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Infertile and Less Infertile Forest Types in the Ukrainian Carpathians: Classification and Complementation

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Abstract. Forest typology is yet to get sufficiently integrated into related ecological and geographical sciences. The succession of plant phytocenoses necessitates constant adjustments to forest types. The discussed studies have been conducted to improve the classification of forest types in the Ukrainian Carpathians and bring the description closer to the actual distribution of vegetation within the studied area. The paper provides a detailed analysis of forest typology research for the Ukrainian Carpathians area during late 20th and early 21st century. The forest fund areas of the Carpathian region, which are subordinated to the State Agency of Forest Resources of Ukraine, have been classified by forest vegetation types. Total area of subor and coniferous forest types is 1,493.1 ha and 28,910.2 ha, respectively. The study involved establishing of permanent sample plots on the territory of nature protection institutions and forest management enterprises. According to the findings, it is proposed to complement the classification of subor and coniferous forest type as defined by Z.Yu. Herushynskyi on the territory of the Ukrainian Carpathians with the following types: fresh pine subor forest type, wet pine subor forest type, and wet pine coniferous type. The paper defines the main diagnostic features of the suggested forest types. These subor and coniferous forest types can be clearly distinguished from other forest types by soil and hydrological conditions, and can be used to describe the corresponding forest vegetation types. The correctness of definition of new forest types is confirmed with a set of plant indicator species that have been identified within the relevant areas. The findings provide a better understanding of forest ecology and make a significant contribution to forest typology studies on the territory of the Ukrainian Carpathians. Another step towards researching the patterns of the establishment of plant complexes in the Ukrainian Carpathians has been taken. Forest formations of the Carpathians are presented in more detail in forest typological science

Keywords: forest typology, forest vegetation type, diagnostic features, indicator plants, forest type index, typological profile, ecological figure

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INTRODUCTION

The need to increase productivity and integrated use of wood and non-wood forest resources forces foresters to manage forests on a typological basis differentiated depending on various economic and forestry conditions [1]. Scientific works of a number of Ukrainian researchers are devoted to forest typological studies in the Ukrainian Carpathians [2-4]. At the present stage of development of typological science in Ukraine, researchers are trying to create a detailed typological scheme of forests, which would consider not only edaphic, but also climatic and coenotic factors. At the same time, the forest typology has a significant practical application, as it solves the problem of classification of forest areas that are homogeneous in soil, hydrological, climatic, and forest site conditions. This results in the possibility to develop uniform requirements for forestry management.

The constant development of main conditions of the forest and ecological method of forest type diagnosis, the development of quantitative approaches to the assessment of edatops, and the expansion of possible areas of application makes it universally applicable in both industry and research. The forest typology is the basis for close to nature forestry, the methods of which are most relevant in forestry and environmental management in the context of climate change.

Forest typology is yet to get sufficiently integrated into related ecological and geographical sciences. The succession of plant phytocenoses forces to make constant adjustments of forest types. One of the reasons behind such a state is the lack of quantitative determination of edatope.

A number of researchers have been introducing adjustments to the existing model to improve the existing classification system. In particular, A. Shvydenko suggested to introduce additional trophotopes and hyhrotopes [5]. At the same time, O. Migunova argued about the need to combine the existing edaphic grid with the predominant soil rocks and the content of certain chemical compounds (phosphate anhydride and potassium oxide) [6], and assumed the possibility of applying the principles of the forest ecological classification system for the classification of nature as a whole. The study involved the analysis of subor and coniferous forest types aiming to improve the forest topology, establishment of permanent sample plots within the tree stands that did not meet the existing diagnostic features aiming to detect and diagnose new forest types.

Considering the global climate change on our planet that leads to drying of spruce forests, Scots pine deserves the attention of foresters as an indigenous, reclamation, forest forming tree species, and not only as a relict species that is in a need of careful protection. Proper diagnosis of forest types would allow carrying out all necessary forestry and environmental measures correctly to form the forthcoming tree stand composition, living ground cover, undergrowth, and other forest elements as close to the natural forest habitat as possible. In particular, natural stands of Scots pine should be used for both protective and forest breeding purposes. To solve these problems, foremost, it is necessary to study relevant issues related to forestry and ecological features of the formation of these stands, along with their spatial and morphological structure. This knowledge will help to properly carry out further research, especially in forestry, geobotany, dendrology, soil science, geology, etc.

MATERIALS AND METHODS

Objects of the study have been determined within the Ukrainian Carpathians using own experimental research based on the materials from forest management expedition databases, state forest inventory data, and additional information obtained during communication with forest workers on the territory of the study area.

The choice of areas for establishing the set of sample plots was based on the previous inventory and a route method of inspection of the studied objects. Field research included establishment of sample plots according to the standard of organisation of Ukraine 02.02-37-476:2006 [7] and processing of the obtained data according to the generally accepted methods in forestry and inventory research [2; 3; 8; 9]

The work within the permanent sample plots involved the following:

1. Complete enumeration of trees with simultaneous measurement of DBH. Tree numbering was performed using white paint on the same side of the trunk that is relative to the sample plot.

2. Height measurement was performed using a laser altimeter TruPulse 360B with an accuracy of 0.1 m according to the method of using the device.

3. Assigning individual coordinates to each tree by using a pre-established relative grid of coordinates within the sample plot area [10; 11].

4. Assessment of the sanitary condition of trees and their categorisation in accordance with the "Sanitary rules in the forests of Ukraine".

5. Counting the undergrowth within the sample plot area separately for each species. Simultaneously, undergrowth has been distributed into one-, two-, five-, seven-, and ten-year age groups. Coordinates of the undergrowth location have been recorded as well.

6. Identification of all types of grass cover and determination of dominant and co-dominant species, along with identification of indicator plant species that are relevant to forest vegetation conditions.

7. Recording the outline of the living above ground cover distribution using a coordinate grid to determine the percentage and nature of its spatial scattering.

8. Excavation of soil profile and determination of soil horizons within the sample plots where the soil was well-formed.

9. Taking photos of work stages, types of living above

ground cover, creators of mycorrhiza, pathogens, and pests for further illustration of the research.

