Overview of ecosystem services valuation approaches through the prism of their application to determine damages caused by rf hostilities in Ukraine

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This analytical document provides fundamental provisions of ecosystem services concept, highlighting its urgency at the current stage of social development. The analytical document explains the notion “ecosystem services”, appoaches to their systematization and value identification, describes accepted methods for ecosystem services economic value assessment and current limitations in their application. Consideration of fundamental provisions of ecosystem services concept through the prism of hosilities enabled us to outline the possibility of using ecosystem approach to identify and assess losses afflicted to the Ukrainian ecosystems and biodiversity by the military agrresion of the russian federation.

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Content

SUMMARY

Analytical document describes the essence of the ecosystem approach. This concept is attractive as it is integrative and interdisciplinary, and also incorporates the synergy between environmental, social and economic elements. At the current stage of society development, implementation of the ecosystem service (ES) concept into practice will provide broader opportunities for balanced nature use.

The paper describes historical evolution of the notions applied in the ES concept to ensure better understanding of the discussion about the essence of such notions as environmental systems functions, services and benefits, which take place in modern interdisciplinary ecosystem discourse. Interpretation of the ES notion, defined in the UN OOH MEA report is taken as the foundation. These are direct and indirect ways the ecosystems contribute to the human well-being and welfare. Currently ES are mainly anthropocentric in terms of its essence: ES value is defined in the benefits for an individual and society. There is no definite correspondence between services and benefits: one service generates several benefits, and getting a certain benefit usually requires several services. Benefits may not coincide with services in space and time.

Importance of the ecosystem services is more and more reflected in the related projects and scientific publications, and also in legal and political tools. ES are addressed in the planning documents defining the policy of nature use. In particular, the EU 2020 and 2030 Biodiversity Strategies recognize the importance of ecosystems and their services support and restoration, approve mapping and evaluation of ES condition and economic value in the EU territory, as well as their integration into inventory and reporting systems all over Europe. Importance of the ES is highlighted also on the sectoral level. In Ukraine ES also show significant potential for efficient

protection of ecosystems and biodiversity by listing their benefits and creating payment mechanisms for their outcomes to support well-grounded managerial decision making.

The document considers various functional classifications of the ES and takes as the foundation international ecosystem services classification (Common International Classification of Ecosystem Services, CICES), developed in cooperation with the UN Statistics Department and European Environment Agency (EEA). This functional classification offers the unified definition and standard typology of ecosystem services in the EU. Certainly, the list of ES is not limited to those included into this classification. Spatial approach to ES classification is also important, as spatial and temporal caracteristics of nature systems are in the core of managerial and political decisions.

Understanding of the ES value depends on the considered multitude of such value evaluation variants existing due to variety of outlooks (philosophical views, cultural concepts, various subjects). Understanding of the ES value will help review the approaches to ecosystems and the ways they are linked to the welfare of people. Economic valuation (monetization) of the ES is necessary to calculate the scale of losses we incur when losing ecosystems and species. The most widespread structure to identify ES contribution to the human welfare is general economic value consisting of consumer and non-consumer ES value.

The most complete description of ES economic valuation can be found in the System of Environmental and Economic Accounting. The general recommendation is to use direct market valuation methods. In case there are no ES market prices, which are directly defined by market relations, they can be valuated at the cost of similar markets, related markets or using the production cost. It is advisable to use the methods in the following order:

1) methods where the ES value is directly defined by the markets;
2) methods where the ES value is obtained from the markets of similar goods and services;
3) methods where the ES value is included in the market operations;
4) methods where the ES value is based on the calculation of expenses on related goods and services;

5) methods where the ES value is based on the expected expenditures or markets;
6) other available methods.

The other challenges are identification of indicators that can be used to evaluate (measure, assess the volume) the ES and development of the ES mapping tools, insufficient data and the problem of geographical disproportions in the monetization of one and the same ES. Even bigger challenge is monetization of the ES loss cost, when the ecosystem is impaired and the ES quality is deteriorating and/or is lost. At the same time, currently there are no methods available that could establish the cost of each of the ecosystem values. Monetary valuations do not encompass the non-monetary benefits provided by ecosystem services. Therefore, it is not understandable how it is possible to monetize, for example, culture-related ES or those present on the scale of a planetary system.

There is a gap in understanding warfare practices impact on the environment. A separate problem is the quantitative evaluation of the environmental systems and their degradation to meet the legal criteria used in the legal field. Such factors as the degree of impact on the ES and its spatial distribution pose huge difficulties regarding their quantitative definition and evaluation. Due to these obstacles ES valuation during the war will inevitably depend on the expert opinion. Apart from a range of indefinite issues, the text provides examples of ecosystem services valuation during the war, as well as conceptual scheme for choosing the framework of environmental damage assessment and its economic value estimation, which was used in practice. We provide major conclusions on the possibilities of using the methods for ecosystem services economic value estimation to identify losses inflicted to Ukraine by the military aggression of the russian federation.

List of Abbreviations

ES — ecosystem services

CICES — Common International Classification of Ecosystem Services

EEA — European Environment Agency

ESMERALDA — Enhancing ecoSysteM sERvices mApping for poLicy and Decision mAking

ESP — Ecosystem Services Partnership

IPBES — Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services

MAES — Mapping and Assessment of Ecosystems and their Services

MEA — Millennium Ecosystem Assessment

OpenNESS — Operationalisation of Natural Capital and Ecosystem Services

OPERAs — Operational Potential of Ecosystem Research Applications

SEEA EA — System of Environmental Economic Accounting Ecosystem Accounting

TEEB — Economics of Ecosystems and Biodiversity

TEV — Total Economic Value

VEDA — Methodologies for economic valuation of environmental damage

WAVES — Wealth Accounting and the Valuation of Ecosystem Services

1

ECOSYSTEM APPROACH OR ES CONCEPTUALIZATION

1.1. The core of ecosystem approach

At the end of the 20th century, considering the growing needs of humanity in the limited natural resources of the Earth and the growing load on the ecological balance, which is also manifested in the loss of biodiversity and climate changes, international environmental discussion developed the concept of "ecosystem services".

The concept of ecosystem services (ES) is to take into account environmental services to a greater extent in the decision-making process — services provided to us by nature for free — and to ensure sustainable use of land and resources in order to counteract excessive consumption and deterioration of natural living conditions.

The attractiveness of the ES concept lies in its integrative, interdisciplinary nature, as well as in the connection of environmental and socio-economic elements. However, the concept of ES is not completely new. The fact that nature and/or ecosystems provide free services to humans, such as decomposition, water purification and water flow formation, or oxygen production, has been known for a long time. Back in 1949, Bobek and Schmidthűsen introduced the concept of "potential" — "spatial arrangement of opportunities for development provided by nature".

The concept of ES differs from the concept of natural spatial potential for two reasons. Firstly, the evaluation[1] of ES is anthropocentric, that is, it

[1] The term **ES evaluation** hereinafter is used in its phylosophical-metrological meaning — establishing the significance and value of the ES for an individual/society. However, in economic valuation of the ES (expression of commercial values in monetary forms) we use the term **monetization** (monetary valuation).

considers the ES impact on the quality of life of a person. Secondly, various functions, benefits, and services of nature, which often constitute "public goods" are measured (if possible) using a single standard that reconciles environmental, economic, and societal interests. To this end, a monetary valuation has been proposed to be achieved through a methodological mix of direct and indirect market valuation. However, there are still serious critical arguments regarding the market valuation of non-market assets. As a result, recently there has been a tendency to move away from the concept of ES valuation exclusively in monetary terms, and use a wider range of indicators instead[2].

There is no single approach to the implementation of the ecosystem services concept that would correspond to the ecological conditions of each specific natural and territorial complex. Implementation of the ecosystem approach in the practical activities of society requires significant work: generalization and systematization of the ecosystem services concept provisions, classification of ES, development of effective research methods and mechanisms of ES introduction into the economic and cultural life of society, as well as research into the state of ecosystems and their economic significance[3].

1.2. The notion of "ecosystem services"

The notion of "ecosystem services" for the first time was used by the British scientist E. F. Schumacher in his work "Small is Beautiful: Economics as if People Mattered" (1973). Researching deep interdependence of humans and environment, he introduces the term "ecosystem (environmental or natural) services".

The description of the concept was first given by Paul and Anna Ehrlich (1981), who interpreted services as functions of ecosystems used by society. However, it should be indicated that at this stage the concept of ecosystem services was used mostly for cognitive purposes to demonstrate the impact of biodiversity loss on the functions of ecosystems and, consequently, on human well-being.

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2 https://doi.org/10.1007/978-3-662-44143-5

3 https://geology-dnu.dp.ua/index.php/GG/article/view/701/604

In the modern interdisciplinary ecosystem discourse there are long and rigorous discussions about the essence of such concepts as the functions, services and benefits of ecological systems.

