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Current increment of ecosystem services in permanent sample plots within the forest stands of the Feofania park-monument

Roman Feshchenko

PhD Student
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/ 0000-0002-8987-5000

Yaroslav Kovbasa*

PhD in Agricultural Sciences, Senior Researcher
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0002-1291-7049

Raisa Matyashuk

PhD in Biological Sciences
State Institution "Institute for Evolutionary Ecology of the National Academy of Sciences of Ukraine"
03143, 37 Academician Lebedev Str., Kyiv, Ukraine
https://orcid.org/ 0000-0003-1929-0522

Svitlana Bilous

PhD in Biological Sciences, Associate Professor
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
University of Applied Sciences Weihenstephan-Triesdorf
85354, 3 Hans Carl-von-Carlowitz-Platz, Freising, Germany
https://orcid.org/0000-0002-1682-5352

Olena Naumovska

PhD in Agricultural Sciences, Associate Professor
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/ 0000-0002-5938-8471

Andrii Bilous

Doctor of Agricultural Sciences, Professor
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0002-7589-4307

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**Corresponding author*

Abstract. Despite the fact that forests in nature conservation areas are of mature and over-mature age, they have a leading role in the production of ecosystem services, in particular in ensuring biodiversity. In the typical sense, at the mature and over-mature age of stands, the growth of live biomass and carbon sequestration almost stops, and the death of trees leads to a negative change in the stock. The purpose of the study is to substantiate the ability of over-mature forests to accumulate live biomass under the condition of the formation of multi-tiered and different-age stands. The research was conducted on four permanent sample plots of the Feofania park-monument, which were established in 2016 and 2017. The method of approximate mensuration was used to study the current growth of ecosystem services. The method of dendrochronology was used to analyse annual rings. The age range of experimental stands is between 80 and 180 years. Experimental stands of all sample plots are characterized by high-level productivity, compared to model data on the productivity of stands in Ukraine and the European part of Eurasia. According to the results of the research, it was established that the biggest current increment of ecosystem services is formed in the uneven-aged stand with the centuries-old common oak trees of the overstory. The results of the research can be used in practice for the management of nature conservation areas and improvement of the management of over-mature forests

Keywords: live biomass; carbon; energy; oxygen production; age; relative stocking; site index

Introduction

Forest ecosystems are able to produce ecosystem services on the territory of the environmental fund, provided that a balanced approach to nature management is observed. The main goal of forestry is to ensure the continuity of the functioning of forest ecosystems and maximise the number and productivity of ecosystem services. At the mature age of plantations, the increment of live biomass and carbon sequestration almost stops, and the death of trees leads to a negative change in the stock.

The concept of ecosystem services is an active area of interdisciplinary research involving representatives of natural and socio-economic sciences (Braat & de Groot, 2012), and the situation in this field is changing very rapidly. Today, there are many interpretations of the concepts of “environmental services”, “ecosystem services” and related “ecological functions”, “ecosystem functions”. It also traces the uncertainty in the methods and approaches used to assess the economic potential of resources as a powerful lever of economic management. In global understanding, one of the latest constructive papers in the field of ecosystem service identification was the study by T. Brown *et al.* (2007). They highlighted ecosystem benefits and ecosystem services. The benefits group has included non-renewable goods (rocks, minerals, fossil fuels) and those that are restored (animals, plants, water, air, soil, recreation, aesthetics). Forest biomass is an essential indicator for monitoring the Earth’s ecosystems and climate. D. Schepaschenko *et al.* (2019) prove that this is an important contribution to greenhouse gas accounting, assessment of carbon loss and forest degradation, evaluation of renewable energy potential and development of climate change mitigation policies. Patterns of carbon sequestration in forest ecosystem components reflect the accumulative potential of forest biomass in the context of anthropogenic environmental transformation (Bilous *et al.*, 2019). In the study of strategic guidelines for ecosystem services in wetlands, E.V. Mishenin & N.V. Degtyar (2016) presented a decomposition of wetland ecosystem services management strategies detailed on the following features: general and dominant strategies, strategies on how to achieve the goal of managing ecosystem services, strategies on the nature of the behaviour of wetland ecosystem services management entities, and target strategies on the capacity of such services. O.R. Pelyukh & L.D. Zahvoyska (2017), considering methodological approaches to estimating the cost of forest ecosystem services, established that the method of the selective experiment allows for assessment of the marginal utility of individual attributes of forest ecosystems that have the properties of public benefits. This estimate can be presented in various units of measurement, in particular, in monetary terms. Investigating the causes of deforestation in the tropics, using high-resolution maps and increased sample sizes, has helped to better identify the key factors leading to deforestation. This has been confirmed by the study carried out by the researchers J.C. Laso Bayas *et al.* (2022).

