UDC 330.15:502.33

Marharyta Radomska, PhD, Ass. Prof., Associate Professor of the Department of Environmental Sciences
ORCID ID: 0000-0002-8096-0313 ***e-mail:*** m.m.radomskaya@gmail.com

Oksana Tykhenko, Doctor of Technical Sciences, Ass. Prof., Professor of the Department of Environmental Sciences
ORCID ID: 0000-0001-6459-6497 ***e-mail:*** okstih@ua.fm

Taras Nazarkov, MSc, PhD student of the Department of Environmental Sciences
ORCID ID: 0000-0002-9971-9423 ***e-mail:*** tnazarkov28@gmail.com

National Aviation University, Kyiv, Ukraine

ECONOMIC VALUATION OF ECOSYSTEM SERVICES OF NATURAL PLANT ASSOCIATIONS OF THE PLUZHNE FORESTRY

Abstract. *Ecosystem services are the basis of human development and existence. The resilience and balance of ecosystems is the key to the well-being and comfort of the human race, but their role and value of services provided is often underestimated. The aim of the given research is to conduct economic assessment of ecosystem services of natural plant associations of the selected area – Pluzhne forestry. Forests are known to provide the most diverse and comprehensive complex of ecosystem services and thus represent complicated object for assessment. The first step of the assessment included formulation of the list of ecosystem services to be included into the assessment procedure, giving priority to the most well-studied. The second step was aimed at determination of the unit prices for the chosen services. They were elaborated based on similar valuations, sufficiently supported by research data. The resulted cost of ecosystem services provided were compared to the assessments, performed for forest ecosystems in Ukraine and European countries, which is an element of novelty and originality. Although there are noticeable deviations in specific value of ecosystem services per unit of forest area, the general trend in consistent with European experience. The reasons of differences could be explained by the choice of approaches to unit prices evaluation and list of services included into assessment. The obtained data are important for raising awareness of local population and authorities about the importance of ecosystems functioning and need to invest resources in their support and protection. Research works of such kind are still rare in Ukrainian academic sphere despite their high importance for efficient management of environment quality and use. Thus, there is a clear need develop this research field and the given research contributes theoretical and applied provisions for further assessments of such kind.*
Keywords: *forest ecosystem; support of ecosystem services; unit service price; direct and indirect valuation.*

https://doi.org/10.32347/2411-4049.2023.1.43-58

Introduction

The concept of ecosystem services, as certain benefits received by a person from nature in its modern formulation, originated in 70s and went though some steps of reconsideration and terminological variations: nature services (Holdren, Ehrlich, 1974; Westman, 1977), environmental services (Wilson, Matthews, 1970); public services of the global environment (Ehrlich et al., 1977) and nature functions (De Groot, 1992), and finally, ecosystem services (ecosystem services Ehrlich, Ehrlich, 1981). The final formulation, which is now widely accepted and used in the given research, was established in the Millennium Ecosystem Assessment (MEA) (2003, 2005) [1]. The central idea of this collective work under the auspices of the UN was to form clear understanding of nature role in our well-being. The reflection of this task is seen in multiple works on the identification and valuation of ecosystem services that followed the publication of this report.

According to the Millennium Ecosystem Assessment, ecosystem services can be divided into the following four classes:

1. Provisioning Services represent materials and products that people extract from nature, including food, drinking water, timber, etc.

2. Regulating Services are natural process, which make life possible for people: cleaning air and water, decomposition of wastes, prevention of erosion. All these processes work together to make environment safe, functional and resilient.

3. Cultural Services include attributes of nature, able to provide spiritual and cultural needs and development of people, recreation, research and education.

4. Supporting Services are fundamental process, which make ecosystems themselves able to exist and function. These are natural processes, such as photosynthesis, nutrient cycling, the creation of soils, the water cycle, etc. Without supporting services, provisional, regulating, and cultural services wouldn't exist.

The formulation of the fact, that nature makes key contribution to our well-being, the concept of ecosystem services implies the need to account these services in making decisions about nature use and expansion of human activity. Therefore, ecosystem services are gaining recognition in the national environmental policies and legislation of many countries, undergo spatial attribution and financial valuation with corresponding market development. The most important achievement in the field of ecosystem services research is the fact that they are not considered inexhaustible and free. Most countries gradually realize that ecosystem services must be paid for and at the same time must be preserved and developed.

Different ecosystems provide the necessary services to varying degrees and assortment. This must be accounted when planning economic and protection measures. Moreover, under current intensity of human intervention into natural ecosystems a compulsory element of any policy or project is the purposeful support of ecosystem services.

Conceptual framework: forest ecosystem services

Existing international guidance documents such as the UN Forest Instrument and the UN Strategic Plan for Forests provide a framework for national actions and international cooperation to sustainable management of forests. This framework is also the tool for integration of forest ecosystem services support into all aspects of national policymaking and planning. Countries must introduce legal incentives to acknowledge the role of ecosystem services in the overall national prosperity and environmental safety.

A range of comprehensive theoretical and practical works cover many of the aspects of forest ecosystems functioning and their role in the balance of biosphere and human civilization. In particular, Jenkins and Schaap state that the support of ecosystem services from forests is the way to achieve not only SDG 15, but generally progress to sustainability at regional and further to national level [2]. Through the analysis of the related publication it is possible to see that number of identified ecosystem services is growing and has already reached 100 [3]. The issues of forest ecosystem services are most intensively studied in the USA, Australia, the United Kingdom, Canada, Germany and Spain [4]. The number of such research is growing since there is increasing interest to the assessment of ecosystem resilience and ability to sustain the welfare of population.

