

Platon Tretyak

Higher school "Prekarpathian Forestry College", e-mail platon.tretyak@gmail.com

Iryna Pozynytych, Anastasiia Savytska

State Museum of Natural History of National Academy of Sciences of Ukraine, e-mail pozychka@gmail.com;

Ihor Boychuk

Osmolods'ke State Enterprise of Forestry Management, e-mail boychuk.ihor@gmail.com

FORESTS WITH SWISS STONE PINE (*Pinus cembra* L.) IN GORGANY RANGE (EASTERN CARPATHIANS, UKRAINE)

*LASY Z UDZIALEM LIMBY (*Pinus cembra* L.) W GORGANACH (KARPATY WSCHODNIE, UKRAINA)*

Key words: forest distribution, surface structure, altitude, slopes, soil conditions, old-growth forest stands, participation.

Słowa kluczowe: rozmieszczenie lasów, struktura powierzchni, wysokość, nachylenie, warunki glebowe, starodrzewia, udział.

Abstract. The article present results of the research on the location and structure of forests, where the *Pinus cembra* trees grow. Surface structures were measured according to stand age classes and habitat categories. The total surface of plots, where old-age forests grow was summed up. The species composition of forest stands and plant communities on the whole is generalized. The values of forest plots areas in which the *Pinus cembra* trees constitute part of the volume of stands of 10%, 20% or more are summarized. To preserve the *Pinus cembra* population, it is recommended to expand the network of protected areas.

INTRODUCTION

The IUCN Red List of Threatened Species (tm) attributes *Pinus cembra* to the Least Concern species category. The species belongs to the Least Concern list in the European Union 28 member states. Swiss stone pine is widespread in the Alps and Carpathians mountain ranges and protected well in many forest reserves. The trees of this species grow at 1,100-2,500 (2,700) m a.s.l. in several regions of the Alps. *Pinus cembra* continues to expand its altitudinal extent. *Pinus cembra* trees are slow growing and can live to old age (over 1,000 years) and have rot-resistant wood (Caudullo, G., de Rigo, D., 2016).

The total area of forests in which the trees of *Pinus cembra* spread over the world is estimated to cover over 30 thousand hectares. Such forests grow in the Alps and Carpathian Mountains of central Europe, in Poland (Tatra Mountains),

Switzerland, France, Italy, Austria, Germany, Slovenia, Slovakia (Tatra Mountains), Romania and Ukraine (Ulber, M., Gugerli, F., Bozic, G., 2004). The researchers made detailed maps of the *Pinus cembra* area in Europe, in particular the Eastern and Southern Carpathians. There is currently on regional areas no logging in forests, where *Pinus cembra* spread.

In Romania, the trees of this species grow isolated or in groups at the upper forest limit in post-glacial valleys of the Calimani, Rodnei, Fagaras, Parang mountains and especially in the Retezat mountains, where they located in the regions over 2000 m a.s.l. (Blada, I., 2008).

In Poland and Slovakia in the Tatra region the population of *Pinus cembra* occupies area of 300 hectares and comprise about 12,000 trees, about 4,000 of which is located in Poland (Chmiel, J., 1996). Despite high fragmentation and small size of local habitats of *Pinus cembra* population in the Tatra Mountains, the reduction threat to the species in this area is absent (Dzialuk, A., Chybicki, I., Gout, R., Mączka, T., Fleischer, P., Konrad, H., Curtu, A. L., Sofletea, N., Valadon, A., 2014). The species are protected in the Tatra National Park (Poland) and Tatra National Park (Slovakia).

In Ukraine, the total area of forests with *Pinus cembra* is estimated at 5,000 hectares (Tasjenkevych, L. O., Mel'nyk, V. I., Sirenko, O. G., 2009). The population is protected, as defined by the Law of Ukraine "On the Red Book of Ukraine". The regime of complete protection of forest ecosystems in which the *Pinus cembra* is represented in nature reserves, national natural parks, regional reserves and etc. is provided.

The research of the distribution of the *Pinus cembra* population in the Carpathians has found its place in the proceedings of scientists of Austro-Hungarian in the 19th century. However, main scientific works appeared only in the first half of the 20th century. The first was a scientific article by W. Szafer (1914), in which the distribution of *Pinus cembra* trees in the upper reach of the Limnitsa River was described. Also, A. Kozikowski (1914) published the results of the analysis of the growth of this species trees. A complete bibliography and an original scientific generalization are given in the work of Professor Andrzej Środoń (1936). His map and the list of places of distribution of this population in the Carpathians of the Poland of those years are exceptionally important, in particular in the Gorgany range. This is very valuable information for monitoring comparisons.

The Gorgany range is a geographic region in Eastern Carpathians Mountains. (Ukraine). It is located within coordinates Lat 48.28157–48.79601° and Lon 23.87744–24.56500°. Its area is approximately 250 000 hectares. The elevation amplitude is between 450 and 1836 m a.s.l. This is an original and unique mountain region in Central and Eastern Europe. Mountain ridges consist of solid sandstone. Stone deposits cover large areas on their steep slopes. Mixed fir-spruce-beech forests are prevailing here. In the mountain forest upper belt the spruce stands grow. On the forest upper limit the marginal vegetation has a natural ecocline character between the subalpine shrubs *Pinus mugo* Turra and mountain spruce forests.

It is located at an altitude of 1400-1600 m a.s.l. There are almost no mountain pastures in this area. In the Gorgany range, the largest in the Carpathian Mountains areas of forests, in which the Swiss pine trees grow, are concentrated.

