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THERMOPHILOUS *PINUS NIGRA* DOMINATED FOREST ON LIMESTONE ON VLAINA MOUNTAIN IN NORTH MACEDONIA

Dejan Mandžukovski, Aco Teofilovski

Public enterprise for managing state own forests ¨Nacionalni sumi¨,
Skopje, RN Macedonia

e-mail: d_mandzukovski@yahoo.com

This paper describes a newly identified forest community, *Cytiso jankae - Pinetum nigrae* ass. nova, dominated by black pine (*Pinus nigra*), which develops on limestone and under thermophilous conditions on Vlaina Mountain (Mt) (at 790–1060 m a.s.l.) in North Macedonia. For the analysis, a numerical database of phytocenological relevés from the central and southern parts of the Balkan Peninsula and own data, where black pine predominates, was compiled. Numerical classification and ordination were performed using the PC-ORD and JUICE software packages. Synoptic and analytical tables have been compiled based on the analyses and diagnostic species were identified through the calculation of the Phi-coefficient. The obtained results provide a significant contribution to the understanding of the distribution and syntaxonomy of this pine forest community that develops on Vlaina Mt. This research also highlights the ecological importance of this forest community and its role in preserving natural habitats. This plant community belongs to the class *Quercetea pubescentis*, order *Quercetalia pubescenti-petraeae,* and alliance *Fraxino orni-Ostryion*.

Keywords: thermophilous; *Fraxino orni – Ostryon*; forest vegetation; classification; ordination; *Pinus nigra*

INTRODUCTION

Thermophilous pine - dominated forests in North Macedonia have been studied by various researchers [1–8], primarily focusing on their syntaxonomy and ecological characteristics. However, there remain unstudied communities and unresolved issues related to syntaxonomy, particularly concerning relict scots and black pine forests, pine forests within the oak belt, and potentially other types of pine-dominated communities. Additionally, certain nomenclatural issues within these communities remain unsolved. Addressing these gaps through systematic field studies, ecological surveys, and syntaxonomic reviews will enhance our understanding of pine forests and contribute to their conservation and management. Such efforts are essential for developing effective strategies to preserve these unique ecosystems and their biodiversity.

In the region, of the central southern parts of the Balkans, phytocenological studies of the black pine forets have been conducted in Bulgaria [9–11], Greece [12–16], and Albania [17].

Pinus nigra-dominated forests on primary habitats, developing under thermophilous conditions, are characterized by a shallow soil cover and are typically found on basophilous substrates. These forests exhibit high stability, with evolutionary changes occurring very slowly. They host relict, endemic, and rare species, some of which are closely associated with the pine forest ecosystems. Additionally, these forests serve as nurseries from which the pines have spread into secondary habitats [2].

The vegetation in the *Pinus nigra*-dominated forests on limestone at Vlaina Mt. in North Macedonia has not been comprehensively studied so far. Phytocenological studies focusing on black pine-dominated forestes have been conducted in the

northwestern parts of Vlaina Mt., however, these studies were carried out on the Bulgarian side of the border using the dominant methodology. [9, 11].

Research on the forest vegetation of Malesh and Pijanec [5], of which Vlaina Mt. is a part, did not highlight primary habitats on limestone for the relic black pine in the region. However, within the oak belt, the presence of the association *Querco-Ostryetum carpinifoliae* was recorded in several small areas, which holds theoretical significance regarding the potential primary habitats of black pine. At Golak, the silicate parent material revealed a mesophilous character of the species, whereas at Planenica, the occurrence of thermophilous species such as *Sesleria latifolia, Laser trilobum, Helleborus odorus, Geranium sanguineum*, and *Aegonychon purpurocoaeruleum* was noted [5].

From a floristic perspective, Teofilovski [18–20] has provided data on new and rare species for North Macedonia, identified within the black pine forest above the village of Zvegor on Vlaina Mt.

Recent vegetation field research has revealed that some black pine stands above Zvegor village exhibit a pronounced thermophilous character and primarily develop on basophillous parent material. Their specific floristic composition and ecological features distinguish them from other black pine forest communities developing on limestone in the surrounding areas of the central and southern Balkans. These distinctions were further supported by numerical analysis.

From a conservation aspect, habitats dominated by black pine (*Pinus nigra)*, are included in Anex I of the European Union's Habitats Directive 92/43 under the following code 9530 * (Sub-) Mediterranean pine forests with endemic black pines. Additionally, black pine communities have been assessed in the Red List Assessment of European Habitats [21] as "Least Concern" within the habitat G3.4b – Temperate and sub-Mediterranean montane *Pinus sylvestris-nigra* woodland.

The present study aims to establish a classification scheme for the relict *Pinus nigra*-dominated forest community on limestone on Vlaina Mt., on the Macedonian side of the range.

MATERIAL AND METHODS

Study area

Vlaina Mt. is a border mountain, with part of the national border between North Macedonia and Bulgaria running along its ridge. The study sites are located on the Macedonian-facing slopes of Vlaina Mt., near the village of Zvegor, extending up to the Macedonian-Bulgarian border within the municipality of Delčevo (Figure 1, 2). The geological substrate of the researched area is predominantly limestone, covering approximately 250 hectares.

Figure 1. Location of North Macedonia (shaded polygon) within Southeastern Europe (left) and the position of the study area (shaded circle) on Vlaina Mt. in North Macedonia (right).