10. Collection of cones and needles, sampling of wood, fruiting bodies of fungi, and soil of all horizons for further laboratory research.

Typological analysis of subor and coniferous forest types in the territory of the Ukrainian Carpathians was carried out using own research, the conclusions of other researchers along with the forest inventory data. Determination of forest types and distribution of tree stands within natural and successive categories was made in accordance with the generally accepted forestry methods and on the basis of the Pohrebniak & Vorobiov forest typology grid, and using practical recommendations suggested by Herushynskyi [3].

The obtained results of measurements and observations were processed using standard methods of statistical analysis as developed by the Department of Forest Inventory and Forest Management of the Ukrainian National Forestry University. All photos and tables in the paper represent own research results.

RESULTS AND DISCUSSION

Initial data. Forest fund areas of the Carpathian region have been divided based on the materials from forest management expedition databases by types of forest vegetation conditions. According to the findings, the majority of subor forest areas are located on the territory of Ivano-Frankivsk region (fresh subor conditions – 118.8 ha (8.0%), humid subor conditions – 1,230.6 ha (82.4%), moist subor conditions – 1.6 ha (0.1%), wet subor conditions – 132.2 ha (8.9%). As of the Lviv region, subor areas are located on the territory of the Sambir State Forest Management Enterprise (dry subor conditions – 0.5 ha (0.03%), fresh subor conditions – 9.4 ha (6.3%). The total area of subor forests on the territory of the Ukrainian Carpathians is 1,493.1 ha. The total area of coniferous forests on the territory of the Ukrainian Carpathians is 28,190.2 ha. The vast majority of coniferous forest conditions are managed by the Ivano-Frankivsk Regional Forest and Hunting Management Enterprise – 79.58% (dry coniferous forest conditions – 3 ha, fresh coniferous forest conditions – 333.5 ha (1.15%), humid coniferous forest conditions – 21,954.9 ha (75.94%), wet coniferous forest conditions – 716.2 ha (2.48%). As of the Lviv Regional Forest and Hunting Management Enterprise, coniferous forest conditions are present on the area of 2,633.3 ha (9.11%), while Chernivtsi and Zakarpattia Regional Forest and Hunting Management Enterprises manage 1,374.3 ha (4.75%) and 1,895.0 ha (6.55%) of coniferous forest areas.

Research of predecessors. Herushynskyi has established 5 permanent sample plots in the areas of fresh subor forest types and 10 permanent sample plots in the areas of humid subor forest types during his studies of forest typological features of the Carpathian forests [10]. Based on the carried-out researches, Herushynskyi considers the types of Scots pine forest to be interregional for the Pokuty-Marmorosh part of the Ukrainian Carpathians. As a result of his typological study, Herushynskyi described all forest types he discovered on the territory of the Ukrainian Carpathians, including subor and coniferous ones [3]. This work is the basis for determining forest types for scientific and practical purposes. It identifies the main indicator plants for the proposed forest types.

However, R. Yatsyk [12] cites the most common forest types of *Pinus sylvestris* L. of relict origin in the Ukrainian Carpathians based on his own research. The author notes such less common forest types as moist spruce-pine Carpathian coniferous forest type, moist spruce-pine Carpathian coniferous forest type, and wet pine coniferous forest type. The forest types have not been identified earlier by Herushynskyi.

Shevchenko suggests the division of pine forests and their types depending on the ecological conditions. In particular, into coniferous forest types with the dominance of *Pinus sylvestris* L. but sufficient admixture of *Picea abies* (L.) Karsten, *Betula pendula* Roth, and *Abies alba* Mill. in trophotopes from B_2 to B_5. Trophotope B_3 is predominant among all relict pine forests [10].

Milkina (1987) provides a detailed description of cenoses which have *Pinus sylvestris* L. in tree species composition on the territory of the Ukrainian Carpathians [12]. The author divides pine forests, in particular in coniferous forest types, into three main sub-formations. These sub-formations, in their turn, are divided into associations and sub-associations.

Sub-formation *Pineta sylvestris* consists of the following monodominant pine cenoses (associations): *Pinetum vaccinioso-hylocomiosum* and *Pinetum myrtilloso-hylocomiosum* (those are formed within the forest type B_4-Ps individually in the geographical tracts "Sokil", "Bredulets", "Pichne"); *Pinetum empetroso-hylocomiosum*; *Pinetum sphagnosum* as divided into 4 sub-associations: (a) *Pinetum myrtilloso-sphagnosum* (forest type B_4-Ps, individual trees of spruce can be found in the second storey and has class V^a bonitet); (b) *Pinetum eriophoroso-sphagnosum* (pure tree stands with slightly higher productivity in forest type B_5-Ps with the climatic admixture of *Betula pubescens* Ehrh. of less than 500 trees per ha of undergrowth).

Sub-formation *Piceeto-Pinetum* represents spruce-pine cenoses, which mostly grow within coniferous forest conditions and represent a transitional form of cenoses between pure pine stands and spruce stands. It is represented by such associations as *Piceeto-Pinetum myrtilloso-hylocomiosum* (forest type – B_2-paPs, B_3-paPs); *Piceeto-Pinetum myrtilloso-sphagnosum typicum* (forest type – B_4-paPs, and can be found in the geographical tracts "Liutoshary"). Sub-formation *Abieto-Piceeto-Pineta* is represented by the association *Abieto-Piceeto-Pineta myrtilloso-hylocomiosum* (forest type – B_3-paPs).

Practical review and analysis of previous research. A visual inspection has been carried out for tree stands,

which had corresponded to the previously described forest types. Observations have been used for visual comparison with stands that have distinctive features. The following forest types have been distinguished within subor forest vegetation types:

Forest type – humid spruce and pine subor type (A_3-paPs) is common in the upper belt of the Ukrainian Carpathians (Pokuty Carpathians, Gorgany) within the heights of 900-1,450 m above sea level, on slopes with a steepness of 15-30°, and on fine soils in micro-depressions and crevices of rock placers. The composition of the stand is dominated by *Pinus sylvestris* L. and *Picea abies* (L.) Karsten (class IV bonitet mostly) (Fig. 1) with an admixture of *Betula pendula* Roth. *Sorbus aucuparia* L. is present as a part of a sparse undergrowth. *Vaccinium myrtillus* L., *Calluna vulgaris* (L.) Hull, *Empetrum nigrum* L. and mosses, less herbaceous species, predominate in the layer of above-ground cover.