Forest loss risk management is a priority for forest conservation and enhancement and increasing the current production of ecosystem services. The analysis of scientific papers and practical measures that determine the process of formation of the concept of ecosystem services shows that there is no clear unity of understanding of the mechanisms of its practical implementation and development tools. The purpose of the study was to substantiate the ability of over-mature plantations to increase live biomass and sequestrate carbon under the condition of forming multi canopy layers and uneven-aged stands.

Materials and Methods

Experimental studies were conducted on four permanent sample plots in the period from 2016 to 2021, which are situated within the territory of the Feofania park-monument, a nationally substantial landscape art park located on a portion of an elevated forest-steppe plateau that borders with the Polissya region of Ukraine. In accordance with the geo-botanical zoning, the territory of the park belongs to the Podilsk-Serednioprydniprovska province. The relief is formed by valley-girder, hilly, dissected ravines. The soil cover is mostly represented by Grey podzolic, forest, sod-podzolic, and Meadow-swamp types (United Nations Framework Convention ..., 1996). According to the floral classification, the forest stands of the tract belong to the association *Galeobdoloni luteae-Carpinetum* (Goncharenko *et al.*, 2013).

The research consisted of quantitative and qualitative assessment of the bio-production process in forest ecosystems, accounting of quantitative parameters of ecosystem services, verification, interpretation, and practical application of mathematical models and information support for quantitative assessment of forest ecosystem services, and determination of the social and economic significance of ecosystem functions of forest phytocenoses for sustainable development of forest stands were studied in Ukraine by Ya.P. Didukh & U.M. Alioshkina (2007), R.D. Vasylyshyn, (2013), M. Matsala *et al.* (2021) and others.

During the study, the Convention on Biological Diversity (1992) standards were observed. Observing permanent sample plots (Fig. 1) and collecting forest inventory data were realized ed in accordance with SOU 02.02-37-476:2006. "Sample plots for forest management planning. Method of creating" (2006). All permanent sample plots were homogeneous in terms of structure and parameters and experienced minimal forest management impact.

Figure 2 shows a general diagram of the ecosystem services assessment methodology that was used to achieve the study goal. Assessment of ecosystem services was conducted by direct measurement of the diameter of trees of the permanent sample plots at a height of 1.3 m, height of trees, crown length and their geographical coordinates.

Figure 1. Location of embedded permanent sample plots
Source: Google satellite image in the background

