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Distribution of virgin and old-growth forests in the territory of the Carpathian National Nature Park (Ukraine)

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ABSTRACT

The article presents the results of aninventory of old-growth forests and virgin forests with in the Carpathian National Nature Park, the largest and oldest protected area in Ukraine. Based on fieldwork, 2,612.0 hectares of the park's forests were classified as virgin and quasi-virgin forests, including 445.0 hectares of virgin forests. The largest areas of quasi-virgin forests were identified in the Bystretske Nature Conservation and Research Section (888.0 ha), while the largest areas of virgin forests were found in the Vysokohirne Nature Conservation and Research Section (304.3 ha).

Keywords: Carpathian Convention, Carpathian National Natural Park, virginforests, quasi-virginforests, natural forests.

INTRODUCTION

The exceptional value of old-growth forests (virgin forests, quasi-virgin forests, and natural forests) for forestry and nature conservation was recognized by scientists (Diaci, 2005, Frey, et al., 2016, DellaSala, et al., 2022). However, active efforts to preserve them in the Ukrainian Carpathians began in the late 20th and early 21st centuries, based on publications of Parpan (Parpan, et al., 2017), and Hámor (Hamor and Commarmot et al., 2011, Hamor, 2023). The data collected by scientists on biodiversity, structure, and dynamics (succession) of old-growth forests have provided grounds to state the urgent need for their preservation, as well as the quantitative and qualitative indicators that allow for determining the classification of a particular forest area as an old-growth forest.

It has been found that the structural complexity of virgin forests, including the presence of deadwood and multi-layered crowns, provides ecological stability that cannot be replicated in industrial forestry (Parpan, et al., 2017). Primary forests store 30–60% more carbon than logged forests. Large, old trees provide stable microclimates and are blueprints for forest restoration, acting as biological anchors in a changing climate (DellaSala, et al., 2022). The characteristics of old-growth forests reduce maximum spring and summer air temperatures... conservation strategies should focus on preserving old-growth characteristics such as closed canopies and complex understory to mitigate climate warming (Frey, et al., 2016).

The Carpathian National Natural Park covers an area of 50,495 hectares and is located in the eastern part of the northern slope of the Ukrainian Carpathians, within the territory of four territorial communities in Ivano-Frankivsk region. Its territory stretches nearly 60 km from north to south and over 20 km from west to east. This is the largest in area and the oldest national nature park in Ukraine.

The functional zoning of the Carpathian National Nature Park territory, which was carried out in 2003 in accordance with the requirements of the Law of Ukraine "On the Natural Reserve Fund of Ukraine," consists of the following zones: protected zone – 11,401.4 ha or 22.6%; regulated recreation zone – 25,953.1 ha or 51.4%; stationary recreation zone – 106.6 ha or 0.2% and management zone – 13,033.9 ha or 25.8%.

The relief of the Carpathian National Nature Park is mainly represented by the medium-high mountains of Chornohora and the Central Gorgany, Pokuttya and the Outer Gorgany, as well as the Hutsul Verkhovyna. The park also contains the highest peaks of the Ukrainian Carpathians, primarily Hoverla (2061 m).

The hydrology of the Carpathian National Nature Park is primarily formed by waters of the Prut River basin, with part of the area being drained by the waters of the Chornyi Cheremosh River basin. The river nourishment is predominantly mixed (rainfall, groundwater, and snowmelt). The share of rainfall nourishment constitutes up to 35%. River runoff is characterized by floods predominantly in the warm season, with short periods of winter low water and an indistinct spring high-water period. The flow rate of local rivers generally ranges from 0.5 to 1.5 m/s.

The territory of the Carpathian National Nature Park is located in a transitional climate zone from Atlantic to continental, with the predominance of Atlantic air masses. It is characterized by cool temperatures and excessive moisture, which result in a cold spring, a cool summer, a moderately warm autumn, and a mild winter. Climatic conditions vary according to different forms of relief and altitude above sea level – the higher the elevation, the lower the temperature and the greater the amount of precipitation.

The main type of plant communities in the territory of the Carpathian National Nature Park is forest ecosystems, which cover more than 75% of the area.

