IDENTIFICATION OF VIRGIN AND QUASI-VIRGIN FORESTS IN THE UZHANSKYI NATIONAL NATURE PARK

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Background. Modern anthropogenic activities have significantly contributed to the decrease of primeval, quasi-primeval, and old-growth forests worldwide and in Europe in particular, leading to catastrophic changes. Such forests are key reservoirs of floral and faunal diversity and play a crucial role in climate regulation. This study is dedicated to the conservation of biodiversity in forest ecosystems of the Carpathian region of Ukraine through the identification of primeval and quasi-primeval forests within the Kostryna Nature Conservation and Research Department (NCRD) of the Uzhanskyi National Nature Park in Zakarpattia Oblast (Ukraine).

Materials and Methods. The affiliation of specific natural forest tracts in the Carpathians was determined based on desk and field research.

Results. The most significant forest areas were found to be natural habitats of *Fagus sylvatica* L. stands with admixtures of *Quercus petraea* L*., Acer pseudoplatanus L.*, *Ulmus glabra* Huds., and *Carpinus betulus* L. It was found that the species composition of admixtures in beech forests is significantly influenced by vertical zonation and associated soil conditions. On the southern peaks and slopes of Mount Knyahynitsa, within the altitudes of 400–600 m above sea level, the presence of pure beech forests was noted, which is associated with optimally favorable climatic and soil conditions for the growth and development of endemic species.

Conclusions. Within the studied areas (Domashinsky Verkh Mountain and Knyagynitsa Mountain), 36 inventory points of primeval forest systems were identified, totaling 1,075 ha, along with 3 quasi-primeval ecosystems, each covering 8.6 ha. The need to designate them separately is indicated by the exclusively natural origin of old-growth (156–196 years) stands of *F. sylvatica*, *Q. petraea*, *C. betulus*, *A. pseudoplatanus*, and *U. glabra.* These primeval and quasi-primeval forest ecosystems are characterized by complex horizontal and vertical structures with the presence of three and four layers. The studied forest ecosystems belong to the first site quality class, highlighting their ecological importance for biodiversity conservation, soil erosion prevention, soil environment restoration, and maintaining ecological balance.

Keywords: beech primeval forests, beech quasi-primeval forests, Carpathian region of Ukraine, natural forest ecosystems, biodiversity conservation

INTRODUCTION

The foundation for biodiversity conservation and the sustainable development of forest ecosystems in the Carpathian region of Ukraine lies in natural regeneration, with beech primeval forests playing an integral role at its core (Kholiavchuk *et al.*, 2024; Spracklen & Spracklen, 2020; Thomas *et al.*, 2022). These forests are the most vital hotspots of floral and faunal diversity (Yan, 2023; Debryniuk *et al.*, 2023; Ustymenko *et al.*, 2022). Equally important is their biospheric function – ensuring ecological stability and resilience to climate change (Gea-Izquierdo & Sánchez-González, 2022; Gschwantner *et al.*, 2024; Piovesan *et al.*, 2022; Mirzabaev & Wuepper, 2023). Untouched forest ecosystems perform essential environmental functions such as absorbing excess carbon (Brienen *et al.*, 2020), regulating the water balance, and preserving and restoring soil quality (Cannon *et al.*, 2022; Shparyk *et al.*, 2020; Gilhen-Baker *et al.*, 2022; Berges & Dupouey, 2021; Marín *et al.*, 2021; Nolan *et al.*, 2022).

The main causes of primeval forest loss across different regions of the world are anthropogenic activities that disrupt ecosystem balance (Berges & Dupouey, 2021; Marín *et al.*, 2021; Nolan *et al.*, 2022). These causes also include the effects of human activity, such as global warming, changes in precipitation patterns, soil degradation, and the displacement of native flora and fauna species (Lyubynskyi *et al.*, 2024; Zhao *et al.*, 2022).

Primeval and quasi-primeval forests of the Ukrainian Carpathians are a national treasure of the Ukrainian people and hold international significance. Their identification serves as a reference for the natural development of forest ecosystems and carries scientific, educational, economic, and political value (Vondrak *et al.*, 2018). Due to the region's terrain and inaccessibility, the Carpathian Mountains have retained the largest share of primeval forests in Europe (Teslovych & Krychevska, 2021), with the largest area located in Zakarpattia Oblast. The identified areas of primeval, quasi-primeval, and natural forests in Zakarpattia total 63,000 ha (official website of the Department of Ecology and Natural Resources of the Transcarpathian Regional State Administration).

