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Ecosystem services and hydropower:
pilot application of European tools in the river basin of the EaP countries

Eco-Tiras

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Ecosystem services and hydropower: pilot application of European tools in the river basin of the EaP countries

Policy paper

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POLICY PAPER

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ABSTRACT

The policy paper "Ecosystem services and hydropower: pilot application of European tools in the river basins of the EaP countries" presents an overview of the European experience of mapping and assessment of ecosystem and their services, in particular the current typology of ecosystems and ecosystem services, mapping tools and assessment methods. On the example of pilot river basins of the Eastern Partnership countries: Armenia, Azerbaijan, Moldova and Ukraine, a pilot application of tools for mapping and assessment of ecosystems and their services to determine their value and loss under the influence of hydropower was performed. Recommendations for the implementation of mapping and assessment of ecosystems and their services in the procedures of Strategic Environmental Assessment and Environmental Impact Assessment to take into account the integrated impact of hydropower programs and projects.

This publication was produced within the framework of the project "Ecosystem services and hydropower: pilot application of European tools in the river basins of the EaP countries", implemented by the International Association of River Keepers "Eco-TIRAS" together with the National Ecological Center of Ukraine, "KHAZER" Ecological and Cultural NGO (Armenia), Azerbaijan Ornithological Society and NGO "Ecosphere" (Ukraine).

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Grants are available for CSOs from the Eastern Partnership and EU countries. Key areas of support are democracy and human rights, economic integration, environment and energy, contacts between people, social and labor policies.

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ABBREVIATIONS AND ACRONYMS

ARIES	The ARtificial Intelligence for Ecosystem Services
CBD	Convention on Biological Diversity
CICES	The Common International Classification of Ecosystem Service
DHPC	Dniester hydropower complex
ES	Ecosystem service
ESMERALDA	Enhancing ecoSysteM sERvices mApping for poLicy and Decision mAking
EUNIS	European nature information system
HPP	Hydropower plant
INCA	Integrated system of Natural Capital and ecosystem services Accounting
InVEST	The Integrated Tool to Value Ecosystem Services and their trade-offs
MAES	Mapping and assessment of ecosystems and their services
MEA (MA)	Millennium Ecosystem Assessment
NCA	Natural capital accounting
OpenNESS	Operationalization of Natural capital and Ecosystem Services: from concepts to real-world applications
OPERAs	Operational Potential of Ecosystem Research Applications
TEEB	The Economics of Ecosystems and Biodiversity
WFD	EU Water Framework Directive

ECOSYSTEM SERVICE DEFINITIONS

Ecosystem: a dynamic complex of plant, animal, and microorganism communities and their non-living environment interacting as a functional unit (MA, 2005). For practical purposes it is important to define the spatial dimensions of concern.

Ecosystem assessment: a social process through which the findings of science concerning the causes of ecosystem change, their consequences for human well-being, and management and policy options are brought to bear on the needs of decision-makers (UK NEA, 2011).

Ecosystem condition: The capacity of an ecosystem to yield services, relative to its potential capacity (MA, 2005). For the purpose of MAES, ecosystem condition is, however, usually used as a synonym for "ecosystem state".

Ecosystem function: Subset of the interactions between biophysical structures, biodiversity and ecosystem processes that underpin the capacity of an ecosystem to provide ecosystem services (TEEB, 2010).

Ecosystem process: Any change or reaction, which occurs within ecosystems, physical, chemical or biological. Ecosystem processes include decomposition, production, nutrient cycling, and fluxes of nutrients and energy (MA, 2005).

Ecosystem services: contributions of ecosystem structure and function–in combination with other inputs–to human wellbeing (Burkhard et al., 2012a).

Ecosystem structures: biophysical architecture of ecosystems; species composition making up the architecture may vary (TEEB, 2010).

Ecosystem functions: intermediate between ecosystem processes and services and can be defined as the capacity of ecosystems to provide goods and services that satisfy human needs, directly and indirectly (de Groot et al., 2010).

Intermediate ecosystem services: biological, chemical, and physical interactions between ecosystem components. E.g., ecosystem functions and processes are not end-products; they are intermediate to the production of final ecosystem services (Boyd and Banzhaf, 2007).

Final ecosystem services: Direct contributions to human well-being. Depending on their degree of connection to human welfare, ecosystem services can be considered as intermediate or as final services (Fisher et al., 2009).

Ecosystem service supply: refers to the capacity of a particular area to provide a specific bundle of ecosystem goods and services within a given time period (Burkhard et al., 2012b). Depends on different sets of landscape properties that influence the level of service supply (Willemen et al., 2012).

Ecosystem service demand: is the sum of all ecosystem goods and services currently consumed or used in a particular area over a given time period (Burkhard et al., 2012b).

Ecosystem service providing units/areas: spatial units that are the source of ecosystem service (Syrbe and Walz, 2012). Includes the total collection of organisms and their traits required to deliver a given ecosystem service at the level needed by service beneficiaries (Vandewalle et al., 2009). Commensurate with ecosystem service supply.

Ecosystem service benefiting areas: the complement to ecosystem service providing areas. Ecosystem service benefiting areas may be far distant from the relevant providing areas. The structural characteristics of a benefiting area must be such that the area can take advantage of an ecosystem service (Syrbe and Walz, 2012). Commensurate with ecosystem service demand.

Ecosystem service trade-offs: The way in which one ecosystem service responds to a change in another ecosystem service (Millennium Ecosystem Assessment, 2005).

Ecosystem state: The physical, chemical and biological condition of an ecosystem at a particular point in time which can also be referred to as its quality.

Ecosystem status: An ecosystem state defined among several well-defined categories including its legal status. It is usually measured against time and compared to an agreed target in EU environmental directives (e.g. Habitats Directive, Water Framework Directive, Marine Strategy Framework Directive), e.g. “conservation status”.

Habitat: The physical location or type of environment in which an organism or biological population lives or occurs. Terrestrial or aquatic areas distinguished by geographic, abiotic and biotic features, whether entirely natural or seminatural.

Human well-being: A context- and situation-dependent state, comprising basic material for a good life, freedom and choice, health and bodily well-being, good social relations, security, peace of mind and spiritual experience (MA, 2005).

Value: The contribution of an action or object to user-specified goals, objectives or conditions (MA, 2005).

Source Crossman et al., 2013, and Maes et al., 2014.

EXECUTIVE SUMMARY

This analytical document was prepared to review the European experience of mapping and assessment of ecosystems and their services, in particular the current typology of ecosystems and classifications of ecosystem services, mapping tools and methods of their assessment, as well as identifying opportunities and barriers to mapping and assessing ecosystems and their services in the countries of the Eastern Partnership, on the example of their river basins.

Until now, ecosystem services of rivers and adjacent ecosystems remain out of focus when considering hydropower development plans and individual hydropower projects in countries of the Eastern Partnership. The procedures for their strategic environmental assessment and environmental impact assessment do not require the identification and assessment of ecosystems and the services they provide. Ignoring the ecosystem approach leads to increased negative impact on ecosystems by hydropower, their further degradation, loss of many vital ecosystem services. In addition, it contributes to the spread of unsubstantiated ideas about the relative cheapness of electricity generated by HPPs and PSPs. Given the largely critical condition of rivers due to their over-regulation and over-operation, as well as the growing impact of climate change, which leads to depletion of water resources, the implementation of ecosystem services and the decision-making process on sites is essential.

In accordance with its European integration commitments, like Moldova and Ukraine have approved at the legislative level some intentions intention to introduce an ecosystem approach to all areas of socio-economic development as a basis for achieving good environmental status. The strategy of the state ecological policy until 2030 envisages the development of the institution of ecosystem services, which should provide opportunities for balanced (sustainable) development of society. It is assumed that by 2030 the biological diversity of Ukraine, which provides ecosystem services, should be preserved, assessed and restored accordingly.

In order to implement practical tools for mapping and assessing ecosystems and their services, the countries of the Eastern Partnership, should benefit from the European experience gained in implementing the EU Biodiversity Strategy until 2020 and plans to conserve and restore river ecosystems under the new EU 2030 Biodiversity Strategy.

The concept of ecosystem services has been actively developing in the European Union over the last decade. It is seen as a comprehensive basis for the analysis and adoption of compromise decisions. The inclusion of ecosystem services in impact assessment procedures (strategic environmental assessment and environmental impact assessment) expands their scope from purely environmental considerations to other aspects of human well-being. Ecosystem services can be used at all stages of impact assessment, including scoping (to indicate the service on which the activity depends and on which it affects), consultation (helping to focus discussions and stakeholder engagement), impact assessment and trade-offs of alternative solutions, and proposing mitigation measures.

The Working Group on Mapping and Evaluation of Ecosystems and Their Services (MAES), established as part of the implementation of the EU Biodiversity Strategy until 2020, has developed a typology of ecosystems that includes 12 main types that correspond to the highest levels of EUNIS habitat classification. The same working group proposed to use the CISES classification of ecosystem services, which is considered to be the reference and to allow the transition from other common classifications. The aim of CICES is to classify finite ecosystem services, which are defined as the contribution of ecosystems to human well-being. These contributions are determined by what "ecosystems make directly" for humans. The latest version of CICES (V5.1) also includes inanimate parts of ecosystems, such as water, mineral resources, wind and solar energy, which is important for its application in the field of hydropower.

Ecosystem mapping provides information on their spatial distribution and distribution of major types and is the starting point for assessing the status of each ecosystem and, subsequently, the identification and evaluation of ecosystem services.

Within the framework of a number of projects supported by the European Union, such as ESMERALDA, OPERAs, OpenNESS and others, the existing tools for the assessment of ecosystem services were considered and the experience of their application was systematized. The expediency of applying a multilevel approach, which provides the optimal choice of tools for mapping and evaluation of ecosystem services in accordance with the information requirements needed to make management decisions, is noted. One of the tools that can be used at different levels is the InVEST software package developed by Stanford University as part of the Natural Capital Project, which is a set of models that help to quantify and reflect the value of ecosystem services.

The choice of a pilot river basin is primarily due to the long-term impact of hydropower on river and related ecosystems in the Carpathian region. Mapping of the ecosystems of the Uzh river basin was performed using an open map of the Copernicus Global Land Cover. This service was available from May 2019, and from September 2020 it displays dynamic data of the earth's surface for 5 years – annually from 2015 to 2019. At the same time, the mapping of ecosystems highlighted a common problem for the Eastern Partnership countries, which is the lack of coverage territories of the countries with the Corine Land Cover map – the basis for the map of ecosystems of Europe.

The use of the InVEST software package to assess the ecosystem services of the river basin has already shown the lack of necessary information on the state of the environment. The list of data needed for evaluation includes such parameters as precipitation and their distribution, evapotranspiration, root layer depth, water evaporation by plants, available water content in soils, types of land use, boundaries of basins and sub-basins, etc.

Analysis of the availability and accessibility of the necessary input data for the assessment of ecosystem services shows that at the national level the data are either mostly absent or are available with limited or paid access, such as data on precipitation, temperature, flow of the river. There are also no available digital boundaries of river basins and sub-basins, and their allocation is quite a time-consuming task.

Identified barriers to the introduction of ecosystem services in the hydropower sector are compiled into several groups: legislative, institutional, regulatory and methodological. Overcoming them should be one of the priorities of state policy in the field of environmental protection and the basis for the preservation and restoration of river and associated ecosystems.

The Eastern Partnership countries should work more actively with European institutions responsible for the development of the ecosystem approach and ecosystem services. As a party to the Convention on Biological Diversity, Ukraine should participate more actively in the work of the Intergovernmental Scientific and Policy Platform on Biodiversity and use the experience of the platform and the European Working Group MAES to develop a regulatory framework for ecosystem approach and projects.

1. MAPPING AND ASSESSMENT OF ECOSYSTEMS AND THEIR SERVICES

Mapping and assessment of ecosystems and their services (MAES) are important in the decision-making process for the development of territories, including when considering plans for the development of hydropower or individual hydropower projects. The ecosystems (ES) concept provides a comprehensive framework for trade-off analysis, addressing compromises between competing land uses and assisting to facilitate planning and development decisions across sectors, scales and administrative boundaries (Fürst et al. 2017).

ES mapping and assessment results can support sustainable management of natural resources, environmental protection, spatial panning, and landscape planning; and can be applied to the development of nature-based solutions and environmental education (Geneletti and Adem Esmail, 2018). ES can be included within the impact assessment procedures (e.g. Strategic Environmental Assessment of plans and programs, and Environmental Impact Assessments of projects), thus extending the scope of impact assessment from purely environmental considerations to other dimensions of human well-being.

ES mapping and assessment can improve the overall outcome of actions, reduce the likelihood of plan or project delays due to unforeseen impacts, and reduce reputational risk to public authorities and developers from unintended social impacts. ES can be applied in all stages of impact assessment, including scoping (to indicate ES on which action depends as well as services it affects), consultations (helping to focus debate and engagement of stakeholders), assessing impacts and trade-offs of development alternatives as well as proposing mitigation measures (Geneletti & Mandle, 2017).

Nevertheless, there is still a need to develop guidance and criteria on how to apply ES within different planning contexts as well as through the decision-making process (Fürst, 2017). Furthermore, integration of various MAES methods and tools are required to address the complexity of socio-ecological systems, and support the decision-making process across different scales and sectors.

Development of mapping and assessment of ES in the European Union was connected with implementation of the EU Biodiversity (BD) Strategy to 2020. Action 5 of the EU BD to 2020 called Member States to map and assess the state of ecosystems and their services in their national territory with the assistance of the European Commission. They had to also assess the economic value of such services, and promote the integration of these values into accounting and reporting systems at EU and national level by 2020 (see Target 2, Action 5). It was established a Working Group on Mapping and Assessment of Ecosystems which developed common analytical framework for MAES as well as typologies of ecosystems for mapping and a typology of ecosystem services for accounting[1].

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[1] https://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/index_en.htm

1.1. A typology of ecosystems for mapping

An ecosystem is usually defined as a complex of living organisms with their (abiotic) environment and their mutual relations. The EU Habitats Directive does not define ecosystems but natural habitats. Natural habitats mean terrestrial or aquatic areas distinguished by geographic, abiotic and biotic features, whether entirely natural or semi-natural.

MAES proposed typology distinguishes 12 main ecosystem types based on the higher levels of the EUNIS Habitat Classification[2], which is a European reference classification with cross linkages to the habitat types listed in Annex I of the Habitats Directive[3] (Table 1.1).

Table 1.1. Typology of ecosystems for mapping (from Maes et al., 2013)[4]

MAES level 1 ecosystem category	MAES level 2 ecosystem type	Description
Terrestrial	Urban	Urban, industrial, commercial and transport areas, urban green areas, mines, dumping and construction sites.
	Cropland	The main food production area including both intensively managed ecosystems and multifunctional areas supporting many semi- and natural species along with food production (lower intensity management). Includes regularly or recently cultivated agricultural, horticultural and domestic habitats and agro-ecosystems with significant coverage of natural vegetation (agricultural mosaics).
	Grassland	Areas covered by a mix of annual and perennial grass and herbaceous non-woody species (including tall forbs, mosses and lichens) with little or no tree cover. The two main types are managed pastures and semi-natural (extensively managed) grasslands.
	Woodland and forest	Areas dominated by woody vegetation of various ages or with succession climax vegetation types on most of the area, supporting many ecosystem services. Information on ecosystem structure (age class, species diversity, etc.) is especially important for this ecosystem type.

2 https://www.eea.europa.eu/data-and-maps/data/eunis-habitat-classification
3 https://ec.europa.eu/environment/nature/legislation/habitatsdirective/index_en.htm
4 https://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/pdf/MAES-WorkingPaper2013.pdf

	Heathland and shrub	Heathland and shrub are areas with vegetation dominated by shrubs or dwarf shrubs. They are mostly secondary ecosystems with unfavourable natural conditions. They include moors, heathland and sclerophyllous (small, hard-leaved) vegetation.
	Sparsely vegetated land	Sparsely vegetated land often has extreme natural conditions that might support particular species. They include bare rocks, glaciers and dunes, beaches and sand plains.
	Wetlands	Inland wetlands are predominantly water-logged specific plant and animal communities supporting water regulation and peat-related processes. Includes natural or modified mires, bogs and fens, as well as peat extraction sites.
Freshwater	Rivers and lakes	Permanent freshwater inland surface waters, including water courses and water bodies.
Marine	Marine inlets and transitional waters	Ecosystems on the land–water interface under the influence of tides and with salinity higher than 0.5 %. Includes coastal wetlands, lagoons, estuaries and other transitional waters, fjords and sea lochs and embayments.
	Coastal	Shallow coastal marine systems that experience significant land-based influences. These systems undergo diurnal fluctuations in temperature, salinity and turbidity, and they are subject to wave disturbance. Depth is between 50 and 70 m.
	Shelf	Marine systems away from coastal influence, down to the shelf break. They experience more stable temperature and salinity regimes than coastal systems, and their seabed is below wave disturbance. They are usually about 200 m deep.
	Open ocean	Marine systems beyond the shelf break with very stable temperature and salinity regimes, in particular in the deep seabed. Depth is beyond 200 m.

1.2. A typology of ecosystem services

Ecosystem services provide a range of benefits, and can be separated into three main categories: provisioning services, which include food provision or timber production; regulating services, which include air and water filtration, pollination and climate regulation and protection against natural disasters such as flooding; and cultural ecosystem services, which include recreation and leisure, education, aesthetic and spiritual benefits[5]. These services can be considered flows, derived

[5] Natural capital accounting. Overview and progress in the European Union : 6th report (2019) https://doi.org/10.2779/819449

from stocks of ecosystem assets. Such stocks are referred to as Natural Capital, a term which describes Earth's natural assets, including soil, air, water, and living things, existing as complex ecosystems – as well as the related ecosystem services that human societies need in order to survive and thrive.

Three international classification systems are available to classify ecosystem services:

- MEA or MA (Millennium Ecosystem Assessment);
- TEEB (The Economics of Ecosystems and Biodiversity);
- CICES (The Common International Classification of Ecosystem Services).

In essence, they relate to a large extent to each other; all three include provisioning, regulating and cultural services. Each classification has its own advantages and disadvantages due to the specific context within which they were developed.

MAES was proposed to use the CISES classification[6] that builds on the existing classifications (MEA, TEEB) but focuses on the ecosystem service dimension. In the CICES system services are either provided by living organisms (biota) or by a combination of living organisms and abiotic processes. CICES developed for environmental accounting purposes is proposed as classification system of ecosystem services as it offers a structure that links with the framework of the UN System of Environmental-Economic Accounts (SEEA 2003). was intended as a reference classification that would allow translation between different ES classification systems, such as those used by the Millennium Ecosystem Assessment (MEA) and The Economics of Ecosystems and Biodiversity (TEEB), and in many aspects, it follows the concepts of these initiatives.