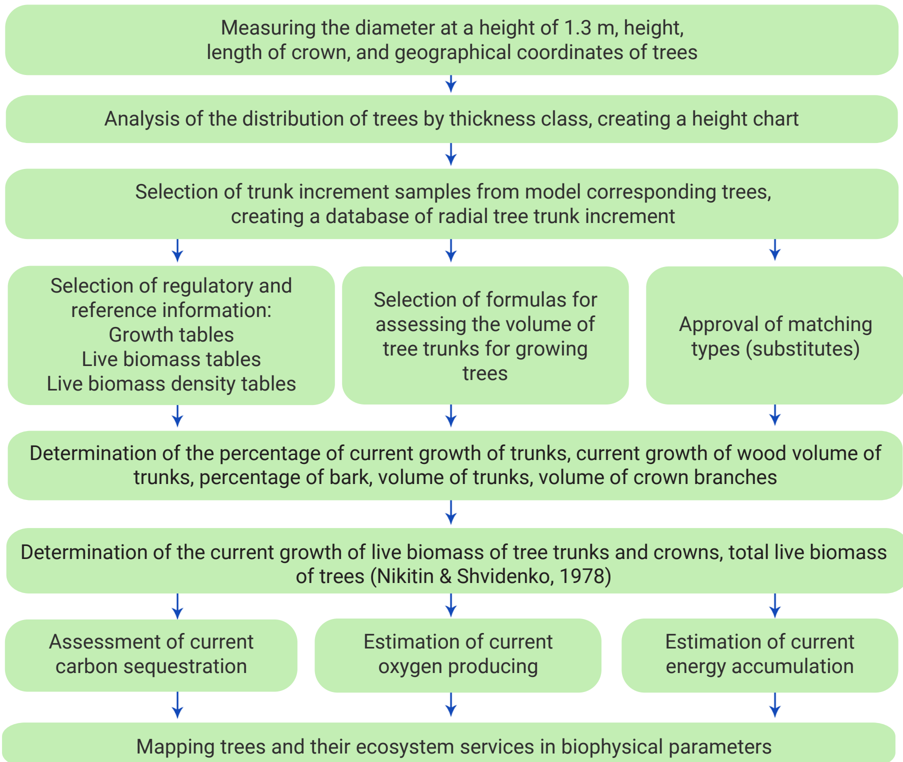

Figure 2. Scheme of methodology for evaluating ecosystem services of trees
Source: compiled by A. Bilous

Then, the analysis of the distribution of trees by thickness degrees and construction of a height curve was conducted. The next step involved sampling trunk growth from model matching trees and creating a database of radial tree trunk growth. The selection of regulatory reference information involved the use of growth tables, live biomass tables, and density tables (Lakyda *et al.*, 2011). Subsequently, the volume of trunks for growing trees was determined.

The percentage of current increment of trunks, current increment in the volume of wood trunks, percentage of bark, volume of trunks, and volume of crown branches was determined to fully assess the ecosystem services of forest stands of the research object, which allowed determining the intensity of current increment of live biomass of trunks and crowns of trees, and the total live biomass of trees. Subsequently, the main parameters of ecosystem services were evaluated: total carbon of trees and current carbon increment, total amount of oxygen released and its current annual producing, total amount of stored energy and current energy accumulation. The final stage was the mapping of trees and their ecosystem services in biophysical parameters.

Results and Discussion

During the period of laying sample plots, the structure of forest stands by their vital state was analysed (Table 1).

Table 1. Distribution of trees on permanent sample plots by their vital state (2016-2021), pcs

Number of the permanent sample plots	Condition of trees	CABE	ACPL	QURO	TICO	ULLE	ROPS	FREX
2016								
1	Live	-	142	98	1	2	5	-
	Dead	-	6	6	-	-	-	-
2	Live	215	36	33	23	-	-	-
	Dead	2	-	5	-	-	-	-
2017								
3	Live	181	8	7	6	10	1	-
	Dead	1	-	-	-	-	-	-
4	Live	57	73	63	9	1	-	1
	Dead	8	2	8	4	-	-	-
2019								
1	Live	-	139	86	1	2	5	-
	Dead	-	9	18	-	-	-	-
2	Live	208	36	31	23	-	-	-
	Dead	9	-	7	-	-	-	-
3	Live	172	8	7	6	10	1	-
	Dead	10	-	-	-	-	-	-
4	Live	55	71	60	8	1	-	1
	Dead	10	4	11	5	-	-	-
2020								
1	Live	-	139	79	1	2	5	-
	Dead	-	9	25	-	-	-	-
2	Live	207	36	31	23	-	-	-
	Dead	10	-	7	-	-	-	-
3	Live	167	8	7	6	10	1	-
	Dead	15	-	-	-		-	-

Table 1, Continued

Number of the permanent sample plots	Condition of trees	CABE	ACPL	QURO	TICO	ULLE	ROPS	FREX
2020								
4	Live	51	69	57	6	1	-	1
	Dead	14	6	14	7	-	-	-
2021								
1	Live	-	138	73	1	2	5	-
	Dead	-	10	31	-	-	-	-
2	Live	204	35	31	23	-	-	-
	Dead	13	1	7	-	-	-	-
3	Live	162	7	7	5	10	1	-
	Dead	20	1	-	1	-	-	-
4	Live	50	68	57	5	1	-	1
	Dead	15	7	14	8	-	-	-

Note: CABE – Common Hornbeam, ACPL – Sycamore Maple, QURO – Common Oak, TICO – Small-leaved Linden, ULLE – European White Elm, ROPS – Black Locust, FREX – Common Ash
Source: compiled by the authors

Each permanent sample plots (PSP) is represented by typical broad-leaved tree species and is formed by the following composition according to its species structure:

- PSP No. 1 (2016) (the total of counted trees is 260, of these, dead trees – 2.3% Maple, 2.3% Oak), area – 0.51 ha) – Sycamore Maple (ACPL) – 54.6% Common Oak (QURO) – 37.7%, Black Locust (ROPS) – 1.9%, Small-Leaved Linden (TICO) – 0.4%, European White Elm (ULLE) – 0.8%;
- PSP No. 2 (2016) (the total of counted trees is 314 units, of these, dead trees – 0.6% Hornbeam, 1.6% Oak, area – 0.88 ha) – Sycamore Maple (ACPL) – 11.5%, Common Hornbeam (CABE) – 68.5%, Common Oak (QURO) – 10.5%, Small-Leaved Linden (TICO) – 7.3%;
- PSP No. 3 (2017) (the total of registered trees is 214 units, of these, dead trees – 0.5% Hornbeam, area – 0.44 ha) – Sycamore Maple (ACPL) – 3.7%, Common Hornbeam (CABE) – 84.6%, Common Oak (QURO) – 3.3%, Black Locust (ROPS) – 0.5%, Small-Leaved Linden (TICO) – 2.8%, European White Elm (ULLE) – 4,6%;
- PSP No. 4 (2017) (the total of counted trees is 226 units, of which dead trees – 3.5% Hornbeam, 3.5% Oak, 0.9% Maple, 1.8% Linden, area – 0.29 ha) – Sycamore Maple (ACPL) – 32.3%, Common Hornbeam (CABE) – 25.2%, Common Oak (QURO) – 27.9%, Small-Leaved Linden (TICO) – 4.0%, European White Elm (ULLE) – 0.5%, Common Ash (FREX) – 0.4%.

The largest number of the four PSP examined is represented by Maple, Hornbeam, and Oak trees. The density of stands for PSP was – PSP No. 1 – 510 trees per ha, PSP No. 2 – 357 trees per ha, PSP No. 3 – 486 trees per ha, PSP No. 4 – 779 trees per ha.

In the first PSP, the number of live Maple trees decreased by 2.8%, Oak – by 25.5%. The living condition of Black Locust, Ash, and Linden remained unchanged, and the share of dead Oak and Maple units was already 11.9% and 3.8% of the total number of trees, respectively. According to the vital state of plantations, the structure of the second PSP is formed with an advantage of Hornbeam – 204 trees. The number of dead trees increased to 13 trees, which is 4.1%. Among dead trees, the number of Oak and Maple trees also increased, their share is 2.2% and 0.3% of the total number of trees in the PSP, respectively. The largest amount of dead wood in the third PSP was formed by Hornbeam (9.3%) and Maple and Linden (0.5%). The fourth PSP according to the dynamics of dead trees formation is characterised by an increase in the share of dead Hornbeam and Oak trees, which is 6.6% and 6.2% of the total number of trees in the PSP, and the share of Linden and Maple – 3.5% and 3.1%.

Based on the results of measurements, sampling of tree increment on PSP, and considering the intensity of growth and development of forest stands, the current increment of ecosystem services for each growing tree was estimated. General parameters of current live biomass increment, carbon sequestration, energy storage, and oxygen production are shown in Table 2.

Table 2. Current increment of ecosystem services at PSP No. 1 (2016-2021)

Species of trees	Parameter			
	current live biomass increment, $t \cdot ha^{-1} \cdot yr^{-1}$	current carbon sequestration, $t \cdot ha^{-1} \cdot yr^{-1}$	current energy storage, $GJ \cdot ha^{-1} \cdot yr^{-1}$	current oxygen producing, $t \cdot ha^{-1} \cdot yr^{-1}$
ROPS	0.25	0.12	4.4	0.35
ULLE	0.01	0.01	0.2	0.01
QURO	2.17	1.09	38.9	3.04
ACPL	0.91	0.46	16.3	1.28
TICO	0.01	0.004	0.1	0.01
Total	**3.35**	**1.67**	**59.9**	**4.69**

Source: compiled by the authors

The total live biomass of the stand of the first trial area, considering the trunk of the bark, bark, branches, leaves, roots, green forest floor, and understorey, was 3.35 $t \cdot ha^{-1}$ yr^{-1} the first PSP. The current increase in carbon for the specified period in the study on PSP was 1.67 $t \cdot ha^{-1}$ yr^{-1}.