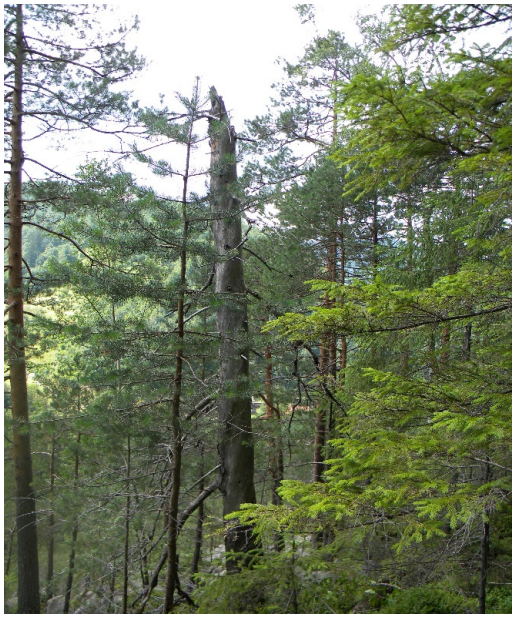


Figure 1. *Humid spruce and pine subor forest type (A_3-paPs)*

Forest type – humid mugo pine subor type (A_3-Pm) can be found in the high mountain belt of the Carpathians within the altitudes of 1,400-1,750 m above sea level on the territory of Chornohora, Chyvchyny, Gorgany, Grynyava mountain massifs. Soils are underdeveloped, low-strength with a small layer of fine soil (up to 25 cm). Tree stand layer is represented by the continuous thickets of *Pinus mugo* Turra with the height of up to 2 m (Fig. 2). *Sorbus aucuparia* L., *Salix caprea* L., *Salix silesiaca* Willd., *Juniperus sibirica* Burgsd. form the layer of a sparse undergrowth. *Vaccinium myrtillus* L., *Vaccinium vitis-idaea* L. and a large variety of herbaceous species can be found within the layer of above-ground cover.

Figure 2. *Humid mugo pine subor forest type (A_3-Pm)*

Forest type – humid stone pine and spruce subor type (A_3-pcPa). This type is common on mountain tops and their slopes within altitudes of 1,250-1,550 m above sea level in Gorgany and Chornohora massifs. Soils are underdeveloped, low-strength with a small layer of fine soil (up to 30 cm), stony. Tree stand is dominated by *Picea abies* (L.) Karsten with an admixture of *Pinus cembrae* L. (class IV bonitet mostly) and *Betula pendula* Roth. (Fig. 3). *Sorbus aucuparia* L., *Salix caprea* L., *Salix silesiaca* Willd., *Juniperus sibirica* Burgsd. represent the layer of undergrowth, while *Vaccinium myrtillus* L. and mosses can be found as above-ground cover. These forests are one of the many virgin areas of the subalpine belt of the Carpathians [14].

***Figure 3**. Humid stone pine and spruce subor forest type (A_3-pcPa)*

Forest type – moist mugo pine subor type (A_4-Pm) is common in the highlands of the Carpathians (Chornohora, Gorgany, Chyvchyny, and Grynyava massifs) on flat locations or concave slopes up to 15° peat-podzol soils within altitudes of 1,300-1,800 m above sea level (Fig. 4). Undergrowth and underbrush are absent in *Pinus mugo* Turra thickets of up to 1.2 m tall. Mosses are commonly present in the above-ground cover, while *Vaccinium myrtillus* L., *Ledum palustre* L., *Oxycoccus microcarpus* Pers., *Empetrum nigrum* L., are represented much less. Similarly to the previously mentioned moist mugo pine subor type, forests of A_4-Pm may have areas of virgin vegetation within the subalpine belt [14].

***Figure 4**. Moist mugo pine subor forest type (A_4-Pm)*

Herushynskyi (1996) has identified and described 16 coniferous forest types, which are composed by almost all forest-forming tree species of the Carpathians. *Fagus sylvatica* L. is a forest-forming species for such forest types as:

– fresh beech coniferous forest type (B_2-Fs) is rather uncommon, but can still be found on the slopes of the Southern exposure in the Pokut Carpathians and Gorgany massif in the altitude range from 500 to 1,200 m above sea level. A stand has low bonitet value and consists of the trees of vegetative origin with low market value (Fig. 5a). Soils are gravelly with the release of the parent rock to the surface [15].

– humid beech coniferous forest type (B_3-Fs) is formed

in similar forest vegetation conditions as B_2-Fs does. However, it is mostly located on the slopes of Northern exposure (Fig. 5b).

Picea abies (L.) Karsten is a forest-forming species for such forest types as:

– humid spruce coniferous forest type (B_3-Pa) is exclusive to the highlands of the Carpathians in the altitude range of 1,000-1,500 m above sea level. regardless of the slope exposure with a slope of 20-30°. Soils do not have a great thickness (only 20-40 cm thick) on rock placers and rubble (Fig. 6a).

– moist spruce coniferous forest type (B_4-Pa) can be found in the highlands of the Carpathians in the lower slopes of the northern exposure. This forest type features peat soils with excessive moisture level. Tree stand have low productivity values and rarely exceed class IV bonitet (Fig. 6b). The vast majority of these forests belong to the virgin areas of the Carpathians [16; 17].

a) fresh beech coniferous forest type (B_2-Fs)

b) humid beech coniferous forest type (B_3-Fs)

***Figure 5**. Coniferous forest types of Fagus sylvatica L.*

a) humid spruce coniferous forest type (B_3-Pa)

b) moist spruce coniferous forest type (B_4-Pa)

***Figure 6**. Pure spruce coniferous forest types*

– humid fir and spruce coniferous type (B_3-aaPa) is formed everywhere in the Carpathians at altitudes of 650-1,300 m above sea level with western and northern exposure of the slopes. Tree stand has an average productivity. Trees of *Abies alba* Mill. have much lower growth rates compared to *Picea abies* (L.) Karsten (Fig. 7a).