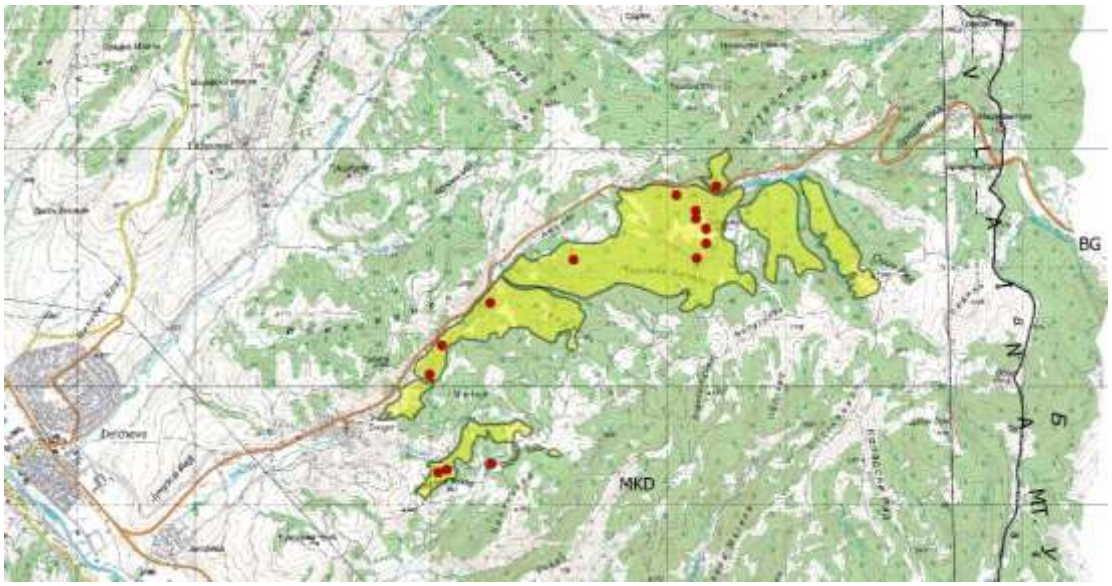

Figure 2. Distribution of relevés and range (shaded polygons) of thermophilous *Pinus nigra*-dominated forests on limestone on Vlaina Mt.

According to the phytogeographical division of vegetation in North Macedonia outlined by Rizovski [22], this region belongs to the Euro-Siberian-North American region and the Aegean province. The study focuses on the Maleshevo-Osogovo sector, specifically the Vlaina Mt. district, which is notable for its relict black pine (*Pinus nigra*) forests on limestone.

Based on the Biogeographical Map of Europe [23], the study area is classified within the Euro-Siberian biogeographical region, the Apennine-Balkan province, and sector 9a.

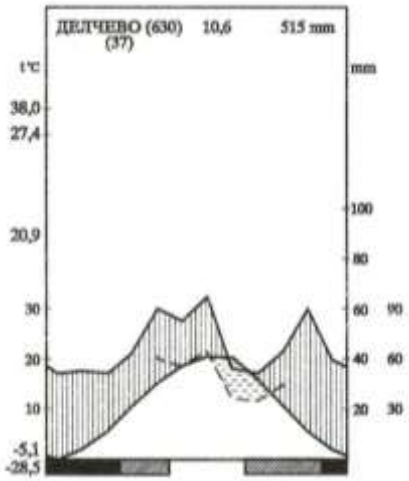

Figure 3. Climadiagram of Delchevo [24]

The climate of the investigated area is warm continental, with an annual average temperature of 10.6°C and a total sum of active temperatures of 3975°C. The annual precipitation is 515 mm, with a drought index of 25 and Lang's rain factor of 48.6 [24]. The climadiagram below (Figure 3) illustrates these parameters.

Data sampling and analysis

During the 2020–2022 field seasons**,** 14 relevés were collected from the study area. The principles and methods of the Zürich-Montpellier School [25,26] were applied. The analytical table (Table 2) presents all 14 relevés, representing the newly described plant association in this study. Plant taxa nomenclature follows the Euro+Med Plant Base (Euro+Med 2006–2024).

The list of our own vegetation relevés, along with those described in the literature, has been entered into the Turboveg database [27]. The relevés were exported to the JUICE software [28] for further analysis. To define plant communities, an agglomerative hierarchical cluster analysis was conducted in PC-ORD [29] using the Sørensen (Bray-Curtis) similarity index**,** Ward's clustering method, and data transformation b = (Xi, j)^p, p = 0.5 (Figure 4). A second analysis was performed using the Sørensen (Bray-Curtis) index with McQuitty's method, as shown in Figure 5.

Diagnostic species were identified by calculating the Phi-coefficient [30], with all clusters standardized to equal size [31]. Only statistically significant Phi-coefficient values, evaluated using Fisher's exact test ($P < 0.05$), were considered. A species was classified as diagnostic if its Phi-coefficient was ≥ 0.3**,** while species with a Phi-

coefficient ≥ 0.5 were considered highly diagnostic. The constancy of species was expressed as percentages in the synoptic table, and relevant literature sources were consulted to further explain their diagnostic significance.

Species with coverage above 70% in at least 5% of the relevés within any cluster were classified as dominants, whereas constant species were those occurring in at least 70% of the relevés in a given cluster.

To assess the similarity between relevés from related plant communities, we used Non-metric Multidimensional Scaling (NMDS) plot analysis in R (R Core Team 2018). Life forms were classified according to Raunkiaer [32] to establish the biological spectrum, while geoelements were determined following Gajić [33] and Pignatti [34]. The results of the numerical analysis were used to develop the analytical table (Table 2).

The new syntaxa were named following the 4th edition of the International Code of Phytosociological Nomenclature [35], and the nomenclature of higher-rank syntaxa was harmonized with Mucina et al. [36].

RESULTS AND DISCUSSION

We initially conducted a cluster analysis using a database comprising 326 vegetation relevés dominated by *Pinus nigra* from the central and southern Balkans, including Albania (AL), Bulgaria (BG), Greece (GR), and North Macedonia (MK). The results are presented as a dendrogram (Figure 4).