Table 1.1

Understanding the notions "ecosystem functions" and "ecosystem services"[4]

Author, source	Ecosystem function, environmental function	Ecosystem service
P. Ehrlich, A. Ehrlich, 1981	Combination of processes undergoing in ecosystems.	Ecosystem functions used by the society.
R. Costanza et al., 1997, p. 253–254	Habitats, biological or systemic properties or processes in ecosystems.	Ecosystems goods (for example, food) and services (for example, waste assimilation) represent benefits that human population direcly or indirectly obtains from ecosystem functions.
R. de Groot et al., 2002, p. 394–395	Ability of natural processes and components to produce benefits and services that directly or indirectly meet human needs.	If one applied human values, then ecosystems benefits and services are reconceptualization of ecosystem functions observed.
MEA, 2005, p. V	—	Benefits people obtain from ecosystems. Humans as biological species, irrespective of its ability to mitigate the effects of negative environmental changes, fundamentally depend on the flow of ecosystem services.

[4] http://fasu.nltu.edu.ua/index.php/nplanu/article/view/350

R. Haines-Young, M. Potschin, 2009, p. 81	Ecosystem ability or potential to provide services, stipulated by its structural properties or processes it supports.	Contribution to the human well-being, jointly and directly made by biotic and abiotic ecosystem components; "ultimate product" of nature. Functions are transformed into services when there is a beneficiary.
TEEB, 2010	Part of the synergy between structure and processes that safeguard the ecosystem ability to provide goods and services.	Direct or indirect contribution of ecosystem into human welfare. Synonym to the notion "ecosystem services and benefits".

In the ecological and economic discourse the concepts and functions of ecological systems are reconsidered and reconceptualized into economic categories of amenities, utilities, benefits, goods and services, since these concepts are of anthropocentric nature. The mapping of ecological structures and processes is carried out in concepts based on assessments and values, while biogeochemical and informational processes are projected onto the plane of economic categories and relations.

Ecosystem services are direct and indirect contributions of ecosystems to human well-being and wellfare, as stated in the UN Millennium Ecosystem Assessment (2005), one of the main documents on the concept of ecosystem services.

Nowadays, there are a number of approaches to the interpretation of the essence of ecosystem services and their classification, of which three are the most common: IEA, TEEV and CICES.

The IEA (2005) approach interprets services as benefits obtained by people from ecosystems. Indicating the difference between services and benefits, which is not taken into account in the IEA approach, as well as overcoming the problem of "double counting", the TEEB (2010) approach defines services as the direct or indirect contribution of ecosystems to human well-being. According to CICES (2012), ecosystem services are the contributions that ecosystems make to human well-being. These are ready-made services in the sense that they are ecosystem benefits that directly affect well-being.

There is no one-to-one correspondence between services and benefits, one service generates several benefits, and several services are usually needed to obtain a certain benefit. Benefits may not coincide with services in space and time. In addition, it should be stressed that value and cost are not considered by us as synonymous concepts, but rather as such that complement each other[5]. Let us consider the example of forest ecosystem and its services.

Table 1.2

Cascade model of ES formation and identification and their values (adaptation from Potschin, Haines-Young, 2013) p.[6]

ECOSYSTEMS, BIODIVERSITY				SOCIAL AND ECONOMIC SYSTEM	
Forest ecosystems ⇨	**Functions** ⇨	**Ecosystem services**	⇨	**Benefits** ⇨	**Values/costs**
Biophysical **structure and processes**	Properties and processes in ecosystem	Reconceptualized functions, contribution to well-being	**Availability of consumers**	Benefits for people	Knowledge, feelings, information
Landscapes, forest stands, habitats, streams	Water circulation and filtration, biomass conversion and growth, wind speed decline	Wood products, flood and erosion protection, recreational attractiveness		Fresh air, construction materials, reduction of damages from floods and erosion, recreational attractiveness	Non-monetary (qualitative, quantitative) and monetary (costs) evaluation of forest ecosystem services: cost of wood, readiness to pay for forest protection

5 **Value** is the property of a certain object or phenomenon to meet the needs, desires, interests of a social subject (an individual, group of people, society). It is subjective. **Cost** — expressed in monetary value the price of something that appears from market interaction, i.e. as a result of demand and supply interaction in the market. Partially it is also subjective and depends on the level of society development, including economic one, development of market relations.

6 https://cices.eu/content/uploads/sites/8/2017/12/3_Potschin_RHY_2016_Defining-ES_CICES.pdf

Discussion on the specification of the essence of ecosystem services and benefits concept may seem too academic, however, accurate defintions of the structure, processes, services and benefits are necessary to ensure correct information exchange and making well-grounded decisions[7].

1.3. Importance of the ES

Currently the number of scientific research in ecosystem services shows significant growth. More than 3000 articles covering the topic in question are produced annually. It stimulates the institutions to develop additional thematic projects, including Millennium Ecosystem Assessment, The Economics of Ecosystems and Biodiversity (TEEB[8]), TruCost, Ecosystem Services Partnership (ESP), the Intergovernmental Science-Policy Platform on Biodivesity and Ecosystem Services (IPBES[9]) etc.

The importance of ecosystem services is more and more reflected in legal and policy instruments. ES is taken into account in planning documents defining the policy of nature use. In particular, the EU Biodiversity Strategies 2020 and 2030 recognize the importance of maintaining and restoring ecosystems and their services. Thus, Action 5 Task 2 of the EU Biodiversity Strategy endorses the mapping and assessment of the state and economic value of ecosystem services throughout the EU, as well as their integration into accounting and reporting systems across Europe.

In March 2021 the UN adopted statistical database System of Environmental Economic Accounting Ecosystem Accounting (SEEA EA) to account biodiversity and ecosystems in the national economic planning and tracing changes in the ecosystems and their services[10]. Ecosystem accounting in the EU is the integrated and comprehensive statistical standard to organize data about habitats and landscapes, measuring ecosystem services, tracing

7 http://fasu.nltu.edu.ua/index.php/nplanu/article/view/350/266

8 http://www.teebweb.org

9 https://ipbes.net/assessment-reports/eca (data on value of certain types of ES in USD per year by countries/ for Ukraine almost no data because of no relevant research performed)

10 https://ec.europa.eu/eurostat/web/products-eurostat-news/-/cn-20210311-1

changes in ecosystems assets and linking this information to economic and other types of human activities.

The European Commission has published “A Review of Ecosystem Service Valuation Progress and Approaches by the Member States of the European Union”, including, for example, projects TEEB, ESMERALDA, IPBES, OPERAs, OpenNESS etc.[11]

The importance of the ES is also noted by industries (in sectors). For example, regarding forest ecosystems — the UN Forum on Forests, a subsidiary body established by the Economic and Social Council, has adopted a non-binding legal document on all types of forests that encourages, as part of national policy, recognizing a range of values derived from the goods and services provided by forests and trees outside forests; and also, the display of such values on the market in accordance with the national legislation[12].

In Ukraine, the potential of ES is also significant for the effective protection of forests by accounting for their benefits and creating mechanisms to pay for their results, to support informed decision-making in forest management[13]. All this shows that now ecosystem services concept is widely accepted and is actively developing.

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11 https://ec.europa.eu/environment/nature/capital_accounting/pdf/eu_es_valuation_review.pdf

12 https://www.un.org/esa/forests/wp-content/uploads/2013/09/E-2007-42-UNFF7Report.pdf

13 http://www.agrosvit.info/pdf/11_2021/7.pdf

2

CLASSIFICATION OF ECOSYSTEM SERVICES

2.1. ES functional systematization

ES identification and description was made as far back as 1997 by Roberto Constanza et al. At that time they defined 17 ecosystem services for 16 biomes, however, they did not divide them into groups[14]. In 2005 MEA divided all the ES into four categories:

- *regulating:* regulating climate, floods and disease spread, water purification etc.;
- *provisioning:* food, water, timber, fuel, materials, etc.;
- *cultural services*: aesthetic, spiritual, educational, recreational;
- *supporting services*: nutritional substances turnover, soil formation and primary production[15].

Later, in particular, in TEEB projects (2010), supporting services were included into the category of regulating services, and there was a separate category of habitat services[16].

In CICES (2018) three categories of ES were identified: provisioning, regulation and maintenance and cultural; CICES does not distinguish the so called supporting services. The afore-mentioned categories are divided into 20 groups and 48 classes.

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[14] https://www.nature.com/articles/387253a0

[15] MEA (Millennium Ecosystem Assessment). Ecosystems and Human Well-Being: Synthesis. — Washington: Island Press, 2005. — 155 p.

[16] TEEB (The Economics of Ecosystems and Biodiversity). Ecological and Economic Foundations / Edited by P. Kumar. — London and Washington: Earthscan, 2010. — 422 p.

Table 2.1

Comparison of ES categories in different classifications

The project offering the classification	Categories of ecosystem services				
	regulation	support	provisioning	cultural	habitat
MEA, 2005	regulation	supporting	provisioning	cultural	
TEEB, 2010	regulating		provisioning	cultural & amenity	habitat
CICES, 2018	regulation & maintenance		provisioning	cultural	

Formation of Common International Classification of Ecosystem Services, CICES)[17], started in 2010 as cooperation between the UN Statistics Department and European Environment Agency (EEA) to ensure transparency of information exchange on ecosystem services and their integration into accounting systems. As a result of its development, a unified definition and standardized typology of ecosystems services in the EU was offered, ecosystem services mapping and assessment was launched, and several European countries have already conducted systematic assessment of national ecosystems, among them are Great Britain (2011), Spain (2013), etc.