Zakarpattia is the most forested region of Ukraine, with over 52 % of its territory covered by forests (Teslovych & Krychevska, 2021). The share of objects and territories of the nature reserve fund in Zakarpattia accounts for 16.1 % of the regional ecological network (Official website of the Department of Ecology and Natural Resources of the

Transcarpathian Regional State Administration). However, primeval forest ecosystems in Zakarpattia remain of significant scientific interest and require ongoing monitoring.

The Uzhanskyi National Nature Park is a structural component of the East Carpathians International Biosphere Reserve (Official website of the Uzhanskyi National Nature Park), whose primary goal is the preservation of unique beech primeval forests of the Carpathian Mountains. Field observations and comprehensive analyses for identifying primeval (and quasi-primeval) ecological systems in the Uzhanskyi National Nature Park have so far been insufficiently provided and remain a relevant area of research.

The unique forest ecosystems of the Uzhanskyi National Nature Park and the slopes of the Ukrainian Carpathians have been preserved as relic examples of untouched nature. Such systems require protection and continuous monitoring and serve as valuable objects for scientific research and discovery. Since 2007, the primeval forests of the Uzhanskyi National Nature Park have been included in the UNESCO World Heritage list (Official website of the Uzhanskyi National Nature Park). They cover an area of 6,100 ha within the protected area together with the buffer zone within the protected area (**Fig. 1**). The trees are 150–200 years old, and the dominant forest types are beech-fir and beech-maple stands with admixtures of other native tree species (Shparyk *et al.*, 2021).

According to research (Spracklen & Spracklen, 2020), during 2010–2019, violations in primeval forests were detected across 1,335 ha in Europe, with the highest concentration in the Carpathian Mountains of southwestern Ukraine. Despite inclusion in the UNESCO World Heritage list and improvements in forest protection legislation (Moratorium on logging in Carpathian old-growth forests of Ukraine), violations have decreased but not disappeared entirely. Currently, only one-third of the old-growth forests in the Ukrainian Carpathians are located within protected areas, highlighting the need for identification studies and the inclusion of these forests in conservation zones.

The first studies of forests located in the territory of the modern Uzhansky National Nature Park were initiated by A. Zlatnik in the 1930s. The aim was to study the unique beech (Fageta sylvaticae), maple-beech (Acereto-pseudoplatani-Fagetum) and fir-beech (Abieto-Fagetum) natural forests of the Stuzhitsa region of the Carpathians. The Czech professor A. Zlatnik established monitoring sites in the Yasyn tract within the Stuzhytsia forest massif and on Mount Yavoryk (Stoyko & Kopach, 2012; Zlatnik, 1938).

To assess primeval and old-growth forests, scientists at the Uzhanskyi National Nature Park laid out permanent sample plots between 2010 and 2012; however, the studies remain incomplete.

A comprehensive analysis to identify primeval ecosystems within the Uzhanskyi National Nature Park remains incomplete (Stoyka, 2007), especially in terms of field research. Previous efforts have been mostly fragmented. To date, there is still no systematic approach to the identification and monitoring of natural primeval forests within Zakarpattia Oblast.

MATERIALS AND METHODS

The methodologies for identifying primeval, quasi-primeval, and old-growth forests vary, although recent global efforts aim to standardize them (Liu *et al.*, 2022; Marín *et al.*, 2021; Shparyk *et al.*, 2021).

The identification of primeval and quasi-primeval forests within the protected areas of the Kostryna Nature Conservation and Research Department (NCRD) of

the Uzhanskyi National Nature Park was carried out throughout 2024 using the standard methodology approved by Order No. 161 of the Ministry of Ecology and Natural Resources of Ukraine, dated May 18, 2018 (Official website of the Ministry of Ecology and Natural Resources of Ukraine; Forest Code of Ukraine).

According to the methodology, the assessment of forest ecosystems in the Uzhanskyi NNP (Kostryna NCRD) was carried out in three stages (Mostepanyuk, 2016): (1) desk-based research; (2) field investigations; (3) analytical (final) stage.

The desk-based research included the analysis of forest inventory descriptions, scientific literature, and cartographic materials. Field investigations involved monitoring activities and the direct study of primeval forest ecosystems, as well as conducting descriptions. The final stage included the analysis of structural and functional characteristics of forest ecosystems in the protected area, as well as the assessment of their conservation status and classification as either primeval or quasi-primeval.

The study focused on forest stands of the dominant forest-forming species _Fagus sylvatica_ L., aged 176–196 years, and ranging in height from 25 to 40 m. The identified primeval forest clusters ranged in area from 50 to 70 ha, according to the methodology.

The criteria and indicators included: the origin and composition of the tree stands, forest area and shape, anthropogenic disturbances, and the presence of infrastructure, based on data from the forest land inventory (Official website of the Western Interregional Forestry and Hunting Department).