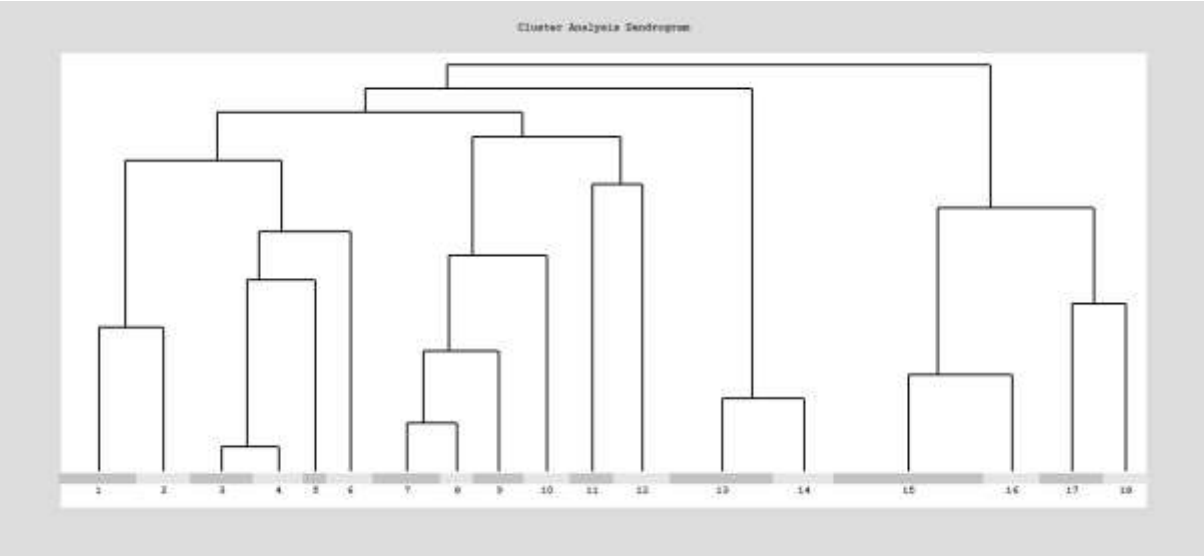

Figure 4. Dendrogram of hierarchical clustering of 326 vegetation relevés into 18 clusters using Sørensen (Bray-Curtis) similarity and Ward's method.

Legend: cluster 1 and cluster 2 – all. *Chamaecytiso hirsute – Pinion pallasianae*, (GR); clusters 3, 4, 5 (BG) and cluster 6 own relevés (MK)- all. *Fraxino orni – Ostryon*; clusters 7, 8,9,10,11, 12 all. *Fraxino orni – Pinion nigrae* (MK & GR); clusters 13, 14 all. *Fraxino orni – Pinion nigrae* (BG); clusters 15,16,17,18 group of releves distributed in AL

The relevés classified within the *Fraxino orni – Ostryon* were elaborated separately. The results, presented as a dendrogram (Figure 5), show that they are grouped in four clusters, each representing an independent syntaxon. Cluster 1 represents ass. *Lathyro laxiflori-Pinetum pallasianae*, cluster 2 represents ass. *Junipero deltoidi-Pineteum pallasianae*, both of these associations have been previously described from Bulgaria [11]. Clusters 3 and 4 consists of communities from two different regions of North Macedonia, based on our unpublished relevés from fieldwork. Among them, cluster 4 represents relevés of the thermophilous *Pinus nigra*-dominated forests on limestone on Vlaina Mt.

The non-metric multidimensional scaling (NMDS) analysis (Figure 6) and the PC-ORD dendrogram analysis (Figure 5) highlight the differences among the four analyzed associations within the *Fraxino orni – Ostryon alliance*, demonstrating their distinctiveness.

According to the hierarchical classification (Figure 5), the thermophilous *Pinus nigra*-dominated forests on limestone from Vlaina Mt.

are classified under cluster 4. Analysis using JUICE software generated a synoptic table, identifying three groups of taxa: diagnostic, constant, and dominant. These findings indicate that the vegetation relevés from Vlaina Mt. are distinct from those found in other parts of the Balkans.

Following the preparation of the synoptic table (Table 1) and a comparative analysis between our records and existing literature on known communities within the *Fraxino orni – Ostryon* alliance in the central and southern Balkans, we concluded that the thermophilous *P. nigra*-dominated forests on limestone from Vlaina Mt. contain a sufficient number of diagnostic species. This diversity supports the establishment of a new plant association:

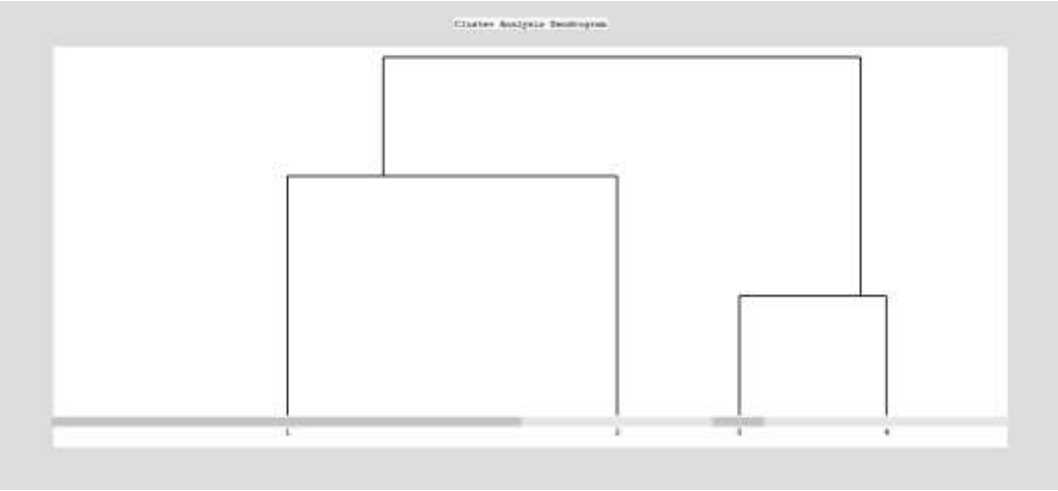

Figure 5: Dendrogram of hierarchical clustering of 55 vegetation relevés of the *Fraxino orni – Ostryon* distributed in Bulgaria and N. Macedonia, grouped into four clusters using Sørensen (Bray -Curtis) similarity and McQuitty's method: cluster 1 – *Lathyro laxiflori-Pinetum pallasianae* (BG), cluster 2 – *Junipero deltoidi-Pineteum pallasianae* (BG); cluster 3 – Unpublish releves (MK); cluster 4 – own relevés from Vlaina Mt. (MK)