In Ukrainian research community the theme of ecosystem services is also gaining popularity. L. M. Arkhypova, B. V. Burkynskyi, V. F. Horiachuk, N. V. Dehtiar, E. V. Mishenin, A. A. Osaul, M. M. Prykhodko, I. P. Solovii, M. A. Fedorenko, M. A. Holubets have published relevant works, however, most of them deal with ecosystem services as components of natural resources potential of territories [5]. At the same time ecosystem services are gradually becoming a factor of importance in making decisions about land use practices [6] and in the support of environmental safety at urban areas [7]. As for the forests ecosystem services specifically, a limited number of works is available; the most cited are focused on recreational services [8], restoration of degraded forest for the provision of ecosystem services [9], rural communities' dependence on provisioning forest ecosystem services [10] and source of financial support for sustainable transformations in the region [11].

Mechanisms of forest services provision represent a broad field of research, which grants new opportunities for provision of many human needs and builds up understanding of the nature's functioning regularities [12]. The core of ecosystem services provision by forests is biodiversity of forest communities [13, 14], which is currently decreasing due to practice of substitution reforestation with single species plantations [15]. Moreover, even the commercial plantations of mixed composition have higher potential for ecosystem services provision compared to respective plant monocultures [16]. The other parameters like stand-level forest attributes (including structure, composition, vertical and horizontal stand heterogeneity) and environmental factors (location, soil depth, pH and slope) of the area are also of great importance [17]. Thus, the most favorable preconditions for the supply of ecosystem services exist in natural forest associations or at least well managed mixed plantations [18]. This provides additional solid reason for the preservation of old-stand forests over any form of reforestation. However, this must be clear not only to scientists, but also to the managers and local communities and the best way to deliver such information is through the monetization of the services provided.

Measuring ecosystem services is currently developing in three major directions – monetary valuation, modeling and mapping, with monetary valuation most popular initially and non-monetary valuation (modeling and mapping) has started to gain popularity in recent years [19]. Mapping is able to present spatial distribution of the services provided, but often lacks the demonstration of the interactions between formation, delivery and consumption [20]. Modeling of ecosystem services uses mechanistic, probabilistic, statistical, GIS and conceptual models, and the mechanic approaches and GIS-based models were the most frequently used. Despite the well developed background, modeling is not the top choice for ecosystem services analysis due to the need in extensive data and use of non-specialized software, which reduces quality of the data received [21]. Finally, valuation of ecosystem services using economic tools is the most widely implemented method generally and for those from forests in particular [22].

The fundamental principles of ecosystem services valuation were set by the research compiled by The Economics of Ecosystems and Biodiversity (TEEB) global initiative. It is an international initiative led by Pavan Sukhdev from 2007 to 2011 to bring into the light the real value of nature functioning [23]. Still the question of economic assessment of ecosystem services has been raised before that and the first publications on the topic are dated with 1995. Since then over a thousand works were published. A meta-analysis of the papers dealing with valuation of ecosystem services over the period from 1995 to 1997 revealed that most of them (80% of studies) considered multiple functions of forests, but the biggest attention was paid to the regulating services [24]. The same analysis has demonstrated that the study of ecosystem services is more active and covers a variety of forests by types and management status, while forests in mountain regions in low to lower-middle income countries were considered in only few works. Some reasons for this disparity in ES research under four themes are discussed, in connection with the global climate change, biodiversity policies, and national, bilateral and multilateral initiatives.

In Ukraine evaluation of forest ecosystem services is also studied, but mostly in the field of theoretical foundations of the assessments [25], generating funds for implementation of sustainable practices in branches of economy [26] and changing composition of plantations towards greater diversity [27]. However, case studies with real valuation data are very limited, but involve different types of forests communities: shelterbelts [28], protected areas [29, 30] and timberlands and forestries [31]. Under such conditions, there is a need to expand the application of forest ecosystem services valuation to enable comparative analysis of forest communities, attract investments in their protection and conservation, as well as aggregate new theoretical data about the functioning of forest ecosystems and develop practical recommendations for the strengthening of services provision. So, **the aim of the research** was to valuate ecosystem services of a forest and compare the results obtained with other case studies available for Ukraine. The sample forest ecosystem for investigation was the Pluzhne forestry.

Methods and materials

Valuation methodology

Forests are known to be suppliers of the most diverse ecosystem services among all types of ecosystems [32, 33], but these depends on their attributes [14]. Quite often the value of forest ecosystems is limited to only provisional services [34] and underrates cultural and supporting services [17]. However, it is necessary to account all the services we are aware of by the date of calculation. At the same time, valuation of service is possible if there is a market for it or the mechanism of its provision produces some measurable and sellable outcomes. In all other cases it is necessary to apply some indirect approaches to evaluate the obtained benefits.

Valuation of ecosystem services is still a complicated task, due to multiple issues and the nature of the most of ecosystem services:

- the larger the scale of the study, the more difficult it is to determine the economic value of forest ecosystem services;
- the results of the assessment of the economic value of forest ecosystem services are valid only for one specific area and cannot be extended to others;
- the value of the economic value of forest ecosystem services may change over time, so it is necessary to periodically review and evaluate them;
- the choice of method affects the resulted sums considerably;
- the volume/amount of the service provided can be measured differently or is accepted based on some evidence, but not direct measurements;
- expert opinion is often a part of all steps of the research and computation procedure, which inevitable reduced the reliability of the obtained results.