The sustainability of the ecosystem of urban Oak stands, due to structural diversity, should become an important tool for protecting the remains of old forests. Human exposure can contribute to tree size differentiation, dead wood formation, and biodiversity maintenance, but will threaten forest stands in large cities in the long run (Morozyuk, 2009). In the current increment in total carbon, Oak stands account for the largest share – 1.09 $t \cdot ha^{-1}$ yr^{-1}, and the smallest on Linden stands – 0.004 $t \cdot ha^{-1}$ yr^{-1}. These indicators closely correlate with the results of the study of the structure of this plantation, which confirms that the main share of them in the first PSP is formed from Oak trees and, accordingly, its plantations have the largest share of sequestrated carbon.

During the growth and development of forest stands in the first PSP, the largest share of current carbon sequestration (Fig. 3) formed from Oak stands – 64.9%. Maple accounts for 27.2%, and the lowest growth rate is observed in Linden trees – 0.2%.

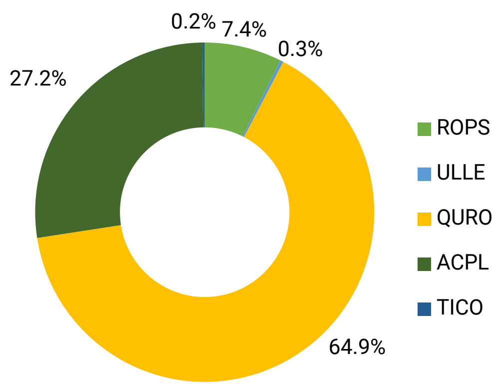

Figure 3. Structure of carbon sequestration by species composition of PSP No. 1 (2016-2021)
Source: compiled by the authors

Parameters of the current increment of ecosystem services of the second PSP (Table 3) are characterised by the formation of the main share due to Common Oak trees.

Table 3. Current increment of ecosystem services at PSP No. 2 (2016-2021)

Species	Parameter			
	current live biomass increment, t·ha^{-1}·yr^{-1}	current carbon sequestration, t·ha^{-1}·yr^{-1}	current energy storage, GJ·ha^{-1}·yr^{-1}	current oxygen producing, t·ha^{-1}·yr^{-1}
CABE	1.23	0.61	21.9	1.72
QURO	3.34	1.67	59.7	4.68
ACPL	0.78	0.39	14.0	1.09
TICO	0.41	0.20	7.3	0.57
Total	**5.75**	**2.88**	**102.9**	**8.06**

Source: compiled by the authors

The current increase in live biomass during the research period was 5.75 t·ha^{-1}·yr^{-1}, and the share of the total number accounted for by Oak trees was 58%. The current increase in carbon, which is formed mainly Oak trees, was 2.88 t·ha^{-1}·yr^{-1} for the study period. Among all the species that form the second PSP in terms of ecosystem services, compared to other species, the lowest growth rate is characteristic of Linden.

The overwhelming proportion of current carbon sequestration (Fig. 4) in the second PSP, was formed from Oak trees, which amounted to almost 58.1%. Hornbeam trees account for 21.3%, and Maple trees – 13.6%. A smaller proportion is formed by Linden trees.

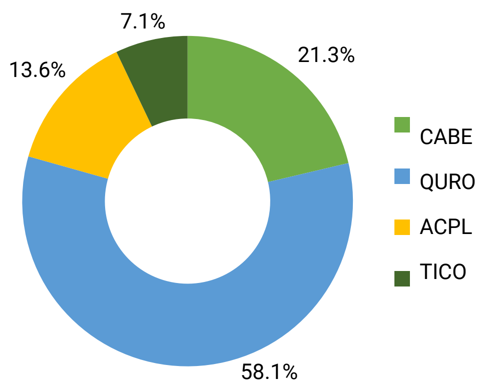

Figure 4. Structure of carbon sequestration by species composition of PSP No. 2 (2016-2021)
Source: compiled by the authors

In the course of investigating the parameters of ecosystem services (Table 4) of the third trial area, it was established that the total current increment of live biomass was 4.78 t·ha^{-1}·yr^{-1}, and the increase in carbon – 2.39 t·ha^{-1}·yr^{-1}. Among the trees that make up the third PSP, Hornbeam and Oak trees can be distinguished by the predominant values of ecosystem services – 3.88 t·ha^{-1}·yr^{-1}, respectively and 2.39 t·ha^{-1}·yr^{-1}.