The CICES classification is considered to provide a flexible and hierarchical classification that can be adapted to the specific situation and needs. CICES has a five-level hierarchical structure (section – division – group – class – class type). The more detailed class types makes the classification more user-friendly and provides greater clarification on what ecosystem services are included within each class. Using a five-level hierarchical structure is in line with United Nations Statistical Division (UNSD) best practice guidance as it allows the five level structure to be used for ecosystem mapping and assessment, while the first four levels can be employed for ecosystem accounting without reducing the utility of the classification for different users.

CICES aims to classify final ecosystem services, which are defined as the contributions that ecosystems make to human well-being. These contributions are framed in "what ecosystems do most directly" for people. Final services are distinct from the goods and benefits that people subsequently derive from them and from functions or characteristics of ecosystems that come together to make something a service. In principle, CICES covers contributions that arise from living processes. However, the latest version (V5.1) includes also the nonliving parts of ecosystems, for example, water, mineral substances, wind, and solar energy.

CICES V5.1, released in 2018, has been developed on the basis of the

6 https://cices.eu/

review of relevant scientific literature and feedback from CICES user community (e.g., expressed in the survey conducted by the European Environment Agency and during workshops held as part of the EU funded ESMERALDA and OpenNESS Projects) (Tabl. 1.2).

Table 1.2. Common International Classification of Ecosystem Services ver. 5.1 (CICES V5.1) to the group level

Biotic ES			
Section	**Division**	**Group**	**Group Code**
Provisioning	Biomass	Cultivated terrestrial plants for nutrition, materials, or energy	1.1.1
		Cultivated aquatic plants for nutrition, materials, or energy	1.1.2
		Reared terrestrial animals for nutrition, materials, or energy	1.1.3
		Reared aquatic animals for nutrition, materials, or energy	1.1.4
		Wild plants (terrestrial and aquatic) for nutrition, materials, or energy	1.1.5
		Wild animals (terrestrial and aquatic) for nutrition, materials, or energy	1.1.6
	Genetic material from all biota (including seed, spore, or gamete production)	Genetic material from plants, algae, or fungi	1.2.1
		Genetic material from animals	1.2.2
Regulation and maintenance	Transformation of biochemical or physical inputs to ecosystems	Mediation of wastes or toxic substances of anthropogenic origin by living processes	2.1.1
		Mediation of nuisances of anthropogenic origin	2.1.2
	Regulation of physical, chemical, biological conditions	Regulation of baseline flows and extreme events	2.2.1
		Lifecycle maintenance, habitat, and gene pool protection	2.2.2
		Pest and disease control	2.2.3
		Regulation of soil quality	2.2.4
		Water conditions	2.2.5
		Atmospheric composition and conditions	2.2.6
Cultural	Direct, in situ and outdoor interactions with living systems that depend on presence in the environmental setting	Physical and experiential interactions with natural environment	3.1.1
		Intellectual and representative interactions with natural environment	3.1.2
	Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	Spiritual, symbolic, and other interactions with natural environment	3.2.1
		Other biotic characteristics that have a nonuse value	3.2.2

Abiotic ES			
Section	Division	Group	Group Code
Provisioning	Water	Surface water used for nutrition, materials or energy	4.2.1
		Ground water for used for nutrition, materials or energy	4.2.2
		Other aqueous ecosystem outputs	4.2.X
	Non-aqueous natural abiotic ecosystem outputs	Mineral substances used for nutrition, materials or energy	4.3.1
		Non-mineral substances or ecosystem properties used for nutrition, materials or energy	4.3.2
		Other mineral or non-mineral substances or ecosystem properties used for nutrition, materials or energy	4.3.2
Regulation and maintenance	Transformation of biochemical or physical inputs to ecosystems	Mediation of waste, toxics and other nuisances by non-living processes	5.1.1
		Mediation of nuisances of anthropogenic origin	5.1.2
	Regulation of physical, chemical, biological conditions	Regulation of baseline flows and extreme events	5.2.1
		Maintenance of physical, chemical, abiotic conditions	5.2.2
	Other type of regulation and maintenance service by abiotic processes	Other	5.3.X
Cultural	Direct, in-situ and outdoor interactions with natural physical systems that depend on presence in the environmental setting	Physical and experiential interactions with natural abiotic components of the environment	6.1.1
		Intellectual and representative interactions with abiotic components of the natural environment	6.1.2
	Indirect, remote, often indoor interactions with physical systems that do not require presence in the environmental setting	Spiritual, symbolic and other interactions with the abiotic components of the natural environment	6.2.1
		Other abiotic characteristics that have a non-use value	6.2.2
	Other abiotic characteristics of nature that have cultural significance	Other	6.3.X

1.3. Mapping of ecosystem and ecosystem services

Mapping ecosystems provides information about the spatial extension and distribution of the main ecosystem types: it is the starting point for assessing the condition of each ecosystem.

Ecosystem mapping is the spatial delineation of ecosystems following an agreed ecosystem typology (ecosystem types), which strongly depends on mapping purpose and scale.

Biophysical quantification and representation of the ES data on maps is fundamental for social and economic mapping and assessment. Both economic and social mapping and assessment can be conducted without precise biophysical quantification for case studies, however reliable biophysical data is required for sustainable use and management of ecosystems, ecosystem services and natural capital accounting at country and EU level. Biophysical data can be gathered either by direct observations and measurements, by indirect methods such as proxies or spatial extrapolation, or by modeling. In practice, multiple different methods are often used together, e.g. via integrated modeling platforms such as InVEST or ARIES, or through purpose-fitted selection of appropriate data and methods (Vihervaara et al., 2018).

1.4. Ecosystem service mapping tools

A widely applied ecosystem service mapping and valuation tool is InVEST, the Integrated Tool to Value Ecosystem Services and their trade-offs. It is an open access GIS-tool collection developed under the Natural Capital Project[7]. It includes separate models for different ecosystem services to be applied and combined to analyse spatial patterns of ecosystem services or track changes caused by land cover change. The complexity of the models available in InVEST varies from proxybased mapping (tier 1) to simple biophysical production equations (tier 2). But the tool has the ability to include third-party complex, site-specific process models (tier 3). The main inputs to InVEST are land cover data and other environmental variables as relevant, and outputs are the estimate of ecosystem services in biophysical and in some cases monetary units[8].

1.5. A tiered approach to mapping and assessing ecosystem services

The vast variety of biophysical mapping methods complicate the selection of an appropriate approach that provides useful information to decision makers in a specific context, i.e. a certain stage of the decision-making process at a specific scale, for a particular set of services, and given particular data availability options. Tiered approaches are a well-known instrument to structure the variety of methods by assigning them to different tier levels. A tiered approach provides guidance in the selection of methods and enhances the comparability of different approaches used, which facilitates communication and supports monitoring over time. Usually, a tier 1 approach uses readily available information while the level of detail of the method increases with higher tier levels. Examples of the implementation of the approach include The Economics of Ecosystems and Biodiversity (TEEB) tiered approach, or the ecosystem services model suite InVEST (Vihervaara et al., 2018).

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7 https://naturalcapitalproject.stanford.edu/software/invest

8 https://doi.org/10.1016/j.ecoser.2013.02.001

A tiered approach for ecosystem services mapping has been suggested by Grêt-Regamey et al. (2017). The different tier levels are distinguished according to the purpose and the level of detail of the ecosystem service analysis that is required. This allows the resulting maps to provide relevant information to decision makers, and avoid the application of over-complex or over-simplified methods.

Before the identification of the relevant tier and associated methods, the goal of the assessment and the different components of the analyzed human-environment system should be described together with their interactions and dependencies. These components include the ecosystems, the services they provide, beneficiaries of these services, as well as governmental and non-governmental institutions. In this step, the system boundaries relevant for the mapping, as well as the scale, should be made explicit. Once these components have been defined, the tier level and associated method can be selected, guided by a decision tree (Vihervaara et al., 2018). The scale of a study determines the accuracy of the data needed for the mapping.

The different tier levels are not related to a certain scale: a tier 1 approach can be applied at the local scale to get a first understanding of the presence, absence and abundance of ecosystem services; a tier 2 or tier 3 approach is required to better target national or even pan-European land management measures.

1.6. Assessment framework for the ecosystem pilots

The MAES conceptual model builds on the premise that the delivery of certain ecosystem services upon which we rely for our socio-economic development and long-term human well-being is strongly dependent on both the spatial accessibility of ecosystems as well as on ecosystem condition. This working hypothesis has been translated into a working structure that has been adopted to guide the work of the ecosystem pilot cases (Fig. 1.1.). In order to provide operational recommendations to both EU and its Member States, the proposed work structure for the 4 ecosystem pilots is based on a 4 step approach: (i) Mapping of the concerned ecosystem; (ii) Assessment of the condition of the ecosystem; (iii) Quantification of the services provided by the ecosystem; and (iv) Compilation of these into an integrated ecosystem assessment (Fig. 1.1.).

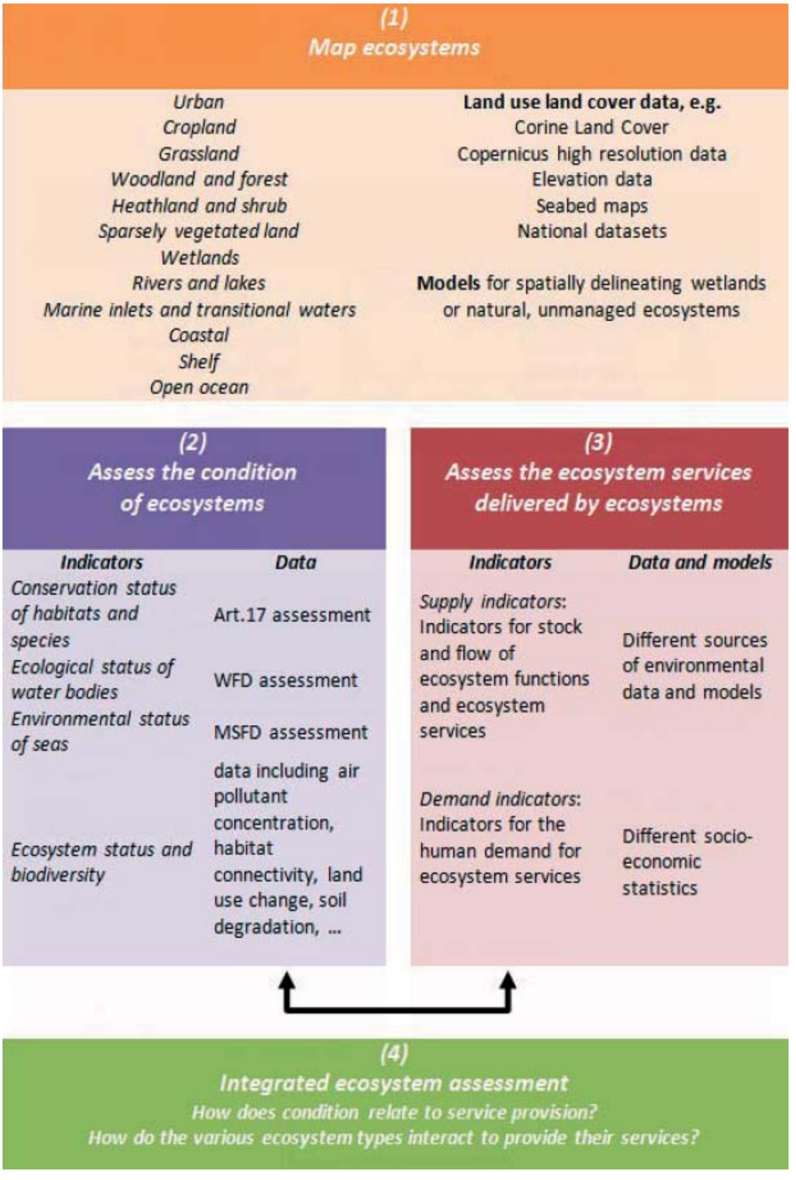

Fig. 1.1. A common assessment framework for the ecosystem pilots

2.PILOT APPLICATION OF EUROPEAN TOOLS IN THE RIVER BASINS OF THE EaP COUNTRIES

2.1. Case studies for Argichi River basin (Armenia)

2.1.1. Characteristics of the pilot basin

The Government of the Republic of Armenia encourages the construction of small hydropower plants under the pretext of "increasing energy security and sustainability", guarantees the purchase of generated electricity and sustainable profitability for the owners of hydropower plants. As a result of the implementation of the small hydropower development program (the number of operating small hydropower plants reached 188, 23 more construction licenses were issued), natural river ecosystems in the Republic of Armenia have been lost.

For a pilot study of ecosystem services, the Argichi River with its drainage basin was selected.

The Argichi River (Ayridzh, Ishkhanaget, Koti) flows in the basin of Lake Sevan in the Gegharkunik region of the Republic of Armenia. It starts from the northern slope of the Gndasar massif of the Geghama plateau, from an altitude of 2600 m asl. Length – 51 km, catchment area – 384 km^2. The river flows into Lake Sevan at an altitude of 1900 meters above sea level. Recharge is mainly thawed (55%) and groundwater (36%), floods are observed in May-June. The average annual flow rate is 5.18 m^3/s, the flow rate is 163 million m^3. Freezes in winter. Water is used for irrigation and energy production.

The following specially protected areas have been created in the river basin:

1. Reserve "Lichk-Argichi" covers an area of 1175 hectares (land – 482 hectares, water – 693 hectares). It includes the Lichk nature reserve, as well as the mouths of the Tsakkar, Lichk and Argichi rivers. The purpose of the reserve is to preserve the Lichka mineral springs, the remains of ponds in the mouths of the Argichi and Lichk rivers, spawning grounds and the development of endemic Sevan trout.

Fig. 2.1. Upper reaches of the Argichi river

2. Natural monuments:

- gorges of the Argichi river with its tributaries (Gridzor and others);
- meanders of the Argichi river, swampy valley, gorges of tributaries flowing down from the northern slopes of the Vardenis ridge, the remains of a natural forest.

2.1.2. Hydropower in the basin

A small HPP (SHPP) “Argichi” with an installed capacity of 9.72 MW has been built and has been operating since 2013 on the Argichi River in its middle and lower reaches. The length of the derivation and pressure pipeline is 9527 meters. In other words, the Argichi River is taken into the pipes of the SHPP along the 9.5 km long river bed.

The estimated pressure at the SHPP is formed due to the difference in elevation along the relief from the intake unit to the SHPP. It is interesting to note that according to the certificate of the Public Services Regulatory Commission (PSRC) dated October 1, 2015, the height difference is 274.8 m; for the project – 253.1; according to company information – 223 meters.

The annual electricity supply to the energy system of the Republic of Armenia is 20.3 million kWh (from year to year this figure ranges from 15 to 35 million kWh). The cost of 1 kWh of electricity supplied to the SHPP is 24.8 drams ($ 5 cents). The operator of the small HPP “Argichi” is “Gidrokorporatsiya” CJSC.

Fig. 2.2. Water intake node of the Argichi SHPP and the gorge of the Argichi river below this node

Fig. 2.3. Water intake unit and fish passage of Argichi SHPP

The photographs show that the river bed is completely blocked by a dam, which is prohibited by Article 32 of the RA Water Code, and the fish passage with its construction cannot ensure the movement (migration) of fish along the river bed.

It can be stated that the Argichi SHPP had a profound, almost catastrophic impact on both the quantity and species composition of the entire ichthyofauna. Thus, it can be argued that both in the commercial sense and in the meaning of the natural ecosystem (including the cichthyofauna), the Argichi River ceased to perform the function of providing ecosystem services.

2.1.3. Types of ecosystems and their conditions

The basin of the Argichi River is located on the territory of 8 settlements with their administrative boundaries. The ecosystems of the basin were mapped using cadastral maps of settlements, cartographic materials of the Sevan National Park and satellite images of the area. For this, the ArcGIS 10.5 software package was used. The available cartographic materials are shown in the same format (shapefile) and the same coordinate system.

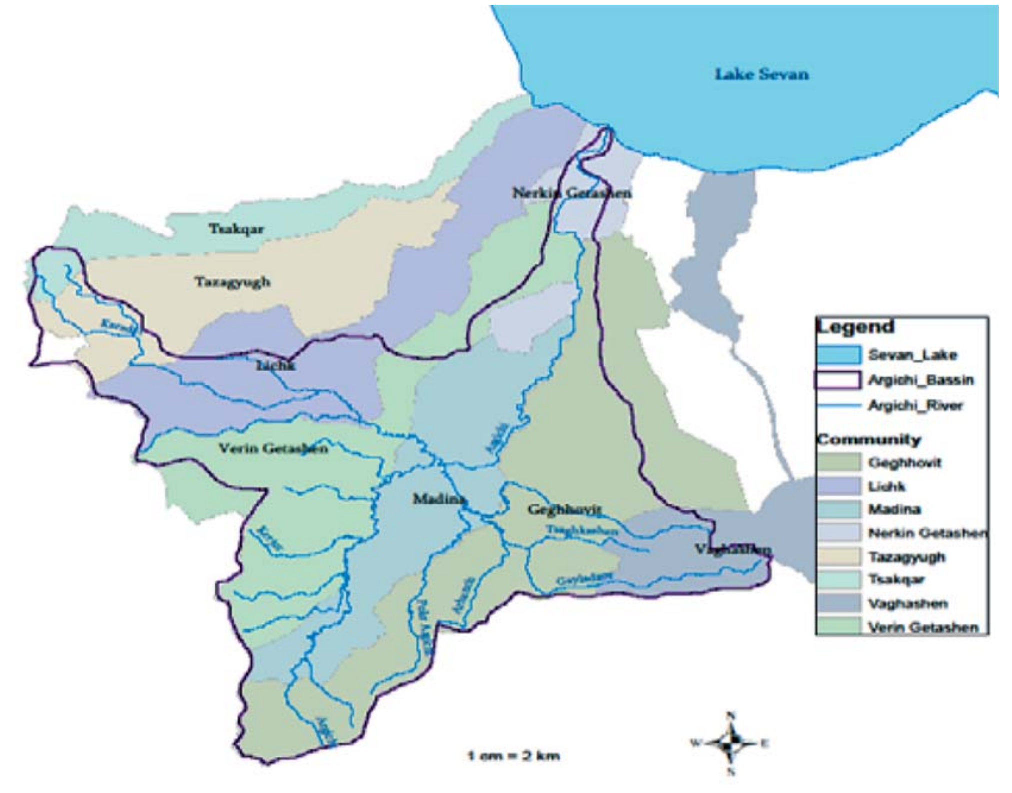

Fig. 2.4. The Argichi River basin map

The heights in the river basin range from 1900 m to 3400 m asl, which determines the diversity of ecosystems and land use forms in the river basin.

