva et al., 2023). A Pulitzer Center grant study (Kenarov, 2014) on the drying of the Kuyalnytskyi estuary reported that salinity levels approach 300%, comparable to the Dead Sea. Table 10 below presents ecological indicators of the Kuyalnik resort ecosystem.

**Table 10.** Ecological and economic parameters of the Kuyalnik resort ecosystem for GEP calculation

Parameter	Indicator
Water flow rate	1,385 m <sup>3</sup> /day
Mud volume	23,848,000 m <sup>3</sup>
Economic value of mud	7 billion USD
Mineral concentration in mud	234–324 g/L
Estuary salinity and drying	300%

According to data (Medina-Santana & Cárdenas-Barrón, 2020), the following economic indicators were selected for calculations:

- The price of a voucher with meals is \$35 per day, for a course lasting 21 days.
- Peloid therapy (mud) – 1.75 USD /procedure.
- Mud applications - 5 USD /procedure.
- Water procedures – 6.25 USD/procedure.

Unfortunately, information about visits is currently unavailable; however, for testing the methodology, data for 2020 can be used, which indicates that approximately 32,100 people visited the sanatorium.

The calculations also take into account the Ministry of Health of Ukraine's methodological recommendations for sanatoriums, which specify that a course of balneotherapy (baths, showers, inhalations) in sanatorium-resort treatment consists of 5–10 procedures. We chose the lower limit (5) to avoid overestimating the

total indicator. For mud-7 procedures, the standard course of mud therapy consists of 7–12 procedures (per the Ministry of Health's medical and technological standards for mud therapy) (Fig. 4).

In the calculation (Table 11), the ecosystem product of mineral waters is estimated solely on the basis of spa procedures, without separately pricing the extracted water volume, thereby avoiding double-counting of the same resource.