Accounting all the mentioned limitations of the forest ecosystem services assessment the valuation of ecosystem services, presented in the given paper was based on a combination of direct and indirect methods, depending on the type of service (Table 1) and prices per unit of services were derived from few sources:

- official financial reports of the forestry (OFR);
- recommendations of the international expert groups;
- data from open access publications;
- personal elaborations, based on the available information about the essence of ecosystem service.

Table 1. Unit prices for ecosystem services

Name of service	Subunit	Units	Price, USD/unit	Source of price and comments
Provisional services				
Wood	*Round timber*	USD/m^3	95	OFR for 2021
	Firewood	USD/m^3	55	OFR for 2021
Non-timber products	*Berries*	USD/kg;	3	Average market price
	Mushrooms	USD/kg (dry mass)	20	Average market price
	Hazelnut	USD/kg	4	Average market price
	Resin	USD/kg	3.75	Average market price
Game	*Roe deer*	USD/ind.	750	Average price in the hunting season 2021–22 based on the analysis of the game reserves in the same oblast
	Boar	USD/ind.	250	
	Fox	USD/ind.	8.75	
	Hare	USD/ind.	6.25	
Grass	*Hay*	USD/t	45	OFR for 2021
	Pasturing	USD/ind.	1.5	Average price established in the oblast based on open data
Medicinal plant	*Rosehip*	USD/kg	10	Average market price
	Leaves of wild strawberry and Blackberry	USD/kg	8.75	Average market price
	Linden	USD/kg	12.5	Average market price
Regulatory service				
Regulation of climate = carbon sequestration	*Carbon storage in soil*	USD/t	40	[2], [35], [36] Accepted accounting the growing price under the pressure of climate change threats
	Carbon used by phytomass	USD/t	40	
Soil stability	*Erosion prevention*	USD/ha	96	[37]
Soil formation	*Soil profile development*	USD/ha	10	[37]
Flood prevention	*Water retention*	USD/ha	820	Elaborated from [37] and [38], accounting low flood risk of study area

Name of service	Subunit	Units	Price, USD/unit	Source of price and comments
Air quality regulation	*Dust retention*	USD/ha	416	[37]
	Oxygen generation	USD/ha	400	Oxygen generated from ha was taken from [39] and combined with market price of oxygen
	Cooling effect	USD/ha	20.75	[37]
Clean water	*Water purification*	USD/ha	96	Elaborated from [40]
Supporting services				
Nutrient cycling and provision	*Mobilization of atmospheric nitrogen*	USD/ha	146	[37]
Adsorption of waste and toxins	*Mineralization and decomposition of dead matter*	USD/kg	87	[37]
Biodiversity	*Genetic resources*	USD/ha	19	Mean values for contingent assessment at the study area and results from [41–42]
Cultural services				
Aesthetic value	*Scenery*	USD/ha	3.5	Data obtained by contingent assessment
Recreation	*Non-organized visitors*	USD/person	4	
Ecotourism	*Organized tourists*	USD/person	5	Data provided by the staff of the forestry, based on the price for excursion.
Educational	*Venue for education*	USD/hour	4	Standard payment for training

Contingent assessment of cultural ecosystem services was conducted according to the recommendations of [43] and involved survey among the population, local to the area. The survey involved 62 respondents, each of whom is a native of the area and has lived there for more than 10 years. The age of the respondents is 18–75 years. The survey was conducted through a personal meeting with each respondent, which included a short 3-minute information introduction. The respondents were asked to suggest how much they are ready to pay for keeping the forest view intact and how much they would pay for the access to the forest for recreation if it stopped to be open access.

Site description

The Pluzhne forestry is a part of the state enterprise "Izyaslav forest enterprize" and is located in its northern part at the territory of Shepetivka administrative district of Khmelnytsky oblast. The area of forestry location belongs to the zone of western forests of the Male (Small) Polissya region. The forest area is 7490 hectares. The climate is temperate continental. The average annual temperature is +7 and the average annual rainfall is 510–580 millimeters. The duration of the growing season is 202 days from April 15 to October 25. The average depth of soil freezing is 73 cm, the maximum – 114 cm. A characteristic feature of the Pluzhne forestry is intensive erosive footprint – the area here is sometimes hilly with gentle slopes. The area is characterized by heavily eroded gray forest and podzolic soils.

The territory includes only forests. There are no water bodies on the territory. The composition of the plant community is dominated by coniferous trees, including Scots pine, Weymouth pine, European spruce and European larch. Overall, the main tree species on the territory of the forestry are pine (59%), oak (20%), birch (8%), alder (7%), spruce and other species (1–2%). The undergrowth mainly consists of buckthorn, mountain ash, hornbeam, hazel, etc.

The annual growth of wood in the tract is 6.7 m^3/ha per year. Recently, much attention has been paid to European and Japanese larch wood species, which are fast-growing and technically valuable wood.

Typical representatives of the fauna: hare, roe deer, wild boar, fox. Moose were spotted a few years ago, but have not been seen in these areas recently. There is also Pluzhne ornithological reserve of local importance in the western part of the Pluzhne forestry. The area of the reserve is 1.4 hectares. It was created in 1992 in order to preserve the natural hydrophytic complex of the wetland forest with a predominance of boreal (coniferous) forest-swamp, swamp and forest plant species, where blue pigeons and black storks (listed in the Red Book of Ukraine and Annex II of the Berne Convention) often settle. Among the species of plants listed in the Red Book, the reserve grows prickly plantain, Devella sedge, large astrantia, and common thicket. Accounting the presence of rare species the position "biodiversity" was added to the list of ecosystem services for the following assessment.