Research of the EU programme "Mapping and Assessment of Ecosystems and Their Services" (MAES)[18] on practical application of MEA, TEEB and CICES has shown that usually the stakeholders identify a much wider range of services than those offered in the aforementioned classifications[19].

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17 https://cices.eu/

18 https://www.maes-explorer.eu/

19 Maes J. Mapping and Assessment of Ecosystems and their Services. An analytical framework for ecosystem assessments under action 5 of the EU biodiversity strategy to 2020 / J. Maes, A. Teller, M. Erhard, C. Liquete, et al. — Luxembourg: Publications office of the European Union, 2013. — 57 p.

Research[20] on ecosystem services classification analysis recommended to use CICES in practice as the most universal one. And regarding different **ecosystem types** — it was recommended to use framework indicators of MAES analytical frames:

- urboecosystems;
- agroecosystems;
- natural ecosystems;
- freshwater ecosystems;
- marine ecosystems.

The research[21] defines distribution and percentage of ecosystems according to EUNIS classification, distinguishing 7 ecosystems (habitats) of the first type, which provide basic ecosystem services in Ukraine, within major landscape types. One should state that certainly the choice of ecosystem detalization level to be used in the study depends on the tasks set and available resources.

2.2. Spatial Approach to ES clustering

If the task is to make landscape management decisions for the provision of ecosystem services at different scales, a useful criterion for classifying ecosystem services is their spatial characteristics. After all, it is important to know what services are provided within a certain landscape and the features of the spatial distribution of these services within this landscape.

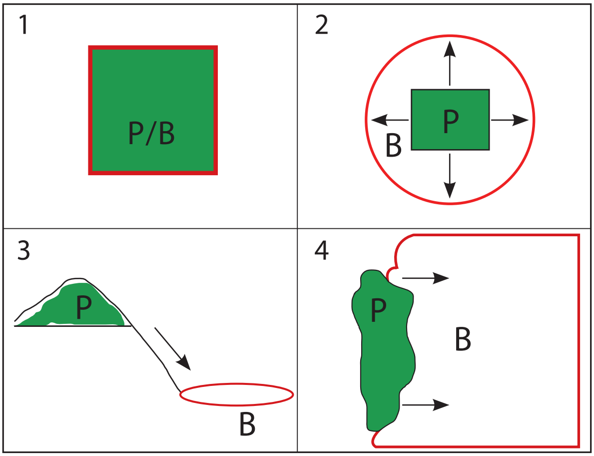
For instance, such approach is used in Water and Habitat EU Directives, which include spatial and time characteristics of natural ecosystems in political decisions. Using spatial features for classification can include categories describing geography of connections between services production and their benefits realization. This classification can include the following categories:

- in situ — wheher the services are provided and benefits are realized in the same place;

[20] https://nrat.ukrintei.ua/searchdoc/0219U102000/

[21] https://geology-dnu.dp.ua/index.php/GG/article/view/701/604

- comprehensive — the services are provided in one place, but are beneficial for the surrounding landscape without certain direction (pollination, protection from floods);
- directed — when services provision brings benefits at a certain place owing to flow direction.



Drawing 2.1. Potential spatial connections between the ES "production" zones (P) and zones ES are provided to (B): 1 — ES "production" and its/their provision happens in the same place (for example, soil formation, raw material provision); 2 — the service is provided in all directions and is useful for the surrounding landscape (for example, pollination, carbon capturing); 3 and 4 — the services have directly streamlined benefits: 3 — the downstream territories get benefits from services, provided in mountainous areas, for example, water regulation services, provided by the forested slopes; 4 — provision of services by coastal wetlands, protecting the shore line from storms and floods[22]

[22] http://dx.doi.org/10.1016/j.ecolecon.2008.09.014

3

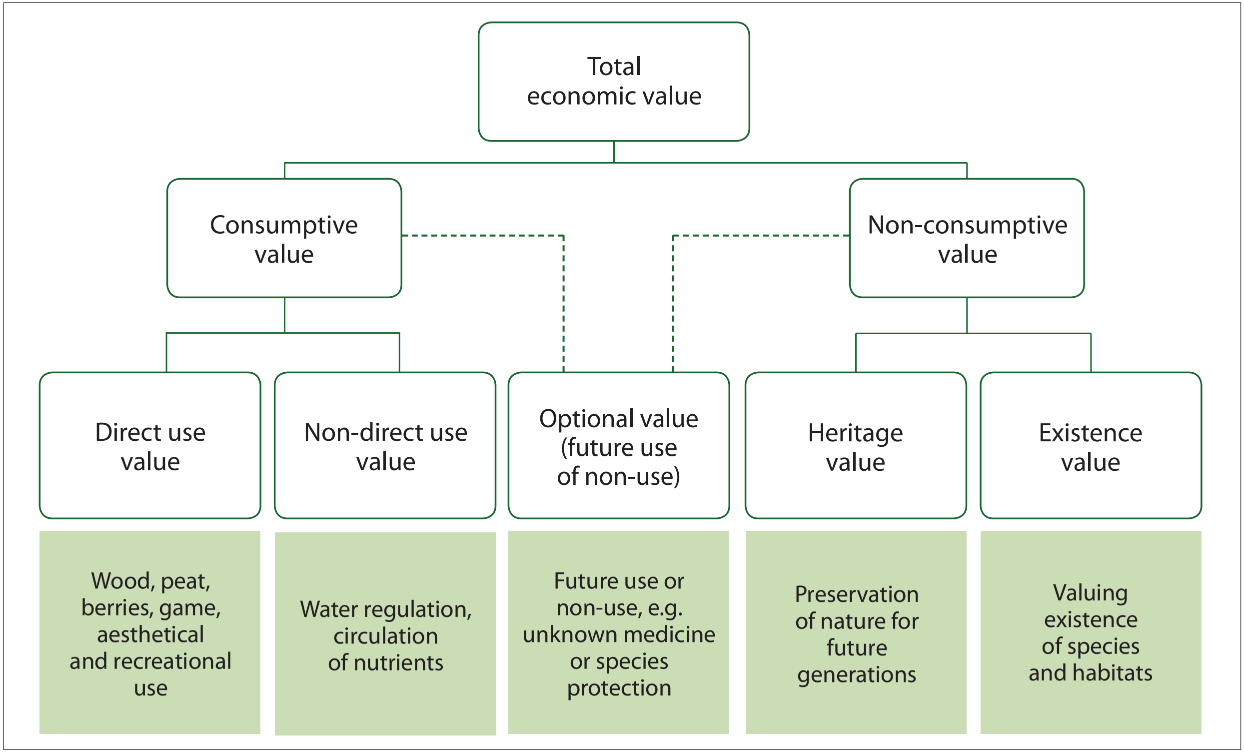
ON THE ISSUE OF VALUE AND ESTIMATION OF THE ECOSYSTEM SERVICES COST

3.1. Approaches and challenges

Dominant discourses and approaches to the value and estimation (including monetization) of ES tend to emphasize the dichotomy between instrumental (anthropocentric) and intrinsic (non-anthropocentric) dimensions of nature. In other words, either the value and cost of nature is considered only from the point of view of a person and for a person, resulting from a utilitarian economic point of view (nature for a person), or the value and cost of nature is a thing in itself, nature has value for nature regardless of the perception of its values by humans (nature for nature). Another, relational approach emphasizes the value of interaction between people and nature, promoting the dichotomy of instrumental and internal.

Understanding of value should be based on value pluralism, which takes into account the multiplicity of options for assessing value due to the existence of a variety of worldviews (philosophical views, cultural concepts, different disciplines).

Understanding the ES value can help reframe views of ecosystems and their relationship to the human wellfare. Monetization of ES is needed in order to assess the extent of the damage we are experiencing as we lose ecosystems and species. According to the Millennium Ecosystem Assessment (MEA), the most widely used framework for determining the contribution of ES to human wellfare) is **Total Economic Value** (TEV).



Drawing 3.1. The structure of total economic value (TEV) (adapted from [23])

[23] https://ipbes.net/economic-valuation

Economic valuation is limited by anthropocentric types of values. The structure of total economic value conceptualizes economic values as "cost of consumption" or "cost of non-consumption", the so called consumer and non-consumer value. Consumer cost consists of direct consumptive (e.g. food), direct non-consumptive (e.g. recreation) and indirect (e.g. pollination) uses. Non-consumptive values consist of heritage values (for future generations), altruistic values (for other people), and existence values (the satisfaction of knowing something exists). In situations of uncertainty of the option, the option of future (non)use of this ecosystem arises. Often, but not necessarily, economic values are expressed using monetary units of measurement.

From an instrumental perspective, ecosystem value must also consider the ability of the system to sustain ecosystem service values under variable and disruptive conditions. This is the so-called insurance value, and it is closely related to the ecosystem sustainability and its ability to self-organization.