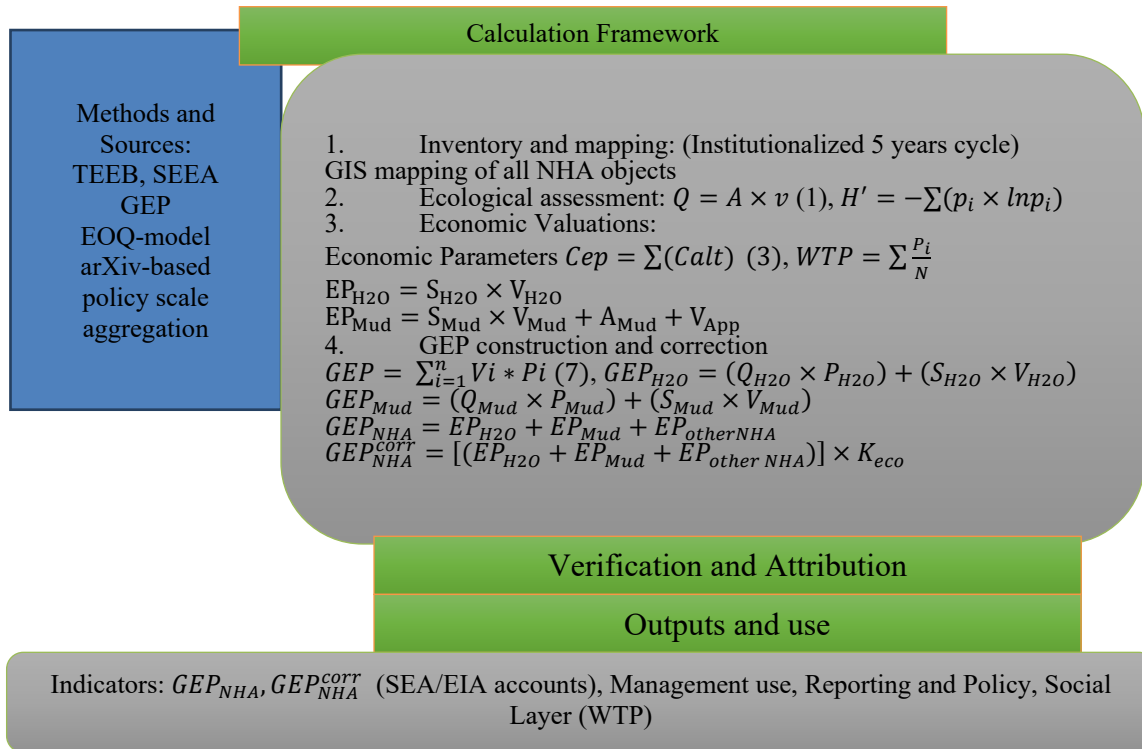


Fig. 4. Hybrid Model GEP of NHA

Table 11. Results of the Annual GEP Calculation for Kuyalnik Resort

Component	Calculation	Value (USD/year)
Mineral Water Procedures	$EP_{H2O} = S_{H2O} \times V_{H2O} = 160.500 \times 6.25$	1003.125
Therapeutic Mud Procedures	$EP_{Mud} = S_{Mud} \times V_{Mud} + A_{Mud} \times V_{App}$ $= 224.700 \times 1.75 + 96,300 \times 5$	874.725
Total GEP (initial)	$GEP = EP_{H2O} + EP_{Mud}$	1877.850
Total GEP (corrected)	$GEP_{corr} = GEP \times K_{eco} = 1877.850 \times 0.8$	1502.280

The ecosystem product of therapeutic muds includes the annual value of mud procedures and applications, in line with SEEA conventions that distinguish between stocks and flows. The initial GEP (1.88 million USD/year) thus reflects the annual flow of ecosystem services generated by the resort's mineral water and mud therapy. The corrected GEP ( $GEP_{corr}$ ) (1.50 million USD/year) applies the ecological sustainability coefficient  $K_{eco} = 0.8$ , which adjusts the monetary value to account for the environmental pressure and regeneration capacity of the Natural Healing Assets, ensuring consistency with sustainability-oriented accounting (SEEA/GEP).

### 5. Discussion

The presented model (Fig. 5) illustrates an integrated framework for assessing the Gross Ecosystem Product (GEP) of natural healing assets, combining ecological, economic, and social determinants within a single valuation system. The model operationalizes the methodological logic described earlier through three interconnected analytical blocks and a verification block, which ensures a clear separation between the value of ecosystem services and market-generated revenues.

The authors developed a methodological approach focused on the sectoral significance of capitalizing on natural healing assets and ecosystem services. In this approach, ecosystem services from the use of natural

healing assets are separated from the product itself and integrated into a capitalization mechanism aligned with the principles of sustainable development, thereby distinguishing it from existing accounting methods. This enables a transition from environmental accounting to economic planning.

This distinction avoids double-counting, ensuring that ecosystem service accounting accurately reflects the potential societal value of natural assets, while business revenues remain within the domain of financial reporting.

The model provides a systemic linkage between physical ecological parameters, economic valuation techniques, and social perception indicators. It substantiates the dual nature of NHA as both economic and ecological capital, and delivers a practical algorithm for integrating their assessment into national and regional planning systems.

The methodological approach developed by the authors proves that, unlike existing GEP calculation methods, it is expanded by integrating ecosystem products, rehabilitation effects, and adjustments for ecological sustainability into a single system for capitalizing on natural healing assets and allows expanding the system of ecological and economic accounting to support strategic managerial economic decisions. In the article, the authors prove that natural healing assets simultaneously affect the formation of both natural capital and human capital through rehabilitation and health effects.

Thus, the main differences from the GEP and SEEA approaches are that the proposed hybrid model integrates natural healing assets and rehabilitation ecosystem services into a single capitalization indicator, provides for adjustments through the coefficient of ecological sustainability, and makes a significant economic contribution to the development of the state.

The calculations indicate the economic value of the natural healing assets (NHA) of the Kuyalnik resort in monetary terms. The gross ecosystem product of NHA is approximately UAH 544 million per year (USD 13.6 million). Taking into account the ecological sustainability coefficient (0.8), it shows that the resource is partially naturally restored, but there is a risk of depletion. The main obstacle to obtaining additional income from NHA in the form of taxes and fees from business entities is that natural resources are not recorded as assets in state financial systems (there is no SEEA system). Currently, the state receives only taxes, fees, and license fees from sanatoriums and entrepreneurs' activities. There is also no system of rent payment for NHA: enterprises pay only general taxes (VAT, personal income tax, single tax), but do not pay for the actual extraction or use of mineral water or mud as for natural capital. Lack of control over use – resources are extracted without precise accounting mechanisms (there are no exact volumes of extraction, only permissible under SEA and EIA). The existing institutional accounting systems do not account for the assessment of natural healing assets in the state accounting system, as a result of the analysis carried out through the assessment of GEP.