Unfortunately, during the past two centuries the *Pinus cembra* population in the Gorgany range has undergone a significant reduction due to the forest exploitation. The materials of the State Central Historical Archive in Lviv are indicative of the large-scale extent of the deforestation in region. In particular the trees of the *Pinus cembra* a large number was cutting (Stojko, Tretyak, Bojchuk 1999). Particularly large-scale logging of forests took place here in the second half of the 19th and in the second half of the 20th century (Tretiak, Bojczuk 1997).

However, already in the first half of the twentieth century, due to the active position of the scientific community and intellectuals, in particular, Professor W. Szafer (1914) and Professor A. Środoń (1936), the cutting of *Pinus cembra* trees in the Carpathians was discontinued. In order to protect this population the first reserves in the Gorgany range were created. In 1919 there was organized the forest reserve „Gorgan“ on the area of 500 hectares. In 1938 its area was extended to 1121.58 hectares. In 1934, the *Pinus cembra* forest reserve "Jajko" (area 270 ha) was created. Here some *Pinus cembra* trees from the age of 100 to 600 years had a height of 28 m and a diameter at breast height – 1 m (Rymarowicz 1995, Tretiak (red.) 1998).

Extremely intensive forest use was practiced in the Carpathian Mountains, in particular in the Gorgany range, in the 50-60 years of the 20th century (Tretiak 1998a, 1998b). It was then that almost all available the old age forests were completely cut down. This also applies to forests that included *Pinus cembra* trees. It is known that then in the Soviet Union there were no environmental laws that would protect the Carpathian forests (Gensiruk, Bondar 1973).

After the Second World War, the study of the distribution of *Pinus cembra* in Gorgany range carried out K. K. Smagluk (1972). He summed up the results of the inventory of forests and discovered tree stands, in which the trees of this species grew, on an area of about 6,000 hectares. Most of these forests grew in Gorgany range, about 5,500 hectares. Such forests were concentrated mainly in the belt of mountain spruce forests at an altitude of 1,300–1,500 m a.s.l. They rarely grew at lower levels and even at an altitude of 800 m a.s.l. Also, this scientist has researched the biometric indices of the six of the *Pinus cembra* model trees They grew at an altitude of 1,330–1,460 m a.l.s. Their age reached 138–310 years, the height – 11–22.3 m, the thickness of trunks at breast height (DBH) – 19–63 cm, the volume – 0.17–3.04 m³.

Dendrometric studies of growth of the *Pinus cembra* trees were conducted in the Gorgany range during the last decade by researchers from the Precarpathian School of Forestry in Bolechov (Ukraine). The results of these studies were similar to the previous ones (Tretiak, Czernevyy 2013, Tretyak, Czernevyy 2018). In general, the average growth rate of trees in height was very slow. The growth of *Pinus cembra* trees in height were maximal at the age of 30–100 years. It reaches

0.18 m·yr⁻¹. Later it is significantly reduced. At the age of 200–350 years it is only 0.02–0.05 m·yr⁻¹ and their height reaches to 15–18 (26) m. The maximum growth of the diameter at the height of the breasts of these trees trunks was detected at the age of 40–100 and 250–330 years. Its maximum reaches only 0.03 m·yr⁻¹. At the age of 200–350 years, this diameter of the trunks is 0.3–0.55 (0.95) m. The growth of the volume of these trunks are culminated at the age of 300–320 years, when it reaches almost 0.02 m³·yr⁻¹. The maximum volume of trunks in age 200–300 years reaches 0.3–2.2 (4.5) m³. Such biometric parameters of the growth rate of pine trees growing near the upper forest line in Gorgany range, give reason to believe that their mature biological age occurs after 300 years, when the annual growth rate of the trunk volume reaches a maximum. Existing spruce forests containing Swiss stone pine trees with a DBH of more than 0.5 m can be considered as the remains of virgin forests, since they have be at least 200 years old. Similar results have been obtained for such mountainous forests in the Austrian Alps (Li M.-H., Yang, J., 2004).

Nevertheless, the natural forest vegetation is relatively well preserved in the region, and the population of the Swiss stone pine is widespread in large areas. However, forests in the lower and middle parts of the slopes to altitude of 1,100—1,300 m a.s.l. were already twice felled, in the 19th and 20th centuries. The population of *Pinus cembra* in these places suffered from anthropogenic reduction.

Today the population of *Pinus cembra* is reliably protected only on relatively small areas in the "Gorgany" Nature Reserve, two National Nature Parks and other separate reserves. However, most of the part of this population is outside the protected areas. During the last 20 years in the Carpathian Mountain Forests of Ukraine intensive logging is practiced. Forest felling is permitted on mountain slopes to a height of 1,100 m a.s.l. Therefore, despite the fact that Ukrainian legislation prohibits the deforestation of Swiss pine trees, the reality may be different. After all, the Swiss pine trees do not grow in plots of cut off forests. Thus, there is a potential threat to reduce the population of this species through of the forest exploitation.

Therefore, the purpose of our study was to analyze the current state of the population of *Pinus cembra* in the Gorgany range. Such information is necessary to preserve the remains of the natural population of this species.