The origin and composition of tree stands were identified based on the analysis of forest management materials and field data, which examined species composition, origin, structure, and deadwood. To identify a forest as primeval or near-primeval forests, all forest types must be composed of indigenous, i.e. native tree or shrub species characteristic of the given area. Their origin must be exclusively natural. These forests are characterized by a mosaic horizontal structure, vertical stratification typical of a given forest type, and the presence of all development stages of the tree stands (i.e., cycles). Natural forests are characterized by complex age, vertical, and horizontal structures with a predominance of mature or overmature tree species.

In primeval forests, the deadwood (lying deadwood and standing dead trees) is present in all decomposition stages across the entire area. Quasi-primeval forests also contain deadwood in most decomposition stages. If only some decomposition stages are present, the stand is categorized as a "natural forest."

The presence of infrastructure in primeval forest systems allows only traces of pedestrian activity, limited to a single footpath up to 1 meter wide. Quasi-primeval forests may contain remnants of old roads, provided they are no longer in use. Natural forests may show signs of old infrastructure or minimal transport activity (such as bicycles, sleds, etc.).

Areas that show no signs of logging or timber harvesting have been classified as primeval forests. Quasi-primeval forests may include the removal of up to five trees per hectare from the main layer without affecting forest development.

No signs of commercial non-timber product harvesting are allowed; small-scale foraging without visible signs is acceptable. No signs of grazing are allowed in primeval forests, while seasonal passage of animals is allowed in quasi-primeval ones.

A forest stand can be identified as primeval if it has a complex structure (three or more layers) that includes all forest development stages, and exhibits high age and size diversity. If a stand includes not all development stages and has a simpler structure (only one or two layers), it is classified as quasi-primeval. It should be mentioned that undergrowth is considered a separate layer.

The natural regeneration level of forest ecosystems is determined by the amount of undergrowth in thousands of pieces per hectare. An area can be classified as primeval or quasi-primeval if the regeneration level is sufficient for the formation of the indigenous tree stand.

Deadwood (lying and standing) presence was assessed based on large, old trees at different decomposition stages across the entire area. A forest area qualifies as primeval if deadwood in all four decomposition stages is present; for quasi-primeval, three to four stages are required.

- Stage 1: fresh, not yet decomposed wood, with a knife blade penetrating only through the bark (with light pressure along the wood fibers).
- Stage 2: initial decomposition, a knife blade penetrates through the bark and a few centimeters into the wood.
- Stage 3: intensive decomposition, a knife blade penetrates through the bark and fully into the wood.
- Stage 4: complete decomposition, full-length penetration both along and across the grain.

Fullness of the stand is an important characteristic of forest ecosystems, which shows the degree of density of trees in the stand and their use of available space. This value is calculated as the ratio of the sum of the cross-sectional areas of a forest-forming species to the sum of the cross-sectional areas per 1 ha of a normal stand of the same species (Mostepanyuk, 2016) (according to yield tables).

RESULTS AND DISCUSSION

The Kostryna NCRD covers an area of 2,535.8 ha and is located in the southwestern part of the Uzhanskyi NNP. Forests make up approximately 80 % of the territory. The share of the Kostryna NCRD alone constitutes 17 % of the covered territory (14904.6 ha) and 5.5 % of the total area of the park (46147.0 ha).

The balance of timber stock and natural resilience of the forests of the Kostryna NCRD varies across development stages; however, primeval forests maintain equilibrium between growth and dieback. Due to natural selection, old-growth forests of the Carpathians are best adapted to biotic and abiotic factors, which increases their resilience. The identified primeval forests exhibit strong self-regulation capacity, meaning they can compensate for random changes and restore population balance and species composition. Such interspecific competition is observed within the protected areas of the Kostryna NCRD between two tree species: *F. sylvatica* and *Acer pseudoplatanus* L. (plant names are given in accordance with WFO Plant List (https://wfoplantlist.org))

Field research revealed a stable composition of native species: *F. sylvatica* with admixtures of *Quercus petraea* (Matt.) Liebl., *A. pseudoplatanus*, *Ulmus glabra* Huds., and *Carpinus betulus* L. It should be mentioned that the admixture type significantly depends on the vertical zonation of the protected area. At lower elevations (up to 300–400 m.a.s.l.), *C. betulus* dominates the admixtures, while on poor soils (rocky screes), *Q. petraea* prevails. At elevations of 400 and 800 m.a.s.l., pure beech forests are predominant, as natural conditions within this range are most favorable for *F. sylvatica.* At around 800 m and higher, the proportion of *F. sylvatica.* can reach up to 50 %. Admixtures at these elevations also include *Ulmus minor* and *A. pseudoplatanus*. *Fraxinus excelsior* L. is typical of southern slopes above 800 m, while on the northern slopes, appear isolated *Picea abies* and *Abies alba.*

The primeval forest stands of the Kostryna NCRD within the Uzhanskyi National Nature Park are characterized by multi-layered and age-diverse structures. This promotes the uninterrupted development of forest ecosystems through the natural dieback of old trees and the regeneration of a new generation of stands. The development of primeval forests occurs in three main dynamic stages: growth, maturity, and decay. Notably, in smaller protected areas, these stages create a mosaic structure. During the maturity of the stand, canopy density increases, while in the decay stage, dead trees create open spaces for the growth of young stands.