The area is dominated by coniferous forests of common spruce (*Picea abies* L. Karsten), which is the main or associated species on almost 80% of the total forested area.

Coniferous forests dominated by species such as white fir (*Abies alba* Mill. LC.) and mountain pine (*Pinus mugo.* Turra) are also well represented, whereas forests of Scots pine (*Pinus sylvestris* L.) and European larch (*Larix decidua* Mill. *L. europaea* D.C.).) occur in isolated forest plots.

Among the broadleaf forests, the most widespread in the territory of the Carpathian National Nature Park are forests dominated by European beech (*Fagus sylvatica* L.), which cover more than 10 % of the area. Broadleaf forests with dominant species such as grey alder (*Alnus incana* L. Moench L.C.), pendulous birch (*Betul apendula*), and sycamore (*Acer pseudoplatanus* L.) are also well represented, while forests of English oak (*Quercus robur* L.) and green alder (*Alnus viridis* (Chaix) D.C.) are represented by individual forest plots.

The main types of human activity in the territory of the Carpathian National Nature Park are as follows:

- forestry (logging and non-timber forest product collection),
- agriculture (live stock farming),
- tourism services,
- folk crafts (wool processing, souvenirs, pottery, blacksmithing),
- household services.

As of the beginning of 2019, the classification of forest plots as virgin forests, quasi-virgin forests, and natural forests was established on an area of 2,581.4 ha within the territory of the Carpathian National Nature Park, of which virgin forests were identified on 22.0 ha.

The goal of our study was to determine the characteristics of the distribution of primeval forests and old-growth forests in the territory of the Carpathian National Nature Park.

MATERIALS AND METHODS

The classification of forest areas as virgin forests, quasi-virgin forests, and natural forests within the territory of the Carpathian National Nature Park was conducted in accordance with the Methodology for Determining the Classification of Forest Areas as Virgin Forests, Quasi-Virgin Forests, and Natural Forests, approved by Order №. 161 of the Ministry of Ecology and Natural Resources of Ukraine on May 18, 2018. This classification also takes into account the provisions of the Law of Ukraine "On Amendments to Certain Legislative Acts of Ukraine Regarding the Protection of Virgin Forests in Accordance with the Framework Convention on the Protection and Sustainable Development of the Carpathians" (Carpathian Convention). It also complies with the provisions of the Forest Code of Ukraine.

According to the approved Methodology, the work was carried out in three stages:

- desk-based analysis,
- field research,
- final (analytical) stage.

During the first, desk-based analysis stage, forest areas that potentially meet the criteria for classification as virgin forests, quasi-virgin forests, or natural forests – outlined in Appendix 1 of the Methodology – were identified for further on-site assessment. This selection was based on forest inventory data, analysis of scientific literature, archival and other materials, as well as information provided by forestry professionals, the public, and local residents.

Potential sites are selected based on the following criteria:

- the age of the stand (mature and overmature native stands are chosen, taking into account the corresponding age of maturity, as well as all stands older than 120 years at the time of the survey);
- origin (lack of information regarding the establishment of forest plantations in the area);
- composition (the stand is formed exclusively by native species, and there should be no foreign species in the stand);
- anthropogenic impact (absence of documented information regarding logging, timber production, industrial (mass) harvesting of non-timber forest products, forest litter collection, or livestock grazing in the area);
- area (during the analysis of forest inventory data, all sites are selected regardless of their size, with subsequent research on their location).Sites or groups of sites that form a single massif (cluster) with a total area of at least 20 ha and are surrounded by natural boundaries of particularly protected forest areas, designated on the slopes of ravines, gullies, cliffs, scree slopes, and landslides, along riverbanks, around the sources of rivers, lakes, and reservoirs (riparian forest areas), or sites with stands that include relict and endemic tree species covering an area of at least 4 ha, are subject to field verification;
- shape (the distance between any two opposite boundaries through the center of the site (massif) must be at least 200 meters, except for sites surrounded by natural boundaries of particularly protected forest areas, designated on the slopes of ravines, gullies, cliffs, scree slopes, and landslides, along riverbanks, around the sources of rivers, lakes, and reservoirs (riparian forest areas), or sites with stands that include relict and endemic tree species).