MATERIALS AND METHODS

Information about the spread of plots with forests that contain *Pinus cembra* are presented in our database. This is online resource "Former Forests of the Carpathian part of the Dniester river basin as of 01-01-2001. Database and Web Search Engine" (<http://econtsh.astra.in.ua/lis.php?lang=en>). The authors of this online resource are Prof. Dr. Biol. Sciences P. Tretyak, Ass. Prof. PhD. A. Kostenko, PhD I. Patsura, Ing. A. Savchyn, Magr. A. Savytska, Magr. I. Pozynych. The information presented in it is based on the documents of inventory of forests of 1996-2000 years. It reflects

the state of the forests of the region at the beginning of the 21st century, that is, before the forest use of the last 20 years. According to the needs of the information-analytical system on the Internet, it is restructured and supplemented with other data, in particular, by the categories of local types of trophots and hydrophytes, as well as the geological substrate and relevant plant communities, etc.

Abbreviations of categories of information serve this purpose. The most common of them are given in the relevant reference tables. For example, the species compositions of each stands are represented standardly, by the parts of the stand volume. For this purpose, the alphabetical abbreviations of the species names are used, before which coefficients of their participation in the stand volume are indicated. These coefficients are presented on a 10-step scale of parts of stand volume (1 = 10% ... 10 = 100%). Also, it is supplemented "+" symbol, which means an admixture below 5%. From the presented database, information about the stands, in which the trees *Pinus cembra* grow, can be obtained. For this purpose, the button "???" should be activated in the "Composition" position in the menu of top banner. This brings up the reference table "Nomenclature and abbreviations of tree species in the tree stands" on the screen. Next, an abbreviation of the corresponding species needs to be found. In our case, this is the species "*Pinus cembra*". It is marked with the acronym "P-ce". In order to get information about all the plots on which stands grow, which include the trees of this species, "Custom Filter" search frame needs to be performed. First, the name of the field in which to search should be selected from the drop-down list. In our example it is "Composition". Next, in the right field, the acronym for the species name must be specified, that is "P-ce". Then the "Apply" button must be activated. The system displays the information about all the plots on the screen, with *Pinus cembra* trees, . In total, be 827 sub-compartments there are found. Their total area is 5,053.9 hectares. These are the land uses of 8 State Enterprise of Forestry Managements and Nature Reserve "Gorgany". The portion of these lands now belongs to the National Natural Park "Syn'ogora", founded in 2006. (Table 1). If, before the abbreviation of the species is indicated by the coefficient of participation of its trees in the volume of the stand, for example, "3P-ce", then the information is displayed only for those plots where the stands grow, which contain 30% of the *Pinus cembra* trees in their volume. 28 of such plots are found and their total area is 93.3 hectares.

The presented online information-analytical system is original and unique in Ukraine. For its own use, it has considerably wider analytical capabilities. Analytical procedures by using SQL subject-specific query technologies were performed. The structure of surface areas was calculated according to stand age classes and habitat categories. Also, the differentiation of areas of stands depending on the height above the sea level, the angle of inclination and the exposure of the slopes was analyzed. A similar analysis was made regarding the differentiation of stands surfaces with different contents of the *Pinus cembra* trees. This takes into account the coefficients of their participation (decimal parts) in the volume of stands.

Structural floristic features of the forests in which *Pinus cembra* trees grow were established on the basis of the generalized results of the study of 39 phytocoenosis. The study of the floristic structure of four layers of plant communities on the plots of 400 m² was carried out. All the phytosociological data description was recorded according to the modern principles of Braun-Banquet's methodology (Mróz W. (ed.) 2012). The composition and construction of plant communities and methods of their study were used traditionally (Pawłowski, B. 1977). Structural levels of the plant communities: A - trees, B - shrubs, C - herbs, D – mosses. The modern Nomination of species is applied (Global Biodiversity Information Facility 2019.). Indicators of the certain taxon cenopopulations representation: C – constancy, the percentage of phytocoenotic relevés in which taxon is present (I: 0–20%, II: 21–40%, III: 41–60%, IV: 61–80%, V: 81–100%); CR – the percentage of cover ratio (representing the mean cover of given species cenopopulations from the all relevés).

RESULTS

At the beginning of the 21st century, the largest forest areas, in which Swiss stone pines grow, were regularly located on the upper part of the highest mountain