As noted above, in the third PSP, Hornbeam and Oak are the main trees that have formed the largest share of ecosystem services (Fig. 5).

Table 4. Current increment of ecosystem services PSP No. 3 (2017-2021)

Species	Parameter			
	current live biomass increment, t·ha^{-1}·yr^{-1}	current carbon sequestration, t·ha^{-1}·yr^{-1}	current energy storage, GJ·ha^{-1}·yr^{-1}	current oxygen producing, t·ha^{-1}·yr^{-1}
ROPS	0.02	0.01	0.4	0.03
ULLE	0.18	0.09	3.2	0.25
CABE	2.77	1.39	49.6	3.88
QURO	1.71	0.85	30.5	2.39
ACPL	0.03	0.02	0.6	0.05
TICO	0.07	0.03	1.2	0.1
Total	**4.78**	**2.39**	**85.5**	**6.70**

Source: compiled by the authors

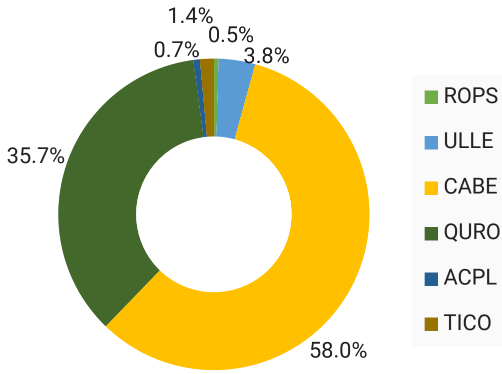

Figure 5. Structure of carbon sequestration by species composition of PSP No. 3 (2017-2021)
Source: compiled by the authors

Thus, carbon sequestration, as one of the determining parameters of ecosystem services, mainly belongs to Hornbeam – 58.0% and Oak – 35.7%, and the smallest share to – Maple – 0.7%.

The fourth PSP, according to the examined growth parameters, is characterized by the following values: the total current increase in live biomass was 3.31 t·ha^{-1}·yr^{-1}, carbon – 1.65 t·ha^{-1} yr^{-1} and oxygen 4.63 t·ha^{-1}·yr^{-1} (Table 5).

Table 5. Current increase in indicators of ecosystem services PSP No. 4 (2017-2021

Species	Parameter			
	current live biomass increment, t·ha^{-1}·yr^{-1}	current carbon sequestration, t·ha^{-1}·yr^{-1}	current energy storage, GJ·ha^{-1}·yr^{-1}	current oxygen producing, t·ha^{-1}·yr^{-1}
ULLE	0.001	0.001	0.03	0.002
CABE	0.2	0.1	3.6	0.28
QURO	2.37	1.19	42.4	3.32
ACPL	0.61	0.30	10.9	0.85
TICO	0.06	0.03	1.0	0.08
FREX	0.07	0.04	1.3	0.1
Total	**3.31**	**1.65**	**59.2**	**4.63**

Source: compiled by the authors

The highest share among the species that PSP No. 4 belongs to Oak – 72% and the minimum – to Elm. In terms of the increase in carbon sequestration, the advantage here belongs to Oak plantations – 71.7% (Fig. 6). The rest is formed from Maple – 18.1%, Hornbeam – 6.1%, and Ash – 2.1%. The minimum increment belongs to Elm – 0.06%.

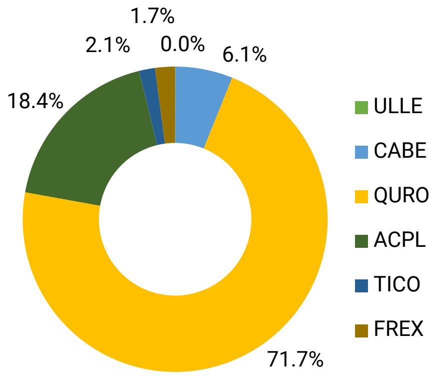

Figure 6. Structure of carbon sequestration by species composition of PSP No. 4 (2017-2021)
Source: compiled by the authors

Thus, among the permanent sample plots, the current increment of ecosystem services parameters was most intense in the second permanent sample plots, and among the trees forming the studied plantations, the Common Oak prevailed in growth.