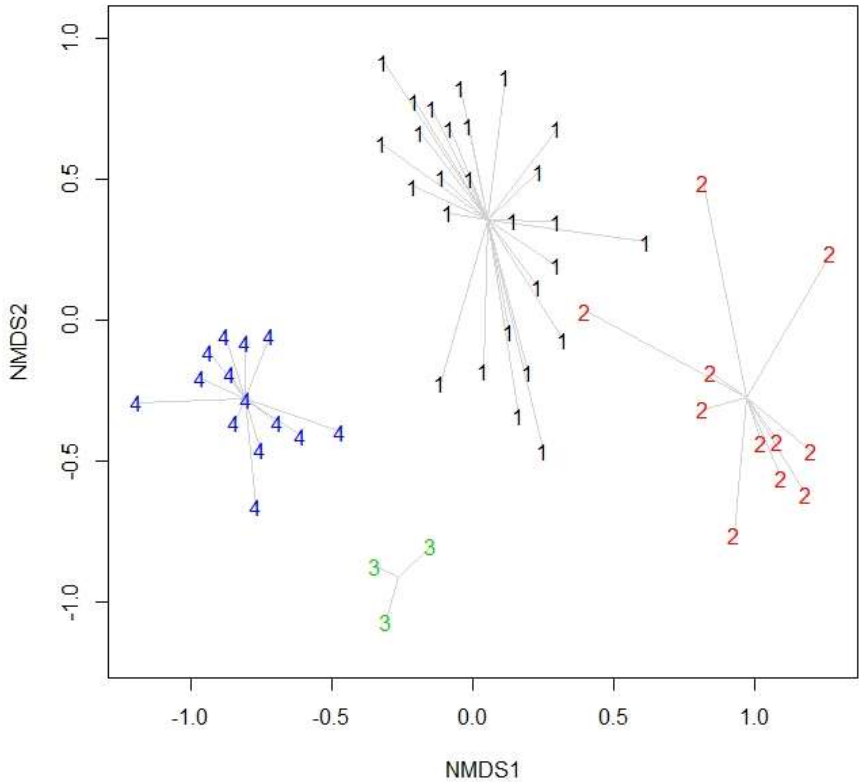

Figure 6: NMDS ordination plot analysis comparing the four most similar plant associations within the Fraxino orni – Ostryon alliance: 1 – ass. *Lathyro laxiflori-Pinetum pallasianae* (BG), 2 – ass. *Junipero deltoidi-Pineteum pallasianae* (BG), 3 – Unpublish releves (MK), 4 – Own relevés from Vlaina Mt. (MK)

Table 1. Synoptic table of diagnostic species from 55 vegetation relevés, grouped into four clusters: cluster 1 – *Lathyro laxiflori-Pinetum pallasianae* (BG), cluster 2 – *Junipero deltoidi-Pinetum pallasianae* (BG), cluster 3 – Unpublished relevés (MK), cluster 4 – Own relevés from Vlaina Mt. (MK).

Percentage synoptic table with fidelity {Phi coeff. C } (4 columns)				
Group number	I	II	III	IV
Number of relevés	27	11	3	14
Juniperus deltoides	---	83.4	---	---
Stellaria media	---	81.6	---	---
Scilla bifolia	---	75.3	---	---
Dianthus petraeus	---	75.3	---	---
Moehringia pendula	---	75.3	---	---
Cytisus petrovicii	---	---	100	---
Aurinia saxatilis	---	---	100	---
Centaurea stoebe	---	---	100	---
Satureja montana	---	---	100	---
Euphorbia glabriflora	---	---	100	---
Hypericum olympicum f. *tenuifolium*	---	---	100	---
Festuca heterophylla	---	---	95.3	---
Genista tinctoria	---	---	95.3	---
Asperula purpurea	---	---	91.3	---
Galium paschale	---	---	91.3	---
Cotinus coggygria	---	---	87	---
Carex digitata	---	---	78.1	---
Thesium divaricatum	---	---	77.5	---
Linum thracicum	---	---	77.5	---
Peucedanum austriacum	---	---	77.5	---
Osyris alba	---	---	77.5	---
Jurinea mollis	---	---	77.5	---
Frangula rupestris	---	---	77.5	---
Inula ensifolia	---	---	74.5	14.9
Iris sintenisii	---	---	74.4	---
Onosma heterophylla	---	---	71.8	---
Cytisus jankae	---	---	---	100
Euphorbia cyparissias	---	---	---	100
Genista januensis	---	---	---	95.2
Brachypodium pinnatum	---	---	---	90.5
Geranium sanguineum	---	---	---	85.3
Ostrya carpinifolia	---	---	---	82.8
Cytisus hirsutus	---	---	---	75.8
Euphorbia barrelieri	---	---	---	75.8
Carex halleriana	---	---	---	70.7
Cotoneaster tomentosus	---	---	---	70.7

Association *Cytiso jankae - Pinetum nigrae* ass. nova, Mandžukovski & Teofilovski (cluster 4 in Figure 5), holotypus relevé № 3 hoc loco (Table 2).

Below, we present the diagnostic, constant, and dominant taxa identified through the analysis, along with the habitat characteristics and their syntaxonomical hierarchical position.

Diagnostic species: *Ostrya carpinifolia, Cotoneaster tomentosus, Cytisus hirsutus, Genista januensis, Cytisus jankae, Brachypodium pinnatum, Carex halleriana, Euphorbia barrelieri, Euphorbia cyparissias, Geranium sanguineum.* **Constant species:** *Pinus nigra, Quercus pubescens, Juniperus oxycedrus, Sorbus torminalis, Cornus mas, Fraxinus ornus, Rosa canina, Juniperus communis, Carlina vulgaris, Danaa cornubiensis, Dorycnium herbaceum, Leontodon crispus, Teucrium chamaedrys, Trifolium alpestre.* **Dominant species:** *Pinus nigra, Ostrya carpinifolia, Cytisus jankae, Anthericum ramosum.*

Table 2. Analytical table of the association *Cytiso jankae - Pinetum nigrae* ass. nova