Currently, there are no methods that could assign cost to each of the ecosystem values, that is, express the value of the ES in a monetary equivalent. After all, monetary valuations do not cover the non-monetary benefits provided by ecosystem services. That is, it is not clear how it is possible to monetize, for example, culture-related ESs or those that operate on the scale of the planetary system.

Moreover, the search and selection of indicators that could be used to evaluate (measure, determine the scope of) ES is just going on. Thus, in Germany, a list of indicators, units of measurement and methods for the National System of Evaluation and Monitoring of ES is only being developed[24].

Another challenge is mapping and development of tools to distribute data on the ES[25]. At the same time, it is stressed that the use of spatial model for quantitative evaluation of actual ES flow is promising[26]. Even greater challenge is monetization of ES loss cost, when ecosystem is damaged and

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24 https://www.sciencedirect.com/science/article/pii/S1470160X22001753?via%3Dihub

25 https://doi.org/10.1016/j.ecoser.2014.12.002

26 https://www.sciencedirect.com/science/article/pii/S2212041619302815

the ES quality is deteriorating and/or is lost. Therefore, it is very difficult to evaluate (monetize) the losses of the ecosystem services due to ecosystem damage[27].

3.2. Methods for ES economic valuation

Multiple international projects in many countries of the world elaborated the methodology for biodiversity and ecosystem services valuation. For example, we have considered the following ones:

- Economics of Ecosystems and Biodiversity (TEEB)[28],
- Enhancing ecoSysteM sERvices mApping for poLicy and Decision mAking (ESMERALDA)[29],
- Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)[30],
- Operational Potential of Ecosystem Research Application (ORERAs)[31],
- Operationalization (application) of natural capital and ecosystem services (OpenNESS)[32],
- System of Environmental-Economic Accounting Ecosystem Accounting (SEEA EA)[33] etc.

The most detailed description of the ES economic valuation methods is provided in SEEA EA[34]. The general recommendation is to use the methods of direct market valuation. In case there are no market prices for the ES, which are directly identified by market relations, they can be valuated

27 https://wesr.unep.org/media/docs/assessments/loss_and_damage.pdf

28 https://teebweb.org/

29 http://www.maes-explorer.eu/

30 https://ipbes.net/global-assessment, https://doi.org/10.5281/zenodo.3831673

31 https://www.operas-project.eu/

32 http://www.openness-project.eu/about

33 https://seea.un.org/ecosystem-accounting

34 https://seea.un.org/sites/seea.un.org/files/documents/EA/seea_ea_white_cover_final.pdf

at the prices of similar markets, related markets or using the production cost. SEEA EA recommends using methods in the following order:

1) methods where the ES cost is directly identified by the markets;
2) methods where the ES cost is obtained from markets for similar goods and services;
3) methods where the ES cost is embodied in market transactions;
4) methods where the ES cost is based on revealed expenditures on related goods and services;
5) methods where the ES cost is based on expected expenditures or markets;
6) other valuation methods available.

1. Methods where the ecosystem services prices are directly identified by the market

Mehod of directly observed values. The most direct method of determining ES prices and value. It is based on the direct determination of the ES cost based on the real market price. For example, if a wetland provides a water treatment service, and the wetland's owners or managers can charge a water company that withdraws water for municipal use, there is a transaction of the ES provided by the ecosystem that can be observed and recorded. An example when the cost is determined by the market is also the cost of forest felling, which is charged to logging companies. Another example is land rental prices in agriculture, where there are markets to rent land for crop production or livestock grazing. The rental price can be used to determine the prices and accounting for the relevant biomass services.

Although using directly available prices is the easiest and one of the best methods, the resulting prices may underestimate the true value of the ES. Most often, such a result is a reflection of existing institutional mechanisms. For example, it is known that the rent for natural resources that are extracted with open access is close to zero. An example of such resources in Ukraine can be berries and mushrooms, when the population is not charged the rent for gathering, and in the case of industrial harvesting, the rent fee is very low. Thus, in the Rivne region, the rental rate for blueberry picking for 2022 was set in the amount of 1,20 UAH/kg, and in 2021 — 1,87 UAH/kg[35], while the

[35] https://rv.tax.gov.ua/media-ark/news-ark/589636.html

purchase price of blueberries from the population is 40–60 UAH/kg, and the market prices (wholesale and retail) are much higher.

Another example of market-valued ESs are prices from emissions trading systems, which can be used to estimate the value of global climate regulation services based on carbon sequestration. The number of countries with such trading systems is growing, as is the amount of carbon traded, thus, these markets can provide relevant price data.

Market prices can be used provided that the trading system and institutional mechanisms for determining the value of a particular ES are sufficiently mature. If the trading system is considered underdeveloped, an alternative is to use more readily available data on emission reduction cost or other data.

It should be noted that if market-determined prices are not considered economically meaningful (such cases may arise, for example, in the context of national park entrance fees), the present value of ES should not be used, and alternative valuation methods should be applied. In addition, the size of the markets and their maturity should be taken into account. Using prices in small or immature markets may not be sufficiently representative to be used in ecosystem accounting.

2. Methods where the ES price is obtained from markets for similar goods and services

Prices from similar markets. If market prices for specific ESs are not determined, valuation according to market price equivalents can provide an approximation of market prices. Market prices should be taken from markets where the same or similar goods are sold in sufficient quantities and under similar circumstances. If there is no relevant market in which a particular good or service is traded, an estimate of their value can be obtained from market prices for similar goods and services by adjusting for the quality of the service and other differences.

For example, when non-timber forest products (such as mushrooms) from one forest are sold but from a similar forest are not, prices determined in the first market can be used to estimate non-timber forest products from the latter, taking into account product differences and other factors. In this method the price in the comparable market should to be adjusted for any costs incurred in supplying the good or service to ensure that the price used refers to the ecosystem service. Moreover, it is considered that the flows of (non-market) ES (in this example, gathering mushrooms) are not so significant that they can change the observed price and demand for a good or service from a similar market.

3. Methods where the ES price is embodied in market transactions

Residual value and resource rent methods. The residual value and resource rent methods estimate the value of ES by taking the gross value of the final market good for which ES is an input and then subtracting the value of all other inputs, including labor and other costs. Depending on the amount of data (e.g. location-specific or industry-wide), the estimated residual value is a direct estimate that can be used to determine the price of the ES.

In practice, when applying these methods, a number of difficulties may arise. First of all, the residual value may reflect a combination of other non-reimbursed and indirect costs, and distinguishing the ES contribution may be difficult. Secondly, the assessment is subject to errors in the calculation of the value of all "paid" expenses. Thirdly, the size of the residual value will be directly influenced by the institutional mechanisms of ecosystem use. It should be noted that this method is most easily applied using broad data at the industry level, and the final estimates of the ES cost may lack the detail necessary to determine monetary values for the specific location of the service. At the same time, since this method is applied on the basis of observed data, the values and prices estimated using this methodology will reflect the current institutional context of ES use and can provide a basis for its monetization.

Productivity change method. In this method, ES is considered a component in the production of a marketable product. Thus, changes in ES will lead to changes in the volume of production of goods sold, with other conditions being equal. The cost of the service is determined in three stages. First of all, the marginal contribution of the ES is estimated as a change in the cost of production due to a change in the ES offer. Secondly, the marginal contribution is multiplied by the price of the market product to obtain the marginal price for the ES. Thirdly, this marginal price is multiplied by the physical quantity of ES provided to obtain the cost of the ES. These ratios should be estimated for one accounting period, given that they may change over time. For example, we find the following formula for calculating the cost of ES of pollinating insects in the project WAVES[36]:

cost of a pollinator = the probability that this seed will not be pollinated by another pollinator (wind, other pollinators, artificial pollination, etc.) × the price of the product obtained as a result of pollination × the number of seeds that can be pollinated by it.

The productivity change method has been used to estimate the value of services provided by water and other agricultural resources, such as pollination, in different locations where detailed data are available to assess ecosystem production functions. Another example is the natural improvement of water quality that increases the commercial value of fisheries while simultaneously increasing the fishermen's income. However, if multiple commodities and ESs are involved, determining the production contribution and marginal price of an individual ES can be complicated as there will be a number of factors that need to be taken into consideration. In addition, the method may require large amounts of data and scaling may be difficult.

Hedonic pricing method. ES cost may be reflected in the price the individuals are ready to pay for the ecosystem services-related benefits. Hedonistic pricing method estimates differential gain to real estate price or lease fee (or other complicated goods) arising due to the influence of ecosystem characteristics (for instance, clean air, local parks) on this cost. This method is usually used to measure services related to amenities given to residents in some areas. To measure this effect all the other property characteristics (including its size, number of rooms, central heating, garage area, etc.) should be standardized and included into analysis. One should also pay attention to geograpahic and ecosystem property features.

Within the context of ecosystem accounting division of these values into the part, which is explained by ecosystem characteristics, and the part, explained by other property characteristics, can be used for the estimation of the corresponding ES value (for example, air filtration, recreation) for

[36] https://www.wavespartnership.org/sites/waves/files/images/Phil_8.%20Valuation%20session%20Sept2014.pdf

the specific property. If hedonistic pricing method is used to the real estate cost, and not the lease fee, the final prices should be converted, for them to be related to annual servces volume.