– humid stone pine and spruce coniferous forest type (B_3-pcPa) is common mainly for Gorgany massif in the upper part of the forest cover at absolute altitudes of 1,300-1,500 m above sea level. However, it can be found on small area within Chornohora and Pokyty massifs of Carpathians as well. Tree stand has an average productivity and class II or III of bonitet. *Pinus cembrae* L. is mainly present in the overstory (Fig. 7b). These forests on the territory of the Ukrainian Carpathians have been disturbed severely or destroyed because of the valuable qualities of *Pinus cembrae* L. timber [18].

– humid larch, stone pine and spruce coniferous forest type (B_3-ldpcPa) is exclusive to Gorgany on the slopes of the southern exposure in the altitude range of 1,000-1,300 m above sea level. Soils are poorly developed, very stony. Tree stands have class II or III of bonitet.

– moist stone pine and spruce coniferous forest type (B_4-pcPa) is common for heights of 1,100-1,400 m above sea level in the same conditions as B_3-pcPa, except for the slope steepness. It is lower for B_4-pcPa compared to B_3-pcPa and helps to retain moisture better. Soils are underdeveloped and include peat (Fig. 7c).

a) humid fir and spruce coniferous forest type (B_3-aaPa)

b) humid stone pine and spruce coniferous forest type (B_3-pcPa)

c) moist stone pine and spruce coniferous forest type (B_4-pcPa)

***Figure 7**. Spruce subor forest types*

Quercus petraeae Liebl. acts as a forest-forming species for a single forest type – fresh sessile oak coniferous forest type (B_2-Qp). It is limited to Zakarpattia and Prykarpattia geographical regions on the southern exposures of slopes with absolute heights of 150-550 m above sea level. Tree stands of sessile oak have low density and low bonitet values (Fig. 8).

***Figure 8**. Fresh sessile oak coniferous forest type (B_2-Qp)*

Similarly, to *Quercus petraeae* Liebl., *Alnus viridis* (Chaix.) D.C. can be found within one forest type only – humid green alder coniferous forest type (B_3-Av). It is common in the highlands of the Carpathians in the subalpine zone. Mostly, this forest type is confined to the places of formation of high mountain streams (Fig. 9).

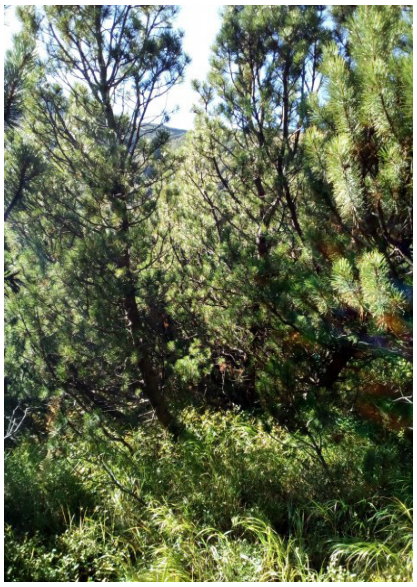
***Figure 9**. Humid green alder coniferous forest type (B_3-Av)*

Pinus mugo Turra is a forest-forming tree species for such three forest types as:

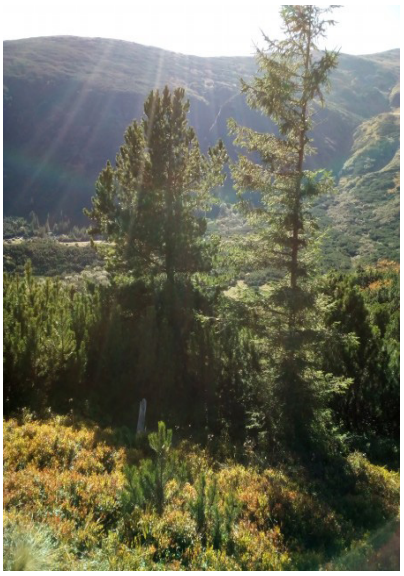
– humid mugo pine coniferous forest type (B_3-Pm) can be found everywhere in the Carpathians at altitudes of 1,450-1,750 m above sea level. This is one of the most common forest types for *Pinus mugo* Turra. Tree stand is represented by continuous thickets over 2 m high (Fig. 10a).

– humid stone pine and mugo pine coniferous forest type (B_3-pcPm) can be found in Gorgany and Chornohora massifs of the Ukrainian Carpathians. A special feature of this forest type is the presence of isolated *Pinus cembrae* L. trees (see Fig. 10b).

– moist mugo pine coniferous forest type (B_4-Pm) is common for the altitude range of 1,250-1,550 m above sea level, on gentle slopes with a slope of not more than 35° with peat soils (Fig. 10c).



a) humid mugo pine coniferous forest type (B_3-Pm)



b) humid stone pine and mugo pine coniferous forest type (B_3-pcPm)

c) moist mugo pine coniferous forest type (B_4-Pm)

***Figure 10**. Mugo pine coniferous forest types*

Pinus sylvestris L. is a forest-forming species for such three forest types as:

– fresh spruce and pine coniferous forest type (B_2-paPs) can be found on the southern exposures of the slopes with rocky placers of Yamne sandstone of III-IV category in the altitude range of 500-900 m above sea level. *Pinus sylvestris* L. is the primary forest-forming species here, while *Picea abies* (L.) Karsten is usually present as an admixture and second storey of the tree stand. Relative density of the tree stand does not exceed 0.7 (Fig. 11a). Tree stand has a grouped spatial distribution and is concentrated in places of accumulation of organic matter;