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Locality	Vlaina Mt.	Vlaina Mt.	Vlaina Mt.	Vlaina Mt.	Vlaina Mt.	Vlaina Mt.	Vlaina Mt.	Vlaina Mt.	Vlaina Mt.	Vlaina Mt.	Vlaina Mt.	Vlaina Mt.	Vlaina Mt.	Vlaina Mt.	
Altitude (m)	1050	1060	1030	1010	1030	1060	957	994	987	869	957	855	811	792	
Exposition	N	N	N	SW	SW	S	N	N	S	N	N	N	N	N	
Slope	25	25	30	35	35	35	35	35	35	25	10	35	35	15	
Geological substratum	Limestone	Limestone	Limestone	Limestone	Limestone	Limestone	Limestone	Limestone	Limestone	Limestone	Limestone	Limestone	Limestone	Limestone	
Size of relevé (m2)	200	200	200	200	200	200	400	400	400	400	400	400	400	400	
Date	30.07.2022	30.07.2022	30.07.2022	31.07.2022	31.07.2022	31.07.2022	25.06.2020	25.06.2020	25.06.2020	24.06.2020	24.06.2020	24.06.2020	24.06.2020	24.06.2020	
Latitude	41.98001	41.982222	41.983611	41.98	41.983	41.98482	41.96415	41.98545	41.981111	41.96415	41.96472	41.97161	41.973797	41.97694	
Longitude	22.83145	22.845	22.844	22.844	22.844	22.84205	22.81717	22.84616	22.845	22.81717	22.82264	22.8165	22.81781	22.82284	
Characteristic species of Ass. *Cytiso jankae -Pinetum nigrae* ass. nova, holotypus releve № 3 hoc loco															Constancy
Pinus nigra	1	5	5	5	5	5	5	5	5	5	4	4	5	5	4	V
Cytisus jankae	5	1	1	+	3	1	5	1	+	2	+	1	1	1	1	V
Euphorbia cyparissias	6	+	+	+	+	+	+	+	+	+	+	+	1	+	+	V
Genista januensis	4	+	+	+	+	+	+	+	+	+	1	+	+	1	.	V
Brachypodium pinnatum	6	1	1	1	1	1	.	1	1	.	1	+	+	+	+	IV
Geranium sanguineum	6	+	1	1	+	.	+	+	+	.	+	1	1	1	+	IV
Carex halleriana	6	1	+	1	+	.	.	.	.	.	+	1	+	.	1	III
Cytisus hirsutus	4	+	+	+	+	+	.	+	.	+	+	.	+	.	.	III
Alliance *Fraxino orni-Ostryion* Tomažič 1940																
Fraxinus ornus	3	2	2	2	2	+	2	2	2	2	2	2	2	2	2	V
Ostrya carpinifolia	3	+	2	2	.	.	.	+	+	+	3	2	2	3	2	IV
Cotoneaster tomentosus	4	+	+	1	+	+	.	+	1	+	.	.	.	.	.	III
Cornus mas	3	+	+	+	+	.	.	.	+	+	+	+	+	.	.	III
Anthericum ramosum	6	+	+	3	+	.	+	.	.	.	.	.	.	.	.	II
Sorbus aria	6	.	.	.	+	+	.	.	.	.	.	.	.	.	.	I
Alliance *Carpinion orientali*s Horvat 1958																
Juniperus oxycedrus	2	+	+	.	+	+	.	.	+	+	+	+	+	+	+	IV
Carpinus orientalis	3	.	.	.	.	.	.	.	.	.	.	+	2	2	2	III
Alliance *Fraxino orni-Pinion nigrae* Em 1978, order Erico-Pinetalia Horvat 1959 and class Erico-Pinetea Horvat 1959																
Euphorbia barrelieri	6	+	1	+	+	+	+	+	+	+	.	.	.	.	.	IV
Carex humilis	6	.	.	.	1	1	2	2	+	2	.	.	.	.	.	III
Hieracium pannosum	6	.	.	.	.	.	.	1	+	+	.	.	+	.	.	II
Cephalaria flava	6	+	+	.	+	1	.	.	.	.	.	+	.	.	.	II
Pulsatilla montana ssp. *slaviankae*	6	.	.	+	+	+	+	.	.	.	.	.	.	.	.	II
Order Quercetalia pubescenti-petraeae Klika 1933 and class Quercetea pubescentis Doing-Kraft ex Scamoni et Passarge 1959																
Quercus pubescens	1	+	.	+	+	+	+	+	+	+	2	2	2	2	2	V
Sorbus torminalis	2	+	.	+	+	+	+	+	.	+	+	+	+	+	+	IV
Crataegus orientalis	4	.	.	.	.	.	.	.	.	.	+	+	.	.	.	II

Table 2 Continues

Quercus cerris	2	+	+	+	.	.	.	.	+	+	.	.	.	.	.	III
Dorycnium herbaceum	6	+	.	+	+	+	.	+	.	+	+	+	+	1	1	IV
Anemone sylvestris	6	1	2	1	.	.	.	+	+	.	.	.	.	.	.	III
Hieracium chalcidicum subsp. *macropannosum*	6	+	+	2	+	+	.	.	.	.	.	.	.	.	.	III
Primula veris	6	+	+	+	.	.	.	.	+	.	+	.	+	.	.	III
Tanacetum corymbosum	6	.	.	+	.	.	.	.	+	.	+	.	.	.	.	II
Sorbus domestica	2	+	+	.	.	.	.	.	.	.	+	.	.	.	.	II
Limodorum abortivum	6	.	+	.	.	.	.	.	.	+	.	.	.	.	.	II
Clinopodium vulgare	6	.	+	.	.	.	.	.	.	.	.	.	+	.	.	II
Hippocrepis emerus ssp. emerus	2	.	.	.	.	.	.	.	.	.	.	.	1	1	.	II
Luzula forsteri	6	.	.	.	.	.	.	.	.	.	.	.	+	.	.	I
Euphorbia amygdaloides	6	.	.	.	.	.	.	+	.	.	.	.	.	.	.	I
Class *Carpino-Fagetea sylvaticae* Jakuch ex Passarge 1968																
Fagus sylvatica	1	+	.	+	+	.	.	+	+	.	.	.	.	.	.	III
Campanula trachelium	6	1	.	+	+	.	.	+	+	.	1	1	.	.	.	III
Cephalanthera rubra	6	.	.	.	.	.	.	+	+	+	+	1	.	.	.	III
Melica uniflora	6	.	.	.	.	.	.	.	.	.	.	.	+	.	.	I
Prunus cerasifera	2	.	.	.	.	.	.	+	.	.	.	.	.	.	.	I
Prunus avium	1	.	.	.	.	.	.	.	.	.	.	+	.	.	.	I
Aremonia agrimonoides	6	.	.	.	.	.	.	.	.	.	.	+	.	.	.	I
other species																
Teucrium chamaedrys	6	.	.	.	1	1	+	.	.	.	+	1	1	1	1	IV
Carlina vulgaris	6	+	+	+	+	+	.	+	.	+	+	+	.	+	+	IV
Physospermum cornubiense	6	+	+	+	+	+	+	.	+	+	1	+	.	.	.	IV
Juniperus communis	5	+	+	+	+	+	.	+	1	+	.	+	.	.	.	IV
Melampyrum cristatum	6	.	.	.	.	.	.	+	+	.	+	1	+	+	+	III
Centaurea cuneifolia	6	.	+	1	.	.	+	.	.	+	.	+	.	+	+	III
Leontodon crispus	6	+	+	+	+	+	.	+	.	+	.	.	.	+	.	III
Rosa micrantha	4	+	+	+	.	.	.	.	+	.	.	+	.	.	+	III
Pilosella hoppeana	6	+	.	+	+	+	+	.	.	.	.	+	.	.	.	III
Polygala major	6	.	.	.	.	.	.	.	+	.	+	+	+	+	+	III
Trifolium pignantii	6	.	+	.	+	.	.	+	+	.	+	.	+	.	.	III
Helianthemum cannum	6	.	.	.	.	+	.	.	.	+	+	+	.	1	+	III
Hypochaeris maculata	6	+	+	+	+	.	+	1	+	.	.	.	.	.	.	III
Galium album	6	.	+	.	.	.	.	+	+	+	.	1	.	.	.	III
Ononis pusilla	6	.	.	.	+	.	+	+	.	+	.	.	.	+	.	III
Cruciata glabra	6	+	+	.	.	.	.	+	+	.	+	+	+	.	.	III
Clematis vitalba	5	+	+	+	.	+	+	.	.	.	.	.	+	+	.	III
Inula ensifolia	6	.	1	1	+	+	.	.	.	.	+	1	.	+	.	III
Trifolium alpestre	6	1	1	1	.	.	.	1	+	.	1	+	+	.	.	III
Epipactis helleborine	6	+	+	.	+	+	.	+	.	+	.	.	.	.	.	III
Helianthemum nummularium	6	.	.	.	+	+	.	+	.	+	.	.	+	.	.	III
Rosa canina	4	.	+	+	+	+	+	+	+	.	.	+	.	.	+	III
Hieracium murorum	6	+	.	.	+	.	+	1	1	.	.	.	.	.	.	III
Astragalus spruneri	6	.	.	.	.	.	.	.	.	.	+	.	+	1	+	II
Globularia vulgaris	6	+	+	.	.	+	+	.	.	.	.	.	.	.	.	II
Colutea arborescens	4	.	.	.	+	.	.	.	.	.	+	.	.	+	+	II
Viburnum lantana	5	.	2	2	+	+	.	.	.	.	.	.	.	.	.	II
Inula oculus-christi	6	.	+	+	.	+	.	.	.	.	.	.	+	.	.	II
Fumana ericoides	6	.	.	.	.	.	+	.	.	+	.	.	.	+	+	II
Vincetoxicum fuscatum	6	.	.	.	.	+	.	.	.	.	.	+	.	+	+	II
Ferulago sylvatica	6	.	+	+	.	.	.	.	+	+	.	.	+	.	.	II
Saponaria bellidifolia	6	.	.	.	.	.	.	.	.	+	+	+	.	.	.	II
Campanula glomerata	6	.	.	.	.	.	.	.	.	.	.	.	+	+	+	II