Calculation of the ES cost can be used in other fields, for example, by identifying prices for the hectare of agricultural land sold or leased within the context of biomass provision services.

Hedonistic pricing method allows to determine the cost of a service only if there exist a fully informed and fluctuating market, where the buyers can find real estate with characteristics meeting their preferences.

4. Methods where the ES price is based on revealed expenditures on related goods and services

Averting behaviour method. Averting behaviour method suggests that certain individuals and communities lose money on prevention or mitigation of negative consequences and losses caused by negative impact of the environment. The revealed expenditures demonstrate the value of the related ES. For instance, it is related to expenditures on additional filtration to purify polluted water, conditioning to prevent air pollution, etc.

The incurred costs are considered to be the low threshold of ES valuation from mitigation of negative consequences, as one can assume that benefits obtained from negative effects prevention are at least equal to the part of expenditures incurred to prevent them. The advantage of this method is that it is easier to estimate the incurred costs than to estimate the environmental damage prevented. The disadvantage is that the expenditures may not be very sensitive to the differences in the environment quality, therefore, they are not spatially sensitive, meaning that with different conditions of the environment (irrespective of the volume of the positive effect the service has) the cost will be the same. Apart from this, attention should be paid to coordination of expenditures with certain ES, as they can reflect a group of services; and ensure reflection of expenditures only on preventing environmental impact, and not consumer preferences.

Travel cost method. The travel cost method is widely used to estimate the value of recreational sites on the basis of the identified preferences of the visitors. The demand for recreation is estimated by observing the actual number of trips happening with different cost of the trip to the recreation site, supposing people have similar preferences regarding visiting this site. Travel cost data incude information about expenses incurred by the households or individuals to get to the recreation site, entrance fee and also may include costs related to travelling and visiting time. Travel cost data are recorded and take into account peculiarities of recreation sites.

Ecosystem services accounting requires estimation of the cost of exchange of the related ES, as a rule, recreational services. The cost can be estimated on the basis of demand calculated by the exchange cost modelling method. In case there is no calculated demand-based data, the service exchange cost can be approximately determined on the basis of cumulative data on travel cost (for example, fuel spent).

5. Methods where the ES cost is based on expected expenditures or markets

This group of valuation methods is based on expected expenditures valuation if ecosystem service was not provided anymore or was actually sold on the market. Application of these methods is based on logic where the ES loss directly will lead to the increase in expenditures (or reduction of income) for economy and that the market will identify it.

Replacement cost. This method evaluates the cost of ES replacement with something that brings about the same benefits for people. It is also known as a replaced (alternative) cost approach. There can be various replacements, for example, installation of air filtration system in the house which replaces air filtration service provided by trees; sorgo as a cheap feedstuff replacing pasture ecosystem services; water purification station etc. In all the cases, if the replacement makes the same contribution, the ES value is the cost of a replacement element providing the same services as one quantitative ES unit (e.g., price per one tonne of feedstuff).

Justification of replacement cost method depends on three conditions: (i) the replacement can perform the same function, as that of a replaced ES; (ii) the replacement used is an alternative with the lowest cost; and (iii) there is readiness to pay for a replacement, if ES is not provided anymore. Thus, the example of pasture providing feedstuff without a cost clearly shows that sorgo is a good replacement of feedstuff, that it is cheaper than other replacements (for example, cattle transfer to the other place, using other feedstuff), and that animal farming will continue if pasture grazing is limited.

Avoided damage costs. The method evaluates ES value on the basis of damage costs that can arise due to the loss of such services. Similar to the replacement cost, this method usually is used for services that will be lost, if there is no ecosystem or it is in a poor condition, therefore the services are not available. Justification of avoided damage cost method also depends on the conditions mentioned above for the replacement cost method. Avoided damage cost method is particularly useful to regulate such services as combatting soil erosion and floods, air filtration and global climate regulation services.

Damage cost valuation allows to identify the costs, which are expected to be avoided with ES provided. For example, air filtration service costs may be related to avoided healthcare costs. In some cases the service can be valuated both with replacement cost method and avoided damage costs method. In this case one should use lower value out of these two calculated costs.

Simulated Exchange Value (SEV) method. This method evaluates potential cost and quantity of services, if ES were sold at the hypothetical market. The method is used by means of using demand functions for the corresponding ES (e.g., estimated with travel costs method or stated preferences method). They are used to calculate the ES cost in case it is actually sold. The simulated exchange value method requires combining demand and supply information and the relevant market structure. Later standard macroeconomic methods are used to get the modelled price that can be used to valuate the ES cost.

6. Other valuation methods

Shadow project cost. This is a variant of the replacement cost method focusing on the hypothetical costs of providing the same ES elsewhere. Among potential alternatives for developing a shadow project there are: assets reconstruction (e.g. providing alternative habitat for endangered wildlife); asset transplantation (for example, moving an existing habitat to a new location); and assets restoration (e.g. improving existing degraded habitat). The three conditions mentioned above for the replacement cost method also apply to this method, also noting that the method is effective only if the shadow project is actually implemented or planned to be implemented. This method is also related to the restoration cost method, which can be applied to assess ecosystem degradation by estimating the costs that must be incurred to restore the ecosystem to its original state.

Opportunity costs of alternative uses. This approach estimates the ES cost by measuring the lost benefits of not using the same ecosystem asset in an alternative way. For example, the cost of ESs resulting from forest not being harvested for timber (e.g. to provide global climate regulation services) can be measured in lost revenue from timber sales. Thus, this approach measures what must be given up in order to provide the ES. The alternative use cost approach is most useful when considering ESs that may be linked to specific objectives, such as the protection of habitats, cultural or historic sites. The main difficulty of the opportunity costs of alternative uses approach is to determine a realistic alternative use, because depending on the choice made, the value of the foregone benefits can vary significantly.

Stated preference methods. Preferences identification methods do not use the information about people's behaviour at the current markets but rather use the information from the questionnaires to get probable answers of people while asking them to describe their actions in hypothetical situations. Stated preference methods do not directly show the exchange cost and, thus, require correction for services monetization. These are major methods to evaluate the values which are not used. Stated preference methods are devided into two broad types: contigent valuation and choice experiments.

Contingent valuation method is a survey-based methodology of identifying advantages, which reveals the behaviours of people at the established markets. The contingent valuation questionnaire describes a hypothetical market where a corresponding product can be traded. This contingent market identifies the very product, institutional context it will be provided in and the way it will be funded. The respondents are asked about their willingness to pay or willingness to accept the hypothetical change in the level of benefits provision, asking them whether they will accept the corresponding scenario. It is supposed that the respondents behave as if they were at the real market.

Choice experiments are the experiments when a person is offered a set of alternative levels of supply of goods or services (usually two or three), in which the characteristics change according to the defined parameters of the service quality and cost. By analyzing the preferences in these different groups of characteristics, it is possible to obtain the value given to each of the characteristics, provided that the groups include a cost variable and a basic package of services is included.

The information obtained from contigent valuation methods and choice experiments is the willingness to pay for ES or the willingness to accept payment for its loss. This information is then used to estimate changes in consumption and production surpluses of the service and, as such, does not provide an estimate of its value. However, by combining information on willingness to pay and acceptance of a payment for service loss, the demand for ES can be determined and used to derive a value using a simulated exchange value method.

Prices from economic modelling. Conceptually, it is possible to derive ES cost from economic models covering relevant information about environmental and economic variables. Prices for ESs (e.g., biomass production services) can be derived from computational models that take into account a wide range of factors and correlations between economic sectors and can be extended to include environmental factors.

Quality methods. There is a set of quality methods, including discussion and groups methods, which can be used to estimate ES value. However, these methods, as a rule, are not designed to determine monetary values.

Group Valuation Method. The approach to estimating the economic value of ES involves the creation of an expert group that will determine its value. In the literature the methods' names may slightly differ, but their essence does not change. Below are the interrelations between services, cost, and the most commonly used ES economic value estimation methods.

Table 3.1

Interrelations between services, cost and methods for economic value estimation[37]

Ecosystem services	Cost of use	Generally accepted methods	Methods that may be potentially used
Regulation services			
Air quality regulation	Cost of indirect use	AC	RC, FI, CV, GV
Climate regulation		AC	RC, FI, CV, GV
Natural disaster prevention		AC, RC, CV	FI, HP, GV
Water flow regulation		FI, AC, DM	RC, HP, GV
Water quality regulation		DM, RC	AC, FI, TC, HP, CV, GV
Soil retention		AC, RC	FI, HP, CV, GV
Soil formation		AC	RC, FI, CV, GV
Waste recycling		RC, CV	AC, FI, HP, GV
Biological control		RC, FI, DM	AC, CV, GV
Provision services			
Food products	The cost of direct exhaustive use, the cost of potential use	DM, FI, CV	RC, GV
Raw material		DM, FI, CV	RC, GV
Genetic resources		DM, FI	AC, RC, CV, GV
Medical resources		DM, FI	AC, RC, CV, GV

37 https://www.enpi-fleg.org/site/assets/files/2131/final_report__i__soloviy__evaluation_of_forest_ecosystem_services_pro-vided_by_forests_of_ukraine_and_proposals_on_pes_mecha.pdf

Continuation of Table 3.1

Cultural services			
Aesthetic value	The cost of direct non-exaustive use, the cost of existance	HP	RC, TC, CV, GV
Recreation		DM, CV, FI, TC, HP	RC
Spiritual and historical values		CV	TC, HP, GV
Cultural values	The cost of direct non-exaustive use	CV	DM, FI, TC, HP, GV
Scientific and educational services		DM	FI, TC, CV, GV

Footnote. Generally accepted methods are methods often applied in literature. Methods of potential use are methods which are not frequently used but potentially could be used.