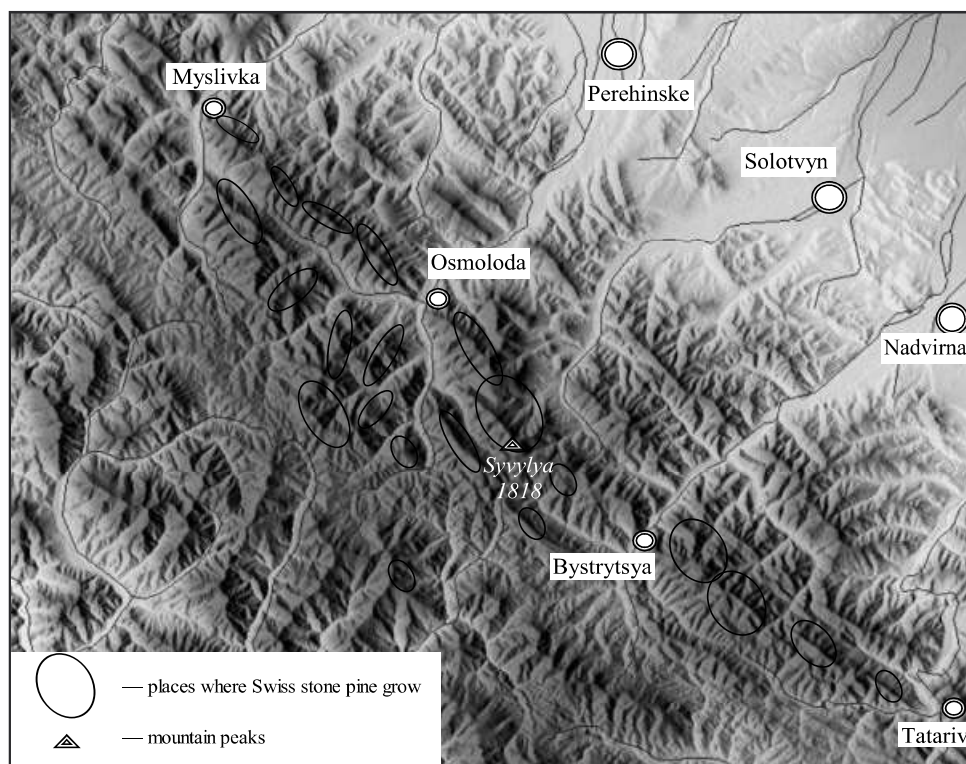


Figure 1. Regular distribution of localities in the Gorgany range where forest stands with Swiss stone pine grows.

Source: Own research.

ranges in basin rivers Lomnytsia and Bystrytsya Solotvynska also Bystrytsya Nadwirińska. These are the massifs Arshitsa, Yayko Ilems'ke, Moloda-Yayko Perygins'ke, Grofa, Parenky, Popadya, Petros, Kanusyak, Ovol, Gorgan, Vysoka, Ihrovyshe, Syvulya, Bushtul, Polensky, Dovbushanka, Synyak, Khomyak and others (Figure 1).

These are the forests within the land use of the Osmolods'ke SEFM, Gorgany NR, Syn'ogora NNP, Nadvirnyans'ke SEFM, Solotvyns'ke SEFM are concentrated. Their total area amounted to about 5,053.9 ha (Table 1). Particularly valuable are old-growth stands (more than 100 years old). Their total area is almost 3,173 ha. The younger stands, aged from 41 to 100 years old are also perspective. Total they occupy almost 811 ha. It is worth drawing attention to a large area of young stands (age up to 40 years old) in which *Pinus cembra* trees grow. Their total area is 1,070 ha.

Many of them grow at an altitude of under to 900 m a.s.l. These are mostly artificial plantings. Their total area is almost 400 ha (Table 2). Above 900 m n.r.m. such young forests occupied almost 670 ha. They are mostly of natural origin, because the planting of artificial forests is almost not practiced here. At the same time, it should be noted that the overwhelming majority of older stands, which contain the Swiss stone pine trees, grow within the altitude of over 1,000 to 1,600 m a.s.l. (Table 2). The largest areas, where such forests grow, are concentrated at an altitude of 1,100—1,500 m a.s.l. These forests are the remains of natural forests. It is obvious that they provided a significant potential for generative recovery and expansion of the Swiss stone pine population in the Gorgany range.

Tab. 1. Structure of areas of surfaces where grow the stands with *Pinus cembra* trees, according to age categories and land users, ha.

Land Users*	Classes of the age of stands, years										Total	
	1 – 20	21 – 40	41 – 60	61 – 80	81 – 100	101 – 120	121 – 140	141 – 160	161 – 180	181 – 200		201 – 220
Bolekhivske SEFM	34.7	24.9	0	0	0	0	0	0	0	0	0	59.6
Broshnivske SEFM	13.2	26	0	0	0	0	0	0	0	0	0	39.2
Gorgany NR	0	41	12.5	51.8	15.1	64.1	66.7	106.9	18.1	8.8		385
Ivano-Frankivske SEFM	0.8	0	0	0	0	0	0	0	0	0	0	0.8
Nadvirnyanske SEFM	27.7	108.9	4.4	2.6	9.4	2.2	0.3	33.8	4.5	19.9	0	213.7
Osmolodske SEFM	220.5	405.9	255.6	222	148.1	326.2	690.4	983.2	416.8	119.7	0	3788.4
Skolivske SEFM	2.3	0	0	0	0	0	0	0	0	0	0	2.3
Solotvynske SEFM	39.4	19.4	1.7	0	33.5	8.2	50	42.5	14.6	0	1.9	211.2
Syn'ogora NNP	35.9	58.9	17.9	0	32.6	0	11	19.7	68.9	10	0	254.9
Vyhodske SEFM	11	0	0	0	3.6	13.2	50	21	0	0	0	98.8
Total	385.5	685	292.1	276.4	242.3	413.9	868.4	1207.1	522.9	158.4	1.9	5,053.9

* NNP - National Natural Park; NR - Nature reserve; SEFM - State Enterprise of Forestry Management
Source: Own research.

Tab. 2. Structure of areas of surfaces where grow stands with *Pinus cembra*, according to age classes and altitude above sea level, ha.