The study of biological productivity involves, first of all, establishing the biological potential of tree species in different growing conditions, which is expressed by the annual production of live biomass, drawing up appropriate criteria for the components of live biomass, productivity maps, etc. (Petrenko, 2002). The results of the investigation of permanent sample plots highlight the dynamics of biophysical parameters of ecosystem services, the assessment of which is based on the study of the bio-productivity of stands. The list of services provided by forest stands, in particular, the nature reserve fund, is much larger than presented in the study and requires a comprehensive approach to their assessment and consideration in the environmental management economy. For example, in the paper of D.C. Donato *et al.* (2012), it is noted that ecosystem services, such as pollution filtration and carbon sequestration, are difficult to replace, and the deterioration of environmental quality due to the loss of ecosystem services is now one of the biggest threats to society and business.

It is important to note that, according to the results given in the study by O.V. Morozyuk (2009), in terms of the scale of production and, especially, the duration of carbon sequestration in trees, forests are recognised as the most reliable system for preventing the greenhouse effect, which is relevant for urban forests in conditions of intense atmospheric pollution from moving and stationary sources.

Given that forest ecosystems serve as the main terrestrial carbon dioxide absorber (Vyshenska, 2014; Prokopuk & Netsvetov, 2016), forestry is one of the main factors that can substantially affect its balance and circulation (Pasternak & Buksha, 2004). This should also be considered when planning forestry activities plantations, which substantially affect the growth and development of stands, and therefore the intensity of carbon storage. It is necessary to consider the fact that much younger stands on PSP No. 1 and No. 4 have a substantially lower current increment of live biomass, compared to older stands on PSP No. 2 and No. 3, which may be due to the lack of economic logging for the formation of plantations, since this is the forest fund of a nature protection object.

Each forest plot produces a different amount of ecosystem services, depending on the species composition, spatial distribution, and other forest stand parameters. As a result of the study by T. Häyhä *et al.* (2015), the annual volume of ecosystem services produced by alpine forest ecosystems was established and their monetary equivalent was determined. Thus, alpine forests annually produce ecosystem services in the amount of 300 to 6100 €·ha^{-1}·yr^{-1}, which is about 820 €·ha^{-1}·yr^{-1} (Grotti *et al.*, 2019). For the development of objects of the nature reserve fund, it is important in the future to move from evaluating ecosystem services in Biophysical terms to determining the cost indicators of the benefits that forests produce for people.

Comparison of the obtained results of the study on all PSP (PSP) with the data of the tables of bioproductivity of Oak stands, according to P. Lakyda *et al.* (2006) and A. Shvidenko *et al.* (2008) indicates a substantially greater current increment of ecosystem services for stands across all PSP compared to regulatory reference data. Notably, the vast majority of theoretical models of live biomass dynamics in plantings over 110-120 years will have a negative value of the current live biomass increment parameters, since the drop in such plantations will prevail over the growth of trees. That is why Figure 7 shows the data obtained by P. Lakyda *et al.* (2006) and A. Shvidenko *et al.* (2008) in negative trends for PSP No. 2 and No. 3.

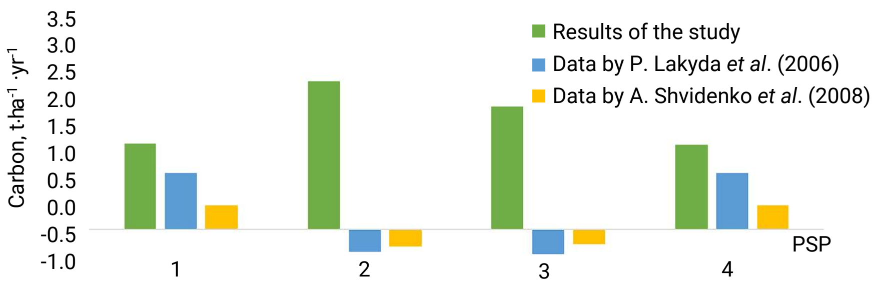

Figure 7. Comparison of data on current carbon sequestration of stands of PSPs (1 – PSP No. 1, 2 – PSP No. 2, 3 – PSP No. 3, 4 – PSP No. 4)
Source: compiled by the authors according to P. Lakyda *et al.* (2006) and A. Shvidenko *et al.* (2008)

Thus, stands on all PSP are characterized by high productivity of ecosystem services compared with the regulatory data on the bio-productivity of stands in Ukraine and the European part of Eurasia. The most substantial feature of trial stands in PSP No. 2 and 3 is the substantially higher productivity of 180-year-old stands, compared to modal stands of the same age and site index.