Economic and social importance of the forestry for local community is very high. Large number of local people works directly in forestry, so they assess forest resources as an opportunity for formal employment. Simultaneously, most of population use forest resources to meet their own needs: harvest firewood, building material, medicinal plants, mushrooms and berries. The forest itself plays a recreational role, but its recreational potential is not fully developed, since there is only one recreation area at the forestry, called "Pine Forest" and ecotourism and other forms of cultural services are just single cases. However, the forestry conducts active education program for school children and that was also accounted in the ecosystem services valuation.

The anthropogenic pressure on the ecosystem is quite noticeable, since mass felling of the tree stand takes place on a constant base, even though it is done according to all requirements. However, this does not negate the fact that this type of economic activity inflicts anthropogenic pressure. As for illegal logging, it is not common in this area. A more serious factor is illegal hunting of animals in terms of seasonal terms, volumes and methods used. The uncontrolled harvesting of medicinal plants, berries, mushrooms by local population is also the case for the given area. However, according to the opinion of the forestry staff and personal survey results during the field trips, the condition of the forest ecosystem at the site is normal, since it doesn't demonstrate degradation of the physical environment quality and plant community depression.

Results and discussions

Using the defined unit prices and specific parameters of the Pluzhne forestry, we have evaluated ecosystem services of this site (Table 2).

Table 2. Calculated costs of ecosystem services

Name of service	Subunit	Price, USD/unit	Number/Units	Cost, USD
Provisional services total = 5401116.656 USD				
Wood	*Round timber*	95	50180[1]	4767100
	Firewood	55	9792[2]	538560
Non-timber products	*Berries*	3	684[1]	2052
	Mushrooms	20	1764[1]	35280
	Hazelnut	4	476[1]	1904
	Resin	3.75	57.175[1]	214.41
Game	*Roe deer*	750	25[3]	18750
	Boar	250	10[3]	2500
	Fox	8.75	32[3]	280
	Hare	6.25	63[3]	393.75
Grass	*Hay*	45	450[1]	20250
	Pasturing	1.5	175[1]	262.5
Medicinal plant	*Rosehip*	10	7[1]	70
	Leaves of wild strawberry and blackberry	8.75	400[1]	3500
	Linden	12.5	800[1]	10000
Regulatory services total = 20932677.5 USD				
Regulation of climate = carbon sequestration	*Carbon storage in soil*	40	149800[4]	5992000
	Carbon storage in phytomass	40	25466[4]	1018640
Soil stability	*Erosion prevention*	96	7490[5]	719040
Soil formation	*Soil profile development*	10	7490[5]	74900
Flood prevention	*Water retention*	820	7490[5]	6141800
Air quality regulation	*Dust retention*	416	7490[5]	3115840
	Oxygen generation	400	7490[5]	2996000
	Cooling effect	20.75	7490[5]	155417.5
Clean water	*Water purification*	96	7490[5]	719040
Supporting services total = 1887480 USD				
Nutrient cycling and provision	*Mobilization of atmospheric nitrogen*	146	7490[5]	1093540
Adsorption of waste and toxins	*Mineralization and decomposition of dead matter*	87	7490[5]	651630
Biodiversity	*Genetic resources*	19	7490[5]	142310

Name of service	Subunit	Price, USD/unit	Number/Units	Cost, USD
Cultural services total = 50521 USD				
Aesthetic value	*Scenery*	3.5	7490[5]	26215
Recreation	*Non-organized visitors*	4	3700[6]	14800
Ecotourism	*Organized tourists*	5	1870[7]	9350
Educational	*Venue for education*	4	39[8]	156

Comments:

[1]Data represent maximal possible harvest based on the type of forest and percentage of productive area (based on the staff assessment), as well as records of the forestry for the previous years.

[2]Data about volumes of goods and services are derived from the official financial reports of the forestry.

[3]Number of each game type allowed for hunting at the territory of the forestry from official call for hunting season 2021–2022.

[4]Average annual sequestration rate of carbon by phytomass and soil was derived from [44] and [45] respectively and multiplied by the area of the forested territory.

[5]Service is provided by the whole area of the forest.

[6]Recreation is only possible at the territory, limited by the economic activity area and preserved area.

[7]Areas, possessing ecotourism potential represent approximately 25% of the forestry according to the staff.

[8]The area of 39 ha is allocated for the educational activity according to the official information from the staff.

So, for the given forestry provides ecosystem services by 28271795.16 USD annually, based on the above presented methodology and approximation. The most financially valuable are regulatory services, accounting limitations of our knowledge and market for most of them, this figure might be even underestimated. The supporting services are obviously underestimated too, since only three of them, for which some economic valuations are available in the open source publications, are accounted. Provisional services are the most accurately calculated, because they are provided by market prices and data on quantitative characteristics from official reports of the forestry. Direct cultural services occupy the last place due to their underdevelopment and non-prevalence in this area.

The most important issue of the obtained valuation is the choice of unit prices. They are partially derived from open access works for forests of the similar type or at least the same natural zone. Moreover, some of them are referred to different periods and are the subject of the USD purchasing power changes. However, the cost of the service might be modified by other environmental, economic and political issues, which doesn't follow financial trends. This is especially seen in the case of carbon sequestration, which will probably increase its value under the pressure of environmental problems induced and international responsibilities on climate change mitigation taken by the countries. This possibility is already under consideration in the recent research and was accounted in the unit price definition. But the factors of anthropogenic pressure and climate change and other impacts may change over time, modifying the quality and quantity of the delivered services.

Another possible limitation of the valuation covers the indirect valuation of cultural prices using contingent assessment. The results of such studies are highly dependent on the educational component, public awareness and environmental policy of the country on the whole. They are also affected by the demographic characteristics of respondents and focus of the assessment, for which survey is conducted, which is widely discussed in literature [46].