Two clusters were selected for the study (**Fig. 1**). Cluster 1 covers Mount Domashynskyi Verkh, while Cluster 2 covers Mount Knyagynitsa.
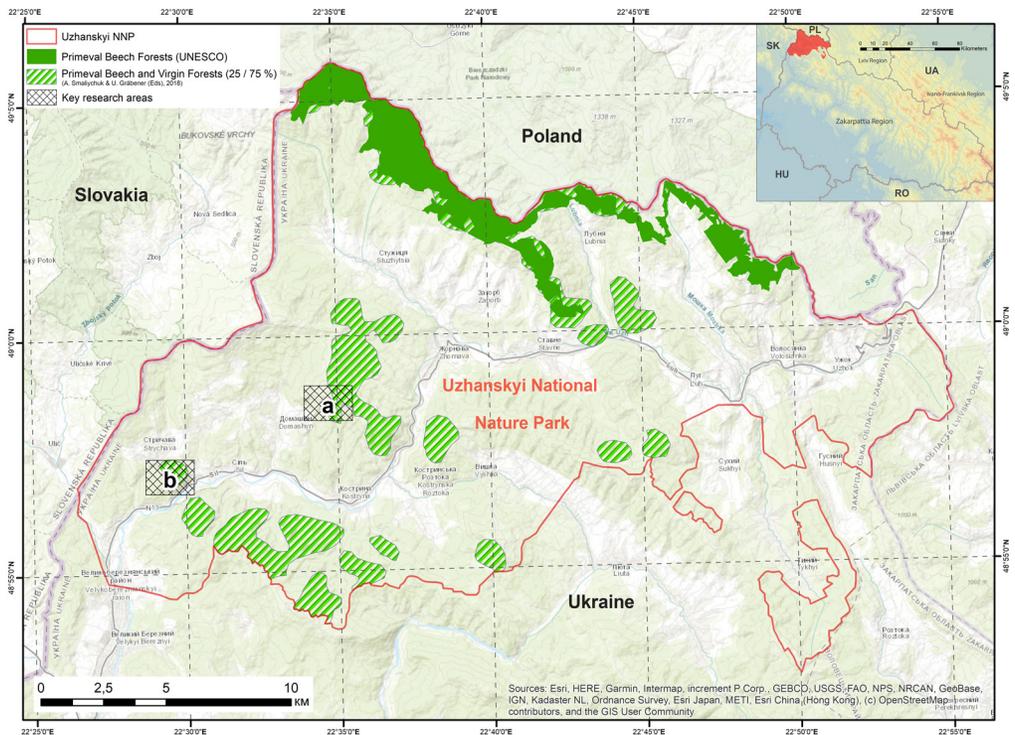
Fig. 1. Uzhanskyi National Nature Park. Identified primeval forests (UNESCO) and research areas
Note: Cluster 1 – a; Cluster 2 – b. **Source:** created by the authors

The studied Cluster 1 covers an area of 94.8 ha and is located on the southern megaslope of the Carpathian Mountains (**Fig. 2**).