Conclusions

The establishment of regularities of the main processes of growth and development of forests depends on the study of the main forest stand parameters on permanent sample plots. The implementation of successive stages of performing forest measurements in the field and combining them with existing models or standards fully allows for assessing the increment of ecosystem services of forest stands.

Assessment of biophysical parameters of ecosystem services allows for identifying the ecological significance of forest stands of objects of the nature reserve fund, which in the future may potentially have economic significance, which is especially important within urban ecosystems.

Studies have shown that forest stands with 180-year-old Oak trees in the overstory have a high level of production of ecosystem services, in particular, carbon sequestration and oxygen production. In two PSP, old Common Oak trees are key to carbon storage, and the current carbon sequestration is conducted by younger trees of the midstory of plantations.

As part of the study, a justification was added for the advantages of plantations many-layed, uneven-aged and diverse in species structure for producing ecosystem services, which is primarily important for the arrangement and management of forest stands within the nature reserves. It is important to expand the network of permanent sample plots, conduct systematic comprehensive case studies, and check the existing regulatory and reference support for trees and stands of the main forest-forming species of Ukraine.

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Conflict of Interest

The authors declare no conflict of interest.

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Поточний приріст екосистемних послуг на постійних пробних площах у деревостанах парку-пам'ятки «Феофанія»

Роман Олександрович Фещенко

Здобувач PhD
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
https://orcid.org/ 0000-0002-8987-5000

Ярослав Володимирович Ковбаса

Кандидат сільськогосподарських наук
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
https://orcid.org/0000-0002-1291-7049

Раїса Костянтинівна Матяшук

Кандидат біологічних наук
Державна установа «Інститут еволюційної екології Національної академії наук України»
03143, вул. Академіка Лебедєва, 37, м. Київ, Україна
https://orcid.org/ 0000-0003-1929-0522

Світлана Юріївна Білоус

Кандидат біологічних наук, доцент
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
Університет прикладних наук Вайенштефан-Тріздорф
85354, Hans Carl-von-Carlowitz-Platz, 3, м. Фрайзінг, Німеччина
https://orcid.org/0000-0002-1682-5352

Олена Іванівна Наумовська

Кандидат сільськогосподарських наук, доцент
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
https://orcid.org/ 0000-0002-5938-8471

Андрій Михайлович Білоус

Доктор сільськогосподарських наук, професор
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони 15, м. Київ, Україна
https://orcid.org/0000-0002-7589-4307

Анотація. Незважаючи на те, що ліси на природоохоронних територіях переважно є стиглими та перестиглими, вони мають провідну роль у продукуванні екосистемних послуг, зокрема у підтримці біорізноманіття. У класичному розумінні, у стиглому та перестиглому віці деревостанів приріст живої біомаси та поглинання вуглецю насаджень майже припиняється, а відпад дерев призводить до негативної зміни запасу. Мета дослідження – обґрунтувати здатність перестиглих лісів накопичувати фітомасу за умови формування багатоярусних та різновікових насаджень. Дослідження було проведено на чотирьох постійних пробних площах парку-пам'ятки «Феофанія», закладених у 2016 та 2017 роках. Для вивчення поточного приросту екосистемних послуг використано метод наближених таксацій. Для аналізу річних кілець використано метод дендрохронології. Віковий діапазон дослідних насаджень – від 80 до 180 років. Дослідні насадження всіх пробних ділянок характеризуються високим рівнем продуктивності порівняно з модельними даними про продуктивність насаджень України та Європейської частини Євразії. За результатами досліджень встановлено, що найбільший поточний приріст екосистемних послуг формується в різновіковому насадженні з багатовіковими деревами дуба звичайного у верхньому ярусі. Результати досліджень можуть бути використані на практиці для управління природоохоронними територіями та вдосконалення проектування переформування насаджень

Ключові слова: фітомаса; вуглець; енергія; киснепродуктивність; вік; відносна повнота; клас бонітету