– humid spruce pine coniferous forest type (B_3-paPs) is the most common type of relict forest of *Pinus sylvestris* L. in the Carpathians, which is common on rocky placers of Yamne sandstone. It occurs on the southern, southwestern and north-eastern exposures of slopes with an altitude range of 600-1,100 m above sea level [10]. The rocky outcrops of Yamne sandstone within this forest type are categorised into III-IV categories depending on the slope and height above sea level (Fig. 11b). *Pinus sylvestris* L. is the primary forest-forming species here as well. *Picea abies* (L.) Karsten is present as a 30-40% admixture within the tree stand;

– moist spruce pine coniferous forest type (B_4-paPs) occurs quite rarely on the rocky outcrops of Yamne sandstone of III-V categories and is quite common in peat bogs of river terraces of mountain rivers. The process of formation of this type of forest is similar to the one of A_4-paPs on rock placers with the only difference related to the thickness and fertility, which are higher for B_4-paPs. This forest type is concentrated on the edges of swamps with small micro-elevations. The primary forest-forming species is *Pinus sylvestris* L. *Picea abies* (L.) Karsten can be found as an admixture, but not more than 20% of the tree stand composition (Fig. 11c).

a) fresh spruce and pine coniferous forest type (B_2-paPs) *b) humid spruce pine coniferous forest type (B_3-paPs)* *c) moist spruce pine coniferous forest type (B_4-paPs)*

***Figure 11**. Pine coniferous forest types*

Study results. After a detailed analysis of previous scientific and research work [2; 3; 9; 12; 13] and forest management expedition databases, it has been found that there is a significant share of forests, which have *Pinus sylvestris* L. within their composition. Such forests are studied insufficiently, or not described at all. The practice of forest typological study had been continued in subor (Table 1) and coniferous (Table 2) forest types of *Pinus sylvestris* L. within the Ukrainian Carpathians and established numerous sample plots on the territory of forest management enterprises and nature protection institutions.

***Table 1**. Characteristics of permanent sample plots on the territory of coniferous areas of the Ukrainian Carpathians*

INDICATORS		Sample plot (SP)									
		1	2	3	4	5	6	7	8	9	10
Enterprise		Carpathian State Special Forestry Enterprise of Agro-Industrial Complex			Bolekhiv State Forest Management Enterprise	Carpathian National Nature Park	Nadvirna State Forest Management Enterprise		Mizhhiria State Forest Management Enterprise	Vyhoda State Forest Management Enterprise	
Forest district		Roztokivske			Solotvynske	Yamnenske	Zelenske		Izkivske	Mizunske	
Population		Bukovynska			Bubnynska	Mykulychynska	Zelenske		Holiatynska	Mizunske	
Geographical tract		Protiati Kaminnia			Skeli Dovbusha	Pohary	Bredulets		Holiatyn	Shyrkovets	
Status		Geological natural monument of local importance			Natural monument of state importance	–	Natural monument of state importance		Natural monument of state importance	Hydrological natural monument of state importance	
Compartment		12	12	12	9	12	5	5	9	13	13
Section		22	23	22	1	21	10	10	47	18	18
Coordinates	Longitude	48° 09’ 55.9”	48° 10’ 00.2”	48° 09’ 48.9”	49° 02’ 35.0”	48° 25’ 30.8”	–	–	48° 39’ 03.8”	48° 54’ 22.3”	48° 54’ 27.0”
	Latitude	25° 09’ 90”	25° 09’ 17”	25° 09’ 56”	23° 40’ 57”	24° 36’ 36.9”	–	–	23° 26’ 45.8”	23° 50’ 48.9”	23° 50’ 50.4”
Altitude, m		726	670	750	650	660	726	720	777	490	489
Slope exposure		S-W	S-W	S-W	S-W	S	S-W	S-W	S-W	–	–
Slope steepness, degrees		8-50	8-50	8-50	8-50	18	5-15	2-3	15-30	–	–
SP area, ha		0.25	0.22	0.04	0.35	0.2	0.045	0.045	0.48	0.21	0.2

Table 1, Continued

INDICATORS		Sample plot (SP) 1	2	3	4	5	6	7	8	9	10
Enterprise		Carpathian State Special Forestry Enterprise of Agro-Industrial Complex			Bolekhiv State Forest Management Enterprise	Carpathian National Nature Park	Nadvirna State Forest Management Enterprise		Mizhhiria State Forest Management Enterprise	Vyhoda State Forest Management Enterprise	
Forest vegetation type		A_2	A_2	A_2	A_2	A_2	A_3	A_4	A_2	A_5	A_5
Forest type index		A_2-Ps	A_2-Ps	A_2-Ps	A_2-Ps	A_2-Ps	A_3-Ps	A_4-Ps	A_2-Ps	A_5-Ps	A_5-Ps
Stand composition		80%Ps15%Pa 5%Bp	50%Ps 45%Pa5%Bp	90%Ps 5%Bp5%Pa	90%Ps5%Bp 5%Fs	90%Ps10%Bp	100%Ps	100%Ps	80%Ps 20%Pa	80%Ps 10%Pa10%Ai	90%Ps 5%Bp5%Pa
Absolute basal area	m^2/plot	3.33	1.3	0.7	2.28	6.66	0.22	0.59	12.59	6.2	4.18
	m^2/ha	13.3	5.9	17.4	6.5	33.3	5.0	13.01	26.2	29.5	20.9
Volume	m^3/plot	21.53	7.73	4.31	12.97	52.88	0.52	2.60	101.8	44.18	15.24
	m^3/ha	86.1	35.1	107.8	337.1	264.4	11.6	58.0	212.1	210.4	76.2
Relative density		0.4	0.3	0.4	0.3	0.6	0.4	0.5	0.5	0.3-0.7	0.6
Bonitet		V	V	V	V	IV	V^b	V^a	III-IV	IV-V^a	V^a

Note: *Aa – Abies alba Mill.; Ai – Alnus incana (L.) Moench); Bp – Betula pendula Roth.; Bpb – Betula pubescens Ehrh.; Fs – Fagus sylvatica L.; Ps – Pinus sylvestris L.; Pa – Picea abies (L.) Karsten*

Table 2. *Characteristics of permanent sample plots on the territory of coniferous areas of the Ukrainian Carpathians*