Altitude m a.s.l.	Classes of the age of stands. years											Total
	1 – 20	21 – 40	41 – 60	61 – 80	81 – 100	101 – 120	121 – 140	141 – 160	161 – 180	181 – 200	201 – 220	
NO*	132.7	203.9	24	77.6	81.9	54.5	218.6	185.5	121	29.9	1.9	1131.5
401–500	0	1.1	00	0	0	0	0	0	0	0	0	1.1
501–600	11.3	2.2	0	0	0	0	0	0	0	0	0	13.5
601–700	10	0	0	0	0	0	0	0	0	0	0	10
701–800	6.9	8.3	0	0.5	0	0	0	0	0	0	0	15.7
801–900	8.9	11.4	0	0	0	4.1	0	0	0	0	0	24.4
901–1000	13.4	40.5	0	3.9	0	7.8	0	3.9	0	0	0	69.5
1001–1100	50.5	68.5	4.2	20.4	0	31.5	23.3	26.7	0	1.5	0	226.6
1101–1200	68.7	130.2	28.6	32.7	20.9	63	64.8	171.3	55.5	11	0	646.7
1201–1300	49.4	55.4	99.9	68.3	62.5	87.7	122.4	140.5	76.7	7.7	0	770.5
1301–1400	33.7	128.6	56.1	38.9	44.4	95.7	304.6	377.2	172.3	20.7	0	1272.2
1401–1500	0	19.2	77.9	34.1	31.7	68.5	102.8	219.4	85.5	58.7	0	697.8
1501–1600	0	15.7	1.4	0	0.9	1.1	31.9	82.6	11.9	28.9	0	174.4
Total	385.5	685	292.1	276.4	242.3	413.9	868.4	1207.1	522.9	158.4	1.9	5,053.9

* NO – subcompartment for which altitude above sea level is not specified.

Source: Own research.

In the Gorgany range, most spruce forests with Swiss stone pine, grow on oligo-mesotrophic soils at an altitude of 1,300 - 1,600 m a.s.l. These are periodically fresh or moist fairly poor soils with a thin brown earth horizon (*Cambic Leptosols*) on the surface of not-calcareous extremely rocky deposits (Figure 2a). A significantly smaller area (20%) is occupied by such forests that grow in mesotrophic conditions on acidic periodically moist and wet-hygrophilic stony brown earth soils (*Cambic Leptosols* and *Leptic Cambisols*). Fragmental spruce stands with separate Swiss cedar trees that grow in oligotrophic conditions on periodically dry or fresh *Lithic Leptosols* or *Dystric Regosols* on not-calcareous hard blocks of sandstone, are very rare and occur on small surfaces.

Most spruce stands with Swiss stone pine trees grow on steep slopes 16 - 35 degrees within the height of 1,100 - 1,300 m a.s.l. (30%), as well as 1,300 - 1,400 m a.s.l. (25 %).

Above, at an altitude of 1,400 - 1,500 m a.s.l., they are fewer stands, in general only 14%. Almost 20% of these forests grow on very steep slopes above 1,300 m a.s.l. (Figure 2b).

Most forests with Swiss stone pine are concentrated on the southwest slopes (23%). The least of them are on eastern (7%) and northern expositions (5%). On the rest of the slopes, the proportion of such forests is approximately the same; it is 11–15%. Horizontal surfaces in the mountains are rare. In general, they occupy

a small area. Therefore, in such places (within 1000—1200 m a.s.l.), forests with Swiss pine stone occupy small areas (Figure 2c).

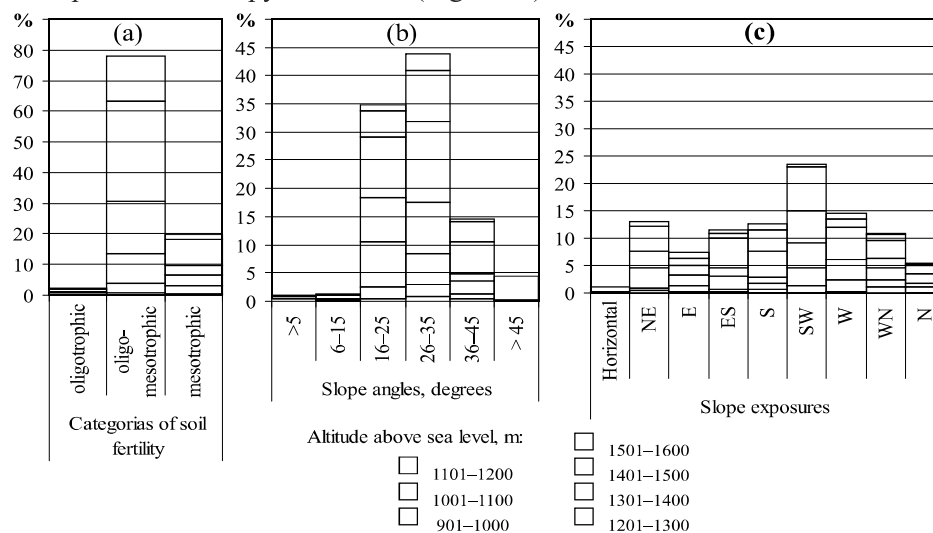


Figure 2. Distribution of surface areas in the Gorgany range where Swiss stone pine grow depending on altitude above sea level and categories of soil fertility (a), slopes angle (b) also slopes exposure (c).

Source: Own research.

Most spruce forests contain only some Swiss stone pine trees. To the altitude of 1,300 m a.s.l. these forests also contain separate trees of *Fagus sylvatica* L., *Acer pseudoplatanus* L., *Betula pendula* Roth, *Betula pubescens* Ehrh., *Sorbus aucuparia* L. and others. More than 1,500 ha occupy the stands, in the volume of which the *Pinus cembra* trees constitutes 10% or 20%. Unique is stands, which have in volume 30%, 40%, 50% or more of these trees. They are almost 175 hectares in the Gorgany range. s The stands which have 60% and 70% of the *Pinus cembra* trees deserve particular attention. They occupy an area of 24.6 ha (Table 3).

Tab.3. Structure of surface area where old age stands (over 100 years age) grow according with to *Pinus cembra* participation and altitude above sea level, ha.