Abbreviations:
DM — direct market;
AC — avoided cost;
RC — replacement cost;
FI — factor income;
TC — travel cost;
HP — hedonic pricing;
CV — contingent valuation;
GV — group valuation.

3.3. Challenges of ES economic valuation

Insufficient data for ES volume evaluation and ES monetization. In 2020 at the conference in Hannover, Germany, ESP summarized pilot project on ES valuation. 3 valuations were based on statistical data and 5 on modelling results[38].

For example, during implementation of TEEB projects in russia (Table 3.2) method of direct qualitative valuation (method 1) was used to estimate only 5 ES from 31, method of indirect qualitative valuation (method 2) — 7 ES, scoring method — 9 ES, and for 10 ES there was only evaluation task set due to impossibility to conduct analysis following one of three aforementioned methods, or lack of data[39].

Table 3.2

Methods for ecosystem services valuation

ES	Methods			
	1	2	3	4
1. Productive (provisioning)				
Wood production	X			
Non-wood production of forest and other terrestrial ecosystems	X			
Production of fodder on natural pastures (hayfields were not taken into consideration)		X		
Production of freshwater ecosystems, primarily fish				X
Game production	X			
Production of honey in natural areas				X
2. Environment-forming (regulating)				
Climate and atmosphere regulation				
Biogeochemical climate regulation				
Carbon storage	X			
Regulation of greenhouse gas flows (only CO_2 was considered)	X			
Biogeophysical climate regulation				X
Air purification by vegetation (absorption of pollutants by suburban forests)		X		

38 https://www.researchgate.net/publication/349345509_Ecosystem_and_ecosystem_services_accounts_time_for_applications

39 http://teeb.biodiversity.ru/publications/Ecosystem-Services-Russia_V1_eng_web.pdf

Hydrosphere regulation				
Water protection and water regulation				
Regulation of runoff volume		X		
Regulation of runoff variability (runoff stabilization)		X		
Assurance of water quality by terrestrial ecosystems		X		
Assurance of water quality by freshwater ecosystems (water self-purification and dilution)		X		
Soil formation and protection				
Soil protection from erosion				
Soil protection from water erosion			X	
Soil protection from wind erosion			X	
Prevention of damage from soil washing into water bodies				X
Prevention of damage from landslides and mudflows				X
Establishment of soil bioproductivity				X
Self-purification of soils			X	
Regulation of cryogenic processes		X		
Regulation of biological processes important for the economy and for security				
Ecosystem regulation of species with economic importance (agricultural and forest pests, invasive and synanthropic species)				X
Pollination of farm crops			X	
Ecosystem regulation of species with medical biomedical and veterinary importance				X
3. Informational (cultural)				
Genetic resources of wild species and populations			X	
Information on structure and functioning of natural systems that can be used by humans			X	
Aesthetic and educational importance of natural systems			X	
Ethical, spiritual and religious importance of natural systems				X
4. Recreational				
Formation of natural conditions for daily recreation near home, weekend recreation, recreation at summer cottages			X	
Formation of natural conditions for educational and active tourism in the nature			X	
Formation of natural conditions for resort recreation (except seacoasts)				X

Geographic disproportions of ES monetization

Apart from seemingly global universality of ecosystem services, the cost of one and the same ES will be different for two or even more orders in different countries worldwide.

For instance, the research (2010)[40] evaluates the cost of certain types of ES of moderate/boreal forests as 443 USD/ha/year, namely:

- climate regulation — 129 USD/ha/year;
- soil formation — 15 USD/ha/year;
- waste recycling — 128 USD/ha/year;
- biological control — 6 USD/ha/year;
- food production — 88 USD/ha/year;
- raw material — 37 USD/ha/year;
- recreation — 53 USD/ha/year;
- cultural ES — 3 USD/ha/year.

Analysis of the forest ES cost in some forest areas, countries and regions shows extensive variations from 8 USD/ha to 4080 USD/ha. It is indicated that estimated value of Japanese forest (22700 USD/ha) can be considered as such that is beyond the threshold of normal values of forest ES value indicator. Thus, it depends on the level of social and economic development of the countries, their culture and traditions.

Differences in ES monetization can be observed within one country, in particular due to *various methodological approaches to monetization and time dynamics*. Thus, for example, in the article (2014)[41] the value of ES provided by Czech forests amounts to 90000 EUR/ha/year, while in the article (2021)[42] they are valued approximately at 2842 USD/ha/year.

Another example, the article (2016)[43] indicates the cost of such forest ES as water regulation and air quality provision — on average 1541 USD/ha/year; wild species diversity — 1279 USD/ha/year. At the same time TEEB

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40 https://doi.org/10.1016/j.ecolecon.2013.05.005

41 https://doi.org/10.1016/j.ecoser.2014.03.001

42 https://doi.org/10.1016/j.ecoser.2021.101262

43 https://doi.org/10.1016/j.worlddev.2015.10.002

gives the following value to these ES (respectively) — 57–7135 USD/ha/year, 6–5277 USD/ha/year (as of 2010).

Such discrepancies in the figures of the ES economic valuation show that:

1) the ecosystems in question can be similar, however, can be characterized by a different set of services and, consequently, have their own economic value (that is why the ecosystem should be extremely detailed);
2) the scholars in various countries of the world have different conceptual views regarding the essence of ES and, logically, use different approaches to the definition of ES, provided by ecosystems. It means that in this area there is no universality;
3) the volume of the information available was insufficient for the comprehensive and full economic valuation of all the ES for selected objects of research;
4) the data obtained are of one-time nature and have not taken into account the tendencies of ecosystem modern changes and potential optimal condition of their functioning;
5) the topicality of the issue in question accounts for the lack of optimal methodology to evaluate economic value of the ES, which would address their multi-aspect nature[44].

[44] http://www.economy.nayka.com.ua/?op=1&z=959

4

WARFARE AND ECOSYSTEM SERVICES

The environmental impact of wars has been known for many centuries: intentional destruction or depletion of natural resources, such as forests, arable lands, water resources is quite widespread. Intensive environmental impact along with higher environmental awareness and changes in the very nature of warfare brought up the issue of the targeted and associated environmental damage, necessitating the importance of researching the links between the military actions and the environment.

Machlis and Hanson in their work "Warfare Ecology" offered the taxonomy of warfare, which includes:

- preparations for war (drills, developing infrastructure, manufacturing material means);
- war (physical acts of aggression and defense);
- post-conflict stage (disposal of weapons and disarmament, peacekeeping, reconstruction of infrastructure, etc.).

They also emphasized the need for more detailed research into the environmental impacts of this wide range of activities. However, even now there still remains a gap in the understanding of the state of the environment through the prism of the practice of warfare. In an ideal situation ecological systems and their services would be well understood, the impacts of war and their effects would be quantified, and legislation would be introduced to ensure their absence or, if they did occur, provide for the appropriate compensation. Environmental legislation relating to war has existed for some time, recognizing its effects on the environment, but remains largely ineffective, in part due to a lack of understanding of ecosystems and the environmental effects of war, as well as ineffective valuation mechanisms and a lack of understanding the ways to restore damaged ecosystems. These obstacles are still difficult to overcome.

4.1. Environmental impact of war: the regulatory prism

In 2009, the United Nations Environment Program (UNEP) conducted a review of environmental legislation on warfare. It stated that current legal frameworks do not adequately address environmental issues during armed conflicts for several reasons:

- The relevant articles do not provide adequate environmental protection due to the strict criteria used to demonstrate harm.
- Some provisions of humanitarian law protecting civilian property offer indirect environmental protection that is still unclear.
- Lack of case law on wartime environmental protection due to the limited number of cases brought to court.
- There is no permanent international mechanism for monitoring and eliminating environmental damage during armed conflicts.
- The general principles of humanism are insufficient to limit damage to the environment.
- There is no standard definition of what is "conflict resource" and when sanctions should be imposed to prevent exploitation of such resources[45].

The program found that environmental damage that contributes to war crimes, crimes against humanity and genocide is considered a criminal offense under international law; that international environmental law is applied during armed conflicts and can be used as a basis for protection; commission-courts and tribunals can be used to investigate environmental damage caused by international and internal armed conflicts. However, it is difficult to take actions on the basis of each of these findings and it is necessary to provide sufficient evidence of environmental impact.