INDICATORS		Sample plot (SP) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Enterprise		Carpathian State Special Forestry Enterprise of Agro-Industrial Complex		Carpathian National Nature Park			Osmoloda State Forest Management Enterprise												
Forest district		Roztokivske	Tatarivske		Pidlisnivske	Zhenetske	Yamnenske	Anhelivske	Krasnianske									Osmolodske	
Population		Bukovynska	Tatarivske			Palianytska	Mykulychynska	Anhelivske	Krasnianske									Osmolodske	
Geographical tract		Protiati Kaminnia	Bredulets			Popovychivske	Pohary	Sokil	Turova dacha									Liutoshary	
Status		Geological natural monument of state importance	Natural monument of state importance			Protected area of the park			Botanical natural monument of state importance	Natural monument of state importance								Natural monument of local importance	
Compartment		12	12	1	1	8	5	22	13	25	26	14	14	14	14	14	14	14	6
Section		22	22	1	3	3	21	20	21	9	1	5	28	18	37	20	23	31	19
Coordinates	Longitude	48° 09' 55.7"	48° 09' 56.4"	48° 22' 12.1"	48° 22' 06.5"	48° 22' 13.8"	48° 22' 16.7"	48° 20' 48.9"	48° 25' 13.8"	48° 41' 56.7"	48° 41' 59.1"	48° 51' 16.1"	48° 51' 16.1"	48° 51' 11.1"	48° 51' 03.5"	48° 50' 51.4"	48° 56' 21.7"	48° 51' 12.1"	48° 39' 33.9"
	Latitude	25° 09' 35"	25° 09' 27"	24° 33' 16"	24° 33' 19.5"	24° 33' 17.8"	24° 33' 04"	24° 29' 29.8"	24° 36' 36.9"	24° 05' 05.9"	24° 05' 05.9"	24° 14' 33.5"	24° 14' 56.2"	24° 14' 56.2"	24° 23' 24.4"	24° 14' 23.6"	24° 14' 56.2"	24° 14' 24.6"	24° 01' 50.1"
Altitude, m		699	684	730	750	730	720	863	670	970	980	444	453	453	454	454	450	452	707
Slope exposure		S-W	S-W	S-W	S-W	N-E	S-W	S-W	S	S-W	S-W	–	–	–	–	–	–	–	–
Slope steepness, degrees		8-50	8-50	16	15	16	45	20	10	17	14	–	–	–	–	–	–	–	–
SP area, ha		0.13	0.13	0.2	0.2	0.21	0.21	0.21	0.21	0.21	0.21	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2

Table 2, Continued

INDICATORS	Sample plot (SP)																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Enterprise	Carpathian State Special Forestry Enterprise of Agro-Industrial Complex		Carpathian National Nature Park						Osmoloda State Forest Management Enterprise									
Forest type index	B_2-paPs	B_2-paPs	B_3-paPs	B_3-paPs	B_3-paPs	B_3-paPs	B_2-paPs	B_2-paPs	B_3-paPs	B_3-paPs	B_4-paPs	B_4-paPs	B_4-paPs	B_5-Ps	B_5-Ps	B_5-Ps	B_4-paPs	B_5-Ps
Stand composition	70%Ps20%Pa5%Bp5%Fs	80Fs16%Ps2%Pa2%Bp	90%Ps5%Pa5%Bp	96%Ps2%Pa2%Bp 50%Pa30%Ps20%Bp	80%Ps10%Pa10%Aa 60%Pa20%Aa10%Ps10%Fs	50%Ps20Aa20%Bp10%Pa 40%Pa30%Ps20%Bp10%Aa	90%Ps10%Pa 70%Pa20%Ps10%Bp	90%Ps6%Pa2%Aa2%Bp	100%Ps 60%Ps30%Bp10%Pa	90%Ps5%Bp5%Pa 80%Pa10%Ps5%Bp5%Aa	100%Ps 80%Pa10%Bpb10%Ps	90%Ps5%Pa5%Bpb	90%Ps5%Pa5%Bpb	100%Ps 60%Ps30%Bpb10%Pa	95%Ps5%Bp 80%Ps10%Pa10%Bpb	96%Ps2%Pa2%Bpb	90%Ps5%Pa5%Bpb	95%Ps5%Pa
Basal area, m^2/plot	1.08	2.28	5.3	9.4	9.82	11.33	6.78	11.09	8.35	10.41	8.44	9.12	12	7.87	5.68	8.26	9.11	5.22
Basal area, m^2/ha	8.3	17.5	26.7	47	46.8	53.9	32.3	52.8	39.8	49.6	42.2	43.4	39.9	39.3	28.4	41.3	45.6	26.1
Volume, m^3/plot	6.18	15.11	32.82	79.01	83.24	80.23	60.12	109.2	72.01	90.15	87.9	90.1	145	65.32	46.33	77.9	91.21	30.27
Volume, m^3/ha	47.5	116.2	164.1	395	396.4	382.1	286.3	520.1	342.9	429.3	439.5	429	483	326.6	231.7	389	456.1	151.4
Relative density	0.3	0.5	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.7	0.7	0.8	0.6	0.7	0.6	0.7	0.9	0.7
Bonitet	V	V	IV	III	III	III	III	III	III	III	II	III	II	III	IV	III	II	V

***Note**: Aa – Abies alba Mill; Ai – Alnus incana (L.) Moench); Bp – Betula pendula Roth.; Bpb – Betula pubescens Ehrh; Fs – Fagus sylvatica L.; Ps – Pinus sylvestris L.; Pa – Picea abies (L.) Karsten*

Detailed analysis of the results of the forest typological study and characteristics of diagnostic features of the studied pine forest types allow to complement existing classification of subor and coniferous pine forest types of Herushynskyi (1996) for the Ukrainian Carpathians with the following three forest types: fresh pine subor forest type (A_2-Ps), wet pine subor forest type (A_5-Ps), and wet pine coniferous forest type (B_5-Ps) [10; 11; 19] (Table 3).