A virgin forest (virgin forest ecosystem) is an ancient, primordial forest (natural forest ecosystem) that has formed naturally and, during its development, has not been subjected to direct anthropogenic influence.

Quasi-virginforests are conditionally virgin ecosystems where there has been slight, temporary anthropogenic influence that has not altered the natural structure of the forest stands. When this influence ceases, the natural state of the ecosystems is fully restored within a short period.

Natural forests (natural forest ecosystems) are forests (forest ecosystems) where anthropogenic influence has occurred locally and temporarily, but it has not altered the cenotic structure of the phytocenoses. As a result, these natural forest ecosystems are capable of regenerating (restoring) naturally within a short period to a state similar to that of virgin forest ecosystems.

During the field research, surveys were conducted at each site selected during the desk-based analysis, following the Methodology. Each forest area was visually surveyed at inventory points (at least one inventory point per 3 hectares or on smaller areas).

At each inventory point, the following were assessed:

- species composition and its compliance with the forest type;
- natural origin of the stand;
- the presence of trees in the main canopy that, under the forest conditions of this particular site, have reached the age-related physiological limit, exhibit exceptional (maximum) dimensions, and show signs of age-related mortality;
- the number and distribution of trees that have reached the age-related physiological limit;
- the presence of dead wood from old, large trees (fallen trunks and standing dead trees) at various stages of decomposition throughout the entire area of the site. The volume was assessed in $m^3 \cdot ha^{-1}$, and the number of decomposition stages present was also evaluated. Dead wood was classified into four stages (classes) of decomposition: I – fresh or not yet decomposed wood (a knife blade, when lightly pressed along the wood fibers, penetrates only through the bark); II – Initial decomposition

(the knife blade, when lightly pressed along the wood fibers, penetrates through the bark and several centimeters into the wood); III – intensive decomposition (the knife blade, when lightly pressed along the wood fibers, penetrates through the bark and into the wood along its entire length); IV – complete decomposition (the knife blade, when lightly pressed, penetrates the wood along its entire length, both along and across the fibers);

- the vertical and horizontal structure of the stand;
- the amount of natural regeneration;
- the presence of forestry infrastructure or its remnants, such as roads, skid trails, sluices for timber floating, fish breeding dams, cables for skidding, loading ramps for timber trucks, charcoal kilns, etc.;
- the presence of signs of logging;
- the presence of signs of non-timber forest product harvesting;
- the condition of the forest litter;
- the presence of signs of livestock grazing;
- the presence of signs and the extent of recreational impact.

At each point of taxation, its coordinates were recorded using geo-positioning devices, and georeferenced photographs of the stand were taken.

The final result of the field research for the identification of virgin forests, quasi-virgin forests, and natural forests is the completed Identification Form and the preliminary conclusion regarding the compliance of a specific forest area or its parts with the criteria for virgin forests, quasi-virgin forests, or natural forests.

RESULTS

According to the approved methodology, during the desk-based stage, based on the data from the previous forest inventory, forest areas totaling 11,555.7 hectares within the Carpathian National Nature Park were selected, which potentially could meet the criteria for classification as virgin forests, quasi-virgin forests, or natural forests. This selection was made because, based on the database, it is very difficult to determine the compliance of specific indicators with the established criteria.

The distribution of the forest areas that could potentially meet the criteria for classification as virgin forests, quasi-virgin forests, or natural forests, according to the nature conservation research sections, shows that the largest areas of such forests are located in the Hoverlianske, Zhenetske, and Bystretske sections (Table 1).

DISCUSSION

Research on virgin forests in the Carpathian National Nature Park over the past 20 years has gone from local descriptions to large-scale international inventory and digital monitoring. KNPP, as the oldest national park in Ukraine, has become a key platform for studying high-altitude spruce (fir) and mixed virgin forests of Chornohora.