Quantitative assessment of ecological systems and their degradation to satisfy the legal criteria used remains a particular problem. The most relevant clarifications relate to the definitions of "widespread", "long-term" and "severe", which are key terms defining the levels of exposure that are prohibited in wartime and are used differently in different legal instruments. These terms

45 https://www.unep.org/resources/report/protecting-environment-during-armed-conflict-inventory-and-analysis-international

first appear in the UN Convention on the Prohibition of Military or Other Uses of Environmental Modification (ENMOD) (1976)[46].

Article II of the Convention defines: the technique of environment modification is any technique of change by deliberate manipulation of natural processes: the dynamics, composition or structure of the soil, including its biota, lithosphere, hydrosphere and atmosphere, or outer space. And also: "widespread" refers to "spatial territory of several hundred square kilometers"; "long-term" — "a period of months or approximately a season"; and "serious" refers to "serious or significant violation or damage to human life, natural economic resources or other assets".

According to preliminary estimates, the russian warfare in Ukraine and the degree of its environmental damage meets these definitions. Environment in Ukraine suffers from multiple[47, 48, 49] unprecedented[50, 51] impact of warfare, natural resources are occupied in large territories[52], some of them for eight years already. Moreover, the impact of russian war against Ukraine is felt throughout the planet[53].

Using an ES framework may be the best way to assess and quantify such impact in ways that can be understood by experts in different disciplinary contexts and can be most useful in meeting legal criteria. In times of war it is particularly important to establish guilt, taking into account the potentially extreme environmental consequences[54].

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46 https://www.un.org/disarmament/enmod/

47 https://uncg.org.ua/z-24-liutoho-v-zoni-vidchuzhennia-vyhorilo-ponad-22000-ha-naslidky-okupatsii-prodovzhuiut-zavdavaty-shkody-dovkilliu/

48 https://suspilne.media/258084-ekoinspekcia-pidrahuvala-zbitki-vid-znisenna-rf-grebli-oskilskogo-vodoshovisa-na-harkivsini/

49 https://life.pravda.com.ua/society/2022/05/19/248719/

50 https://www.nytimes.com/2022/04/13/science/war-environmental-impact-ukraine.html

51 https://uwecworkgroup.info/pollution-of-the-bug-estuary-following-damage-to-mykolaivs-main-wastewater-treatment-facility/

52 https://www.washingtonpost.com/world/2022/08/10/ukraine-russia-energy-mineral-wealth/

53 https://www.nytimes.com/2022/09/27/opinion/ukraine-war-environment.html

54 https://ciaotest.cc.columbia.edu/journals/riia/v90i4/f_0032205_26201.pdf

4.2. ES valuation within the context of warfare

The environmental effects of war have been well documented in terms of hazardous impacts and resource depletion. In particular, impact of radiation from nuclear explosions (Hiroshima and Nagasaki during World War II), forest degradation due to the use of defoliants (Vietnam War), and depletion of important mineral resources (nickel and copper in civil conflicts in sub-Saharan Africa, oil — war in the Gulf). However, the cost of war for the environment is not as well understood and documented.

Recent years see the development of quantity-related valuation of the ES due to the growing susceptibility to the use of financial incentives to achieve desired social and environmental outcomes. Within the context of hostilities ES assessment can be applied to assess environmental damage, hold perpetrators accountable and quantify reparations that reflect the wider effects of war in a way that is relevant to society at this stage of its development.

At the same time, considering complexity of warfare effects for environmental, physical, economic and social factors, valuation of ecosystem services loss remains "rather art, than science"[55]. Factors such as the magnitude of impact on ecosystem services (degree of impact) and its spatial distribution are extremely difficult to quantify and predict. Due to its complexity, the assessment of ecosystem services in wartime will inevitably depend on expert opinion. Then important questions arise. Who are the experts to assess the environmental cost of a particular war, and how objective are they? Who makes the decision after the assessments? What legal mechanisms exist to ensure that decisions are not influenced by special interests? Such questions are particularly important in a post-conflict context, where the stakes are high and failure to achieve a satisfactory outcome may lead to further negative environmental and societal consequences.

The approach to determine impact and response is post-normal science. It is suitable for solving problems when facts are uncertain, values are disputable, stakes are high, and decisions are urgent. Post-normal science is a method

[55] Asit K. Biswas, 'Scientific assessment of the long-term environmental consequences of war', in Jay E. Austin and Carl E. Bruch, eds, The environmental consequences of war (Cambridge: Cambridge University Press, 2010), p. 310.

of approaching a scientific research that clearly encourages integration of a wide range of stakeholders beyond the traditional competence of a "scientific expert", as there are multiple forms of knowledge that can help address large, complex and uncertain questions that require urgent attention and cannot be separately resolved by the conventional forms of scientific inquiry[56]. The stakeholders group includes individuals with different experience, expertise and ideas related to environmental system.

Certainly it is necessary to find a balance between formalized knowledge (theoretical, empirical knowledge of the environment, survey and analysis methods, understanding of legislation, policy and remedial action) and experience that can come from local ecological knowledge of affected ecosystems. In other words, local people can describe and articulate the values (economic or any other) they attribute to certain species or ecological processes (e.g., changes in hydrology that reduce soil moisture in agricultural systems) better than outsiders.

The knowledge base is only part of the challenge. ES valuation in the context of war is extremely difficult. ESs themselves are difficult to assess (measure) due to their incomplete understanding, especially for affected communities. This in turn means that it is often extremely difficult to quantify how a change in ecosystem condition or function will lead to changes in the ecosystem services provided.

Environmental conditions are difficult to measure, and there is often lack of data that would allow scientists to establish a "pre-war" baseline for assessing damage. Even if environmental data for the pre-war period are available, their quality is in many cases mediocre. Post-war assessments of environmental conditions are also complicated by security concerns. Remote sensing methods can play a crucial role in assessing ecosystem services where access is difficult, but this may not be sufficient and may even lead to inconsistent or invalid results.

Lack of adequate relevant knowledge on how to assess damage to ecosystem services is another critical issue. Assessing the total environmental damage from war requires specialists with professional knowledge in the fields of biological taxonomy, environmental economics and social sciences.

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[56] https://doi.org/10.1016/0016-3287(93)90022-L

Different aspects of the environment are sensitive to war in their own unique ways. For example, a lot depends on the history of the development of an ecosystem in question, on the pre-war degradation level, current ecological quality (ecosystem health). Empirical evidence supports the idea of differential sensitivity, and there are even some examples demonstrating that warfare can benefit some aspects of the environment, for example by disrupting or ultimately destroying activities that cause environmental damage. For instance, spontaneous reforestation in post-war Puerto Rico[57] or ecosystem preservation due to limited access (demilitarized area between North and South Koreas). Still one should be skeptical about potential envi-romental benefits of war, and they should not be used for the justification of war in view of social losses that will significantly outweigh any potential environmental benefits. Warfare cases with positive environmental impact are limited and rather are an exception than norm.

Discussions about the environmental cost of war focus on the economic aspects out of necessity. Quantification in monetary terms is potentially more likely to make a compelling case for justifiable compensation than criteria related to biodiversity loss or ecosystem health, for which it is more difficult for society and governments to define specific values of loss. It is easier to understand losses from the viewpoint of yield than to quantify the cost of wetland destruction because estimating the economic value of lost crop production is much easier than monetizing lost biodiversity or deteriorated air quality.

There are various methods to assess the monetary value of ecosystems. Most of them are market methods. However, countries/regions in conflict or recovering from war are unlikely to have stable functioning markets. And even if they are restored, prices are likely to be distorted due to access-related difficulties, security concerns or product shortages. Owners of scarce resources can also take advantage of the situation to artificially inflate prices.

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[57] Thomas K. Rudel, Marla Perez-Lugo and Heather Zichal, 'When fields revert to forest: development and spontaneous reforestation in post-war Puerto Rico', Professional Geographer 52: 3, Sept. 2010, pp. 386–97.

Table 4.1

Example of ecosystem services valuation within the context of hostilities

Method		Potential application in case of hostilities	Advantages	Disadvantages
Of stated benefits	***Direct markets***			
	Production factor	Quantify production loss in terms of lower productivity of timber and non-timber forest products due to post-war forest degradation.	Data can be obtained from communities living in the affected area or from businesses that have economic interests in the area.	Data may not always be available, and it may be difficult to objectively separate product losses from non-war related activities.
	Production/ consumption surplus	Destruction of freshwater habitats can result in fish populations decrease. Fishermen will spend more resources on each unit of fish caught, which will lead to an increase in the cost of production. Consumers can answer that they will not buy more expensive fish. Based on	If data is available, it is based on consumer behavior in the market and is likely to be more easily accepted and understood by society.	Markets can be distorted by various social and political conditions, including monopolistic markets, especially in the post-war context.

Continuation of Table 4.1

Of stated benefits (continuation)		this behavior, it is possible to quantify production and consumption surplus.		
	Protection costs	Estimate the total cost of post-war recovery activities, including the cost of installing water treatment tanks, landscape restoration schemes and tree planting.	As several humanitarian and reconstruction organizations may be involved in post-war restoration, data on the cost of various operations may be available.	A war-affected area may be abandoned with no intention of recovery for several decades, and therefore, may lack data to assess damage to ecosystem services.
	Surrogate markets			
	Hedonistic pricing	Monitoring real estate prices in a region recently affected by conflict, where the key differentiator is the availability of environmental services from which people can get livelihoods (e.g. a fishing lake).	Where housing is rapidly rebuilt after the conflict, housing prices can be tracked over time to determine the value of the environment over a certain period.	Fully- abandoned areas may not have surrogate markets anymore.