***Table 3**. Suggested complementation of pine forest types for the territory of the Ukrainian Carpathians**

Forest vegetation type	Characteristic admixture	Forest type name	Forest type index	Natural stand composition
A_2	–	*Fresh pine subor forest type*	*A_2-Ps*	*100%Ps*
A_3	Spruce	Humid spruce and pine subor forest type	A_3-paPs	80%Ps20%Pa
A_4	Spruce	Moist spruce and pine subor forest type	A_4- paPs	80%Ps20%Pa
A_5	–	*Wet pine subor forest type*	*A_5- Ps*	*100%Ps*
B_2	Spruce	Fresh spruce and pine coniferous forest type	B_2- paPs	80%Ps20%Pa
B_3	Spruce	Humid spruce and pine coniferous forest type	B_3- paPs	60%Ps40%Pa
B_4	Spruce	Moist spruce and pine coniferous forest type	B_4- paPs	70%Ps30%Pa
B_5	–	*Wet pine coniferous forest type*	*B_5- Ps*	*100%Ps*

***Note**: *In italics – suggested complementation for topological structure of subor and coniferous pine forest types in the Ukrainian Carpathians according to Herushynskyi (1996)*

Fresh pine subor forest type (A_2-Ps) can be found on rocks and rock placers of Yamne sandstone of the category V, which are concentrated on the southern slope exposures with the steepness of 25° or more, and within the altitude ranges of 500-1,100 m above sea level. *Pinus sylvestris* L. is the primary forest forming tree species, while *Betula pendula* Roth can be spotted as an admixture. Tree stand is one-storey and has a grouped spatial distribution. Relict stands of *Pinus sylvestris* L. have low productivity and can be categorised to classes V-V[a]

of bonitet. Such stands are concentrated in cracks and depressions of rocks and rock placers, where organic matter has much higher chance to accumulate and moisture to get retained (Fig. 12). Undergrowth is almost absent. Yet some seldom trees of *Sorbus aucuparia* L. can still be found. Natural regeneration is rather weak. Understory is present in the quantity of around 1,000-1,500 trees/ha and mostly consists of *Pinus sylvestris* L. with scarce presence of *Betula pendula* Roth. The above-ground cover is rather poor. It has grouped spatial distribution and is concentrated in the same spots as trees. The above-ground cover consists of *Vaccinium vitis-idaea* L. (mostly), *Vaccinium myrtillus* L., *Sedum acre* L., *Festuca ovina* L., *Polytrichum commune Hedw.* and other mosses can be found as well.

Figure 12. *Fresh pine subor forest type (A_2-Ps)*

Wet pine subor forest type (A_5-Ps) is common for peat bogs of river terraces with a high coefficient of humidity. In particular, geographical tracts "Shyrkovets" or "Turova dacha". This forest type is formed by pure pine stands with low productivity values (V^a-V^b classes of bonitet). Tree stands are one-storied and have a grouped spatial distribution (Fig. 13). A large number of pine trees have twisted stem, with poorly developed crown, and in some places, they take the form of a bush because of the high humidity. Undergrowth is absent, and the quantity of understory does not get higher than 2,000-2,500 trees/ha. The latter consists of *Pinus sylvestris* L. only. Undergrowth can only be spotted on micro-elevations with thinned above-ground cover. The above-ground cover itself is well developed and takes around 90-100% of area coverage. It consists of *Vaccinium myrtillus* L., *Vaccinium vitis-idaea* L., *Ledum palustre* L., *Oxycoccus palustris* Pers, *Vaccinium uliginosum* L., *Empetrum nigrum* L. and other species. Mosses are represented by *Sphagnum sp.* with some groups of *Polytrichum commune Hedw.*

Figure 13. *Wet pine subor forest type (A_5-Ps)*

Wet pine coniferous forest type (B_5-Ps) can be found on peat bogs of river terraces within the territory of geographical tracts "Liutoshary", "Turova dacha", and "Shyrkovets". It differs from A_5-C with a better soil fertility that is caused by slightly lower humidity. The primary forest-forming species is *Pinus sylvestris* L., which grows in one- or two-layered stands. Such species as *Betula pendula* Roth., *Betula pubescens* Ehrh. and *Picea abies* (L.) Karsten can be found as an admixture within the main stand or understory. Single-storied stands are formed in relatively mono-aged plantations up to 140 years old. Older stands are affected by the processes of natural

decay and mortality. As a result, the second storey of the stand gets formed within windows of previously decayed and fallen trees. The productivity of such stands is low. Most stands belong to classes IV-V of bonitet (Fig. 14). Understory is rather poor and is spatially present in groups. Natural regeneration is slow because of the well-spread above-ground vegetation. The latter takes 100% of area coverage. *Pinus sylvestris* L. dominates the undergrowth along with admixture of *Betula pendula* Roth., *Betula pubescens* Ehrh., and *Picea abies* (L.) Karsten. The quantity of undergrowth does not exceed 1,000 trees/ha. The above-ground cover is represented by *Vaccinium myrtillus* L., *Vaccinium vitis-idaea* L., *Ledum palustre* L., *Oxycoccus palustris* Pers, *Vaccinium uliginosum* L., *Empetrum nigrum* L., and *Carex sp.* The mosses cover is dominated by *Sphagnum sp.*

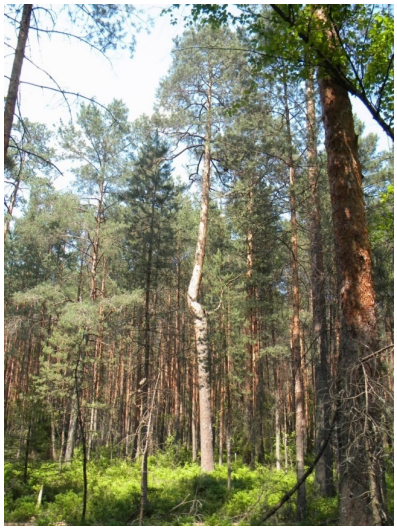


***Figure 14**. Wet pine coniferous forest type (B_5-Ps)*

Practical importance. The distinguishing of new forest types is considered logical and correct given that similar complementation has been adopted on the basis of research and monitoring of the forest typological profile plot of A. Piasetskyi [8; 19]. The complemented forest types have also been understudied for the corresponding study region.