Within this area, the dominant tree species is *F. sylvatica*, with *A. pseudoplatanus* and *U. glabra* prevailing in the admixture. The stand of Cluster 1 is characterized by overall homogeneity; however, the presence of certain „gaps" resulting from the dieback of old trees should be mentioned. All four stages of wood decomposition and natural forest regeneration are observed within the delineated area, with *A. pseudoplatanus* and *F. sylvatica* being dominant. Due to the uneven-aged nature of the stand, three distinct vertical layers are clearly identified within Cluster 1. The absence of organized infrastructure (no roads or tourist trails) has contributed to the preservation of primeval forest stands in the studied area.
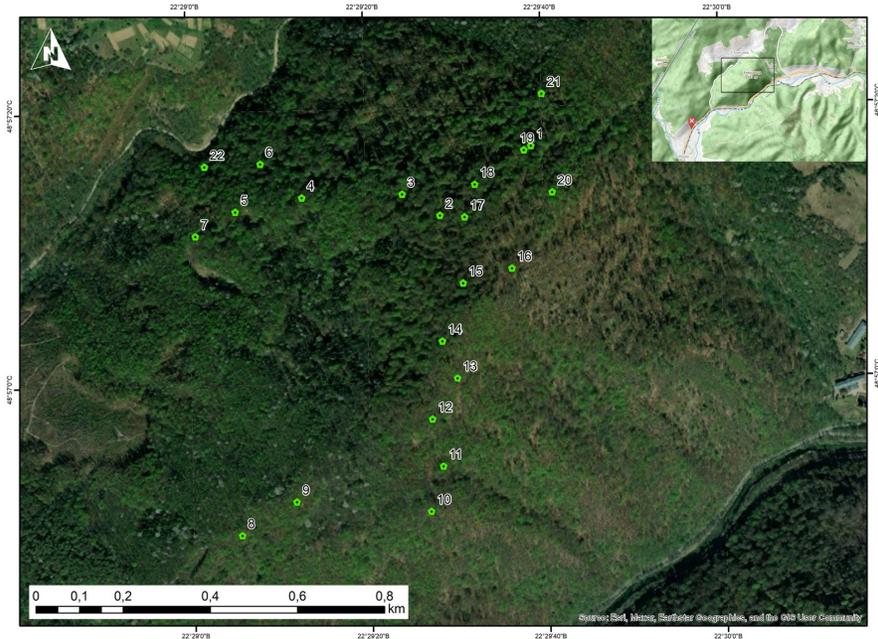
Fig. 2. Kostryna NCRD, taxation points in the Cluster 1
Note: satellite image of Cluster 1. **Source:** created by the authors

The studied Cluster 2 covers the summit of Mount Knyahynytsa and spans an area of 84.2 ha (**Fig. 3**).
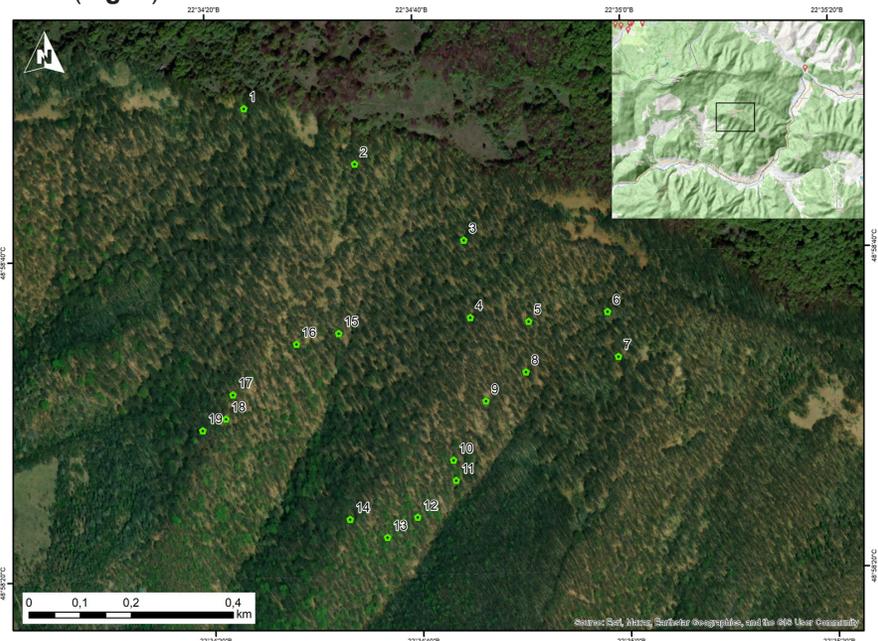
Fig. 3. Kostryna NCRD, taxation points in the Cluster 2
Note: satellite image of Cluster 2. **Source:** created by the authors

The dominant forest-forming species in the identified Cluster 2 is *F. sylvatica* with an admixture of *Q. petraea*. The stands grow on rocky screes on the eastern side, with a steep slope of 35 degrees or more (**Table 1**).

Table 1. Example photo from the tax point in Cluster 2 of the Kostryna NCRD of Uzhanskyi NNP 2024, original photo

Kostryna NCRD Sample plot – 6	Shooting coordinates	
	48°57′16.085″N	22°29′08.124″E

Source: authors' original photo

In Cluster 2, three vertical layers are predominantly observed, which is caused by natural conditions of tree species growth: the soils consist of rocky screes, and there is a lack of sufficient moisture. Only three plots in the given cluster were identified as having a two-layered structure. This is due to the limited number of young tree stands, which consequently prevents the formation of a distinct lower layer.