Table 2 Continues

Prunella laciniata	6	.	+	.	.	.	.	+	.	.	.	.	.	+	.	II
Medicago lupulina	6	.	+	.	.	.	.	.	+	+	.	.	.	.	.	II
Onobrychis arenaria	6	.	+	.	.	.	.	1	.	1	.	.	.	.	.	II
Hypericum rumeliacum	6	.	+	+	.	.	.	.	.	.	.	+	.	.	.	II
Eryngium campestre	6	+	+	.	.	.	+	.	.	.	.	.	.	.	.	II
Rubus canescens	4	+	+	.	.	.	+	.	.	.	.	.	.	.	.	II
Carex filiformis	6	+	+	.	.	+	.	.	.	.	.	.	.	.	.	II
Viburnum opulus	4	.	.	.	.	.	.	2	+	.	.	.	+	.	.	II
Comandra umbellata subsp. *elegans*	5	.	.	.	.	.	.	.	.	.	1	1	.	1	.	II
Teucrium polium	6	.	+	.	.	.	+	.	.	+	.	.	.	.	.	II
Asperula aristata	6	+	+	.	.	.	.	.	.	.	.	.	.	.	.	II
Jurinea arachnoidea	6	.	.	.	+	+	.	.	.	.	.	.	.	.	.	II
Prunella vulgaris	6	1	.	+	.	.	.	.	.	.	.	.	.	.	.	II
Ajuga laxmannii	6	.	+	+	.	.	.	.	.	.	.	.	.	.	.	II
Peucedanum alsaticum	6	+	+	.	.	.	.	.	.	.	.	.	.	.	.	II
Sanguisorba minor	6	+	+	.	.	.	.	.	.	.	.	.	.	.	.	II
Ajuga chamaepitys ssp. chia	6	.	.	+	.	.	.	.	.	.	.	.	.	+	.	II
Pilosella bauhini	6	.	.	.	.	.	.	.	.	.	.	.	.	+	+	II
Origanum vulgare	6	+	+	.	.	.	.	.	.	.	.	.	.	.	.	II
Orchis purpurea	6	.	.	.	.	.	.	.	.	+	.	.	.	+	.	II
Plantago media	6	.	.	.	.	.	.	.	.	.	.	+	+	.	.	II
Calamagrostis varia	6	+	.	.	.	.	.	+	.	.	.	.	.	.	.	II
Inula salicina	6	.	+	.	.	.	.	+	.	.	.	.	.	.	.	II
Muscari comosum	6	+	+	.	.	.	.	.	.	.	.	.	.	.	.	II
Fragaria vesca	6	1	.	+	.	.	.	.	.	.	.	+	+	.	.	II
Carex digitata	6	.	.	.	.	+	.	+	+	.	.	.	+	.	.	II
Laser trilobum	6	.	.	.	1	.	.	.	+	+	.	+	.	.	.	II
Galium paschale	6	.	.	.	.	.	.	.	.	.	.	+	.	+	.	II
Aegonychon purpurocaeruleum	6	.	.	.	.	.	+	.	.	.	+	.	+	.	.	II
Asperula purpurea	6	.	.	.	.	.	+	.	.	.	.	.	.	+	.	II
Viola reichenbachiana	6	.	.	1	.	.	+	+	.	.	.	.	.	.	.	II
Populus tremula	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Hedera helix	4	.	.	.	+	.	.	.	.	.	.	.	+	.	.	I
Onosma heterophylla	6	.	.	.	.	.	+	.	.	.	.	.	.	.	.	I
Campanula persicifolia	6	.	.	.	.	.	.	.	.	.	.	+	.	.	.	I
Securigera varia	6	.	.	+	.	.	.	.	.	.	.	.	.	.	.	I
Cyanus triumfettii	6	.	.	.	.	.	.	+	.	.	.	.	.	.	.	I
Achillea collina	6	.	.	.	.	.	.	.	.	.	.	.	+	.	.	I
Malus florentina	3	.	.	.	.	.	.	.	+	.	.	.	.	.	.	I
Carlina acaulis	6	.	.	.	.	.	.	.	.	.	.	.	.	+	.	I
Jurinea consanguinea	6	.	.	.	.	.	.	.	.	.	.	+	.	.	.	I
Vicia hirsuta	6	+	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Minuartia verna	6	.	.	.	.	.	.	.	.	+	.	.	.	.	.	I
Melilotus officinalis	6	.	.	.	.	.	.	.	.	.	.	.	.	+	.	I
Aethionema saxatile	6	.	.	.	.	.	.	.	.	.	.	.	.	+	.	I
Petrorhagia saxifraga	6	.	.	.	.	.	.	.	.	+	.	.	.	.	.	I
Potentilla hirta	6	.	.	.	.	.	+	.	.	.	.	.	.	.	.	I
Epipactis microphylla	6	.	.	.	.	.	.	.	.	.	.	.	+	.	.	I
Epipactis atrorubens	6	.	.	.	.	.	.	.	.	.	.	.	.	+	.	I
Lathyrus pratensis	6	.	.	.	.	.	.	.	.	.	.	.	+	.	.	I
Veronica austriaca	6	.	+	.	.	.	.	.	.	.	.	.	.	.	.	I
Inula aspera	6	.	.	.	.	.	.	.	.	.	.	.	+	.	.	I
Viola hirta	6	.	.	.	.	.	.	.	.	.	.	.	+	.	.	I
Knautia drymeia	6	.	.	.	.	.	.	.	.	.	.	.	+	.	.	I
Lotus corniculatus	6	.	.	.	.	.	.	.	.	+	.	.	.	.	.	I