Taking into account the methodological suggestions of Herushynskyi (1996), a set of diagnostic features is proposed for the defined subor and coniferous forest types on the territory of the Ukrainian Carpathians (Table 4). The given diagnostic features differ from the others by a number of characteristics and describe the relevant soil, hydrological, and forest vegetation conditions. The correctness of their determination is confirmed with a set of plant indicator species in the relevant areas.

***Table 4**. Diagnostic features of the defined subor and coniferous pine forest types*

Forest vegetation type	Forest type (name and index)	Geographical distribution of the forest	Soil conditions	Forest elements			
				Tree stand		Understory	Above-ground cover
				Natural	Successive		
A_2	Fresh pine subor forest type (A_2-Ps)	On the territory of Pokyty Carpathians and Gorgany. The range of altitudes 500-1,100 m. Based on the rocky outcrops and rocks of Yamne sandstone. Usually, on the southern slope exposures with the slope steepness more than 25°	Soil profile is absent. Fine soil is concentrated exclusively in cracks and depressions of rocks, and their placers of the V category	*Pinus sylvestris* L. is the dominant species (classes V^a-V^b of bonitet). Climatic admixture of *Betula pendula* Roth. Tree stand has grouped spatial distribution. Groups are confined to areas of fine soils	Tree stand of *Betula pendula* Roth.	It is represented by a thinned storey that consists of *Sorbus aucuparia* L. and *Picea abies* (L.) Karsten	It is distributed in the same areas as tree stands. However, above-ground cover can generate larger groups. It is represented by oligotrophic xero- and mesophytes, e.g., *Calluna vulgaris* (L.) Hill., *Vaccinium myrtillus* L., *Vaccinium vitis-idaea* L., *Saxifraga stellaris*, *Sedum acre* L., *Festuca ovina* L., *Polytrichum commune*, *Pleurozium schreberi*, *Hylocomium splendens*, *Cladonia rangiferina* and other

Table 4, Continued

Forest vegetation type	Forest type (name and index)	Geographical distribution of the forest	Soil conditions	Forest elements			
				Tree stand		Understory	Above-ground cover
				Natural	Successive		
B_5	Wet pine coniferous forest type (B_5-Ps)	On the river terraces of the lowlands of the Gorgany massif rivers within the altitude of 450-800 m	Soil profile is represented by a large share of peat deposit of brown peat, which was formed by the constant extinction of sphagnum moss biomass. The occurrence of groundwater is 20-30 cm lower, hence there is no boggy areas and higher share of oxygen in the soil	*Pinus sylvestris* L. (classes IV-V of bonitet) dominates the composition with the admixture of *Betula pubescens* Ehrh. and *Betula pendula* Roth. Tree stands can be one- or two-storied	Tree stand of *Betula pubescens* Ehrh.	It is represented by sparse groups of *Sorbus aucuparia* L., *Salix aurita* L., and *Betula pubescens* Ehrh.	Forms a continuous cover and is represented by the same species as A_5-C with addition of *Carex leporina, Carex nigra, Geum rivale*, and other

CONCLUSIONS

Additional forest types for Scots pine have been suggested for the Ukrainian Carpathians – two in subor and one in coniferous forest conditions. These types differ by the environmental factors from each other and from other forest types. Most importantly, they fully meet the characteristics of the relevant forest vegetation types and conditions. The correctness of their definition and diagnostics is confirmed by the identified indicator plants within the permanent sample plots. The background behind the existence of such forest types can be the subject of future study. The findings elucidate dynamic nature of forest types, provide a better understanding of forest ecology, and make a significant contribution to the forest topology research on the territory of the Ukrainian Carpathians. Another step has been taken towards understanding the patterns of vegetation formation and distribution within the Ukrainian Carpathians. This knowledge will help to carry out further study, especially in forestry, geobotany, dendrology, soil science, geology, etc., in the future.

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Борові та суборові типи лісу в Українських Карпатах: класифікація та доповнення

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Анотація. На сьогодні лісова типологія ще недостатньо інтегрована у суміжні науки екологічного та географічного спрямування, а сукцесії рослинних фітоценозів змушують здійснювати постійне коригування типів лісу. Дані наукові дослідження здійснені з метою удосконалення класифікації типів лісу Українських Карпат та наближення її до дійсного поширення рослинності в регіоні досліджень. Здійснено детальний аналіз лісотипологічних досліджень в Українських Карпатах з часів другої половини XX – початку XXI ст. Виконано розподіл площ лісового фонду Карпатського регіону, що перебувають у підпорядкуванні Державного агентства лісових ресурсів України, за типами лісорослинних умов. Загальна площа борів і суборів Карпатського регіону становить відповідно 1493,1 та 28910,2 га. Закладено низку постійних пробних площ на території природоохоронних установ та лісогосподарських підприємств регіону. На підставі отриманих результатів та їх аналізу запропоновано доповнити класифікацію борових і суборових типів лісу З.Ю. Герушинського (1996) в Українських Карпатах такими типами: свіжий сосновий бір, мокрий сосновий бір і мокрий сосновий субір. У статті наведено основні діагностичні особливості нових типів лісу. Описані борові та суборові типи лісу в Українських Карпатах чітко різняться ґрунтово-гідрологічними умовами від інших типів лісу і характеризують відповідні лісорослинні умови. Правильність їх визначення додатково підтверджується виявленими рослинами-індикаторами на відповідних ділянках. Результати наших досліджень з вивчення біологічної різноманітності рослинності в Українських Карпатах дають змогу краще зрозуміти екологію лісу та додають значний внесок у лісову типологію. Зроблено ще один крок до пізнання закономірностей формування рослинних комплексів в Українських Карпатах та детальніше представлено лісові формації Карпат у лісовій типологічній науці

Ключові слова: лісова типологія, тип лісорослинних умов, діагностичні ознаки, рослини-індикатори, індекс типу лісу, типологічний профіль, екологічна фігура