Altitude m a.s.l.	Participation indicators of <i>Pinus cembra</i> in stand volume (percent)								Total
	+	10	20	30	40	50	60	70	
901–1000	57.5	12	0	0	0	0	0	0	69.5
1001–1100	86	115.5	25.1	0	0	0	0	0	226.6
1101–1200	374.2	182.1	36.2	11.9	17.4	9.1	2.7	13.1	646.7
1201–1300	426.9	174.4	134.8	15.9	10.4	0.4	0	7.7	770.5
1301–1400	725.5	277.4	220.3	23.8	7.7	17.5	0	0	0
1401–1500	343.4	150.7	173.9	18.4	10.3	0	0	0	0
1501–1600	87	17	61.8	8.6	0	0	0	0	0
Total	2100.5	929.1	652.1	78.6	45.8	27	2.7	21.9	3,857.7

* "+" – occurs singly

Source: Own research.

Most spruce stands with a significant part in volume (2 or more tenths) of *Pinus cembra* trees grow on steep slopes (16 - 35 degrees). Most of them are concentrated on the northeast and southwest slopes (Figure 3).

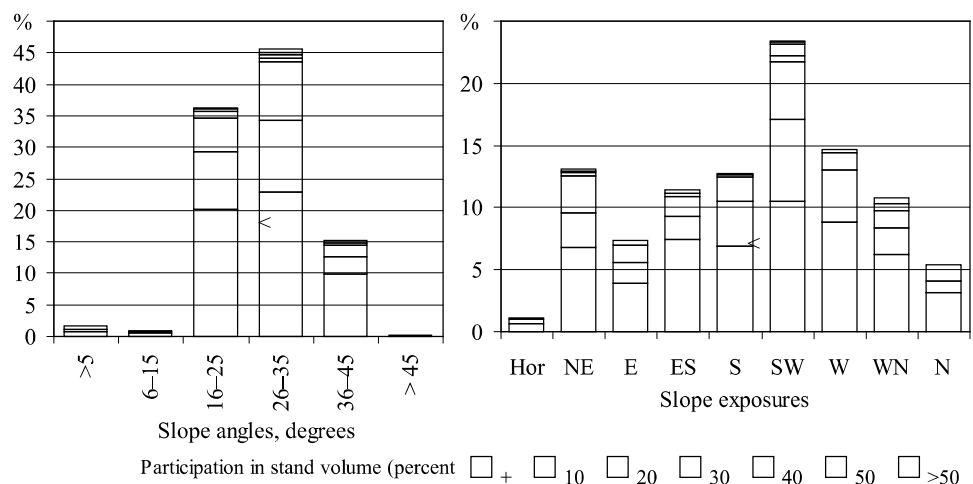


Figure 3. Distribution of surface areas in the Gorgany range depending on *Pinus cembra* participation in stand volume (percents) and slopes angle (a) also slopes exposure (b).
Source: Own research.

In general, the forest in the Gorgany range with Swiss stone pine can be considered as belonging to the association *Pino cembrae-Piceetum* Myczkowski et Lesiński 1974. Based on the results of our research (Tretyak, Pozynych, Sawycka), its phytocoenotic structure is as follows (Table 4). Представлені результати дають підстави виділити для лісів Горган два варіанти цієї асоціації:

Var. *Vaccinio (myrtillus)-Pineto (cembra)-Piceetum* – mountain spruce forests with an associate of Swiss stone pine trees;

Var. *Vaccinio (myrtillus)-Piceeto-Pinetum (cembra)* – mountains forests with Swiss stone pine and fir trees that are co-dominant.

The stand canopies of such forests form *Picea abies*, *Pinus cembra*, *Betula pendula*. There grow singly and occasionally the trees of *Abies alba*, *Acer pseudoplatanus* L., *Betula obscura* A.Kotula, *Betula pubescens* Ehrh., *Fagus sylvatica* L., *Pinus sylvestris* L., *Populus tremula* L.. In the second level of stands there grow singly the trees of *Betula pendula*, *Picea abies*, *Sorbus aucuparia*. Undergrowth of trees is not abundance. Its form *Picea abies*, *Sorbus aucuparia*, *Pinus cembra*, *Betula pendula*. Rarely there also occur the young plants of *Abies alba*, *Acer pseudoplatanus*, *Salix caprea* L., *Salix silesiaca* Willd. Infrequently there grow the shrubs: *Alnus viridis* (Chaix) (Chaix) DC., *Juniperus sibirica* Burgsd., *Lonicera nigra* L., *Pinus mugo* Turra, *Sambucus racemosa* L., *Spiraea media* Franz Schmidt. The cover of small shrubs is thick. It is dominated by *Vaccinium myrtillus* L. *Vaccinium uliginosum* L., *Rhodococcum vitis-idaea* (L.) Avror., *Rubus idaeus* L. and *Rubus caesius* L. or *Rubus saxatilis* L. are infrequent.

Tab.4. The generalized floristic structure of plant communities in which *Pinus cembra* is growing in Gorgany range. The meaning of symbols are given in the MATERIALS AND METHODS section.