Table 1. Areas of potential virgin forests, quasi-virgin forests, or natural forests in the sections of the Carpathian National Nature Park

No.	Nature conservation research sections	Area of potential virgin forests, ha	% of the area
1	Bystretske	1584.4	13.7
2	Vysokohirne	717.6	6.2
3	Voronenkivske	579.4	5.0
4	Vorokhtianske	850.3	7.4
5	Hoverlianske	2388.0	20.7
6	Zhenetske	1675.8	14.5
7	Pidlisnivske	742.8	6.4
8	Tatarivske	641.7	5.6
9	Chornohirske	530.0	4.6
10	Yablunytske	673.1	5.8
11	Yamnianske	772.0	6.7
12	Yaremchanske	400.6	3.5
Total:		11555,7	100,0

During which time, two main stages can be conditionally distinguished:

1. Inventory and mapping stage (2004–2018).

During this main period, attention was paid to the precise definition of the boundaries of virgin forests and their legal consolidation.

As part of the WWF project (2010–2015), large-scale field work was carried out to identify virgin forests. Significant areas of virgin forests were discovered in the highlands (Hoverlianske, Vysokogorne forestry). This became the basis for the adoption of the Law of Ukraine on the Protection of Virgin Forests in 2017.

Primeval forests of the Carpathians serve as the only reliable biological benchmark for evaluating the success of forest restoration. In the Carpathian National Nature Park, these areas represent the maximum possible biodiversity of high-altitude ecosystems (Chernyavskyy, M., et al., 2018). Findings indicate that the primeval spruce and beech forests of Ukraine store significantly higher amounts of biomass and soil carbon than previously estimated for temperate forests. Preserving these stands is a globally significant strategy for carbon sequestration (Keeton, W. S., et al., 2010).

2. Ecosystem Dynamics and Resilience (2018–2024). Current research focuses on how virgin forests respond to climate change.

The area of these selected forest plots was quite significant (over 11.5 thousand hectares), but most of them were excluded from the fieldwork list due to non-compliance with the following criteria for classifying forest areas as virgin forests, quasi-virgin forests, or natural forests:

- the species composition did not correspond to the forest type (it was not native);
- significant anthropogenic impact – due to the presence of information regarding logging, timber harvesting, industrial collection of non-timber forest products, or livestock grazing in the area;
- the shape of the plot – the distance between any two opposite boundaries through the center of the plot was less than 200 meters, except for sites surrounded by natural boundaries of particularly protected forest areas, designated on the slopes of ravines, gullies, cliffs, scree slopes, and landslides, along riverbanks, around the sources of rivers, lakes, and reservoirs (riparian forest areas), or sites with stands that include relict and endemic tree species.

At the final stage, it was confirmed that 53 clusters of forest plots were identified within the Carpathian National Nature Park that meet the criteria and indicators for virgin forests and quasi-virgin forests, in 11 nature conservation research sections of the park, excluding the Voronenkivske. The largest areas of quasi-virgin forests were identified in the Bystretske Section (888.0 ha) (Fig. 1), while the largest areas of virgin forests were identified in the Vysokohirne Section (304.3 ha) (Fig. 2). Also, in 7 clusters, the type of old-growth forests was changed from "quasi-virgin forest" to "virgin forest", meaning the park acquired 7 new clusters of virgin forests covering an area of approximately 400 ha.

Figure. 1. Quasi-virgin forests in the Bystretsky Nature Conservation Research Section

The virgin and quasi-virgin forests of the Carpathian National Nature Park are unevenly distributed among six main species (Fig. 3):

- Spruce (*Picea abies* (L.) Karsten) accounts for more than 47% of these old-growth forests;
- Mountain pine (*Pinus mugo.* Turra) accounts for more than 34%;
- European beech (*Fagus sylvatica* L.) accounts for about 12%;
- Green alder (*Alnus viridis* (Chaix) D.C.), scots pine (*Pinus sylvestris* L.), and white fir (*Abies alba* Mill. LC.) account for between 1% and 4%.

Virgin and quasi-virgin forests of the Carpathian National Nature Park are classified by forest types (Fig. 4):

- conditions of the humid mountain pine subor account for more than 34% of these old-growth forests;
- conditions of the humid pure spruce forest account for more than 24%;
- conditions of the humid spruce-fir beech forest account for about 8%;
- conditions of the humid beech-fir spruce forest account for about 8%;
- conditions of the humid pure spruce subor account for more than 7%;
- conditions of the humid spruce-fir subbeech forest account for more than 4%;
- conditions of the humid beech-spruce subfir forest account for more than 4%;
- the share of the other ten forest types ranges from 0.1% (B3-kSm) to 2.3% (S3-yatsSm);
- the share of the other ten forest types ranges from 0.1% (humid cedar-spruce subor) to 2.3% (humid fir spruce forest).