It proposed to make the following additions to the Strategy for the Formation and Implementation of State Policy in the Field of Ecosystem Services Management for the period until 2030. The section 'Lack of Information on Ecosystem Services and Their Economic Assessment' should be supplemented with information on the absence of an integrated model for assessing NHA and the value of the gross ecosystem product (GEP) to substantiate the economic value of resorts and the rehabilitation sector.

The section 'Strategic Goals and Indicators of Their Achievement' should be supplemented with a paragraph on the inventory and monetary assessment of NHA (GEP) as a priority area of the state's environmental policy.

Section Volume of required financial, material, technical, human, and other resources, add a point on the development of an economic incentive mechanism (tax breaks, green bonds, compensation payments) for entrepreneurs using NHA. Operational implementation plan in 2025–2027 of the Strategy for the formation and implementation of state policy in the field of ecosystem services management for the period until 2030.

Preservation and ensuring the restoration of priority (key) ecosystem services involve the development of regional pilot projects for the inventory of NHA (therapeutic mud, mineral waters) and the determination of the gross ecosystem product (GEP) to assess the investment attractiveness of resorts.

The monitoring and evaluation of the NHA cadastre are conducted, taking into account its economic value to communities and budgets. Add tools for a hybrid methodology to assess  $GEP_{PLA}$ .

## 6. Conclusions

The study summarizes modern approaches to interpreting the key concepts of natural assets and ecosystem products. Natural assets are actually synonymous with natural capital – a set of living and non-living elements of ecosystems that generate flows of ecosystem services. Although Ukrainian legislation does not define this term, its content corresponds to the lists of natural resources set out in the Subsoil Code and other acts. Ecosystem services are defined as the direct or indirect contribution of ecosystems to human well-

being; the state sees the development of these services as a path to sustainable development (enshrined in the environmental policy until 2030). Ecosystem product (Gross Ecosystem Product, GEP) is an economic category that reflects the total value of all goods and services provided by an ecosystem in monetary terms. In international practice, GEP is considered an addition to GDP, enabling the inclusion of nature's contribution to the economy and well-being. The concept of "ecosystem product" is not yet used in Ukrainian law; however, our study demonstrates its feasibility.

A methodological approach to assessing ecosystem services and products of natural healing assets has been developed and refined. It is based on a combination of quantitative environmental assessments (hydrological indicators, water quality, biodiversity, and anthropogenic pressure) with economic assessments (market price methods, replacement costs, and willingness to pay). Algorithms for calculating the gross ecosystem product for NHA have been proposed, which take into account both the direct use of resources (water, mud extraction) and the services derived from them (balneo- and peloidotherapy procedures). The introduction of the ecological sustainability coefficient enabled us to adjust the estimates to account for the system's ecological sustainability. This methodology is universal and can be adapted for the assessment of other natural systems that have both material resources and ecosystem services.

The effectiveness and informativeness of the proposed approaches were confirmed using the Kuyalnyk resort as an example. It is estimated that the total monetary value of ecosystem services and products in the Kuyalnyk estuary amounts to hundreds of millions of UAH per year. In particular, the gross ecosystem product of the resort's NHA (mineral waters and mud) is conservatively estimated at approximately UAH 544 million per year (USD 13.6 million), even accounting for resource sustainability constraints.

The study's outcomes served as the basis for practical recommendations to the authorities. It was proposed to supplement the draft Ecosystem Services Management Strategy with provisions prioritizing the inventory and monetary valuation of natural healing assets. It was also recommended to develop pilot projects for 2025–2027 to assess the GEP for resort areas and to create a national cadaster of NHA, indicating their ecosystem services and values. In the institutional field, the article points out that the main obstacle in the system of national accounts to the implementation of ecosystem accounting and the capitalization of natural healing assets is the legislative and regulatory disproportion between state, regional, and industry regulations governing the economic component of the use of natural healing assets.

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