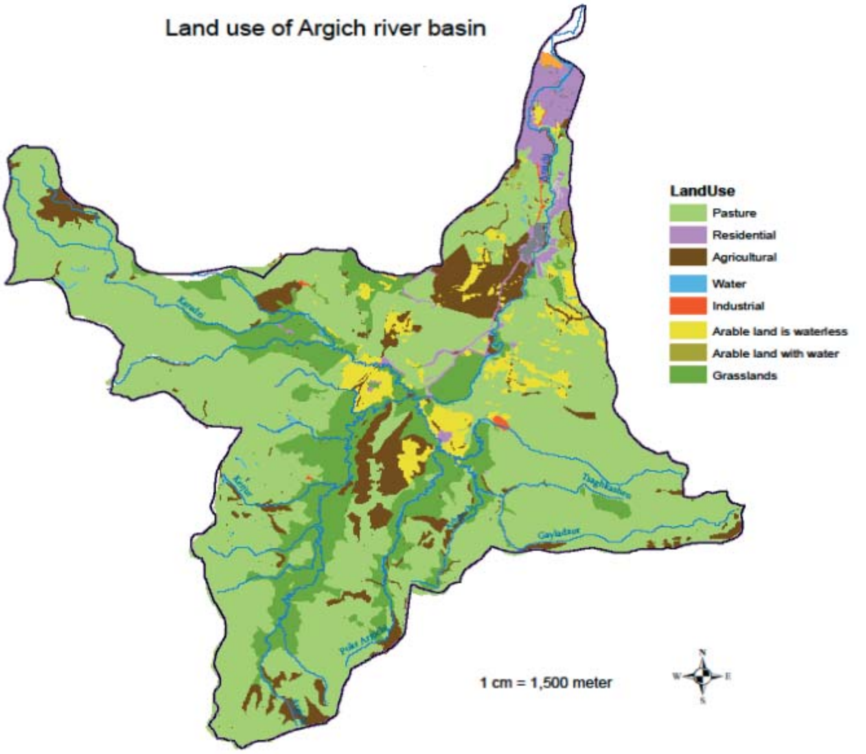

Fig. 2.5. Land use of Argichi River basin

2.1.4. Mapping and valuation of ecosystems and their services

Below are the results of mapping and assessment of ecosystem services in the Argichi river basin, obtained in the framework of the project "Ecosystem services and hydropower. Pilot application of European instruments in the river basins of the Eastern Partnership countries".

Taking into account the possibilities of the project, an assessment was made of the cost of direct use of ecosystem services in the river basin.

The area of each ecosystem is calculated. Then the value of ecosystem services was calculated for each unit of area of each ecosystem (forest, grassland, pasture, horticulture, arable land, irrigated arable land) using the market price method. Using the Modelbuilder tool of the ArcGis software package, a tool was created that allows to integrate the values of all ecosystem services into one layer, due to which the value of ecosystem services was classified (from 0 to 875,000 AMD) and a map of ecosystem services was compiled.

Findings

Research on ecosystem services should lead to the development and implementation of payment schemes for ecosystem services. They must become economically viable mechanisms to regulate and mitigate the harmful effects of hydropower on eco-

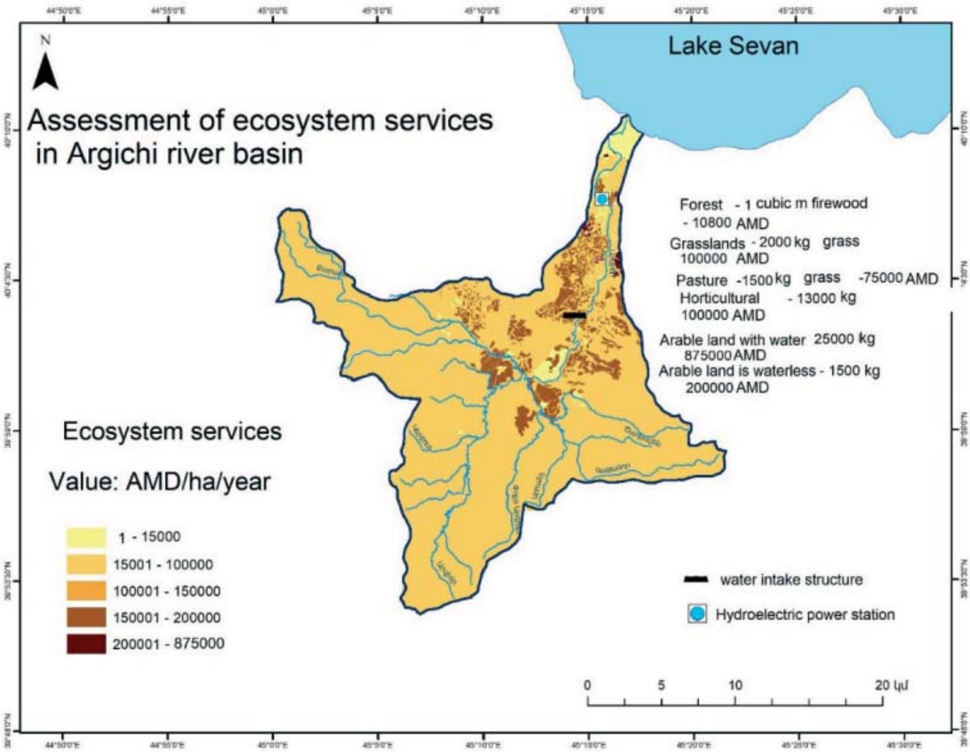

Fig. 2.6. Assessment of ecosystem services in Argichi River basin

systems and people, who must reap the benefits of the ecosystem. For this, it is necessary to adopt the RA Law "On Ecosystem Services", to introduce public-private schemes for "payment for ecosystem services". They may be voluntary at first. Voluntariness is from the sphere of social responsibility, while obligatory ones are quantitatively substantiated environmental and economic figures. Volunteerism, if successful, can become a "fuse" for the dialogue of interested local communities with the business community, and administrative intervention can help to make this service of general value. First, a real "public-private partnership" should take place, and not a "State-Private partnership", which contains the risks of corruption and tends to form an oligarchy.

Payment instruments for ecosystem services must be justified, socially acceptable and clearly quantified (monetized) so that at the monitoring stage they can form the basis for quantitative conclusions.

The introduction of a payment system for ecosystem services cannot replace the existing system of environmental payments; it should become a separate tool.

Payments for environmental protection and nature management, as well as payments for ecosystem services, should be aimed at creating ecological civil investment funds owned by the citizens of Armenia, which will be aimed at restoring ecosystems and ecosystem services that contribute to the socio-economic development of local communities and the country.

2.2. Case studies for the Kura River basin (Azerbaijan)

2.2.1. Characteristics of the pilot basin

The Kura River is located in the South Caucasus (Georgia, Azerbaijan) and Turkey. The largest river. in the Caucasus. The length is 1364 km (according to some sources, 1515 km), the catchment area is 188 thousand km². The sources of the river are located in Turkey, on the Kara Highlands. It enters the territory of Azerbaijan just above the mouth of the river, 122.8 km from the mouth of the river (near the city of Sabirabad), the largest tributary flows into it – the r. Araz. When it flows into the Caspian Sea, it forms a delta with an area of 100 km².

The main tributaries are: on the right, Paravani, Khrami, Agstafa, Shamkir, Terter, on the left – Bolshoi Liakhvi, Aragvi, Gabirry, Ganikh, Agrichai, Turianchay, etc. Belongs to the group of rivers with spring floods. The water is cloudy. It annually carries out an average of 18.5 million cubic meters of sediment to the Caspian Sea. It is widely used in irrigation. It is navigable to Yevlakh.

The Kura River recharge sources is mixed: 36% snow, 30% underground, 20% rain and 14% glacial. The average annual discharge on the border of Turkey and Georgia is about 30 m³ / sec, in Tbilisi 205 m³ / sec, at Mingachevir 402 m³ / sec, at the mouth 575 m³ / sec. The main part of the runoff (up to 70%) falls on the spring. The spring flood occurs from March to May, sometimes dragging on until June. The water of the Kura is turbid (in the lower reaches the turbidity reaches 2.325 g / m³).

The Kura Delta is currently relatively small (17.5 km long and 94 km² in area) and has a simple paddle device. However, earlier the delta was much more complex and had a larger size. The change in the Kura delta is influenced by the fluctuation in the level of the Caspian Sea.

Hydroelectric dams are used to control the Kura water level during floods. Mingachevir reservoir with an area of 605 km² is the largest fresh water reserve in Azerbaijan. In addition, in Azerbaijan, the Kura waters are intensively used for irrigation.

The volume of water resources in the Kura river basin is: the Kura river basin without the Araz (Arax) – 16.8 km³. It should be noted that the volume of 1.3 km³ in the Kura basin is formed on the territory of Turkey and Iran. Outflows for these two river basins are separately 11.8 and 5.8 km³ (17.6 km³ in total). In the Transcaucasian part of the river. In the Transcaucasian part of the Kura basin, the local flow is 21.2 km³, the inflow from Turkey and Iran is 4.7 km³ and the total resources are 25.9 km³.

Directly on the territory of the Republic of Azerbaijan, a runoff is formed in the amount of 7.81 km³. From the neighboring territories of Georgia and Armenia, Russia, Turkey and Iran, 20.3 km³ of water flows.

Calculations have shown that the water balance of the Kura River basin for an average water content year, taking into account all water withdrawals, is characterized by the following values: precipitation 556 mm (104.5 km³) river runoff 152 mm (28.6 km³), of which 87 mm (16.31 km³, 57%) falls on the surface, 65 mm (12.3 km³, 43%) – on the groundwater runoff. The average long-term annual flow module for the entire basin as a whole is 8 l/s/km²). The total evaporation in the basin is 404 mm or 75.89 km³. The runoff coefficient before the confluence of the Araz River into the Kura River varies within the range of 0.30-0.34, and for the entire basin it is on average 0.27.

The average long-term annual amount of precipitation falling on the territory of Azerbaijan is 427 mm. According to water balance calculations, the total evaporation is 308 mm, and the local runoff is 119 mm, i.e. evaporation is 2.6 times the runoff.

Fig. 2.7. Map (scheme) of the Kura River basin

After the construction of dams and the development of irrigated agriculture, the Kura River valley became densely populated, as a result of which increased pollution of the river, increased soil salinity in many places due to the filtration of water from numerous irrigation canals. The anthropogenic load on the landscape has sharply increased and the natural semi-desert territories have significantly decreased.

Water is used primarily for irrigation of fields, in the past – for the production of cotton and grapes, now mainly for irrigation of wheat, as well as of revived viticulture and cotton growing, fodder production. In many places, water is used for drinking. The Mingachevir reservoir and its surroundings are used for recreation.

Use of water resources of Azerbaijan. The main part of the country's water resources is the waters of transboundary rivers, which creates problems in meeting the needs of various water users. It should be noted that within the republic itself, water losses in irrigation canals and water supply systems are quite high. These losses amount comprise about 34.2% of water withdrawals. Only 65.8% of the withdrawn water from water sources is delivered to water consumers. The main water user in Azerbaijan is agriculture, which uses 69.8% of water withdrawn from water sources in 2013; industry used 25.0% of water withdrawals in the same year. The main loss of water occurs in agriculture. The analysis of official data on water use accounting shows that for 1990-2013 the annual volume of water withdrawals was 16.2–12.5 km^3 (Table 2.4). Water withdrawals from underground sources amounted to 1.54-0.51 km^3. During this period, the volume of water withdrawals decreased by about 1.3 times, which is caused by economic reforms carried out in various sectors of the economy, water tariffs and economical use of water.

2.2.2. Hydropower in the Kura River basin

After the Sovietization of Azerbaijan in 1920, small electrical enterprises were nationalized, and the problems of developing the republic's energy economy were solved in the GOELRO plan.

On July 6, 1945, the Central Committee of the All-Union Communist Party (Bolsheviks) and the USSR Council of People's Commissars decided to resume the construction of the Mingechaur hydroelectric complex and carry out irrigation work on the Kura-Araz lowland.

It should be noted that, in general, many unique developments were applied to the construction of a new hydroelectric power station in Azerbaijan. For example, for the first time in the history of Soviet hydraulic construction, a high-pressure earthen dam was erected not from previously accepted soils, but from sandy-gravelly with reinforced concrete structures and structures in the body of the dam. This kind of dam is not afraid of earthquakes. The dam was built 81 m high, its length was 1.550 m, and the volume was 15.6 million cubic meters. m. The thickness at the base is 500 m, in other words, half a kilometer.

The Mingachevir reservoir, resulting from the construction of the hydroelectric power station, lies at an altitude of 83 m above sea level, and the city is under this most dangerous accumulation of water, but the security and technical control system is very well established, although it did not do without accidents. This artificial sea was filled for six years – from 1953 to 1959.

A program for the development of the energy sector of the Republic of Azerbaijan for 2017-2030 is being developed. It provides for an annual growth of electricity consumption at the level of 4%. A connection has been created between the energy system of the Republic of Azerbaijan and the energy systems of the Russian Federation, Georgia, Iran and Turkey. This is also one of the serious factors contributing to the further development of interrelationships between countries, maintaining peace, stability and security in the region.

Tables 2.1 and 2.2 summarize the most important hydroelectric power plants in the Republic of Azerbaijan.

Table 2.1. Large hydroelectric power plants of the Republic of Azerbaijan

Name		Original title	City (neighbor-hood)	Power (MW)	Information
1.	Yenikend HPP	Yenikənd Su Elektrik Stansiyası	Yenikend	150	-
2.	Fizuli HPP	Füzuli Su Elektrik Stansiyası	Fizuli	25	-
3.	Varvara HPP	Varvara Su Elektrik Stansiyası	Yevlakh, Mingachevir, Goygol	16.5	In 2017 it was modernized[9].
4.	HPP Arpachai-1, Arpachai-2 (small HPP, 0.7 MW)	Arpaçay-1, Arpaçay-2 Su Elektrik Stansiyaları	Sharur	21.9	Launched in 2014.
5.	HPP Bilyav	Biləv Su Elektrik Stansiyası	Ordubad	22	Started work in 2010 [10].
6.	Shamkirchay HPP	Şəmkirçay Su Elektrik Stansiyası	Shamkir	25	Started work in November 2014 [7].
7.	Shamkir HPP	Şəmkir Su Elektrik Stansiyası	Shamkir	380	Built in 1982.
8.	Araz hydroelectric complex (Hydroelectric power station)	Araz Su Elektrik Stansiyası	Nakhichevan	44	Located in the territories of Azerbaijan and Iran. Half of the station's capacity is supplied to Iran
9.	Takhtakorpu HPP	Taxtakörpü Su Elektrik Stansiyası	Shabran	25	Located above the Samur River and the reservoir of the same name. The construction of the hydroelectric power plant began in 2007 and began work in 2013.
10.	Mingachevir hydroelectric power station	Mingəçevir Su Elektrik Stansiyası	Mingachevir	402	The largest hydroelectric power plant in Azerbaijan is located on the Kura River. Commissioned in 1954.
11.	Terter hydroelectric power station	Tərtər Su Elektrik Stansiyası	Terter	50	Located on the Tartar River.

Table 2.2. Small HPPs of the Republic of Azerbaijan

	Name	Original title	City	Power (MW)
1.	Vaikhir HPP	Vayxır	Babek	5
2.	Goychay HPP	Göyçay	Goychay	3.1
3.	HPP Ismailly-1	İsmayıllı –1	Ismailly	1.6
4.	HPP Ismailly-2	İsmayıllı-2	Ismailly	1.6
5.	HPP Balakyan-1	Balakən-1	Balakyan	1.5

Fig. 2.8. Mingachevir HPP

Fig. 2.9. Varvara HPP

Fig. 2.10. Ismayilli-2 hydroelectric power plant with an installed capacity of 1.6 MW

2.2.3. Types of ecosystems and their conditions

In the Kura River basin, four large orographic complexes are distinguished: the Greater Caucasus, the South Caucasian intermountain depression, the South Caucasian highlands, a section of the Elburs mountain system – the Talysh mountains with the Lankaran lowland. The Greater Caucasus extends from northwest to southeast for 1100 km and is an integral system of ridges with a pronounced watershed.

To the east of the lower course of the river Ganykh (Alazani) to the river Girdymanchay, there are low ridges and depressions of the Ajinohur low mountains. A vast low-lying part of the Kura depression stretches from the Mingachevir reservoir to the Caspian Sea. It is called the Kura-Araz lowland and is divided into a number of smaller plains. The most western part of it is the Ganja-Gazakh plain, where the cones of the rivers flowing down from the Lesser Caucasus formed wide plumes.

The mountainous areas of the Kura River basin are characterized by deciduous forests of the lower (up to 500 m), middle (500-1700 m) and upper (1770-2400 m) mountain-forest belt. The upper mountain forest belt is also called subalpine, where forests alternate with alpine meadows. Plain and tugai forests (forests along rivers in the semi-desert zone) are characterized by long-peaked oak, hornbeam, various types of elms, poplar and willow. In the middle mountain zone, beech dominates, and in the upper mountain zone, oriental oak, birch, maples, aspen predominate, in dry places – juniper. In the dry foothills, forests of wild pistachio and juniper grow with an admixture of caucasian oak and hornbeam. Plains and foothills up to 400-600 m are represented by semi-deserts with drought-resistant shrubs and grasses (ephemera and ephemeroids).

Ecosystem services are practically not assessed, but they can be roughly calculated based on environmental impact assessment work carried out during the installation of asphalt roads, tons of pipelines, as well as during reconstruction.

The influence of hydropower facilities can be partly clarified when familiarizing with the EIA on projects for the construction of hydropower plants in recent years, however, the impact of hydropower plants built in the Soviet era cannot be established using such documents, since they are not available. Special research is needed here.

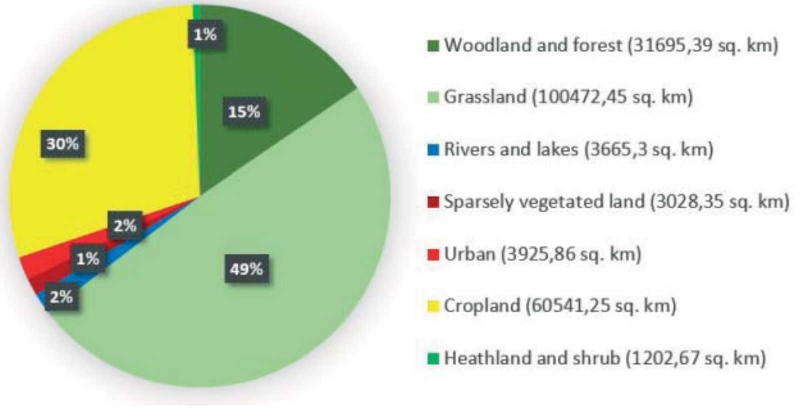

Fig. 2.11. Ecosystem of the Kura River basin

2.2.4. Mapping and valuation of ecosystems and their services

Ecosystem services are practically not assessed, but they can be roughly calculated based on environmental impact assessment work carried out during the installation of asphalt roads, tons of pipelines, as well as during reconstruction.