The studied forest stands within the forest ecosystems of the Kostryna NCRD are of exclusively natural origin and belong to site quality class I. There is no infrastructure (in either of the studied clusters), anthropogenic disturbance (e.g. grazing), or recreational use within the designated protected area. No signs of illegal logging were detected. As a result of indirect use of the forest, only minimal impact was observed, without any disturbance to the forest floor.

It should be noted that there are no synanthropic species of herbaceous plants in the studied areas. It is important to mention that both areas are dominated by small and medium-sized undergrowth, which is characteristic of primeval forests. The amount of undergrowth is within the range of 5–90 thousand pieces per hectare, which is sufficient for their natural regeneration. Dry trees of maximum diameter are present in both study areas (Shparyk *et al.*, 2021).

The forests in both areas may be in a state of decay/destruction, as partial gaps were observed in the studied areas due to the decay of old trees, and self-restoration of the forest is taking place with a predominance of forest beech and maple saplings (Shparyk & Shparyk, 2010).

Based on desk-based and field research in the Kostryna NCRD of the Uzhanskyi NNP, 11 plots with a total area of 179 ha were classified as primeval and quasi-primeval forests (**Tables 2** and **3**).

The data in **Table 2** show that 17 forest inventory plots in Cluster 1 of the Kostryna NCRD can be classified as beech primeval forest ecosystems. The age of old trees within this cluster is 176, 186, and 196 years. The number of layers is predominantly three, with only two plots in the first compartment showing two layers. In all cases, four stages of wood decomposition are present. The volume of deadwood varies significantly, ranging from 5 m³/ha to 50 m³/ha.

In Cluster 1, the herbaceous cover consists of the following plant species: *Carex pilosa* Scop.*, Galium odoratum* (L.) Scop.*, Lunaria rediviva* L.*, Lilium martagon* L.*, Athyrium filix-femina* (L.) Roth*, Dryopteris filix-mas* (L.) Schott. The undergrowth in Cluster 2 consists mainly of *F. sylvatica*, *A. pseudoplatanus* and, to a lesser extent, *U. glabra*.

The analysis of **Table 3** indicates that within Cluster 2, 19 primeval and 3 quasi-primeval ecosystems dominated by *F. sylvatica* were identified. The quasi-primeval systems are characteristic of compartment 18 of the Kostryna NCRD, likely due to the two-layer structure of the tree stands. It was noted that within the studied inventory zones, between 4 and 9 old trees are present, aged 156, 176, and 196 years, which is characteristic of both primeval and quasi-primeval forest systems. In the identified plots of Cluster 2, three or four layers are observed. The distribution of deadwood varies widely, from 3 m³/ha to 40 m³/ha. In all but two plots in Cluster 2, pure beech forests with site quality class I were identified. It makes them particularly valuable and unique in terms of biodiversity conservation. These primeval forests serve as a "natural seed bank" of European importance.

The herbaceous cover in Cluster 2 is poorer and consists of the following plant species: *Carexpilosa* Scop, *Athyrium filix-femina* (L.) Roth, *Dryopteris filix-mas* (L.) Schott,

Table 2. **Results of primeval forest identification in the Kostryna NCRD of Uzhanskyi NNP in 2024 (Cluster 1)**

Quartier	Compartment	Area, ha	Age, years	Age group	Species composition	Layers, number	Relative density	Old trees max. D, pcs.	Deadwood, m³/ha	Number of decay stages, pcs.	Undergrowth, ths. pcs./ha	Preliminary conclusion: primeval, quasi-primeval, natural forest
7	1	51	196	7	9Fs1AP +Fe	2	0.8	3	10	4	20	primeval
7	1	51	196	7	10Fs +Ap,Ug	3	0.7	9	50	4	20	primeval
7	1	51	196	7	10Fs +Ap	3	0.7	5	10	4	20	primeval
7	1	51	196	7	10Fs +Ap	3	0.8	6	15	4	20	primeval
7	1	51	196	7	10Fs + Sycamore,Elm	2	0.7	4	30	4	10	primeval
7	1	51	196	7	5Fs5Ap+Ug	3	0.6	3	10	4	15	primeval
7	1	51	196	7	10Fs +Ap,Ug	3	0.6	6	10	4	30	primeval
7	1	51	196	7	10Fs +Ap,Ug	3	0.7	5	16	4	60	primeval
7	1	51	196	7	10Fs +Ap	3	0.5	8	40	4	20	primeval
7	1	51	196	7	10Fs +Ap	3	0.5	5	30	4	10	primeval
7	8	9.8	176	7	10Fs	3	0.6	7	10	4	30	primeval
7	8	9.8	176	7	10Fs	3	0.7	7	18	4	5	primeval
7	8	9.8	176	7	10Fs	3	0.9	3	5	4	5	primeval
7	8	9.8	176	7	10Fs	3	0.7	5	15	4	10	primeval
7	8	9.8	176	7	10Fs	3	1	4	5	4	10	primeval
7	4	10	186	6	10Fs	3	0.8	6	10	4	20	primeval
7	4	10	186	6	10Fs	3	0.5	15	25	4	50	primeval