In general, all the data obtained are relevant only for this area and for a short period of time. There are not many similar research results for the forests of Ukraine, but their comparison (Table 3) shows that there is a immense difference in the results obtained by assessments due to lack of single standard methodology. However, this is also the case for the similar assessments across Europe, demonstrated in recent meta-analysis [47]. Of the total 60 papers analyzed, the mean value of temperate broadleaf and mixed forests was set at the level of 1204 USD/ha per year, which was much larger compared to the corresponding figure for Mediterranean and conifer forest biomes. The valuations were done using mostly cost-based and price-based methods, when over 80% of provisioning services were valued by direct price-based approaches and cultural services were calculated using indirect (survey) methods, as in the given study. The valuation obtained is based on a limited number of services, on average 8 group of services, including timber and non-timber provision, air quality, climate regulation, habitat maintenance, liquid flows, and leisure.

In the given research the obtained value is higher than those in European publications due to higher number of services accounted and different approach to the calculation of climate regulation: it was done based on the amount of carbon sequestered in phytomass and soil, rather than cost-based approach widely used in similar publications.

Table 3. Comparative analysis of the ecosystem services valuation for selected forests

Name of forest	State enterprise “Pluzhne forestry”	State enterprise "Vovchanske forestry"	National natural park “Holosiivsky”
Location	Shepetivka administrative district of Khmelnytsky oblast	Vovchansk, Kharkiv and Chuhuiv administrative district of Kharkiv oblast	Kyiv city, Kyiv oblast
Area, ha	7490	27930	10988
Composition of phytocenosis	Mixed forest (pine, oak, birch, alder)	Mixed forest (oak, pine, aspen, maple, birch)	Deciduous forest (hornbeam, oak, maple, linden)
Services accounted	Provisioning, regulatory, supporting and cultural	Provisioning, regulatory	Provisioning, regulatory, supporting and cultural
Methods of valuation	Direct, indirect	Direct	Direct
Total value of services provided, USD/ha*	3774.6	4894.8	249297.9
References	Current research	[28]	[29, 48, 49]

*In order to enable a comparison between economic values, they were standardized to 2021 international US$ dollars per hectare per year.

The provision of ecosystem services by the natural environment has always been free of charge. From the point of view of financial payment, few people understand that all natural resources, even if they cannot be assessed as a market commodity, must be paid for. However, the information about the real value of the forests people leave by is important to raise their awareness about the dependence of their well-being on forests. This will contributed to more balanced personal use of forest resources and more attentive public control over the management of forests by authorities. It will also substantiate the need to invest efforts and finance in the actions aimed at the support of ecosystem services provision. In particular, at the local level there is a need to improve environmental awareness of local residents and authorities and develop ecological tourism on the basis of the forestry. At the level of forest enterprises and protected areas the study and valuation of ecosystem services provided should be initiated and supported. For this, the national regulatory framework must be created, including the following measures:

- formulate the role of ecosystem services as a separate commodity/value in legal documents;
- update methodological approaches to the assessment of ecosystem services;
- develop ecosystem services inventory for protected areas and forest enterprises;
- develop and implement action plans at protected areas and forest enterprises directly aimed at the support of ecosystem services.
- develop payment mechanism for these services;
- introduce the closed cycle of funds circulation in the environmental protection system – to self-support nature at the cost of funds received from its own resources.

These measures will develop more sensible and frugal use of natural resources and land use decisions. It will in turn contribute to the resilience of forest ecosystems and sustainability of local communities.

Conclusions

1. Stability and well-being in human existence and ecosystems are interdependent and inseparable. Natural complexes create conditions for humans' existence through a complex of functional processes and interactions, known as ecosystem services.

2. Adequate assessment is needed to preserve and maintain these processes, and currently there is a wide range of methods applicable for the valuation of ecosystem services, including direct and indirect approaches. In most cases a combination of methods should be used to obtain accurate results. And the exact methods applied depend on the type of service. The main valuation methods used in the work are direct and indirect market valuation, contingent assessment.

3. Forests are the most diverse and complex natural ecosystems, and as such they provide the widest range of services that need to be clearly identified and valued in order to be appreciated and protected.

4. The object under investigation was Pluzhne forestry, a part of the state enterprise "Izyaslav forestry". This area is characterized by a fairly high level of biodiversity and natural value, despite the anthropogenic impact. The territory has no water bodies, but is covered by mixed forest, dominated by pine and oak by 90%. It is actively logged according to the regulatory limits and also provides a wide range of non-timber products.

5. The list of ecosystem services, provided by the forestry, was formulated and evaluated using direct and indirect marketing valuation. The results demonstrated that the value of services far exceeds the direct incomes from traditional timber and non-timber products supply to the market. The regulatory services turned to be the most valuable, while cultural ones are the least expensive due to low development of recreational potential of such ecosystems. The supporting services were valued partially – only those, for which some approximations of unit prices are available in the literature. The resulted ecosystem value of 1 ha of the Pluzhne forestry was compared to similar research works of Ukraine and EU showing considerable deviations due to lack of consistent methodology. However, the order of numbers in the value was close to average European assessments.

6. The results of this work are the basis for further study of the forest ecosystem services in our country, both at the local and national level. The recommendations on the support of ecosystem services through the creation of legal framework were given together with the need to improve population and authorities' awareness about the ecosystem services to promote reasonable use and protection of forests and their resources.