Table 2 Continues

Astragalus onobrychis	6	.	.	.	.	.	.	.	.	.	.	.	.	+	.	I
Clinopodium alpinum	6	.	.	.	+	.	.	.	.	.	.	.	.	.	.	I
Medicago prostrata	6	.	+	.	.	.	.	.	.	.	.	.	.	.	.	I
Malus sylvestris	6	.	.	.	.	.	+	.	.	.	.	.	.	.	.	I
Carlina acanthifolia	6	.	.	+	.	.	.	.	.	.	.	.	.	.	.	I
Linum flavum	6	.	.	.	.	.	.	.	+	.	.	.	.	.	.	I
Hieracium racemosum	6	.	.	+	.	.	.	.	.	.	.	.	.	.	.	I
Scorzonera hispanica	6	.	.	.	.	.	.	.	.	.	+	.	.	.	.	I
Arabis hirsuta	6	.	.	.	+	.	.	.	.	.	.	.	.	.	.	I
Poa trivialis	6	.	.	.	.	.	.	.	.	.	.	+	.	.	.	I
Hieracium sparsum	6	.	.	.	.	.	.	.	.	.	.	.	.	+	.	I
Astragalus glycyphyl-loides	6	.	.	.	.	.	.	.	.	+	.	.	.	.	.	I
Campanula lingulata	6	.	.	.	.	.	+	.	.	.	.	.	.	.	.	I
Lonicera xylosteum	6	.	.	.	.	.	.	.	+	.	.	.	.	.	.	I
Ligustrum vulgare	2	.	.	.	.	.	.	.	.	.	.	.	.	+	.	I

The floristic composition of the *Cytiso jankae – Pinetum nigrae* ass. nova is presented in the phytosociological table (Table 2), which includes 14 relevés with a total of 142 recorded species.

The association *Cytiso jankae – Pinetum nigrae* ass. nova (Figure 8) is named after *Cytisus jankae* (Figure 7), marking the first recorded occurrence of this predominantly calciphilous Balkan endemic in the eastern part of North Macedonia. This species is frequently found within the thermophilous *Pinus nigra*-dominated forests on limestone at Vlaina Mt., as well as in shrubby areas at elevations between 700 and 1060 meters. Previously known localities, as reported in the literature, include Prilep (Drenska Planina) [37], Skopje (Sopište, Osinčani), Galičica Mountain, Prilep (Pletvar, Kozjak), and Kičevo (Kafčal) [38]. The record from Skopska Crna Gora (*sub Cytisus supinus* var. *jankae* (Vel.) Stoj. & Stef.) [39] was questioned by Micevski [38] and requires further confirmation.

Figure 7. *Cytisus jankae* Velen

The second dominant species, *Pinus nigra*, is present in all relevés as a constant and dominant species. In some cases, it forms denser stands and morphologically defines the character of the community.

This community also hosts several rare species for the flora of North Macedonia, including *Hieracium chalcidicum* subsp. *macropannosum* [19] (previously recorded as *H. macropannosum*), *Anemone sylvestris*, and *Carex tomentosa* [18,20].

The floristic analysis of the studied community indicates the presence of taxa characteristic of the *Fraxino orni-Ostryion alliance*, including constant tree species such as *Ostrya carpinifolia*, *Fraxinus ornus*, and *Cornus mas*, as noted by several authors [40,41]. Additionally, other species typical of this alliance are present.

Some relevés show similarities to the vegetation of the *Erico-Pinetea* class, as recognized by other authors [42]. Furthermore, transgressive species from the *Fraxino orni-Pinion nigrae* alliance are also found in this forest, particularly at higher altitudes.

Figure 8. Association *Cytiso jankae - Pinetum nigrae* ass. nova on limestone at Vlaina Mt

The community develops across various exposures at altitudes ranging from 700 to 1100 meters above sea level**,** predominantly on limestone. It thrives in areas with very shallow soil, where the parent substrate emerges at the surface in the form of smaller or larger stones. All three vegetation layers are represented, with *Pinus nigra* as the dominant species, forming dense stands in several locations. However, in distinctly rocky areas, the pine cover is less dense. The species regularly undergoes natural regeneration. In the past, silvicultural measures were applied to a small part of the highest areas within the site, but these interventions did not significantly alter the floristic structure of the community.

The syntaxonomic position:

Class: *Quercetea pubescentis* Doing-Kraft ex Scamoni et Passarge 1959

Order: *Quercetalia pubescenti-petraeae* Klika 1933

Alliance: *Fraxino orni-Ostryion* Tomažič 1940

Association: *Cytiso jankae - Pinetum nigrae* ass. nova

From the biological spectrum (*spectrum of life forms*, Figure 9) of the association *Cytiso jankae – Pinetum nigrae* ass. nova, it is evident that the community is dominated by hemicryptophytes, represented in grey on the pie chart, accounting for 61 % of the total species composition. Other life forms occupy smaller proportions within the community.