Note: Fs – *F. sylvatica*, As – *A. pseudoplatanus,* Fe – *F. excelsior*, Qp – *Q. petraea*, Ug – *U. glabra*
Source: developed by the authors based on their own research

Table 3. **Results of primeval and quasi-primeval forest identification in the Kostryna NCRD of Uzhanskyi NNP in 2024 (Cluster 2)**

Quartier	Compartment	Area, ha	Age, years	Age group	Species composition	Layers, number	Relative density	Old trees max. D, pcs.	Deadwood, m³/ha	Number of decay stages, pcs.	Undergrowth, ths. pcs./ha	Preliminary conclusion: primeval, quasi-primeval, natural forest
12	4	34	186	7	10Fs	3	0.8	10	10	4	30	primeval
12	4	34	186	7	10Fs	3	0.6	9	7	3	50	primeval
12	4	34	186	7	10Fs	3	0.9	17	8	3	10	primeval
12	4	34	186	7	10Fs	3	0.7	15	17	4	10	primeval
12	4	34	186	7	10Fs	3	0.6	12	25	4	20	primeval
12	4	34	186	7	10Fs	3	0.5	8	40	4	40	primeval
12	4	34	186	7	10Fs	3	0.6	10	22	4	40	primeval
12	4	34	186	7	10Fs	3	0.6	11	14	4	40	primeval
12	4	34	186	7	10Fs	3	0.8	7	10	4	20	primeval
12	4	34	186	7	10Fs	3	0.7	9	8	4	40	primeval
12	4	34	186	7	10Fs	3	0.5	4	13	3	20	primeval
12	2	16	196	7	10Fs	3	0.5	5	30	3	70	primeval
12	2	16	196	7	10Fs	3	0.4	9	24	4	50	primeval
12	2	16	196	7	10Fs	3	0.7	4	10	3	20	primeval
12	2	16	196	7	10Fs	3	0.6	4	20	4	50	primeval
12	2	16	196	7	10Fs	3	0.8	9	16	4	90	primeval
12	18	8.6	156	5	10Fs	2	0.8	4	3	3	60	quasi-primeval
12	18	8.6	156	5	10Fs	2	0.9	7	9	4	20	quasi-primeval
12	18	8.6	156	5	10Fs +Qp	2	0.8	7	8	3	70	quasi-primeval
12	13	14	176	6	10Fs +Qp	3	0.7	8	12	4	60	primeval
12	13	14	176	6	10Fs	2	0.7	9	5	4	8	primeval
12	13	14	176	6	10Fs	3	0.7	7	10	4	20	primeval

Note: Fs – *F. sylvatica*, As – *A. pseudoplatanus,* Fe – *F. excelsior*, Qp – *Q. petraea*, Ug – *U. glabra*
Source: developed by the authors based on their own research

and *Salvia glutinosa* L. The undergrowth in Cluster 2 is represented mainly by *F. sylvatica* and *A. pseudoplatanus*.

The undergrowth in both clusters is almost absent and occurs only in places with better lighting being represented by *Rubus fruticosus L.*

CONCLUSIONS

It was established that valuable areas of natural *F. sylvatica* habitats exist within the Kostryna NCRD of the Uzhanskyi National Nature Park. The predominant admixture species include *Q. petraea*, *A. pseudoplatanus*, *U. glabra*, and *C. betulus*. Pure beech forests were observed on the southern peaks and slopes of Mount Knyahynytsa at elevations of 400–600 m.a.s.l. These primeval forests are located in zones with the most favorable climatic and soil conditions for the growth of native species, particularly in the southeastern to southwestern part of the mountain, and partially in the northern part at 500 m.a.s.l.

The composition of tree admixtures in the forest systems of the Kostryna NCRD of the Uzhanskyi NNP depends on the vertical zonation of the area: at elevations of 300–400 m.a.s.l. with better soil conditions, *C. betulus* dominates, while on poor rocky screes, more resilient species like *Q. petraea* are found. In mountainous areas above 800 m.a.s.l., the share of *F. sylvatica* decreases to 80 %, while *U. minor* becomes more prevalent. On the southern slopes at the beginning of the subalpine zone, *F. excelsior* is observed, while on the northern slopes, isolated *P. abies* and *A. alba* can be found.