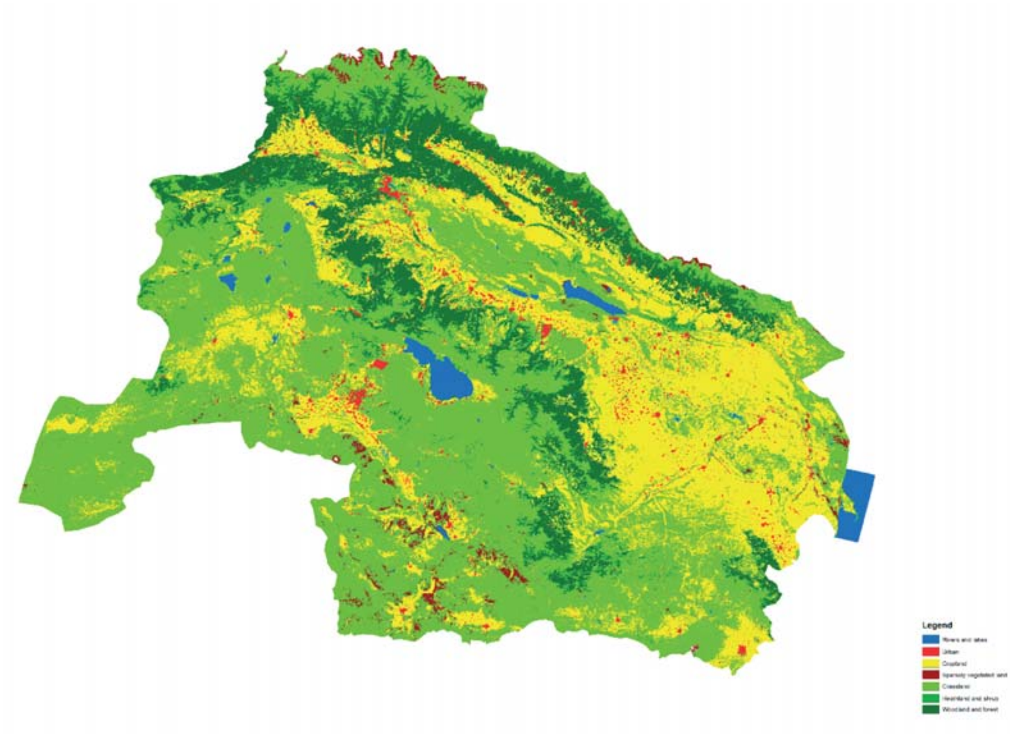

Fig. 2.12. The Kura River Basin Map

2.3. Case studies for the Dniester River basin (Moldova)

2.3.1. Characteristics of the pilot basin

The Dniester is one of the major European rivers flowing into the northwestern part of the Black Sea. The Dniester basin is located on the territory of three countries – the Republic of Moldova, Poland and Ukraine.

Fig 2.13. The Dniester River basin

The Dniester is the largest river in Moldova and the third largest river in Ukraine. The total length of Dniester is about 1362 km, from the source in the Ukrainian Carpathians (near the village Volchye at an altitude of 932 m above sea level) until the confluence within the Dniester estuary, separated from the Black Sea by a sand spit.

Ukraine owns the upper reaches of Dniester and its estuarine part with a total length of 705 km, a section of the river 220 km long is adjacent to Ukraine and Moldova, and a part of the river 437 km long is located on the territory of Moldova. Only a small section of the river Strvyazh, the upper left tributary of the Dniester, belongs to Poland[9].

The area of the Dniester basin is 72.3 thousand km², of which the Ukrainian part is 52.7 thousand km² (72.8%), the Moldovan part is 19.4 thousand km² (26.8%) and the Polish part is 226 km² (0.4%).The length of the Dniester basin is about 700 km, the average width is about 100 km (the maximum is 140 km in the mountainous part and the narrowest is 60 km). A characteristic feature of the Dniester hydrographic network is the absence of large tributaries with a large number of small (more than 16 thousand tributaries up to 10 km long)[10].

The Dniester basin covers significant parts of the territories of seven regions of Ukraine (Lviv, Ivano-Frankivsk, Chernivtsi, Ternopil, Khmelnytsky, Vinnytsia and Odessa) and most (56.34%) of the territory of the Republic of Moldova (19 districts and Transnistria). On the territory of the basin, within the borders of Ukraine, there are 62 cities and 95 urban-type settlements, and within Moldova there are 4 municipalities and 41 cities located on the left and right banks. Almost 8 million people live in the adjacent territories of Ukraine and Moldova, of which over 5.0 million people. – on the territory of Ukraine and 2.74 million – on the territory of Moldova.

The Dniester river is a border river. The Dniester river basin is located on the territory of three states – Poland, Ukraine and Moldova. Despite the fact that the specific part of Poland's territory in the Dniester basin is only 0.4%, it belongs to the transboundary river basins of the European Union[11].

2.3.2. Hydropower in the basin

Three channel reservoirs and a reservoir of a pumped storage power plant (PSPP) have been built on the river. The reservoirs of the Dniester HPPs have a multipurpose and meet the needs of irrigation, water supply, flood control, power generation, shipping, recreation, etc.

The restructuring of the river and estuarine ecosystems of Dniester began in 1955 with the construction of the Dubossary hydroelectric power station. The *Dubossary reservoir*, filled in 1954-1956, carries out seasonal, weekly, and in floods – daily flow regulation. The purpose of the reservoir is to meet the needs of hydropower, irrigation, fisheries and water supply. It is a medium-sized reservoir with shallow depths.

Second wave of significant changes in the 1980s in ecosystems of Dniester is connected with the commissioning of the Dniester hydroelectric complex (the modern name is the Dniester cascade of hydroelectric power plants and pumped storage power plants) (Fig. 2.14).

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9 Dniester Commission website. Region. https://dniester-commission.com/bassejn-reki-dnestr/region/

10 Dniester transboundary river basin management plan. Part 1: General characteristics and assessment of the condition. https://dniester-commission.com/wp-content/uploads/2019/07/Dniester_TDA_July2019.pdf

11 Management of the transboundary basin of the Dniester: the establishment of reference indicators for assessing the ecological status of surface water bodies / ed. S.O. Afanasyev, O.V. Manturova. – К.: Кафедра, 2019. – 376 с. ISBN 978-617-7301-75-1

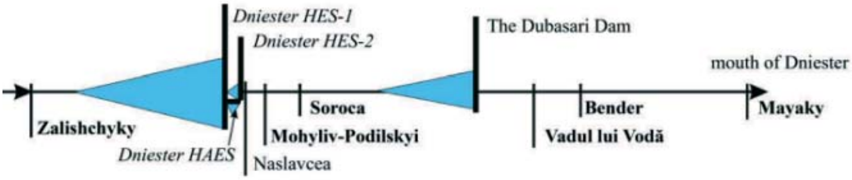

Fig 2.14. Linear layout of hydropower stations and reservoirs

Dniester reservoir, commissioned in December 1981, carries out seasonal – with elements of multi-year – regulation of the Dniester flow. The characteristic features of the reservoir are its great length and depth, relatively small width and significant tortuosity. The purpose of the reservoir is flood control, water consumption, hydropower, irrigation.

Buffer reservoir was formed in 1987 by the construction of a dam at HPP-2 20 kilometers below the Dniester HPP-1 to equalize the flow rate of water that comes from the Dniester reservoir [12].

In the early 2000s, work began on the construction of a pumped storage power plant. After the launch of the first hydroelectric unit of the PSPP in 2009, the buffer reservoir is used as the lower reservoir of the PSPP. It carries out daily and weekly regulation and belongs to small, shallow channel water bodies. On the right bank of the buffer reservoir, an *upper reservoir* of a hydroelectric power station has been created. In terms of morphometric characteristics, it belongs to bulk reservoirs with medium depths.

2.3.3. Types of ecosystems and their conditions

Due to the fact that the scale of the Dniester basin is large enough, the estimated territory was subdivided into smaller sections. Thus, the floodplain of the Dniester in the section from the Dniester hydropower complex to the river mouth was divided into seven parts, with their own sets (clusters) of ecosystems (Table 2.3).

[12] Rules for the operation of the reservoir of the Dniester cascade of hydroelectric power plants and pumped storage power plants at the NPU 77.10 m buffer reservoir. Report and recommendations for the updated draft of the Rules, 2018: https://dniester-commission.com/wp-content/uploads/2018/09/recommendations_operation-rules_Dniester_Serra_Oct2018_Rus-1.pdf

Table 2.3. Area of ecosystem types (km²) in the Moldovan part of the Dniester River basin

Eco-system	Clusters: DHPC -Dubasari	Dubasari reservoir	Dubasari – Raut	Raut – Ichel	Ichel – Bic	Bic – Botna	Botna – Liman	*Total*
Aquatic	23.6	64.1	1.5	4.6	20.8	5.2	17.8	*137.6*
Lakes				0.1	0.3	0.5	4.9	*5.8*
Wetland	0.7	5.2			0.2	0.8	32.0	*38.9*
Forest	2.8	3.8	0.3	2.6	32.8	7.1	29.4	*78.8*
Grassland	25.9	13.8	3.1	22.9	95.3	46.2	135.2	*342.4*
Perennial	0.7	1.8	0.1	8.7	12.8	11.1	13.1	*48.3*
Arable							82.1	*82.1*
Localities	2.5	5.0		2.04	16.6	3.8	21.6	*51.6*
Total:	***56.1***	***93.7***	***5.0***	***40.9***	***178.8***	***74.7***	***336.3***	***785.6***

[1]According to Ecosystem types of Europe – version 3.1. Available at: https://www.eea.europa.eu/data-and-maps/data/ecosystem-types-of-europe-1

Breakdown of the Dniester floodplain into clusters to study the ecosystems and their services

The definition of clusters (sub-basins) that provide water-related ecosystem services in the Moldovan part of the Dniester river basin was based on the principles of the European Water Framework Directive[13].

According to this document, Moldova is located in two ecoregions: the Pontine Province (12) and the Eastern Plains (16).

The dominant geology of the Dniester basin is siliceous; limestone rocks predominate in the northern part. It was also taken into account that within the studied area there are two Ramsar sites – "Ungur-Holoshnitsa" and "Lower Dniester".

The considered territory (785.62 km²) includes the following ecosystems (more than 1200 sites) – water (25.4%), forest (8.35%), grass (47.64%), wetlands (2.5%), as well as perennial plantations (7.49%), arable land (3.49%), built-up areas (5.15%) (Fig. 2.15).

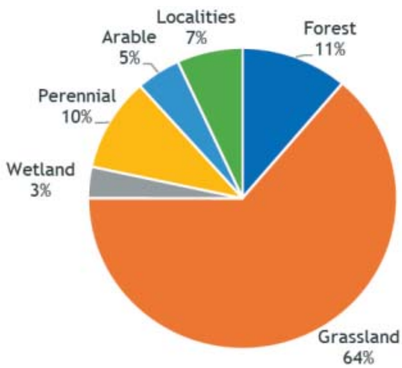

Fig. 2.15. The ratio of ecosystem areas in the Moldavian part of the Dniester river basin

At the same time, the set of ecosystems for each cluster differs both in its composition and in the ratio of areas.

[13] WFD, 2000: The EU Water Framework Directive – integrated river basin management for Europe. Available at: https://ec.europa.eu/environment/water/water-framework/index_en.html\

So, for example, the section next to the dam (from the dam of the hydroelectric complex to the tail of the Dubossary reservoir), having an area of 56.1 km², includes the following ecosystems – aquatic (42.1%), forest (5%), grass (46.2%), wetlands (1.2%), as well as perennial plantations (1.2%), built-up areas (4.5%).

Economic valuation methods can be used to identify changes in the value of ecosystem services under the influence of a wide range of different factors, including hydropower. Since the valuation of ecosystem services is based, along with purely natural and biological factors, on accounting the area occupied by different ecosystems, the ongoing territorial changes should be included as one of the variables of such an assessment.

The solution to this problem can be considered by the example of analyzing changes in the areas of individual ecosystems at the key site located 20 km downstream of the Dniester hydroelectric dam.

In the area of the village of Naslavcha, in the Dniester floodplain, there are several small islands near the banks of the river (Fig. 2.16).

In this figure, the two left maps reflect the state of this natural complex in the periods before and after the

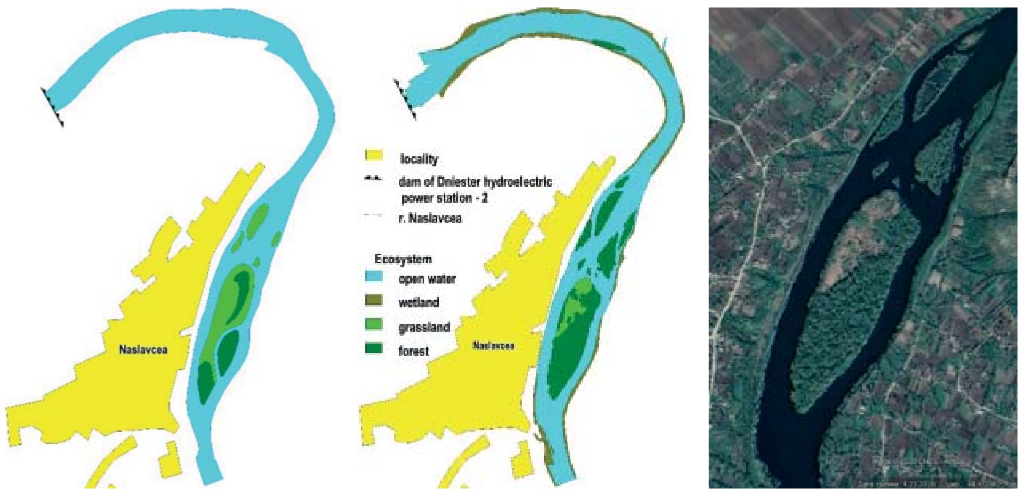

Fig. 2.16. Maps of the studied area before (left) and after (right) the construction of the Dniester hydroelectric complex, as well as a Google map of the studied area as of 2018.

construction of the hydroelectric complex: in 1979 and 2018, respectively. Changes in the size and structure of the components of this natural landscape are clearly visible.

Comparative analysis of the areas occupied by different ecosystems within the studied key area before and after the construction of the Dniester hydroelectric complex revealed the presence of several territorial trends:

1) reduction in the area of the river due to its overgrowth and transformation into swampy areas (wetland);
2) increase in the area of forest ecosystems due to a decrease in herbaceous (grassland) (Table 2.4).

Table 2.4. Changes in the studied area (1979-2018)

Ecosystem	1979		2018		Change	
	км²	%	км²	%	км²	%
Surface water	1,0599	80,20	1,0598	68,64	-0,0001	-11,56
Wetland	0	0,00	0,1756	11,37	0,1756	11,37
Forest	0,0996	7,54	0,2669	17,29	0,1673	9,75
Grassland	0,1620	12,26	0,0421	2,73	-0,1199	-9,53
Total	1,3215	100,00	1,544	100,00	0,2225	

So, on the territory under consideration, practically after the construction of the Dniester hydroelectric complex, the area of open water surface decreased by 11%, and the area of wetlands, respectively, increased by the same amount. The increase in the forest area due to the decrease in herbal ecosystems was about 10%.

Along with the change in the areas of ecosystems, their structure has also changed (Fig. 2.17.).

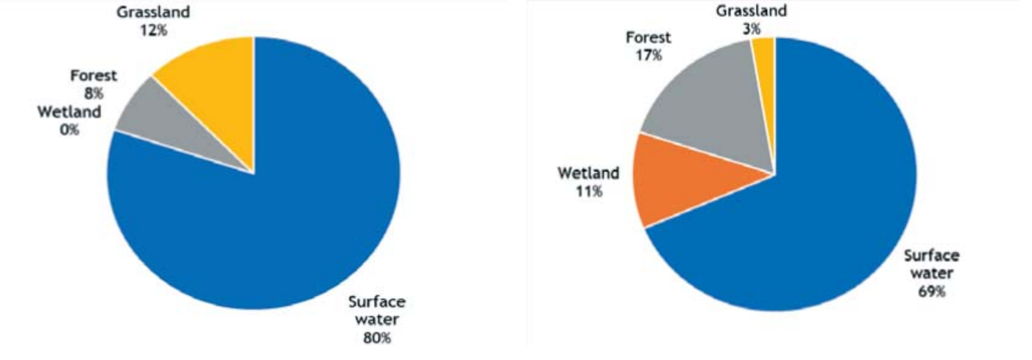

Fig. 2.17. Ecosystem structure of the assessed areas for two compared years (1979 – left; 2018 – right)

The quantitative parameters of the identified dynamics were used to assess the change in the value of ecosystem services in water-related ecosystems (forest, grass, wetland). Trends in area changes suggest an increase in forest ecosystems producing and regulating ecosystem services, as well as regulating ecosystem services of wetland ecosystems (by 9 and 11%, respectively). At the same time, ecosystem services of herbal and aquatic ecosystems are decreasing, incl. due to reducing their area.

2.3.4. Mapping and valuation of ecosystems and their services

Provisioning services

Surface water. The total cost of providing water includes its full economic cost and environmental externalities, associated with public health and ecosystem maintenance. In this duality, the first component consists from water supply cost, e.g., operating and maintenance expenditures and capital charges. In turn, ecosystems maintenance depends on water availability. The most difficult element in

EV of water services is to determinate its market price, usually taken as average price for 1 m^3 of drinking still water (Table 2.5).

Table 2.5. The Dniester annual runoff *(km³)* before and after DHPC construction

Post	Periods		Change
	1951-1980	*1991-2015*	
Zalishchyky	7.03	7.28	0.25
Mohyliv	8.89	8.33	-0.56
Bender	10.22	9.15	-1.07

Such approach, as useful for EV of impacts on water resources, was applied to evaluate losses of the Dniester River provisioning services due to the Dniester Hydropower Complex (DHPC) operation. The estimations were based on comparing the streamflow volume *(Q)* at hydrological posts Zalishchyky, located upstream DHPC, and Mohyliv-Podilskyi and Bender – downstream in periods before (1951-1980) and after (1991-2015) DHPC construction (Table 2.3.). Q decrease downstream the DHPC in 1991-2015, against its increase upstream, indicates its undoubted impact that results in annual economic losses of $30 million in Mohyliv and above twice more – in Bender (at a water price of $25/m^3).

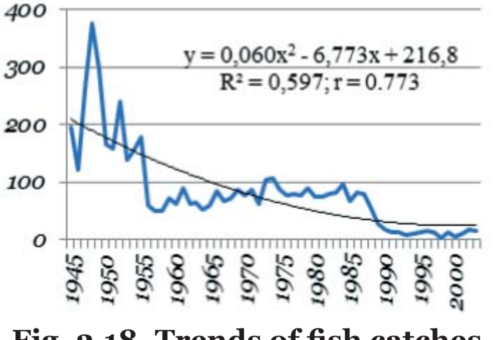

Fig. 2.18. Trends of fish catches in the Dniester River

Fishery. The long-term dynamics of the volumes of commercial fisheries in the Dniester River indicates its significant reduction (Fig. 2.18). This reduction is undoubtedly associated with HPPs construction: the first sharp reduction took place in the 1950s and was caused by the Dubasari HPP construction; the second reduction, occurred in the 1990s, was due to the commissioning of the Dniester hydropower complex.