REFERENCES

1. Millennium Ecosystem Assessment (MEA) (2005). Ecosystems and human well-being. Island Press, Washington.
2. Jenkins, M., & Schaapm B. (2018). Forest Ecosystem Services: Background Analytical Study. Background study prepared for the thirteenth session of the United Nations Forum on Forests.
3. Martín-López, B., Oteros-Rozas, E., Cohen-Shacham, E., Santos-Martín, F., Nieto-Romero, M., Carvalho-Santos, C., ... & Cramer, W. (2016). Ecosystem services supplied by Mediterranean Basin ecosystems. In *Routledge Handbook of Ecosystem Services* (pp. 405–414). Routledge.
4. Aznar-Sánchez, J. A., Belmonte-Ureña, L. J., López-Serrano, M. J., & Velasco-Muñoz, J. F. (2018). Forest ecosystem services: An analysis of worldwide research. *Forests*, *9*(8), 453. https://doi.org/10.3390/f9080453.
5. 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, 387–397. https://doi.org/10.15421/112034.
6. Havrylenko, O., & Tsyhanok, E. (2018). Degradation of ecosystem services of protected areas in urbanized zones. *Bulletin of Taras Shevchenko National University of Kyiv, 4*(73), 10–14. http://doi.org/10.17721/1728-2721.2019.73.2.
7. Soloviy, I. P., Nijnik, M.S., Deyneka, A.M., & Melnykovych, M.P. (2017). Reimagining forest policy, institutions and instruments through concepts of ecosystem services and social innovations: Ukraine in the focus. *Scientific bulletin of UNFU, 27*(8), 82-87. https://doi.org/10.15421/40270812.
8. Holubchak, O., Korol, S., Melnychuk, I., & Prykhodko, M. (2019, October). Optimization of forest ecosystem recreational services formation in conditions of decentralization in Ukraine. In *2019 7th International Conference on Modeling, Development and Strategic Management of Economic System (MDSMES 2019)* (pp. 227–231). Atlantis Press. https://doi.org/10.2991/mdsmes-19.2019.43.
9. Drebot, O., Shvydenko, I., Raichuk, L., Yaremko, O., Symochko, L., Vysochanska, M., ... & Kuchma, M. (2022). Rehabilitation of forest ecosystems taking into account modern international ecological trends in the context of the European green deal. *International Journal of Ecosystems and Ecology Science, 12*(2), 575–584. https://doi.org/10.31407/ijees12.2.

10. Zhyla, T., Soloviy, I., Zhyla, A., & Volosyanchuk, R. (2018). Mountain communities' households dependency on provisioning forest ecosystem services: the case of Ukrainian Carpathians. *Bulletin of the Transilvania University of Brasov. Series II: Forestry, Wood Industry, Agricultural Food Engineering*, 11 (2), 63–80.
11. Dankevych, S. (2021). Development potential of forest ecosystem services in Ukraine as a financial tool to ensure balanced land use. *Agrosvit*, *11*, 45–56. https://doi.org/10.32702/2306-6792.2021.11.45.
12. Mori, A. S., Lertzman, K. P., & Gustafsson, L. (2017). Biodiversity and ecosystem services in forest ecosystems: a research agenda for applied forest ecology. *Journal of Applied Ecology*, *54*(1), 12–27. https://doi.org/10.1111/1365-2664.12669.
13. Isbell, F., Calcagno, V., Hector, A. *et al.* (2011). High plant diversity is needed to maintain ecosystem services. *Nature*, 477, 199–202. https://doi.org/10.1038/nature10282.
14. Gamfeldt, L., Snäll, T., Bagchi, R., Jonsson, M., Gustafsson, L., Kjellander, P., ... & Bengtsson, J. (2013). Higher levels of multiple ecosystem services are found in forests with more tree species. *Nature communications*, *4*(1), 1340. https://doi.org/10.1038/ncomms2328.
15. Brockerhoff, E. G., Barbaro, L., Castagneyrol, B., Forrester, D. I., Gardiner, B., González-Olabarria, J. R., ... & Jactel, H. (2017). Forest biodiversity, ecosystem functioning and the provision of ecosystem services. *Biodiversity and Conservation*, *26*(13), 3005–3035. https://doi.org/10.1007/s10531-017-1453-2.
16. Jonsson, M., Bengtsson, J., Gamfeldt, L., Moen, J., & Snäll, T. (2019). Levels of forest ecosystem services depend on specific mixtures of commercial tree species. *Nature plants*, *5*(2), 141–147. https://doi.org/10.1038/s41477-018-0346-z.
17. Felipe-Lucia, M. R., Soliveres, S., Penone, C., Manning, P., van der Plas, F., Boch, S., ... & Allan, E. (2018). Multiple forest attributes underpin the supply of multiple ecosystem services. *Nature communications*, *9*(1), 4839. https://doi.org/10.1038/s41467-018-07082-4.
18. Le Provost, G., Schenk, N. V., Penone, C., Thiele, J., Westphal, C., Allan, E., ... & Manning, P. (2022). The supply of multiple ecosystem services requires biodiversity across spatial scales. *Nature ecology & evolution*, 7, 236–249. https://doi.org/10.1038/s41559-022-01918-5.
19. Ajrhough, S., Maanan, M., Alaoui, H. M., Rhinane, H., & El Arabi, E. H. (2019). Mapping Forest Ecosystem Services: A Review. *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, 42, 17–22. https://doi.org/10.5194/isprs-archives-XLII-4-W19-17-2019.
20. García-Nieto, A. P., García-Llorente, M., Iniesta-Arandia, I., & Martín-López, B. (2013). Mapping forest ecosystem services: from providing units to beneficiaries. *Ecosystem Services*, 4, 126-138. https://doi.org/10.1016/j.ecoser.2013.03.003.
21. Olosutean, H. (2015). Methods for Modeling Ecosystem Services: A Review. *Management of Sustainable Development*, *7*(1), 5-12. https://doi.org/10.1515/msd-2015-0014.
22. Alix-Garcia, J., & Wolff, H. (2014). Payment for ecosystem services from forests. *Annual Review of Resource Economics*, *6*(1), 361–380. Vol. 6:361–380 https://doi.org/10.1146/annurev-resource-100913-012524.
23. Bishop, J., Brink, P. T., Gundimeda, H., Kumar, P., Nesshöver, C., Schröter-Schlaack, C., ... & Wittmer, H. (2010). The economics of ecosystems and biodiversity: mainstreaming the economics of nature: a synthesis of the approach, conclusions and recommendations of TEEB. (No. 333.95 E19). UNEP, Ginebra (Suiza).
24. Acharya, R. P., Maraseni, T., & Cockfield, G. (2019). Global trend of forest ecosystem services valuation–An analysis of publications. *Ecosystem Services*, *39*, 100979. https://doi.org/10.1016/j.ecoser.2019.100979.
25. Shashula, L.O., Sakal, O.V., & Tretiak, N.A. (2019). Payment for Ecosystem Services in Ukraine: Priority Direction of Revitalization. *Mechanism of Economic Regulation*, 2, 6–16. https://doi.org/10.21272/mer.2019.84.01.
26. Dankevych, S. (2021). Development potential of forest ecosystem services in Ukraine as a financial tool to ensure balanced land use. *Agrosvit*, 11, 45–56. https://doi.org/10.32702/2306&6792.2021.11.45.