Continuation of Table 4.1

Of stated benefits (continuation)	Travel costs	The economic costs of some environmental services can be quantified by adding the amount of money spent by tourists to visiting some ecologically important places. For example, despite security concerns a large number of tourists visited the Nyamuragira volcano in 2011 in the DRC.	Probably the data may be obtained from tourist agencies, tourists and airlines.	It can be very difficult to separate ecological tourism from tourism to the "combat areas".
Stated preference method	Conditional assessment	Surveys can be distributed among stakeholders (local population, biologists, economic and legal experts) to assess environmental conditions before, during and after the war and the overall damage caused by the war.	This method is very flexible and can be used to assess value of the majority of the ES.	May produce inaccurate results due to biases that can arise in the survey or respondents' behaviour.
	Experimenting with choice	Different stakeholders (including local people, biologists, economists) may be given a number of ESs, which will be classified according to the perceived importance and types of interventions (and associated costs) for their post-war recovery.	This method is very flexible and can provide overview of different restoration priorities within the post-war context.	May produce inaccurate results due to biases that can arise in the survey or respondents' behaviour.

If there are no markets for certain goods, information about the economic value of the ES can be obtained from the surrogate markets[58]. The most widespread are property and labour. And again within the context of war the prices for both property and labour force are likely to be too distorted to give useful information for decision making (both during the war and in post-war period).

Some of the most valuable ESs can happen where there is no market activity at all, or where this activity is limited or there is no population. In this context, one can use non-market approaches (for example, the method of stated benefits) to estimate the economic value (monetization) of ES. In this case, there is a dependence of the approach on primary information collected during surveys, interviews and experiments. This method is unlikely to be applicable in the context of hostilities, where key informants and potential local experts may be too traumatized to contribute, or may place greater emphasis on the social significance of war. Other experts not directly affected by the war may provide the information, but the results may be highly conflicting or impossible to be interpreted without local input.

Quantification in ecosystems is always difficult, as they are complex adaptive systems and, therefore, are not easily explained and predicted, and damage assessment in such systems becomes an even more difficult task. This is confirmed by the limited number of studies and lawsuits based on them about damage to ecosystems and their services, which would have similar structures of justification and calculation of damages caused to ecosystems.

The most famous example of such lawsuits are Kuwait's claims against Iraq for environmental damage caused by the latter. These cases were considered by the UN Compensation Commission[59]. Characteristic for this case is the duration of the process (the Commission in this case existed for

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[58] Surrogate markets are markets used instead of absent markets of ecological resources. At least these are existing resource markets where some properties of non-market resources are evaluated. https://www.eea.europa.eu/help/glossary/chm-biodiversity/surrogate-markets

[59] https://uncc.ch/state-kuwait

31 years, after which the compensations were recognized as paid); the high cost of environmental damage assessments and the small compensation compared to those stated in the claims.

One more example is the case of Costa Rica against Nicaragua[60], which highlights the necessity of ***structural approach*** to the development of ***science-based methodology*** of valuating damage caused to ecosystems and calculation of losses (p. 50 Drawing 4.1).

Thus, availability and application of environmental and ESs damage valuation and monetization tools under conditions of war is limited[61] and require improvement.

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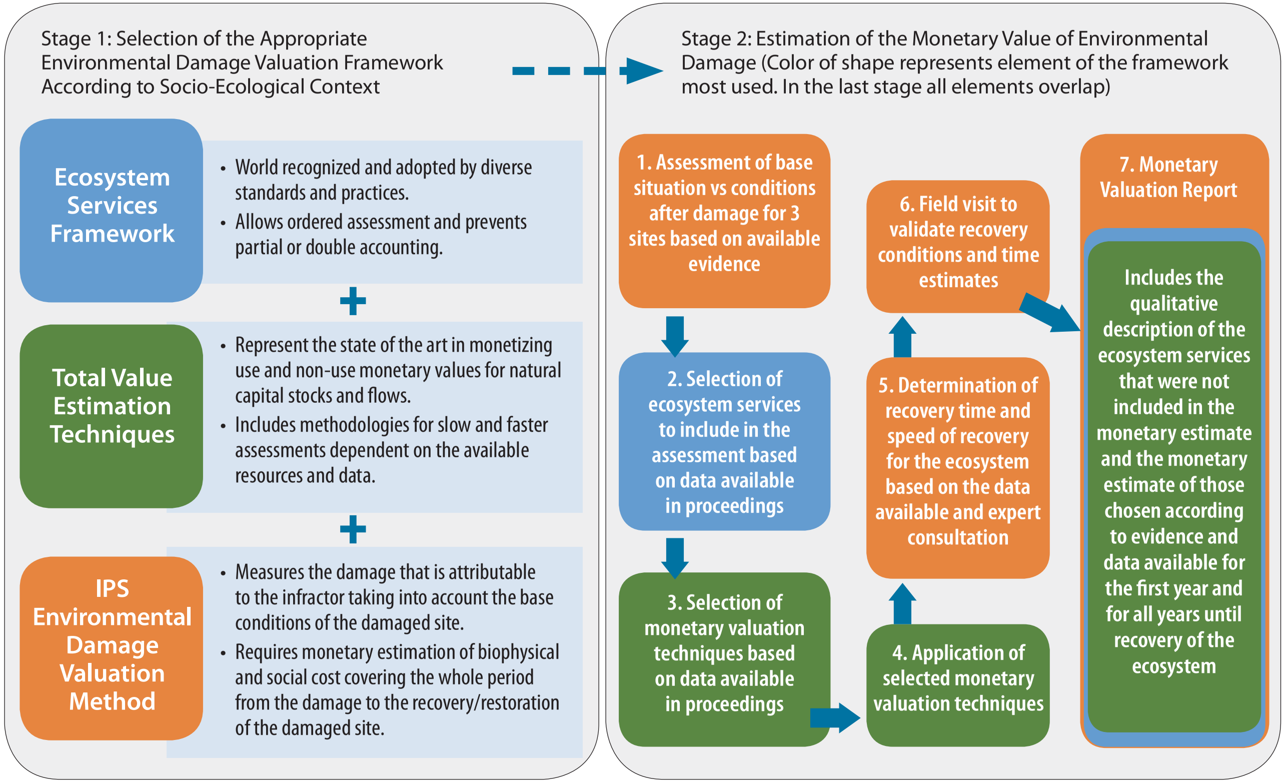
60 https://www.icj-cij.org/public/files/case-related/150/150-20170808-WRI-01-00-EN.pdf

61 https://www.academia.edu/33464736/Scientific_Assessment_of_the_Long_Term_Environmental_Consequences_of_War



Drawing 4.1. Conceptual scheme of selection of the approapriate environmental damage valuation framework and estimation of its monetary value

CONCLUSIONS

Ecosystem services play a potentially important role in post-war recovery. In most cases, recovery studies focus on the ethical, political, legal and social and economic aspects of post-war communities rather than the environment, despite the significance of the latter. However, the importance of ecosystem services is undeniable. Management of natural resources, such as water and biodiversity, in post-war humanitarian improvements to create sustainable and long-term conditions for recovery plays an important role.

Estimation of the economic value (monetization) of ES is a complex process requiring extensive knowledge and large data sets. The majority of methods are based on estimating the market value of ES based on prices in direct, similar or surrogate markets, the absence of which makes their use much more difficult. In addition, an important condition is the determination of the quantitative characteristics of the ES, and in the case of their damage due to military operations, the degree of loss of the benefits provided.

In Ukraine, the situation is further complicated by the fact that information on the characteristics of ecosystems and biological diversity in territories destroyed or damaged by hostilities is often missing or incomplete. For example, on the territory of the forest fund, there is extensive information about the forest, wood stocks, in some cases there is general information about the living above-ground cover, however, there is no information about the protected flora species, let alone data about insects that, for example, can pollinate neighboring gardens or fields, etc. In the territories of the nature reserve fund, in addition to information on forest plantations, there is data on valuable species and habitats, but due to insufficient funding and often lack of experts, such data may be fragmented, narrowly defined or not cover the entire territory.

Taking into account the existing difficulties, it is necessary to decide on the concept of the approach to solving the task, to choose a framework scheme for assessing environmental damage (caused to ecosystems and their ability to provide services) and estimating its economic value. The scheme should include:

1) definition of requirements for the evidence of damage and the process of their collection;
2) a description of the affected services and their value (importance) for society and nature at the national, regional or local levels;
3) indicators for valuating such ESs;
4) methods that can be used to valuate ES taking into account available data on ecosystems, biological and landscape diversity and their dynamics;
5) approaches to the economic valuation of damage caused to the ES.

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Analytical Document

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Overview of ecosystem services valuation approaches through the prism of their application to determine damages caused by rf hostilities in Ukraine

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