Plant communities with a different cover percent of the <i>Pinus cembra</i> trees		All	+, 1 – 5%		6 – 25%		26 – 45%		
Number of plots in relevé		39	17		16		6		
Number of species in relevé		173	95		141		29		
Layer	Species	C	CR	C	CR	C	CR	C	CR
A	<i>Picea abies</i> (L.) Karst.	V	17	V	20	V	15	V	22
A	<i>Pinus cembra</i> L.	V	9	V	1	V	15	V	30
A	<i>Betula pendula</i> Roth	II	26	II	41	III	20	I	5
B	<i>Vaccinium myrtillus</i> L.	V	28	V	32	V	23	V	28
B	<i>Picea abies</i> (L.) Karst.	IV	5	V	3	IV	6	V	7
B	<i>Pinus cembra</i> L.	IV	2	III	1	IV	3	V	3
B	<i>Rhodococcum vitis-idaea</i> (L.) Avror.	IV	3	IV	2	IV	3	III	10
B	<i>Sorbus aucuparia</i> L.	III	1	III	1	III	1	I	1
B	<i>Betula pendula</i> Roth	II	4	II	2	II	8	I	1
B	<i>Pinus mugo</i> Turra	II	50	II	62	I	48	II	15
B	<i>Rubus idaeus</i> L.	II	6	III	2	I	20	I	5
B	<i>Vaccinium uliginosum</i> L.	II	14	II	23	II	5		
B	<i>Abies alba</i> Mill.	I	1	II	1	I	1		
C	<i>Calamagrostis arundinacea</i> (L.) Roth	III	13	IV	12	I	1	II	35
C	<i>Athyrium distentifolium</i> Tausch ex Opiz	II	3	II	4	II	1		
C	<i>Dryopteris austriaca</i> (Jacq.) Woyнар ex Schinz et Thell.	II	2	II	2	III	2	I	1
C	<i>Gentiana asclepiadea</i> L.	II	2	I	2	II	2		
C	<i>Homogyne alpina</i> (L.) Cass.	II	1	II	1	II	1	II	1
C	<i>Huperzia selago</i> (L.) Bernh. ex Schrank et Mart.	II	3	II	3	I	1	II	3
C	<i>Oxalis acetosella</i> L.	II	2	I	1	II	2	III	2
D	<i>Dicranum scoparium</i> Hedw.	III	16	IV	12	III	25	I	5
D	<i>Hylocomium splendens</i> (Hedw.) B.,S. et G.	III	8	IV	8	III	8	I	15
D	<i>Pleurozium schreberi</i> (Brid.) Mitt.	III	13	IV	17	IV	10	I	1
D	<i>Polytrichastrum formosum</i> Hedw. G. L. Sm.	II	5	III	6	II	3		
D	<i>Sphagnum girgensohnii</i> Russ.	II	10	III	12	II	1	I	35

Source: Own research.

Herbaceous layer is sparse. The common species are: *Athyrium distentifolium* Tausch ex Opiz, *Calamagrostis arundinacea*, *Dryopteris austriaca*, *Oxalis acetosella*, Occasionally: *Blechnum spicant* (L.) Roth, *Carex brizoides* L., *Carex sylvatica* Huds., *Cicerbita alpina* (L.) Wallr., *Doronicum austriacum* Jacq, *Dryopteris filix-mas* (L.) Schott, *Empetrum nigrum* L., *Gymnocarpium dryopteris* (L.) Newm., *Hieracium sylvularum* Jord. ex Boreau, *Gentiana asclepiadea* L., *Homogyne alpina* (L.) Cass., *Luzula sylvatica* (Huds.) Gaudin, *Lycopodium annotinum* L., *Lycopodium clavatum* L., *Majanthemum bifolium* (L.) F. W. Schmidt, *Ranunculus platanifolius* L., *Sedum carpaticum* G. Reuss, *Senecio fuchsii* C.C.Gmel., *Senecio nemorensis* L., *Solidago virgaurea* L., *Stellaria nemorum* L., *Streptopus amplexifolius* (L.) DC., *Thalictrum aquilegifolium* L.

Such structural and floristic composition of the described forest communities is similar to mountain spruce forests in the Carpathian Mts. (association - *Abieti-Piceetum* Szaf., Pawi. Et Kulcz. 1923 em. J. Mat. 1978.).

In the investigated plant communities, which *Pinus cembra* occurs, the average projective coverage of bryophytes plants are more than 70%. According to our investigations, the species list of the *Pino cembrae-Piceetum* association in Gorgany range, which includes Swiss pine as a characteristic species, includes also 66 moss species, among them 18 *Marchantiophyta* and 48 *Bryophyta* species. The common species are: *Dicranum scoparium*, *Hylocomium splendens*, *Pleurozium schreberi*, *Polytrichastrum formosum* and occasionally *Dicranum montanum* Hedw., *Plagiothecium undulatum* (Hedw.) B., S. et G. A significant part of the projective cover may include sphagnum mosses, the most common are *Sphagnum capillifolium* (Ehrh.) Hedw. and *S. girgensohnii*. Occasionally occur *Dichodontium pellucidum* (Hedw.) Schimp., *Scapania cuspiduligera* (Nees) Müll. Frib., *Anastrophyllum michauxi* (F. Weber) H. Buch. These hygrophytes determine moist habitat conditions.