27. Zahvoyska, L. (2014). Theoretical approaches to determining economic value of forest ecosystems services: benefits of pure stands transformation into mixed stands. *Proceedings of the Forestry Academy of Sciences of Ukraine,* 12, 201–209.
28. Vysotska, N., Kalashnikov, A., Sydorenko, S., & Yurchenko, V. (2021). Ecosystem services of shelterbelts as the basis of compensatory mechanisms of their creation and maintenance. *Proceedings of the Forestry Academy of Sciences of Ukraine*, 22, 199–208. https://doi.org/10.15421/412118.
29. Shyshchenko, P. H., Havrylenko O. P., & Tsyhanok, Ye. Yu. (2019). Ecosystem value of Holosiyivskyi forest as an urban protected area: causes and consequences of degradation. Ukrainian geographical journal, *4*(108), 40–49. (https://doi.org/10.15407/ugz2019.04.040.
30. Andreieva, V., Voitiuk, V., Kychyliuk, Shepeliuk, M., Hetmanchuk, A., & Derkach, V. (2021). Economic estimation of Cheremsky swamp on the basis of ecosystem services. *Notes in Current Biology, 1*(1), 15–24. https://doi.org/10.29038/NCBio.21.1.15-24.
31. Anisimova, S., & Okovyta, Y. (2022). Ecological and economic assessment of forest ecosystem services on the example of SE "Vovchanske forestry". *Bulletin of Kharkiv National Automobile And Highway University,* 97, 114–121. https://doi.org/0.30977/BUL.2219-5548.2022.97.0.114.
32. Almeida, I., Rösch, C., & Saha, S. (2018). Comparison of Ecosystem Services from Mixed and Monospecific Forests in Southwest Germany: A Survey on Public Perception. *Forests*, *9*(10), 627. https://doi.org/10.3390/f9100627.
33. Bengtsson, J., Bullock, J. M., Egoh, B., Everson, C., Everson, T., O'Connor, T., O'Farrell, P. J., Smith, H. G., & Lindborg, R. (2019). Grasslands – more important for ecosystem services than you might think. *Ecosphere, 10*(2), e02582. https://doi.org/10.1002/ecs2.2582.
34. McGrath, M. J., Luyssaert, S., Meyfroidt, P., Kaplan, J. O., Bürgi, M., Chen, Y., Erb, K., Gimmi, U., McInerney, D., Naudts, K., Otto, J., Pasztor, F., Ryder, J., Schelhaas, M.-J., & Valade, A. (2015). Reconstructing European forest management from 1600 to 2010. *Biogeosciences,* 12, 4291–4316. https://doi.org/10.5194/bg-12-4291-2015.
35. Richards, K. R., & Stokes, C. A. (2004). Review of Forest Carbon Sequestration Cost Studies: A Dozen Years of Research. *Climatic Change, 63,* 1–48. https://doi.org/10.1023/B:CLIM.0000018503.10080.89.
36. Fuller, M., & Dwivedi, P. (2021) The Cost of Carbon Stored on Afforested Lands in the Southern United States. *Trees, Forests and People, 6,* 100129. https://doi.org/10.1016/j.tfp.2021.100129.
37. Krieger, D. J. (2001). The economic values of forest ecosystem services: a review. The Wilderness Society. Washington, DC, USA.
38. Barth, N.-C., & Döll, P. (2016). Assessing the ecosystem service flood protection of a riparian forest by applying a cascade approach. Ecosystem Services, *21*(A), 39–52. https://doi.org/10.1016/j.ecoser.2016.07.012.
39. Monson, R. K. (2014). Ecology of Temperate Forests. In *Ecology and the Environment, the Plant Sciences* (pp. 273–296). Springer: New York, NY, USA.
40. Vesna, V., Maes, J., Petersen, J.E., La Notte, A., Vallecillo, S., Aizpurua, N., Ivits, E., Teller, A. Accounting for ecosystems and their services in the European Union (INCA). (2021). Final report from phase II of the INCA project aiming to develop a pilot for an integrated system of ecosystem accounts for the EU. Statistical report. Publications office of the European Union, Luxembourg.
41. Czajkowski, M., Buszko-Briggs, M., & Hanley, N. (2009). Valuing changes in forest biodiversity. *Ecological Economics, 68*(12), 2910–2917. https://doi.org/10.1016/j.ecolecon.2009.06.016.
42. Garcia, S., Harou, P., Montagné, C., & Stenger, A. (2011). Valuing forest biodiversity through a national survey in France: a dichotomous choice contingent valuation. *International Journal of Biodiversity Science, Ecosystem Services & Management*, *7*(2), 84–97. https://doi.org/10.1080/21513732.2011.628338.