Figure. 2. Virgin forests in the Vysokohirny Nature Conservation Research Section

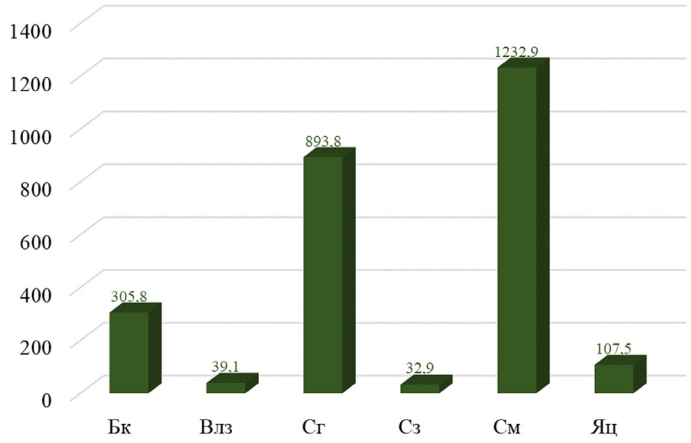

Figure. 3. Areas of virgin and quasi-virgin forests of the Carpathian National Nature Park by dominant tree species

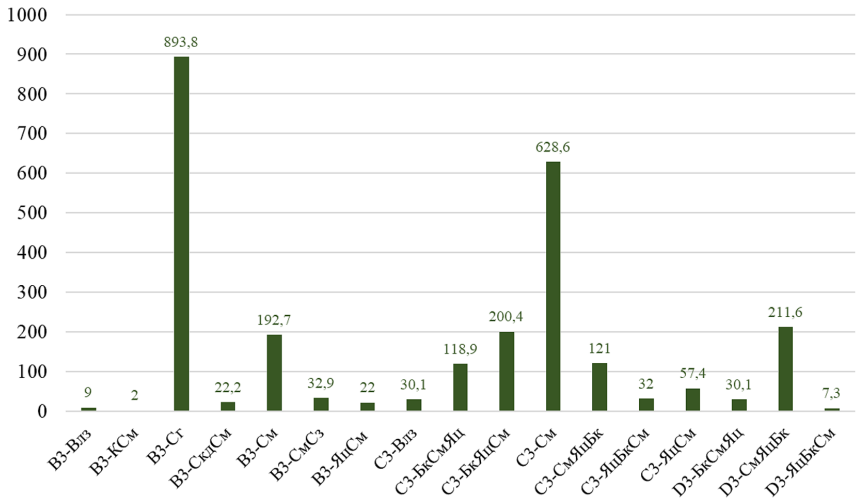

Figure. 4. Areas of virgin and quasi-virgin forests in the territory of the Carpathian National Nature Park by forest types

CONCLUSIONS

Based on the data from the previous forest management, forest plots with an area of 11,555.7 ha were selected within the territory of the Carpathian National Nature Park, which could potentially meet the criteria for classification as virgin forests, quasi-virgin forests, or natural forests.

As a result of the fieldwork, the classification of 2,612.0 hectares of forests within the Carpathian National Nature Park as virgin and quasi-virgin forests was established, of which 445.0 hectares were identified as virgin forests. Among the six main species represented in these old-growth forests, the largest areas are occupied by spruce (*Picea abies* (L.) Karsten.) (47%) and mountain pine (*Pinus mugo.* Turra) (34%). Of the seventeen forest types represented in these old-growth forests, the majority of the area is occupied by the humid mountain pine subor (34%) and the humid pure spruce forest (24%).

Results confirmed that 53 clusters of forest plots covering an area of 2,612.0 ha were identified within the territory of the Carpathian National Nature Park, meeting the criteria and indicators of virgin and quasi-virgin forests. These clusters are located in 11 nature conservation research sections of the Park, excluding the Voronenkivske.

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