Along with a general decrease of fish stocks, the stock of commercially valuable species is especially significant.

For EV of the fishery losses, two approaches have been used:

Cost of direct losses. Based on the world price of freshwater fish ($ 2.35/kg in 2019), the annual losses in Dniester part, e.g. from Rybnitsa to Palanca, were more than $ 172 thousand.

The costs of maintaining the fish habitat. The cost of 150.2 tons of various fish species fries, launched in 1998-2018 in Dubasari reservoir for maintaining its fish stock, amounted ~360,4 USD; this figure can be considered as an equivalent of EV of fish losses.

Regulating services

There are examined the regulating services that to one degree or another relate to climate change and river streamflow. As a study area, wetlands were considered as "hot spots" in the economic assessment on the example of the Ramsar site "Lower Dniester" (Fig. 2.19.).

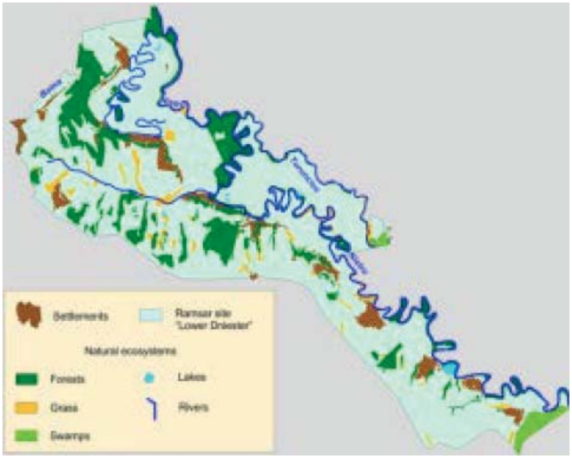

Fig. 2.19. Ramsar site "Lower Dniester" as a case study

Carbon deposit by the Low Dniester forest ecosystems (2.1.1.2). Annual CO_2 accumulation for Moldova's main forest-forming species (oak, poplar, white acacia and other species) is 7.7, 10.7, 8.4 and 4.1 ton/ha, respectively. In March 2020 an average price of CO_2 allowance was 24.1 EUR. Based on forest species composition and area that each occupies in the Lower Dniester, the resulting current EV of their annual carbon deposit service is 1.53 million USD, varying across the territory from <5 to 105 thousand USD (Fig. 2.20.).

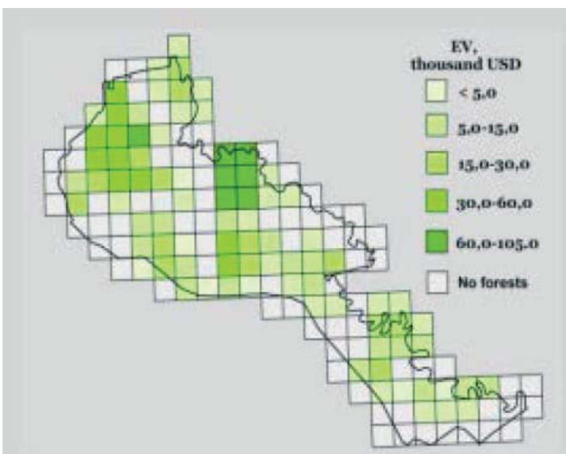

Fig. 2.20. Spatial distribution of the economic value of an annual CO_2 deposit service by the Lower Dniester forest ecosystems

Water protection and regulation (2.2.5.1). The areas with slopes >5°, where forest ecosystems contribute most of all to the surface-underground redistribution of surface runoff, occupy more than 20% of the Lower Dniester territory (Fig. 2.21).

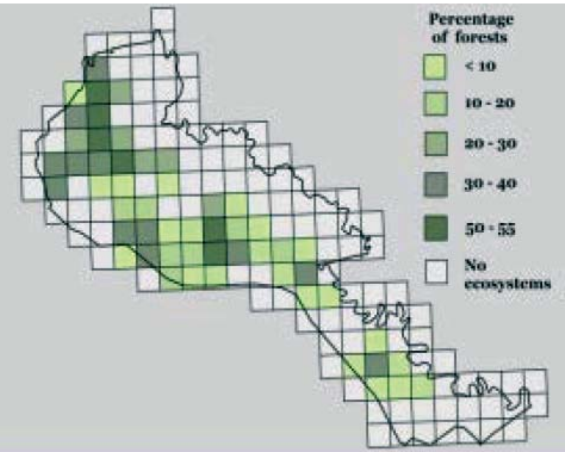

Fig. 2.21. Distribution of sloping forest ecosystems in the Lower Dniester

This factor provides a significant increment in ecosystem waterregulating functions. This service consists in equalizing seasonal fluctuations in a river runoff, preventing its sharp reductions, to reduce floods intensity by redirecting a surface runoff into ground. So, depending on a sloping forest area in the Lower Dniester, the underground water accumulation here is ~485,000 m^3. With a payment for water for industrial enterprises of ~32 MDL/m^3, the total economic effect of such accumulation is about 11.9 million MDL.

Economic valuation of the sorption (water-cleaning) function of swamps is based on a comparison of the fil-

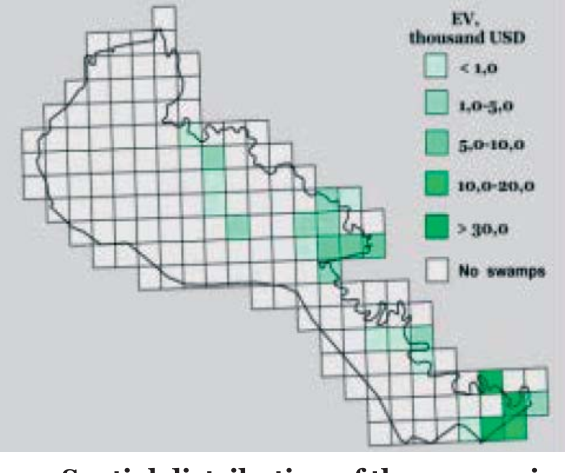

Fig. 2.22. Spatial distribution of the economic value of swamps water-cleaning function

tering ability of their ecosystems with the filtering capacity of an industrial treatment plant. Based on the swamps area of this Ramsar site, the economic value of their absorption services is about 107 USD or 91 USD per ha on average. However, this value, expressed in mapping units, varies from 1,000 to more than 30,000 USD (Fig. 2.22.).

Habitat services (2.2.2.3). The water-regulating DHPC has changed the volume and seasonal distribution of the Dniester's streamflow, often causing its delta draining. Such destructive impact on main representatives of the delta's natural ecosystems has resulted in a catastrophic reduction in populations (by 70-99%) of almost 80% of its fauna.

So, *a glossy ibis (Fig. 2.23)*, which is listed in the Red Books of Moldova and Ukraine, was the most widespread bird in the Dniester delta, where 2,500-3,000 of its adult individuals nest steadily in 1970-1982. However, already in 1988-2002 a number of breeding loafs decreased manyfold here, rangiing from 100-350 adults individuals; the decrease was continuing further and in 2010-2015 this bird has almost disappeared from the delta as a breeding species.

According to the Ukrainian legislation the penalty for the death of one glossy ibis is about 434 USD. Considering this fine as a kind of compensation for the loss of this environmental service, the economic value of glossy ibis disappearance due to hydropower adverse impacts on the Dniester delta can be estimated of 1.0-1.3 million USD.

Fig. 2.23. Glossy ibis

2.4. Case studies for the Uzh River basin (Ukraine)

2.4.1. Characteristics of the pilot basin

The Uzh River originates in the mountains in the northwest of the Zakarpattia region of Ukraine. On the southern slopes of the Verkhovyna watershed, near the Uzhitsky pass, at an altitude of 970 m above sea level, two mountain rivers Uzh and Uzhok merge into a single river, which first flows in a wide intermountain gorge, and then, skirting the western slopes of the Polonyn ridge, near Uzhhorod it reaches the plain territory of the Pannonian lowland.

The Uzh River flows into the river Laborec in Slovakia. In the upper and middle reaches the river Uzh has a mountainous character, below Uzhgorod in the Pannonian lowlands – plain. The length is 133 km, the area of the basin is 2.750 km^2 (within Ukraine 107

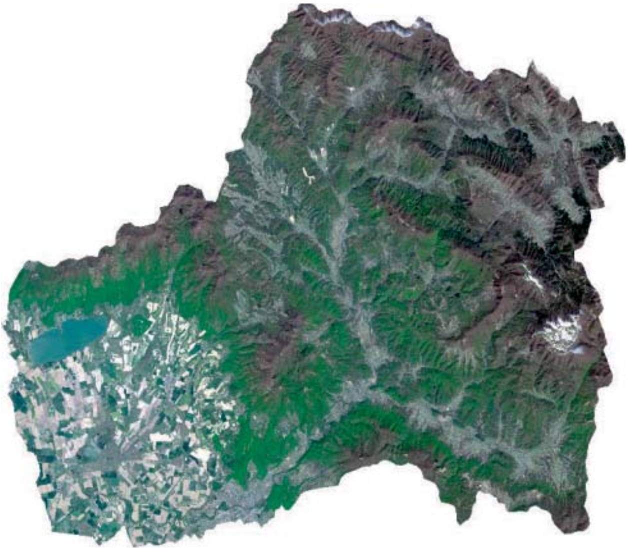

Fig. 2.24. Basin of the river Uzh

km and 1950 km). The width of the valley increases from 15 m (in the upper reaches) to 100–300 m, in the lowlands it reaches 2–2.5 km. The floodplain is intermittent, often asymmetric, 50–500 m wide, and up to 1 km in the lower reaches. The channel is winding, moderately branched, in the upper and middle reaches it is porous, there are low waterfalls, many alluvial islands overgrown with vegetation. The width of the river is mainly 15–30 m, near Uzhhorod – up to 135 m. The slope of the river is 7.2 m/km. Normal water consumption is 29 m/s. The shores are steep, 1-2 m high, sometimes up to 6-8 m, the bottom in the upper and middle reaches is rocky, and in the city of Uzhhorod and below the shores it is silted up. Recharge sources – snow and precipitation. Used for water supply and as a source of hydropower.

2.4.2. Hydropower in the basin

Interest in the energy resources of the mountain rivers of Transcarpathia arose in the last century, in particular in the Czechoslovak period (1919-1939). The scheme of hydropower use of the rivers of the Tisza basin, in particular the river Uzh and its tributaries – the river Luta, was made by Czech specialists. At that time, it was planned to build 14 small hydropower plants on the rivers of Transcarpathia, with a total capacity of up to 62 MW, which were to generate up to 340 million kWh in a year.

It was according to Czech designs that the Onokivska (2.65 MW) and Uzhhorod (1.9 MW) MHPPs were built on the Uzh River in 1937 and put into operation in 1942. These hydraulic structures on the Uzh River have been operating for more than 70 years without reconstruction. This is a very original project of cascade power plants, which are located in a specially created derivation channel, more than 10 km long (Fig. 2.25).

Fig. 2.25. The scheme of regulation of the river Uzh

It is known that in the historical past near the city of Uzhgorod, the river was divided into several branches, so the city periodically suffered from floods and inundations. For a long time, all city quarters were built only on hills. Uzhhorod grew in size after the last side channel of the Maly Uzh River was taken into a pipe and filled up during the construction of the derivation canal. The swampy floodplain was reclaimed, and the main channel was regulated by a stone fortification and embankment dams, where today there are very beautiful Uzhhorod embankments. The derivation canal itself performs two functions: water supply of the old (right) part of the city (water intake is up to 6 million m^3 per year) and water supply to the turbines of two HPPs, which at that time fully supplied the city with electricity.

Fig. 2.26. Onokiivska (left) and Uzhhorod MHPP

Water from the river Uzh is drained into the derivation channel by a transverse dam in the village of Kamyanytsia, located at a distance of 8 km from Uzhgorod. The height of the dam is 3.5 m. All this time, until 2017, the dam operated in overflow mode (Fig. 27). Since 2017, after cleaning the bottom of the canal from silt, the overflow on the dam does not work, only during the seasonal floods – short periods in March and November. Thus, for a long time of the year, a section of the Uzh River, 11 km long, is on the verge of drying up. Due to the deepening of the canal bottom, the volume of water intake from the riverbed for the purposes of electricity generation has increased.

Fig. 2.27. Dam near the village Kamyanytsia during the overflow period (November, 2020)

The dam of this cascade of the MHPP is not equipped with a fishing vessel. That is, it is a physical barrier to fish migration. Currently, an obstacle to fish migration is also the lack of water in the riverbed in the lower reaches. During the limited period, fish and fry fall into the trap of shallow water, when the river turns into many puddles.

In the basin of the Uzh River there is another cascade of backup and derivation MHPPs, already built on the Shypit River: HPP "Shypit-1" (commissioned in 2012, capacity 1.02 MW) and HPP "Shypit-2" (2014, 0.99 MW).

HPP "Shypit-1" is a transverse dam 36 m wide and 4.6 m high. A reservoir with an area of 1000 m2 has been created in the upper reaches. The average depth of the reservoir is 1.5 m, the maximum depth is 4.6 m. The length of the derivation (in the pipe) is 2950 m, the maximum water flow is 2.3 m^3/s. For the first 1.5 years, the HPP operated without a fishing vessel. As a result of protests from environmental organizations a bypass stepped fish boat was built. Its effectiveness has not been proven to date.

Upstream is HPP "Shypit 2". The length of the derivation is 2769 m. The dam is low, overflowing, Grizzly type. There are fish protection structures, bypass step fish. The reservoir, as such, is virtually absent. A low-flowing shallow creek is formed in the upper reaches. The maximum water consumption is 0.9 m^3/s. In our opinion, the biggest problem of this HPP is derivation – about 6 out of 20 km of the river are driven into the pipe for the operation of this cascade of HPPs.

Influence of the MHPP dam on the Uzh River. The dam in the village of Kamyanytsia makes the river impassable in this area. As a result, the species structure of ichthyofauna in the river in the upper reaches and lower reaches is probably very different from that which existed before the construction of the dam. For example, semi-permeable species of fish in the upper reaches are absent: aspen (*Aspius aspius*), pike perch (*Sander lucioperca*), catfish (*Silurus glanis*). In the river they live exclusively in the lower reaches. Above the dam in a typical area from Perechyn to Uzhhorod there are species that do not migrate during spawning. During floods in Uzhhorod, river trout (*Salmo trutta morpha fario*), which lives only in the mountain tributaries of the Uzh, are sometimes demolished. There is currently no chance for trout to return to the mountain cold rivers, except in the upper reaches of Slovak rivers.

During the studies of the seasonal dynamics of the species structure of bird communities of the middle course of the river Uzh during 2015-2020 the negative effect of raising the water level in the river for small snake (*Charadrius dubius*), *mountain wagtail (Motacilla cinerea* Tunstall*), sea buckthorn (Cinclus cinclus) and embankment (Actitis* hypoleucos) – common species for mountain rivers – were found. Prolonged state of high water level in the river, for example, during the construction of a retaining dam and increase the water level in the upper reaches by 2-3 m, leads to the extinction of these species in such areas of the river.

2.4.3. Types of ecosystems and their conditions

According to published estimates, the forest cover of the Uzh River basin is 71%. Of these, operational forests occupy 36.1%, nature protection – 25.1%, recreational and health forests of the green belt of settlements – 14.4%, protective forests, which perform an important hydrological and anti-erosion function – 15.1%, forests on reserve lands and shrubs – 9.4%. The Uzh basin is dominated by beech forest formations (81.4%): pure beech, hornbeam-beech, maple-beech, coniferous-beech. Oak groves (2.4%) also grow in the lower reaches: hornbeam-oak and beech-oak forests. Formations of fir and spruce forests grow in the upper reaches (16.2%): beech-fir and beech-spruce forests. The group of types of maple-beech forests is very rare and is confined to Uzhansky NNP.

The age structure of the forests of the basin is as follows: young forest occupies 11.7% of the area, medieval forests cover 59.1% of the territory, ripening – 12.9%, mature and overripe forests occupy 16.3%.

The remaining 29% of the basin area, according to published estimates, are settlements, agricultural landscapes, roads – big roads, soils and railways. All of them are concentrated in the valley of the river Uzh.

2.4.4. Mapping and assessment of ecosystems and their services

We have already used data from the Copernicus Global Land Service (CGLC) for mapping ecosystems in the river basin. This is the first such service with a resolution of 100 m, which displays coverage for ten basic classes of the earth's surface for the entire planet. This service was launched in May 2019, and from September 2020 it displays dynamic data of the earth's surface for 5 years – annually from 2015 to 2019.

The main source data for the service are PROBA V satellite observations, organized into millions of equivalent Sentinel-2 tiles measuring 110x110 km. Processing in this tile grid in UTM projection ensures high quality and promotes the continuity of Sentinel-2 observations.

An important feature of Copernicus Global Land Service is the display of surface classes according to the UN-FAO Land Classification System (LCCS), which are comparable to the MAES classification (Table 2.6). Since the data on land cover types are comparable to the ecosystem types listed in the MAES classification, the Copernicus Global Land Cover map was used as a basis for developing the Uzh River Basin Ecosystem Map (Fig. 2.28, 2.29).