43. Hirons, M., Comberti, C., & Dunford, R. (2016). Valuing cultural ecosystem services. *Annual Review of Environment and Resources*, *41*(1), 545–574. https://doi.org/10.1146/annurev-environ-110615-085831.
44. Myers, N., & Goreau, T. J. (1991). Tropical forests and the greenhouse effect: a management response. *Climatic Change*, *19*(1-2), 215–225. https://doi.org/10.1007/978-94-017-3608-4_22.
45. Paustian, K., Larson, E., Kent, J., Marx, E., & Swan, A. (2019). Soil C sequestration as a biological negative emission strategy. *Frontiers in Climate*, 1, 8. https://doi.org/10.3389/fclim.2019.00008.
46. Barrio, M., & Loureiro, M. L. (2010). A meta-analysis of contingent valuation forest studies. *Ecological Economics*, *69*(5), 1023–1030. https://doi.org/10.1016/j.ecolecon.2009.11.016.
47. Grammatikopoulou, I., & Vačkářová, D. (2021). The value of forest ecosystem services: A meta-analysis at the European scale and application to national ecosystem accounting. *Ecosystem Services*, *48*, 101262. https://doi.org/10.1016/j.ecoser.2021.101262.
48. National Natural Park "Holosiivsky". Kyiv, Environment. People. Law, 2018.
49. Shyshchenko, P. H., Havrylenko, O. P., & Tsyhanok, Y. Y. (2019). Ecosystem value of holosiyivskyi forest as an urban protected area: Causes and consequences of degradation. *Ukrainian Geographical Journal*, *4*(108), 40–49. https://doi.org/10.15407/ugz2019.04.040.

The article was received 17.11.2022 and was accepted after revision 14.02.2023

М.М. Радомська, О.М. Тихенко, Т.І. Назарков

ЕКОНОМІЧНА ОЦІНКА ЕКОСИСТЕМНИХ ПОСЛУГ ПРИРОДНИХ РОСЛИННИХ АСОЦІАЦІЙ ПЛУЖНЕНСЬКОГО ЛІСГОСПУ

Анотація. Екосистемні послуги є основою безпечного середовища існування людини та забезпечення потреб суспільства. Разом з цим роль і цінність послуг, що надаються природними екосистемами, часто недооцінюють. Метою даного дослідження є проведення економічної оцінки екосистемних послуг природних рослинних угруповань обраної території – Плужненського лісництва. Відомо, що ліси надають найрізноманітніший комплекс екосистемних послуг і тому є складним об'єктом оцінки. На першому етапі дослідження було сформульовано перелік екосистемних послуг лісів, що підлягали наступній оцінці, віддаючи пріоритет найбільш добре вивченим. Другий етап був спрямований на визначення одиничних цін на обрані послуги. Вони були розроблені на основі аналогічних оцінок, достатньо підтверджених даними досліджень. Отриману вартість наданих екосистемних послуг порівнювали з результатами інших авторів, виконаними для лісових екосистем України та країн Європи, що є елементом новизни та оригінальності роботи. Хоча є помітні відхилення в питомій вартості екосистемних послуг на одиницю лісової площі, загальна тенденція узгоджується з європейським досвідом. Причини відмінностей можна пояснити вибором підходів до оцінки одиничних цін та переліку послуг, що були враховані в оцінці. Отримані дані є важливими для підвищення обізнаності місцевого населення та органів влади про важливість функціонування екосистем та необхідність вкладення ресурсів у їх підтримку та захист. Дослідження такого роду все ще є рідкістю в українському науковому середовищі, незважаючи на їх велике значення для ефективного управління якістю та використанням навколишнього середовища. Таким чином, існує очевидна потреба розвивати цю галузь досліджень і дана робота доповнює теоретичні та прикладні положення для подальших оцінок такого роду.

Ключові слова: лісова екосистема; підтримка екосистемних послуг; ціна одиниці послуги; пряма та непряма оцінка.

Стаття надійшла до редакції 17.11.2022 і прийнята до друку після рецензування 14.02.2023

Радомська Маргарита Мирославівна
к.т.н., доц., доцент кафедри екології Національного авіаційного університету
Адреса робоча: пр. Л. Гузара, 1, м. Київ, Україна, 03058
ORCID ID: 0000-0002-8096-0313 ***e-mail:*** m.m.radomskaya@gmail.com

Тихенко Оксана Миколаївна
д.т.н., доц., професор кафедри екології Національного авіаційного університету
Адреса робоча: пр. Л. Гузара, 1, м. Київ, Україна, 03058
ORCID ID: 0000-0001-6459-6497 ***e-mail:*** okstih@ua.fm

Назарков Тарас Ігорович
магістр, аспірант кафедри екології Національного авіаційного університету
Адреса робоча: пр. Л. Гузара, 1, м. Київ, Україна, 03058
ORCID ID: 0000-0002-9971-9423 ***e-mail:*** tnazarkov28@gmail.com