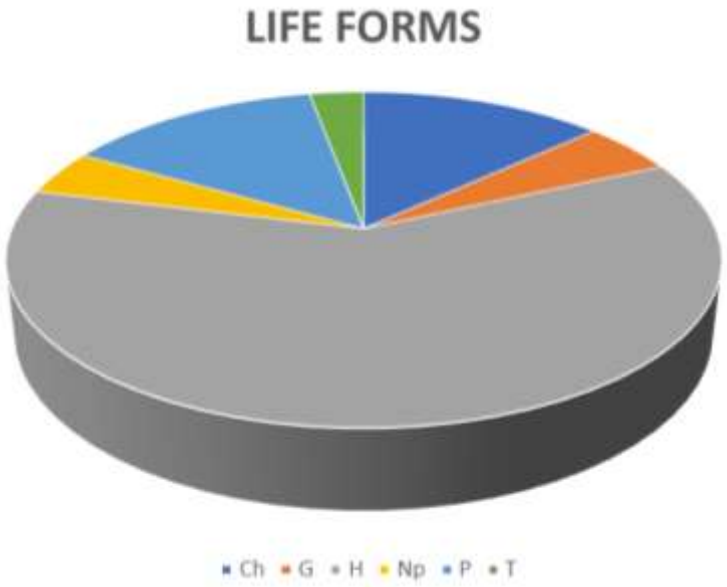

Figure 9. Association: *V - Pinetum nigrae* ass. nova, spectrum of life forms

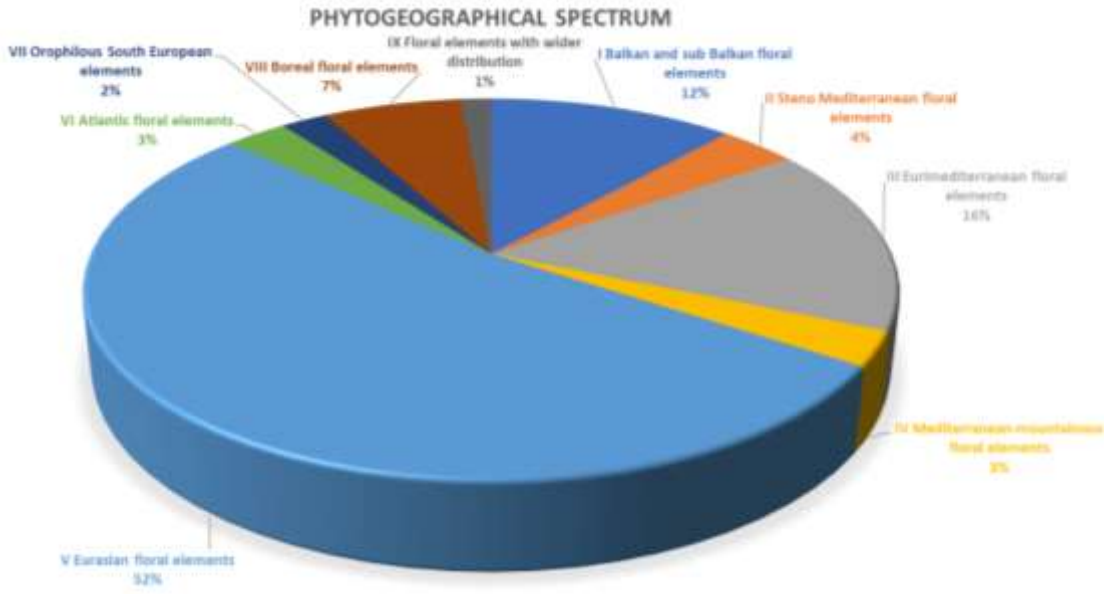

Figure 10. The spectrum of floral elements (phytogeographical spectrum). From the spectrum of floral elements (*phytogeographical spectrum*, Figure 10), it is evident that the Euro-Asiatic floristic element is the most represented, accounting for 52 % of the total species composition. This is followed by the Eurimediterranean floristic elements at 16 % and the Balkan floristic elements at 12 %. The contribution of other floristic elements is relatively minor.

CONCLUSION

The results obtained provide a significant contribution to the understanding of the distribution and syntaxonomy of a pine forest community that develops on Mount Vlaina, within the territory of North Macedonia. This study highlights the ecological importance of this community and its role in the preservation of natural habitats. The analysis of its structure, syntaxonomic classification, and

distribution reveals the specific environmental conditions under which this community thrives, as well as its potential to provide essential ecological functions, including soil stabilization**,** biodiversity conservation, and water regulation.

The significance of this pine forest community extends beyond its ecological value to the urgent need for its preservation, as the area may be sensitive to climate change and human activities. This research can contribute to the development of conservation strategies and the sustainable management of this valuable ecosystem.

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ТЕРМОФИЛНА ШУМА ОД ЦРН БОР *PINUS NIGRA* НА ВАРОВНИЧКА ГЕОЛОШКА ПОДЛОГА НА ПЛАНИНАТА ВЛАИНА ВО СЕВЕРНА МАКЕДОНИЈА

Дејан Манџуковски, Ацо Теофиловски

Јавно претпријатие за стопанисување со државни шуми „Национални шуми“, Скопје, РС Македонија

Во трудот е опишана нова за науката шумска заедница *Cytiso jankae – Pinetum nigrae* ass. nova, во која доминира црниот бор (*Pinus nigra*). Заедницата се развива на варовничка подлога, под термофилни услови на планината Влаина (на надморска височина од 790–1060 м) во Северна Македонија. Добиените резултати претставуваат значаен придонес во познавањето на распространувањето и синтаксономијата на оваа борова шумска заедница. Со истражувањето, се истакнува еколошкото значење на оваа шумска заедница и нејзината улога во зачувувањето на природните живеалишта. Новоопишаната растителна заедница, синтаксономски припаѓа на класата *Quercetea pubescentis*, редот *Quercetalia pubescenti-petraeae* и сојузот *Fraxino orni-Ostryion*.

Клучни зборови: термофилна; *Fraxino orni – Ostryon*; шумска вегетација; класификација; ординација; *Pinus nigra*