Table 2.6. Comparison of CGLC surface classes and MAES ecosystem types

Land Cover Classes (CGLC)	Types of ecosystems (MAES)
Forests	Woodland and forest
Shrubland	Heathland and shrub
Herbaceous vegetation	Grassland
Moss & Lichen	
Snow & Ice	Sparsely vegetated land
Bare / Sparse vegetation	
Cropland	Cropland
Built-up	Urban
Herbaceous wetlands	Wetlands
Permanent water bodies	Rivers and lakes

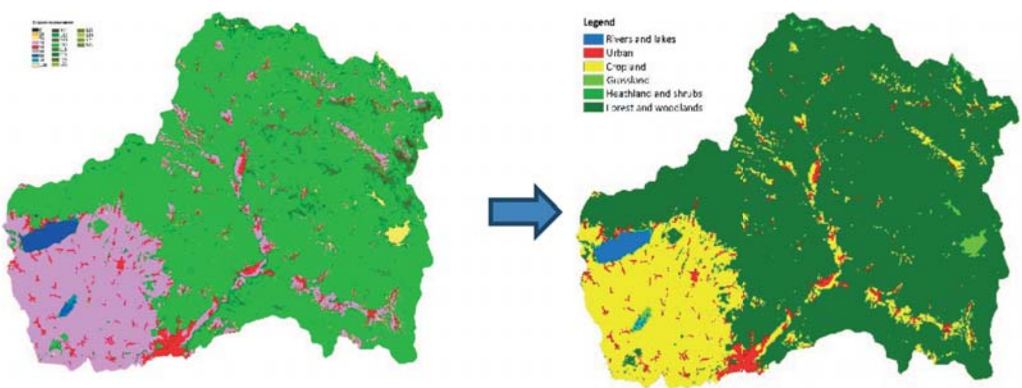

Fig. 2.28. Use of the Copernicus Global Land Cover resource to determine the types of ecosystems of the territory according to the MAES classification (on the example of the Uzh river basin)

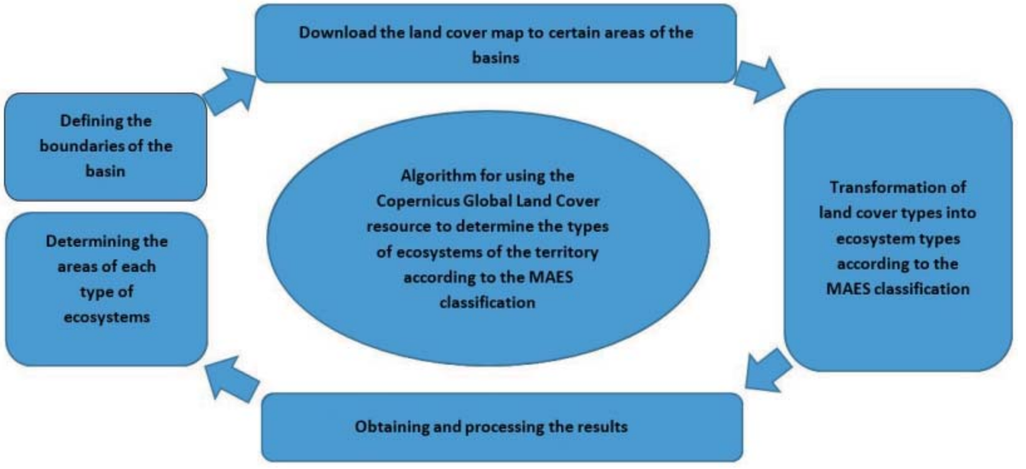

Fig. 2.29. Algorithm for building ecosystem maps

The mapping was performed as close as possible to the methodology used in the EU to build an ecosystem map of the latest version, where the source information is the Corine Land Cover (CLC) data set with the control year 2012. Given that CLC does not cover the territory of Ukraine and other Eastern Partnership countries, these data cannot currently be used to map the ecosystems of these countries.

The obtained mapping data show that ¾ the area of the basin is represented by forested areas and forests, which is slightly higher than the published estimates. Arable land occupies another 1/5 of the territory. In general, wooded areas and arable land cover 95% of the basin area. Other selected ecosystems of the 2nd level according to the KOEP method make up 1–3% of the territory. These are urbanized areas, pastures, rivers and lakes (Fig. 2.30).

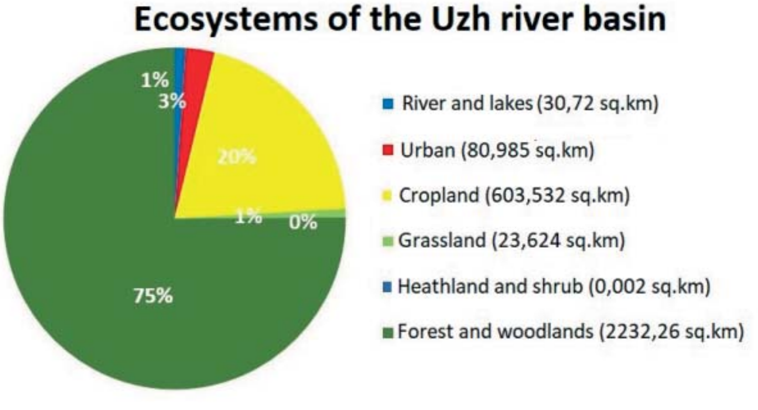

Fig. 2.30. The ratio of areas of ecosystems in the Uzh River basin

Potential ecosystem services have been identified for each of the identified types of river basin ecosystems. Ecosystem services were established according to CICES classification V5.1. The list of ecosystem services (Table 4) is not exhaustive and can be supplemented according to the level of study of the basin area.

A fundamental characteristic of end services is that they remain connected to the basic functions, processes and structures of the ecosystems that generate them. It is important to highlight those characteristics of a living system that combine to form services.

For example, in the case of wood used for building materials, they will include attributes that make a particular wood "workable" as a building material, and include characteristics such as hardness, strength and durability of wood fiber. All these attributes will depend, in turn, on the basic structural properties of the forest, which includes the composition of trees, soil type, nutrient status and growth processes that have formed the operational stands. The amount of wood ready for felling is accepted as a service in CICES.

Services form goods and benefits, as in the case of wood, when it is harvested and crosses the "production boundary". Goods and benefits are essentially seen as derivatives of ecosystem services, they ultimately have value to people. Sometimes goods are considered more tangible, as in the case of recycled wood, which can have a monetary value. Ecosystem "results" may be less tangible, in which case they are often described simply as benefits. For example, in the case of forests, this may include the creation of a forest structure that promotes recreation as a cultural service.

Assessing all the benefits (specific goods and benefits) of certain river basin ecosystem services is a large-scale task that requires both reliable data on the state of the environment and information on the existing use of ecosystem services, as well as the availability of the necessary tools.

A number of applications have been developed to quantify ecosystem services, which are mainly based on the use of GIS tools. In particular, the following tools have become widespread:

- ARIES;
- BeST;
- Co$ting Nature;
- EcoServ-GIS;
- GI Valuation Toolkit;
- i-Tree Eco;
- InVEST;
- Natural Capital Planning Tool;
- ORVal;
- Participatory GIS;
- SENCE;
- TESSA;
- Viridian.

2.4.5. Application of the InVEST tool for assessment of ecosystem services

One of the most widely used tools for assessing ecosystem services in the world is developed by Stanford University in the framework of the Natural Capital Project – is the software package InVEST – Integrated Valuation of Ecosystem Services and Tradeoffs, ie a tool for integrated assessment of ecosystem services and trade-offs between them.

InVEST is a model that helps to quantify and reflect the value of ecosystem services. InVEST is a spatial modeling tool that takes into account changes in ecosystem services, biodiversity conservation and levels of commodity production. Such an approach to quantifying and spatializing the production of ecosystem services can help make decisions to preserve the environment and manage natural resources more efficiently and effectively.

Initially, InVEST was developed as a free extension of the ArcGIS toolkit. It currently offers a set of free, open source software that covers 19 different terrestrial, freshwater, coastal and marine ecosystem services. InVEST has been used in mapping and evaluating ecosystem services in various research projects around the world, especially to analyze trade-offs between ecosystem services and to compare different alternative potential development scenarios.

InVEST models are a standalone application that does not depend on GIS software. You will need GIS software such as QGIS or ArcGIS to view the results.

Table 2.7. Ecosystem services of the river basin According to the CICES V5.1 classification

Type of ecosystem	Class of ecosystem services	Code
Rivers and lakes	Cultivated terrestrial plants (including fungi, algae) grown for nutritional purposes	1.1.1.1.
	Fibres and other materials from cultivated plants, fungi, algae and bacteria for direct use or processing (excluding genetic materials)	1.1.1.2
	Plants cultivated by in- situ aquaculture grown for nutritional purposes	1.1.2.1
	Fibres and other materials from in-situ aquaculture for direct use or processing (excluding genetic materials)	1.1.2.2
	Animals reared by in-situ aquaculture for nutritional purposes	1.1.4.1
	Fibres and other materials from animals grown by in-situ aquaculture for direct use or processing (excluding genetic materials)	1.1.4.2
	Wild plants (terrestrial and aquatic, including fungi, algae) used for nutrition	1.1.5.1
	Fibres and other materials from wild plants for direct use or processing (excluding genetic materials)	1.1.5.2
	Wild animals (terrestrial and aquatic) used for nutritional purposes	1.1.6.1
	Hydrological cycle and water flow regulation (Including flood control, and coastal protection)	2.2.1.3
	Regulation of the chemical condition of freshwaters by living processes	2.2.5.1
	Regulation of chemical composition of atmosphere and oceans	2.2.6.1.
	Regulation of temperature and humidity, including ventilation and transpiration	2.2.6.2.
	Characteristics of living systems that that enable activities promoting health, recuperation or enjoyment through active or immersive interactions	3.1.1.1.
	Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through passive or observational interactions	3.1.1.2.

Type of ecosystem	Class of ecosystem services	Code
	Characteristics of living systems that enable scientific investigation or the creation of traditional ecological knowledge	3.1.2.1.
	Characteristics of living systems that enable education and training	3.1.2.2.
	Characteristics of living systems that enable aesthetic experiences	3.1.2.4.
	Characteristics or features of living systems that have an existence value	3.2.2.1.
	Surface water for drinking	4.2.1.1.
	Surface water used as a material (non-drinking purposes)	4.2.1.2.
	Freshwater surface water used as an energy source	4.2.1.3.
	Ground (and subsurface) water for drinking	4.2.2.1.
	Ground water (and subsurface) used as a material (non-drinking purposes)	4.2.2.2.
	Maintenance and regulation by inorganic natural chemical and physical processes	5.2.2.1.
	Natural, abiotic characteristics of nature that enable active or passive physical and experiential interactions	6.1.1.1.
Cities	-	-
Arable land	Cultivated terrestrial plants (including fungi, algae) grown for nutritional purposes	1.1.1.1
	Fibres and other materials from cultivated plants, fungi, algae and bacteria for direct use or processing (excluding genetic materials)	1.1.1.2.
	Cultivated plants (including fungi, algae) grown as a source of energy	1.1.1.3.
	Animals reared for nutritional purposes	1.1.3.1
	Fibres and other materials from reared animals for direct use or processing (excluding genetic materials)	1.1.3.2
	Animals reared to provide energy (including mechanical)	1.1.3.3
Pastures	Cultivated terrestrial plants (including fungi, algae) grown for nutritional purposes	1.1.1.1.
	Animals reared for nutritional purposes	1.1.3.1.
	Wild plants (terrestrial and aquatic, including fungi, algae) used for nutrition	1.1.5.1
	Fibres and other materials from wild plants for direct use or processing (excluding genetic materials)	1.1.5.2
	Wild plants (terrestrial and aquatic, including fungi, algae) used as a source of energy	1.1.5.3
	Wild animals (terrestrial and aquatic) used for nutritional purposes	1.1.6.1.
	Control of erosion rates	2.2.1.1.
	Hydrological cycle and water flow regulation (Including flood control, and coastal protection)	2.2.1.3
	Wind protection	2.2.1.4
	Seed dispersal	2.2.2.2
Wastelands and shrubs	Wild animals (terrestrial and aquatic) used for nutritional purposes	1.1.6.1.
	Wind protection	2.2.1.4
	Control of erosion rates	2.2.1.1

Type of ecosystem	Class of ecosystem services	Code
Forest areas and forests	Wild plants (terrestrial and aquatic, including fungi, algae) used for nutrition	1.1.5.1
	Fibres and other materials from wild plants for direct use or processing (excluding genetic materials)	1.1.5.2
	Wild plants (terrestrial and aquatic, including fungi, algae) used as a source of energy	1.1.5.3
	Wild animals (terrestrial and aquatic) used for nutritional purposes	1.1.6.1
	Fibres and other materials from wild animals for direct use or processing (excluding genetic materials)	1.1.6.2
	Seeds, spores and other plant materials collected for maintaining or establishing a population	1.2.1.1.
	Hydrological cycle and water flow regulation (Including flood control, and coastal protection)	2.2.1.3.
	Wind protection	2.2.1.4
	Decomposition and fixing processes and their effect on soil quality	2.2.4.2.
	Regulation of chemical composition of atmosphere and oceans	2.2.6.1.
	Regulation of temperature and humidity, including ventilation and transpiration	2.2.6.2.
	Characteristics of living systems that that enable activities promoting health, recuperation or enjoyment through active or immersive interactions	3.1.1.1.
	Characteristics of living systems that enable scientific investigation or the creation of traditional ecological knowledge	3.1.2.1.
	Characteristics of living systems that enable education and training	3.1.2.2.
	Characteristics of living systems that enable aesthetic experiences	3.1.2.4.
	Ground (and subsurface) water for drinking	4.2.2.1.

InVEST models are spatially explicit, using maps as sources of information and generating maps as source data. InVEST produces results either in biophysical units (eg tonnes of carbon sequestration) or in economic units (eg net present value of this carbon sequestration). Spatial resolution analysis is also flexible, allowing users to address issues locally, regionally or globally.

The tool is modular – you do not need to model all these ecosystem services, but you can choose only those that need to be evaluated.

InVEST provides information on how changes in ecosystems can lead to changes in the flow of benefits that ecosystem services provide to humans. Environmental decision-makers inevitably need to assess trade-offs between different types and scenarios of natural resource use. InVEST's multiservice modular design provides an effective tool for studying the possible consequences of alternative management and climate scenarios, as well as for assessing trade-offs between sectors and services. For example, government agencies may use InVEST to make territorial management decisions to provide the desired range of benefits to people or to mitigate the effects, to support natural benefits to society. Environmental organizations can use InVEST to better align their biodiversity objectives with activities that improve people's living conditions. Businesses can use InVEST to decide how and where to invest in natural capital to ensure the sustainability and security of their supply chains.

InVEST can help answer the following questions:

- Where do ecosystem services come from and where are they consumed?
- How does the proposed forest management plan affect biodiversity, water quality and recreation?
- What types of coastal and fisheries policies will work best for sustainable fishing, shoreline protection and recreation?
- Which parts of the catchment provide the highest rates of carbon sequestration, biodiversity and tourism?
- Where can reforestation achieve the greatest benefits of downstream water quality while maintaining or minimizing losses in water flows?
- How will climate change and population growth affect ecosystem services and biodiversity?
- What benefits does marine spatial planning bring to society in addition to fisheries and aquaculture products and safe places for renewable energy facilities?

InVEST uses a simple structure that separates "supply, service, and value" to relate productive functions to the benefits people receive (Fig. 2.31).

Fig. 2.31. Chain of supply of ecosystem services

"Supply" represents what is potentially available in the ecosystem (ie what can provide the structure and functions of the ecosystem). For example, supporting a diversity of fish fauna or high water quality in a river, which supported by the free flow of the river. "Service" includes demand and therefore uses information about the beneficiaries of the service (for example, where people live, important cultural sites, infrastructure, etc.) "Value" includes social benefits and allows the calculation of economic and social indicators (for example, the number of people who used the services of fishing or recreation, the amount of water used for water supply of the required quality, etc.).

The Reservoir Hydropower Production model (also known as Water Yield) of the InVEST software package is used to assess the ecosystem services of river basins. [14]. This model allows to estimate the relative contribution of water from different parts of the landscape, offering an understanding of how changes in land use patterns affect annual surface water and hydropower production. However, the capabilities of the model are much wider. In particular, it was used to assess the change in the provision of three hydrological ecosystem services to the Llobregat River Basin (Spain), which provides drinking water to Barcelona. These are water supply (regulation) and regulation (water purification and erosion control) services.[15].

The idea of this study was to assess the feasibility and obstacles in the application of the "Water Yield" model to assess the ecosystem services of the Uzh River Basin, given the use of the river to generate electricity on the derivation channel by Onokiviyivska and Uzhhorod HPPs (near Uzhgorod). It is assumed that constant current of the river should be provided to support the river and coastal ecosystems of the Uzh River in the section of the flow from the dam in the village. Kamyanytsia to the place of return of the derivation canal in the Uzh River (see fig. 3). With a flow rate of less than 10 cubic meters / s, which in recent years has been observed from June to October (Fig. 10), it is assumed that the diversion of the flow from the river bed will have negative consequences for ecosystems, as a result of which the ecosystem services of river are lost on this section of river. Among such ecosystem services according to the CICES classification it is possible to allocate 1.1.6.1, 2.2.1.3, 2.2.5.1, 2.2.6.1, 2.2.6.2, 3.1.1.1, 3.1.2.1 and others (Table. 4).

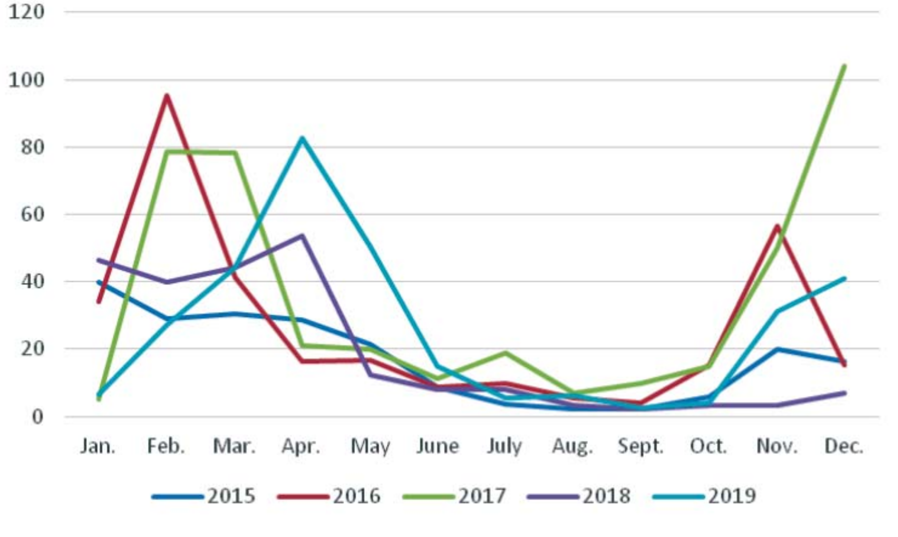

Fig. 2.32. Flow rates of the Uzh River in the area of the city of Uzhgorod

[14] https://naturalcapitalproject.stanford.edu/software/invest-models/reservoir-hydropower-production-water-yield

[15] https://doi.org/10.1016/j.ecolind.2013.01.016

At the same time, it should be noted that the operation of two HPPs on the created derivation channel is the use of ecosystem service 4.2.1.3. Thus, the deepening of the derivation channel and almost complete drainage of water from the natural channel for the use of one ecosystem service has a negative impact on a number of others, at least for this section of the river.

In this and similar cases, the assessment of the impact of hydropower facilities on the environment using the Water Yield model of the InVEST software package allows to assess the water consumption of both existing HPPs and other ecosystem services by maintaining continuous free flow, as well as to predict possible changes in water flow. with land use change and climatic factors, which is extremely important for planning water basin management activities.

Additionally, the Water Yield model can be used, for example, to assess an ecosystem service on water treatment. It consists in the trapping of pollutants by landscapes, which ultimately do not enter the river bed. The benefits of such an ecosystem service can be assessed through the higher quality of water used for water supply, through the determination of the total content of priority pollutants such as nitrogen and phosphorus.