A total of 17 primeval forest inventory points were identified on Mount Domashynskyi Verkh (ecosystem of the studied Cluster 1), and 19 primeval and 3 quasi-primeval eco-systems were identified within the mountain massif of Knyagynitsa (ecosystem of the studied Cluster 2). The classification of these plots as primeval or quasi-primeval is sup-ported by the exclusively natural origin of *F. sylvatica*, *Q. petraea*, *C. betulus*, *A. pseu-doplatanus*, and *U. glabra* aged 156–196 years; the presence of three or four layers; three or four stages of wood decomposition; complete absence of infrastructure and logging traces; site quality class I; and relative stand density of no less than 0.5, indica-ting effective space utilization by the forest stand.

Based on the research findings, we have concluded that these areas should be classified as primeval forest stands requiring conservation and protection. These for-est ecosystems are a vital seed bank for the preservation and natural regeneration of forests of the Carpathian region and fulfill a range of essential ecological functions, including soil protection, water regulation, water conservation, and climate regulation.

CONFLICT OF INTEREST

The authors declare that the research was conducted in the absence of any com-mercial or financial relationships that could be construed as a potential conflict of interest.

AUTHOR CONTRIBUTIONS

Conceptualization, [S.M.]; methodology, [O.Y.; L.R.; L.K.]; investigation, [O.Y.; L.R.; L.K.; S.M.]; resources, [authors initials]; writing – original draft preparation, [O.Y.]; writing – review and editing, [S.M.; L.R.]; visualization, [O.Y.; L.R.; L.K.]; supervision, [S.M.]; project administration, [O.Y.; S.M.].

All authors have read and agreed to the published version of the manuscript.

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ІДЕНТИФІКАЦІЯ ПРАЛІСІВ І КВАЗІПРАЛІСІВ В УЖАНСЬКОМУ НАЦІОНАЛЬНОМУ ПРИРОДНОМУ ПАРКУ

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Обґрунтування. Сучасна антропогенна діяльність значно впливає на зменшення площ пралісів, квазіпралісів і старовікових лісів у світі та Європі зокрема, що тягне за собою катастрофічні зміни. Адже такі ліси є основним осередком різнома-

ніття флори і фауни та відіграють ключову роль у регулюванні клімату. Дослідження присвячено збереженню біорізноманіття лісових екосистем Карпатського регіону України шляхом ідентифікації пралісів і квазіпралісів у Костринському природо-охоронному науково-дослідному відділенні (ПНДВ) Ужанського національного природного парку в Закарпатській області (Україна).

Матеріали та методи. Приналежність окремих природних лісових масивів Карпат встановлено на основі камеральних та польових досліджень, проведених упродовж 2024 р. з використанням стандартної методики визначення приналежності лісових територій пралісів, квазіпралісів і природних лісів, затвердженої наказом № 161 Міністерства екології та природних ресурсів України.

Результати. Вивчено, що найбільш значущими лісовими ділянками є природні місцезростання *Fagus sylvatica* L. з домішками *Quercus petraea* L., *Acer pseudoplatanus* L., *Ulmus glabra* Huds., *Carpinus betulus* L. На південних вершинах і схилах гори "Княгиниця" в межах висот 400–600 м н.р.м. відмічено наявність чистих бучин, що пов'язано з оптимально сприятливими кліматичними та ґрунтовими умовами росту й розвитку.

Встановлено, що на породний склад домішок букових лісових масивів значно впливає вертикальна зональність місцевості й пов'язані з цим ґрунтові умови. Ці пралісові та квазіпралісові екосистеми характеризуються складною горизонтальною й вертикальною структурою з наявністю трьох і чотирьох ярусів.

Висновки. У межах досліджуваних ділянок (Гора Домашинський верх та Гора Княгиниця) Костринського ПНДВ Ужанського НПП виявлено 36 інвентаризаційних пунктів пралісових систем загальною площею 1075 га, а також три квазіпралісові екосистеми площею 8,6 га кожна. Необхідність окремого виділення їх (з подальшим захистом від антропогенного впливу) обумовлена природним походженням старовікових (156–196 років) насаджень *Fagus sylvatica* L., *Quercus petraea* L., *Carpinus betulus* L., *Acer pseudoplatanus* L. та *Ulmus glabra* Huds. Ці пралісові та квазіпралісові лісові екосистеми характеризуються складною горизонтальною й вертикальною структурою з наявністю трьох і чотирьох ярусів. Досліджувані лісові екосистеми належать на обох ділянках до нетрофільних букових лісів, що підкреслює їхнє екологічне значення для збереження біорізноманіття, запобігання ерозії ґрунтів, відновлення ґрунтового середовища та підтримання екологічної рівноваги.