Modeling the relationship between landscape changes and hydrological processes is not simple. Complex models of these connections and related processes (such as the WEAP model) require significant resources and data and require significant experience. InVEST Water Yield maps and models the average annual water consumption for a particular landscape used for hydropower generation, rather than directly considering the impact of land use and land cover changes on hydropower. Instead, the model calculates the relative contribution of each land plot to the average annual hydropower production and the value of this contribution in terms of energy production.

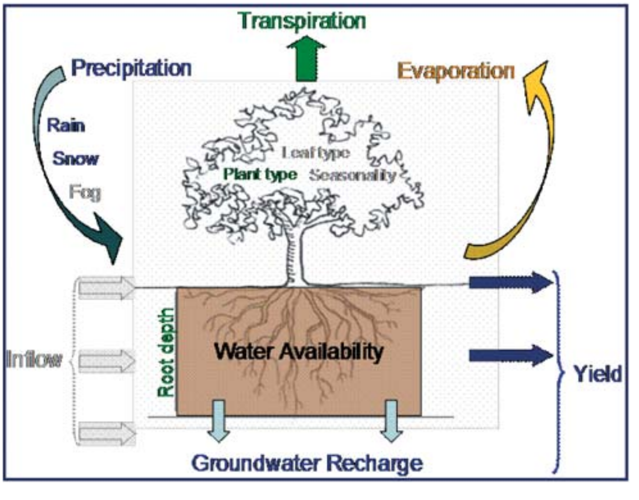

Fig. 2.33. Conceptual scheme of a simplified method of water balance in the Water Yield model

The model has three consecutive components. First, the amount of water flowing from each pixel is defined as the amount of precipitation minus the proportion of water that evaporates. Pixel-scale calculations allow to present the heterogeneity of the main driving factors of runoff formation, such as soil type, precipitation, vegetation type, etc. (Fig. 2.19). Second, according to the average annual runoff, the model calculates the share of surface water that is available for hydropower production. Third, the model estimates the energy produced by water.

Using the InVEST Water Yield model requires data that must be in the same coordinate system. The list of required data includes, in particular, such parameters about the basin area as precipitation and their distribution, evatranspiration, root layer depth, water evaporation by plants, available water content in soils, types of land use, boundaries of basins and sub-basins (Tab. 5).

The analysis of the availability and accessibility of the necessary source data for the use of the InVEST Water Yield model shows that all the necessary data at the national level are either mostly absent or available with limited or paid access, such as rainfall data, temperature, river flow. There are also no available digitized boundaries of river basins and sub-basins.

At the same time, the availability of open data resources covering the entire planet, including Ukraine (see Table 5), allows the use of ecosystem services assessment models, such as InVEST, although at the first assessment level.

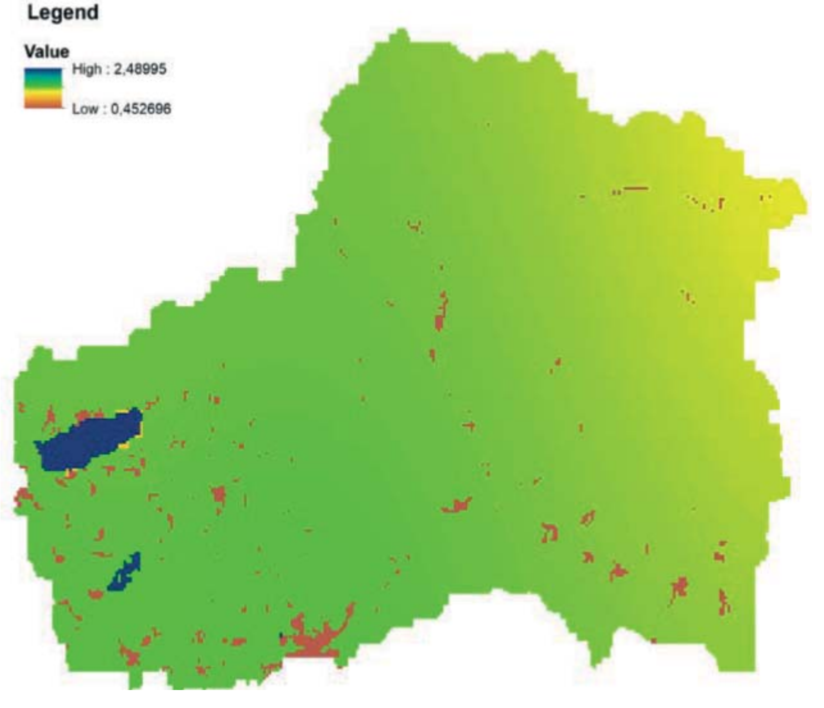

Fig. 2.34. Estimated actual evapotranspiration, mm

The results of the evaluation of the river basin already illustrates the possibilities of the InVEST Water Yield model in particular regarding the assessment of precipitation distribution, evapotranspiration (Fig. 2.20), contribution to the total runoff of the basin. Further research to assess ecosystem services should be aimed at refining the model on the basis of actual data and its verification.

Table 2.8. Basic data required for the operation of the InVEST Water Yield model

№	Parameter name	Data need	Data accessibility in Ukraine
1.	**Workspace (environment)**	Optional (necessary to save model data)	Available on any PC
2.	**Suffix**	Optional (necessary for scenario differentiation)	Available on any PC
3.	**Precipitation** (mm)	Necessarily	No precipitation data are freely available
4.	**Average annual reference evapotranspiration** (mm)	Necessarily	No national data. Proceedings of the International Agricultural Research Advisory Group (CGIAR) based on WorldClim climate data https://cgiarcsi.community/data/global-aridity-and-pet-database/ Crop evaporation – Guidelines for calculating water needs http://www.fao.org/3/X0490E/X0490E00.htm
5.	**Root restricting layer depth** (mm)	Necessarily	No national data. European Soil Database https://esdac.jrc.ec.europa.eu/content/european-soil-database-derived-data FAO Harmonized Soil Database – https://webarchive.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML/
6.	**Water content available to plants** (Share from 0 to 1)	Necessarily	No national data. European Soil Database https://esdac.jrc.ec.europa.eu/content/european-soil-database-derived-data U.S. Department of Agriculture (USDA) materials https://www.ars.usda.gov/research/software/download/?softwareid=492
7.	**Land use / land cover** (LULC codes must correspond to the values of “lucode” in the biophysical table)	Necessarily	There are no current national data. It is possible to use a cadastral map.Data of Copenicus Global Land Cover – https://lcviewer.vito.be Data of Climate Change Initiative (CCI) – http://maps.elie.ucl.ac.be/CCI/viewer/index.php Data of GlobeLand30: Global Geo-information Public Product http://www.globeland30.org/defaults_en.html?type=data&src=/Scripts/map/defaults/En/browse_en.html&head=browse
8.	**Watersheds** (shape-file)	Necessarily	No national data. HydroBASINS: http://hydrosheds.org/ InVest Auxiliary Tool “DelineateIT”
9.	**Sub watersheds** (shape-file)	Necessarily	No national data. HydroBASINS: http://hydrosheds.org/ InVest Auxiliary Tool “DelineateIT”

10.	**Biophysical table** (.csv). Each row is a land use / land cover class, and the columns should be named and defined as follows:	Necessarily	–
10.1.	*lucode (*Unique integer for each class of LULC*)*	Necessarily	It is determined by the type of land use. No national data. It is possible to use a cadastral map. Data of Copenicus Global Land Cover – https://lcviewer.vito.be
10.2.	*LULC_desc (*Descriptive name of the land use / land cover class*)*	Optional	It is determined by the type of land use. No national data. It is possible to use a cadastral map. Data of Copenicus Global Land Cover – https://lcviewer.vito.be
10.3.	*LULC_veg (*vegetative land use*, 1 or 0)*	Necessarily	It is determined by the type of land use. There are no current national data. It is possible to use a cadastral map. Data of Copenicus Global Land Cover – https://lcviewer.vito.be
10.4.	*root_depth (*The maximum root depth*, mm)*	Necessarily	No national data. European soil database https://esdac.jrc.ec.europa.eu/content/european-soil-database-derived-data Harmonized FAO soil database https://webarchive.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML/
10.5.	*Kc evaporation rate of plants, from 0 to 1.5)*	Necessarily	No national data. Guidelines for calculating water needs http://www.fao.org/3/X0490E/X0490E00.htm
11.	Z parameter (Floating point values of the order of 1 to 30, which corresponds to the seasonal distribution of precipitation)	Necessarily	Estimated parameter
12.	**Demand table**	Necessarily, when calculating the water deficit or assessment	–
12.1.	*lucode unique integer for each land use class)*	Necessarily	It is determined by the type of land use. There are no current national data. It is possible to use a cadastral map. Data of Copenicus Global Land Cover – https://lcviewer.vito.be
12.2.	*demand (cwater consumption in pixels, cubic meters / year)*	Necessarily	No national data

13.	**Hydropower assessment table**	Necessarily, if the assessment is carried out	Provided by the HPP operator. The U.S. National Inventory of Dams: http://nid.usace.army.mil/ Global Reservoir and Dam (GRanD) Database: http://www.gwsp.org/products/grand-database.html World Water Development Report II dam database: http://wwdrii.sr.unh.edu/download.html
13.1.	*ws_id (unique integer value for each HPP)*	Necessarily	
13.2.	*station_desc* (name of a HPP*)*	Optional	
13.3.	*efficiency (HPP efficiency, usually from 0.7 to 0.9)*	Necessarily	
13.4.	*fraction (the proportion of water used by hydropower plants)*	Necessarily	
13.5	*height (pressure on* HPP, *m)*	Necessarily	
13.6	*kw_price (cost of kV * h)*	Necessarily	
13.7	*cost (annual cost of HPP operation)*	Necessarily	
13.8	*time_span (duration of HPP operation, years)*	Necessarily	
13.9.	*discount (discount rate,%)*	Necessarily	

3. RECOMMENDATIONS FOR INTEGRATION OF ECOSYSTEM SERVICES INTO THE PRACTICE OF ENVIRONMENTAL ASSESSMENTS OF HYDROENERGY PROGRAMS AND PROJECTS. MOLDOVA AND UKRAINE

3.1. Recommendations for Integration of Ecosystem Services Valuation into Hydro-Construction Practice in Moldova

3.1.1. Using the results of mapping and assessment of ecosystems and their services in the practice of hydro-construction

The attractiveness of the concept of ecosystem services lies in taking into account a wide range of functions of natural capital and is based on its integrational, inter- and transdisciplinary nature, on the connection of environmental and socio-economic aspects. Evaluation of ecosystem services is necessary ***to solve a number of environmental and economic problems of the development of hydroelectric construction***, such as the economic justification of alternatives for the development of the territory; substantiation of additional costs in projects (programs) for environmental protection measures, which, together with environmental, have a large economic effect; prioritization and ranking of investments in the use and protection of ecosystems; provision of payments, credits, loans, grants to preserve ecosystems and their services.

Various methods for assessing ES are ***an important stage in making management decisions*** in the field of hydroelectric construction. The introduction of accounting the value of ecosystem services in business planning is rapidly developing in the world. Within the European Union, territorial modeling and mapping of ecosystem services for ***local business planning*** have acquired the greatest interest. In Moldova, there is still a ***process of realizing*** the importance of economic assessment of biodiversity and ES.

3.1.2. Identification of the main barriers to the implementation of ecosystem services valuation in the practice of hydro-construction

The practical application of the concept of ecosystem services is largely hampered by the lack of adequate methods for assessing their value. The objective reason for the difficulties that arise in the economic assessment of eco-services is the complexity of the organization of natural ecosystems, as well as insufficient knowledge of the functions and ongoing processes. In addition, the collection, analysis and exchange of information on the assessment of eco-services is an important stage in the implementation of the assessment of ecosystem services in the practice of making management decisions. However, in Moldova there is no monitoring system for ecosystem services, and monitoring of natural ecosystems (with the exception of forests) and components of biological diversity is extremely incomplete and does not correspond to the modern level of technology. Bioresource accounting systems do not provide complete data about their condition. The reliability of the official data is low. Many data on the state and dynamics of natural objects and processes are not available in the public domain, as well as publicly available information bases that integrate indicators for assessing ES. When obtaining the necessary information, significant obstacles arise, including those associated with its high cost.

When compiling maps, the most problematic issues are the choice of ES of specific landscapes, operational territorial units, the display of conflicts of interest when assessing ES, which is associated with both insufficient knowledge of the problem and information limitations.

3.1.3. The main directions of integration of the assessment of ecosystem services into the practice of hydroelectric construction

The positive experience of many countries proves the inevitability of drawing attention to economic assessment, monitoring and an adequate information base of the elements of natural capital. The use and implementation of various mechanisms for accounting the ecosystem services (payments, EIA, etc.) is impossible without the development of an ***information retrieval system*** for those indicators that will subsequently be monitored or taken as elements in the calculation of economic assessments (payments / damages). It is necessary to immediately begin to form a national system for monitoring and assessing ecosystem services, as well as taking their value into account when making decisions that affect natural systems. Its absence threatens environmental security and sustainable development of Moldova. It is also necessary to create a generally accepted ***methodology for assessing*** ES and guidelines for their use for specialists making managerial decisions in the field of environmental management. ***Legislative consolidation of obligations***, development of additional requirements for EIA and control over their implementation can give a positive environmental effect. The effectiveness of a rational attitude to nature is ensured ***at the EIA stage*** in the planning of hydraulic construction.

To create a solid foundation for ecosystem-safe hydro construction, a transition to the stage of ***developing standard solutions and scenarios for interaction with designers and builders*** should be ensured, and ***monitoring*** the state of ecosystems and ES should be carried out using GIS technologies under the control of special security agencies.

3.2. Recommendations for Integration of Ecosystem Services Valuation into Hydro-Construction Practice in Ukraine

3.2.1. Basis and state of implementation of ecosystem services assessments

Fulfillment of European integration commitments poses a task for Ukraine to fully and comprehensively implement the ecosystem approach. Ukraine's commitment to the ecosystem approach as the basis for sustainable development is enshrined in the Strategy of State Environmental Policy until 2030, adopted in 2019, which defines the principles of state policy transformation, in which environmental protection is identified as a new key priority. The aim of the state environmental policy is to achieve good environmental status by introducing an ecosystem approach to all areas of socio-economic development of Ukraine in order to ensure the constitutional right of every citizen of Ukraine to a clean and safe environment, introduction of balanced nature management and preservation and restoration of natural ecosystems.

The strategy determines that the introduction of an ecosystem approach to sectoral policies is one of the components on Ukraine's path to a modern systemic environmental policy implemented in the member states of the European Union. One of the five basic goals of the Strategy is to reduce environmental risks in order to minimize their impact on ecosystems, socio-economic development and public health.

The strategy recognizes that the development of ecosystem services will create opportunities for sustainable development of society and the ecosystem. Ukraine's biodiversity, which provides ecosystem services, must be preserved, assessed and restored by 2030.

The implementation of the ecosystem approach and the implementation of the Strategy is primarily possible through the Strategic Environmental Assessment (SEA) and Environmental Impact Assessment (EIA) procedures recently introduced in Ukraine, in accordance with the requirements of the Association Agreement between Ukraine and the European Union. However, there is no legal and methodological basis for the introduction of the ecosystem approach in Ukraine, as in other Eastern Partnership countries.

In Ukraine, the ecosystem approach has not been used in SEA and EIA procedures not only for hydropower plans and programs, but also in general. This is confirmed by numerous reports on EIA of HPP construction projects, published in the Unified Register of EIA, which ignore public recommendations on the application of the ecosystem approach based on the identification and assessment of ecosystem services provided by river and associated ecosystems.

Existing SEA and EIA practices show that they focus, at best, on impacts on certain species of living organisms within certain habitats and do not provide an objective assessment of environmental impacts in terms of ecosystem impacts.

Ecosystem services of rivers are ignored, and their economic value is not assessed and taken into account, which leads to ignoring their loss in the implementation of hydropower programs and projects, as well as to unreasonable ideas about the relative cheapness of electricity produced at HPPs and PSPs.

The introduction of ecosystem services is especially relevant in the context of the new European Union Biodiversity Strategy until 2030, which, among other things, aims to restore the free flow of 25 thousand km of rivers, as well as the UN Declared Decade for Ecosystem Restoration 2021-2030, which was conceived as a mean of highlighting the need for much enhanced global cooperation to restore degraded and destroyed ecosystems.

The application of the ecosystem approach – identification and assessment of ecosystems and their services, prevention of their negative changes and losses due to the impact of hydropower facilities – is a tool for the transition to a balanced hydropower.

3.2.2. Identification of the main barriers to the implementation of ecosystem services assessment

The concept of ecosystem services has been actively developing in the European Union over the last decade. In particular, the ESMERALDA project analyzed existing methods and generalized experience in assessing ecosystem services. There are also cases of estimating the loss of ecosystem services for plans and projects in the field of hydropower (Guihua Wang et al., 2010), which confirm the possibility and necessity of implementing ecosystem services in the decision-making process.

Ukraine's experience in ecosystem services is still limited to scientific publications with an overview and recommendations for the use of ecosystem services (Gavrylenko, 2018, Prykhodko et al., 2020).

The main obstacles to the introduction of ecosystem services in the hydropower sector can be divided into several groups: legislative, institutional, regulatory and methodological.

Legislative obstacles include the lack of regulation at the legislative level of the implementation of the ecosystem approach in sectoral policies and the legal framework for ecosystem services.

The lack of a legal framework identifies gaps in institutions that would be responsible for identifying and mapping ecosystems, determining their status, and implementing appropriate monitoring. The results of the assessment of ecosystems and their services for the river basin have already shown the lack of necessary information on the state of the environment required for the assessment of ecosystems according to the conceptual model of MAES adopted in the EU (see **Fig. 1.1**). The problem of the absence of a system of remote (satellite) monitoring of the territory of Ukraine should be singled out, which does not allow to conduct actual mapping of ecosystems, to monitor changes in their boundaries and condition.

Regulatory barriers include the lack of approved methods for assessing ecosystems and their services in SEA and EIA procedures for hydropower programs and projects. There are no tools for economic evaluation of ecosystem services, poorly developed direction of scientific substantiation of evaluation of ecosystem services. The consequences of gaps in the regulatory framework are the further degradation of vital river and associated ecosystems and their services due to the operation of existing hydropower facilities and the construction of new ones without taking into account and compensating for losses to ecosystems and other users of ecosystem services.

3.2.3. The main directions of integration of ecosystem services assessment

Ukraine, having a difficult history of ruthless exploitation of the major rivers (Dnipro, S. Bug, Dniester, etc.), needs to introduce an ecosystem approach primarily to preserve and restore river and associated ecosystems.

As a party to the Convention on Biological Diversity, Ukraine should participate more actively in the work of the Intergovernmental Scientific and Policy Platform on Biodiversity and use the experience of the platform and the MAES working group to develop a regulatory framework for implementing an ecosystem approach in SEA and EIA procedures, in particular for hydropower programs. and projects.

Methodical documents on conducting SEA and EIA of hydropower programs and projects should be based on the ecosystem approach, provide for the establishment of ecosystems in the area affected by the planned activities, determine their status, identification and assessment of ecosystem services they provide. The purpose of such assessments should be to prevent significant adverse impacts on ecosystems and their services, to minimize residual impacts and to compensate for measures required in the event of ecosystem disturbance and lost ecosystem services. This approach should ensure the preservation of free-flowing rivers, the role of which remains underestimated, mitigate the impact of existing hydropower facilities through their modernization and application of the best available solutions, restoration of ecosystems.

Especially important is the introduction of economic evaluation of ecosystem services, which requires a thorough scientific substantiation. In this regard, it seems appropriate to establish a national scientific expert group to identify key areas of research needed to implement the ecosystem approach and ecosystem services, in particular in the hydropower sector. In addition, such a group should aim to address the general guidelines for mapping and assessing ecosystems and their services and to support the process of their implementation in national policies. Recommendations should be based on the experience of implemented European projects, such as ESMERALDA and OpenNESS, as well as best European and global practices in the use of the ecosystem services tool.

Ukraine should aim to fully join the European system of ecosystem mapping, which is carried out using the service of monitoring the earth's surface of the EU program Copernicus[16]. To do this, Ukraine should adopt the typology of ecosystems used in the EU (see Table 1.1).

A key element not only for the implementation but also for the widespread use of the ecosystem services tool is the improvement of the environmental monitoring system. State policy in the field of environmental protection should aim at reforming the monitoring system, which would allow obtaining the necessary data for mapping and assessment of ecosystems and their services, as well as ensuring convenient formats and free access to data, synchronization of data with relevant European data registers.

For the comprehensive implementation of ecosystem services in decision-making processes in different areas and at different levels, including in the procedures of SEA and EIA of hydropower programs and projects, it is recommended to develop and approve at the governmental level a framework guideline based on European principles[17].

[16] https://www.eea.europa.eu/themes/biodiversity/mapping-europes-ecosystems

[17] https://ec.europa.eu/environment/nature/ecosystems/pdf/SWD_2019_305_F1_STAFF_WORKING_PAPER_EN_V2_P1_1042629.PDF

CONCLUSIONS

Over the last decade, the concept of ecosystem services has been actively developing in the European Union. As part of the implementation of the EU Biodiversity Strategy until 2020, a typology of ecosystems has been developed, a general international classification of ecosystem services CISES has been proposed, existing tools for assessing ecosystem services have been considered and experience in their application has been systematized.

The introduction of ecosystem services is especially relevant in the context of the new European Union Biodiversity Strategy until 2030, which is an integral part of the European Green Course and, inter alia, aims to restore the free flow of 25 thousand km of rivers and the UN Declaration on Ecosystem Restoration of 2021-2030.

The European Commission has developed a guidance document for the integration of ecosystem services in the decision-making process, which notes that SEA and EIA procedures provide key opportunities for the integration of ecosystems and their services in the planning and approval of programs, plans and projects.

At the legislative level, Ukraine has approved the intention to introduce an ecosystem approach to all areas of socio-economic development as a basis for achieving good environmental status. The strategy of the state ecological policy until 2030 envisages the development of the institution of ecosystem services, which should provide opportunities for balanced (sustainable) development of society. However, Ukraine's experience in ecosystem services is still limited to scientific publications with an overview and recommendations for the use of ecosystem services.

Until now, ecosystem services of rivers and adjacent ecosystems remain out of focus when considering hydropower development plans and individual hydropower projects in Ukraine. The procedures for their strategic environmental assessment and environmental impact assessment do not require the identification and assessment of ecosystems and the services they provide.

Ukraine, having a difficult history of ruthless exploitation of major rivers (Dnipro, s. Bug, Dniester, etc.), needs to introduce an ecosystem approach primarily to preserve and restore river and associated ecosystems.

Pilot assessment of ecosystems and their services for the river basin has already identified a number of problems in the use of ecosystem services. They are related both to the lack of legal regulation and to the lack of the necessary registers of open data on the state of the environment, as well as methodological gaps. All of these groups of barriers to the use of ecosystem services are interconnected and need to be addressed comprehensively.

It is recommended to develop methodological documents on SEA and EIA of hydropower programs and projects, which should be based on the ecosystem approach, the need to identify and map ecosystems in the area affected by the planned activities, determine their status, identify and assess ecosystem services they provide. This approach should ensure the preservation of free-flowing rivers, the role of which remains underestimated, mitigate the impact of existing hydropower facilities through their modernization and application of the best available solutions, restoration of ecosystems.

Systematic solutions need to be addressed to improve environmental monitoring, which should provide up-to-date information on the state of ecosystems, as well as access to information related to the environment.

Ukraine, together with other Eastern Partnership countries, should deepen cooperation with the EU to develop an ecosystem approach and ecosystem services. Such cooperation should be comprehensive and include areas of scientific cooperation, development of regulatory and methodological framework, etc.

REFERENCES

Boyd, J., Banzhaf, S., 2007. What are ecosystem services? The need for standardized environmental accounting units. Ecological Economics 63, 616–626.

Burkhard, B., de Groot, R., Costanza, R., Seppelt, R., JArgensen, S.E., Potschin, M., 2012a. Solutions for sustaining natural capital and ecosystem services. Ecological Indicators 21, 1–6.

Burkhard, B., Kroll, F., Nedkov, S., Muller, F., 2012b. Mapping ecosystem service supply, demand and budgets. Ecological Indicators 21, 17–29.

Cazanteva O., Sirodoev G., Corobov R. and Trombitsky I., 2019: Some approaches to the economic valuation of the wetlands biodiversity in Moldova. J. Sci. Res. Stud. 6(3): 34-45.

CICES (Version 5.1), 2018: https://cices.eu/

Corobov R., Cazanteva O., Sirodoev Gh., Trombitsky I. Economic evaluation in the monitoring of Ecosystem services. Methodical Guide. Project BSB165 "HydroEcoNex", Chisinau: Eco-TIRAS, 2020. 86p.

Creation of a system of innovative transboundary monitoring of the transformation of ecosystems in the rivers of the Black Sea basin under the influence of hydropower development and climate change. HydroEcoNex project. – Chişinău: Eco-TIRAS, 2019. – 35 c. ISBN 978-9975-9611-8-9.

Crossman, N.D., Burkhard, B., Nedkov, S., Willemen, L., Petz, K., Palomo, I., Drakou, E. G., Martín-Lopez, B., McPhearson, T., Boyanova, K., Alkemade, R., Egoh, B., Dunbar, M.B., Maes, J., 2013. A blueprint for mapping and modelling ecosystem services. Ecosyst. Serv. 4, 4–14. https://doi.org/10.1016/j.ecoser.2013.02.001.

de Groot, R.S., Alkemade, R., Braat, L., Hein, L., Willemen, L., 2010. Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. Ecological Complexity 7, 260–272.

Dniester Commission website. Region. https://dniester-commission.com/bassejn-reki-dnestr/region/

Dniester transboundary river basin management plan. Part 1: General characteristics and condition assessment, 2019: https://dniester-commission.com/wp-content/uploads/2019/07/Dniester_TDA_July2019.pdf

Economic valuation in the monitoring of ecosystems services: Methodical guide / R. Corobov, O. Cazanteva, Gh. Sirodoev, I. Trombitsky; PROJECT BSB165 "HydroEcoNex". – Chişinău : Eco-Tiras, 2020. – 88 p.

Ecosystem types of Europe – version 3.1, 2019: https://www.eea.europa.eu/data-and-maps/data/ecosystem-types-of-europe-1

FAO. 2020. GLOBEFISH Highlights October 2019 ISSUE, with Jan. – Jun. 2019 Statistics – A quarterly update on world seafood markets. Globefish Highlights no. 4–2019. http://www.fao.org/3/ca7459en/ca7459en.pdf

Fisher, B., Turner, R.K., Morling, P., 2009. Defining and classifying ecosystem services for decision making. Ecological Economics 68, 643–653.

Fürst C., Luque S., Geneletti D., 2017. Nexus thinking – how ecosystem services can contribute to enhancing the cross-scale and cross-sectoral coherence between land use, spatial planning and policy-making, International Journal of Biodiversity Science, Ecosystem Services & Management, 13(1): 412-421.

Gavrylenko O. (2018) Managing ecosystem services: strategy of implementation in Ukraine. Visnyk Kyivskogo na-

cionalnogo universytetu imeni Tarasa Shevchenka GEOGRAFIYA [Bulletin of Taras Shevchenko National University of Kyiv, Geography], 1 (70), 29-35
GEF, 2018: GEF guidance documents to economic valuation of ecosystem services in IW projects, GEF IW:LEARN, 171 p. https://iwlearn.net/resolveuid/0ffc8834-af39-488a-852a-4348fee97b85
Geneletti and Adem Esmail, 2018. Guidelines and recommendations to support the application of the final methods. Deliverable D5.4, EU Horizon 2020 ESMERALDA Project, Grant agreement No. 642007
Geneletti D. & Mandle L., 2017. Mapping of ecosystem services for impact assessment. In: Burkhard B, Maes J (eds.). Mapping Ecosystem Services. Pensoft Publishers, Sofia, 374 pp.
Grêt-Regamey, A., Weibel, B., S.-E.Rabe. & Burkhard, B., 2017. A tiered approach for ecosystem services mapping. In book: Mapping Ecosystem Services, Editors: Benjamin Burkhard, Joachim Maes, pp.213-217. Pensoft Publishers, Sofia, Bulgaria.
Guihua Wang, Qinhua Fang, Luoping Zhang, Weiqi Chen,, Zhenming Chen, Huasheng Hong. (2009). Valuing the effects of hydropower development onwatershed ecosystem services: Case studies in the Jiulong River Watershed, Fujian Province, China. Estuarine, Coastal and Shelf Science 86 (2010) 363–368. doi:10.1016/j.ecss.2009.03.02
How the Dniester hydroelectric complex affects the state of Dniester: an assessment of Moldovan and Ukrainian experts. https://dniester-commission.com/novosti/kak-dnestrovskij-gidrouzel-vliyaet-na-sostoyanie-dnestra-ocenka-moldavskix-i-ukrainskix-ekspertov/
Implementation of ecosystem approach and ecosystem services in hydropower sector of EaP countries: state and challenges / R. Havrilyuk, A. Gabrielian, E. Sultanov, I. Trombitsky, O. Stankevych-Volosianchuk, O. Tarasova. – 2019. – p. 76.
Implementation plan of strategic guidelines for adaptation to climate change in the Dniester basin, 2017: https://www.osce.org/files/f/documents/0/6/366726.pdf
La Notte, A., Vallecillo, S., Polce, C., Zulian, G. & Maes, J., 2017b. Implementing an EU system of accounting for ecosystems and their services. Initial proposals for the implementation of ecosystem service accounts, EUR 28681 EN; Publications Office of the European Union, Luxembourg.
Maes J, Teller A, Erhard M, Grizzetti B, Barredo JI, Paracchini ML, Condé S, Somma F, Orgiazzi A, Jones A, Zulian A, Vallecilo S, Petersen JE, Marquardt D, Kovacevic V, Abdul Malak D, Marin AI, Czúcz B, Mauri A, Loffler P, Bastrup-Birk A, Biala K, Christiansen T, Werner B, 2018. Mapping and Assessment of Ecosystems and their Services: Ananalytical framework for ecosystem condition. Publications office of the European Union, Luxembourg
Maes, J., Teller, A., Erhard, M., Conde, S., Vallecillo Rodriguez, S., Barredo Cano, J.I., Paracchini, M., Abdul Malak, D., Trombetti, M., Vigiak, O., Zulian, G., Addamo, A., Grizzetti, B., Somma, F., Hagyo, A., Vogt, P., Polce, C., Jones, A., Marin, A., Ivits, E., Mauri, A., Rega, C., Czucz, B., Ceccherini, G., Pisoni, E., Ceglar, A., De Palma, P., Cerrani, I., Meroni, M., Caudullo, G., Lugato, E., Vogt, J., Spinoni, J., Cammalleri, C., Bastrup-Birk, A., San-Miguel-Ayanz, J., San Román, S., Kristensen, P., Christiansen, T., Zal, N., De Roo, A., De Jesus Cardoso, A., Pistocchi, A., Del Barrio Alvarellos, I., Tsiamis, K., Gervasini, E., Deriu, I., La Notte, A., Abad Viñas, R., Vizzarri, M., Camia, A., Rob-

ert, N., Kakoulaki, G., Garcia Bendito, E., Panagos, P., Ballabio, C., Scarpa, S., Montanarella, L., Orgiazzi, A., Fernandez Ugalde, O. and Santos-Martín, F., Mapping and Assessment of Ecosystems and their Services: An EU ecosystem assessment, EUR 30161 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-17833-0 (online),978-92-76-22954-4 (supplement), doi:10.2760/757183 (online),10.2760/519233 (supplement), JRC120383.

Maes, J., Teller, A., Erhard, M., Liquete, C., Braat, L., Berry, P., Egoh, B., Puydarrieux, P., Fiorina, C., Santos, F., Paracchini, M. L., Keune, H., Wittmer, H., Hauck, J., Fiala, I., Verburg, P. H., Condé, S., Schägner, J. P., San Miguel, J., Estreguil, C., Ostermann, O., Barredo, J. I., Pereira, H. M., Stott, A., Laporte, V., Meiner, A., Olah, B., Royo Gelabert, E., Spyropoulou, R., Petersen, J. E., Maguire, C., Zal, N., Achilleos, E., Rubin, A., Ledoux, L., Brown, C., Raes, C., Jacobs, S., Vandewalle, M., Connor, D. and Bidoglio, G., 2013, 'Mapping and Assessment of Ecosystems and their Services. An analytical framework for ecosystem assessments under action 5 of the EU biodiversity strategy to 2020', Publications office of the European Union, Luxembourg (http://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/pdf/MAESWorkingPaper 2013.pdf) accessed 26 August 2020.

Maes, J., Teller, A., Erhard, M., Murphy, P., Paracchini,M.L., Barredo ,J.I., Grizzetti,B., Cardoso, A., Somma, F., Petersen, J., Meiner, A., Gelabert, E.R. ,Zal, N., Kristensen, P., Bastrup-Birk, A., Biala, K., Romao, C., Piroddi, C., Fiorina, C., Santos, F., Nar- uševičius, V., Verboven, J., Pereira, H.M., Bengtsson, J., Gocheva, K., Marta-Pedroso, C., Snäll, T., Estreguil, C., SanMiguel, J., Braat,L., Grêt-Regamey, A., Perez-Soba, M., Degeorges, P., Beaufron, G., Lillebø, A., Malak, D.A., Liquete, C., Condé, S., Moen, J., Östergard, H., Czúcz, B., Drakou, E.G., Zulian ,G., Lavalle,C., 2014. Mapping and Assessment of Ecosystems and their Services: Indicators for Ecosystem Assessments Under Action 5 of the EU Biodiversity Strategy to 2020. Publications Office of the European Union, Luxembourg.

Management of the transboundary basin of the Dniester: the establishment of reference indicators for assessing the ecological status of surface water bodies / ed. S.O. Afanasyev, O.V. Manturova. – К.: Кафедра, 2019. – 376 с. ISBN 978-617-7301-75-1

Management plan for the Ramsar area "Lower Dniester", 2017:. http://www.bioticamoldova.org/library/Plan%20managerial%20Nistrul%20de%20Jos.pdf

Management Scenario for Ramsar Site No. 1500 "Ungur-Goloshnitsa" (draft). http://www.bioticamoldova.org/library/SGF%20ManPlan_rus_fin.pdf

Millennium Ecosystem Assessment, 2005. Ecosystems and human well-being: Synthesis. Island Press, Washington, DC.

Millennium Ecosystem Assessment. 2005. Ecosystems and Human Well-being. UNEP, Island Press, Washington DC, 155 p. https://www.millenniumassessment.org/documents/ document.356.aspx.pdf

OSCE, 2019: Analysis of the impact of the reservoirs of the Dniester HPPs on the state of Dniester. https://zoinet.org/wp-content/uploads/2018/01/Dnestr.pdf

Prykhodko, M., Arkhypova, L., Horal, L., & Kozhushko, S. (2020). Concept of ecosystem services and its implementation in Ukraine. *Journal of Geology, Geography and Geoecology*, *29*(2), 387-397. https://doi.org/10.15421/112034

R. Korobov (ed.), 2004: The climate of Moldova in the XXI century: projections of changes, influences, responses. American Foundation for Civil Research and Development for the Former Soviet Union, Chisinau; Concept of a regional strategy for adaptation to climate change: 2012. Public organization "Ecospectrum". Bender.

R. Korobov, I. Trombitsky, G. Syrodoev, A. Andreev, 2014: Vulnerability to Climate Change: Moldovan part of the Dniester basin. International Association of River Keepers Eco-TIRAS, Chisinau.

Reserve "Yagorlyk". Reconstruction and management plan as a way to preserve biological diversity / International ecolog. Association of river keepers "Eco-TIRAS". ; scientific. ed. G.A. Shabanov. – Dubossary: Eco-TIRAS, 2011. – 128 c. https://www.eco-tiras.org/docs/Iagorlyk_small.pdf

Rules for the operation of the reservoir of the Dniester cascade of hydroelectric power plants and pumped storage power plants at the NPU 77.10 m buffer reservoir Report and recommendations for the updated draft of the Rules, 2018: https://dniester-commission.com/wp-content/uploads/2018/09/recommendations_operation-rules_Dniester_Serra_Oct2018_Rus-1.pdf

Shchegolev I.V., Shchegolev S.I., Shchegolev E.I., 2016: Endangered waterbirds in the river deltas of the Northern Black Sea region. Volume 1, Odessa, 258 p. https://www.eco-tiras.org/books/dead_birds.pdf

Strategic guidelines for adaptation to climate change in the Dniester basin, 2015: https://www.osce.org/files/f/documents/0/f/260316.pdf

Syrbe, R.-U., Walz, U., 2012. Spatial indicators for the assessment of ecosystem services: Providing, benefiting and connecting areas and landscape metrics. Ecological Indicators 21, 80–88.

TEEB, 2010. The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations. In: Pushpam Kumar (Ed.), Earthscan, London and Washington.

UK NEA, 2011. The UK National Ecosystem Assessment Technical Report. UNEP-WCMC, Cambridge.

Vihervaara, P., Mononen, L., Nedkov S., Viinikka, A., et al., 2018. Biophysical mapping and assessment methods for ecosystem services. Deliverable D3.3 EU Horizon 2020 ESMERALDA Project, Grant agreement No. 642007.

WFD, 2000: The EU Water Framework Directive – integrated river basin management for Europe. Available at: https://ec.europa.eu/environment/water/water-framework/index_en.html\

Willemen, L., Veldkamp, A., Verburg, P.H., Hein, L., Leemans, R., 2012. A multi-scale modelling approach for analysing landscape service dynamics. Journal of Environmental Management 100, 86–95.