In the Ass. *Pino cembrae-Piceetum* there was found a high number of species of *Marchantiophyta* in relation to mosses (38%). *Marchantiophyta* are represented by the following species: *Tritomaria exsecta* (Schmidel) Loeske, *Anastrophyllum michauxii* (F. Weber) H. Buch, *Barbilophozia attenuata* (Mart.) Loeske., *Bazzania tricrenata* (Wahlenb.) Lindb., *B. trilobata* (L.) Gray, *Blepharostoma trichophyllum* (L.) Dumort., *Calypogeia neesiana* (C. Massal & Carestia) Müll. Frib., *Cephalozia catenulata* (Huebener) Lindb., *C. connivens* (Dicks.) Lindb., *Diplophyllum albicans* (L.) Dumort., *Lejeunea cavifolia* (Ehrh.) Lindb. Emend. Buch, *Lepidozia reptans* (L.) Dumort., *Lophozia bicrenatus* (Schmidel ex Hoffm) Dumort, *Metzgeria conjugata* Lindb., *Ptilidium pulherrimum* (G. Web.) Vainio, *Scapania cuspiduligera* (Nees) Müll. Frib., *S. umbrosa* (Schrad.) Dumort., *S. undulata* (L.) Dumort.

In order preserve bryophyte species richness, forests with *Pinus cembra* need to be protected from the intensive anthropogenic use.

DISCUSSION

The results presented here are the first modern inventory summary and an attempt of qualitative factor analysis of stands structure and features of such habitats. The given data testify that in the Gorgany range there are forests, in which the largest in the Carpathian Mountains *Pinus cembra* population is represented. It is important that this is almost one-sixth of the total area of such forests in the World. This is the north-eastern boundary of the geographical distribution of this species in World. Consequently, these compact, regularly-located forests in the upper parts of the mountains in the Gorgan region are a significant part of the geographical distribution of this species. These forests are the rest of the natural forests remaining from the postglacial period. Unfortunately, from 1970 to 2000, the area of these forests in the Gorgany range decreased from 5.5 to 5 thousand hectares. And this bad trend, apparently, continues in connection with modern intensive forest use. Therefore they need to be stored and restored where they are cut. This is an important scientific and practical problem.

By structure and floristic content spruce forests with *Pinus cembra* trees, which grow in the Gorgany range are generally similar to the local mountain spruce forests (SubAll. *Vaccinio-Piceenion* Oberd. 1957). However, they differ from the similar forests in the Tatras and in the Alps, because they do not contain *Larix decidua* Mill. trees (Holeksa, Szwagrzyk 2012). They differ significantly from the communities of Ass. *Vaccinio-Pinetum cembrae* (Pallmann & Haffter 1933) Oberd. 1962. This is because they do not contain plant species that are characteristic of these phytocoenoses. In addition, spruce forests of *Pinus cembra* in the Gorgany range do not contain plant species that are characteristic and diagnostic for new associations, subassociations, and variants of similar communities in the Tatra Mountains. (Zięba, Różański, Szwagrzyk 2018).

In the future, it might be justified to allocate a new typical for the Gorgany range habitat of montane mixed *Pinus cembra-Picea abies* forests. In the end, this is evidenced by the fact that, unlike other parts of the Carpathian Mountains, in the Gorgany range on the total area of 175 hectares there grow spruce forests with the content in the stand volume from 30 to 50% of the *Pinus cembra* trees. In addition, here, on a total area of 24.6 hectares, these forests grow with the preponderance of most of the Swiss pine trees.

Such unique mixed *Pinus cembra-Picea abies* forests in the Gorgany range that grow outside the protected areas are threatened by the gradual destruction as a result of the forest use. This is because, according to the current legislation of Ukraine, the main forest exploitation is allowed to a height of 1100 meters. But in practice it is understood as the average height of the subcompartments, and therefore the forests are cut down considerably higher up to a height of 1,250 m a.s.l. This is easily confirmed by the data presented on the resource of Google Earth. Therefore, an international initiative to protect Swiss stone pine-spruce forests of Gorgany range is needed. Consequently, it is extremely necessary to include in the structure of the

Natural Reserve "Gorgany" and the National Natural Park "Syn'ogora" all the territories beyond their borders, where the forests of *Pinus cembra* grows.

CONCLUSIONS

In the Gorgany range the forests, with *Pinus cembra* are north-eastern boundary part of geographical distribution of this species. These forests are located compactly and regularly in the upper part of the highest mountain ranges on this region. Their total area is about five thousand hectares that is one-sixth of these forests area and of the *Pinus cembra* population in the world's in general. Regional forests, in which *Pinus cembra* grow, is different from those that grow in the Tatras and the Alps. They are differ by a significant part of the Swiss stone pine trees in the mountains fir-tree stands (total area 200 hectares). In addition, in the composition of such trees there are no *Larix decidua* trees.

Spruce forests that grow in the Gorgany range and contain more than 200 years old *Pinus cembra* trees, are the remains of former Carpathian virgin forests. Therefore, they deserve to be preserved, by engaging its to protected areas. In particular, it is extremely necessary to include in the structure of the Natural Reserve "Gorgany" and the National Natural Park "Syn'ogora" all the territories outside, where *Pinus cembra* grows.

LITERATURE

- Blada, I. (2008). *Pinus cembra* distribution in the Romanian Carpathians. Ann. For. Res. 51, 115–132.
- Caudullo, G., de Rigo, D. (2016). *Pinus cembra* in Europe: distribution, habitat, usage and threats. Chapter March 2016. European Atlas of Forest Tree Species, Editor San-Miguel-Ayanz, J., de Rigo, D., Caudullo, G., Houston Durrant, T., Mauri, A., Publisher: European Commission, 2016, 120–121, ISBN 978-92-79-36740-3, DOI 10.2788/4251.
- Chmiel, J. (1996). *Naturalny zasięg, a rozsiedlenie limby Pinus cembra w Tatrach Polskich [The natural range and the displacement of the Pinus cembra limes in the Polish Tatras]*. Przyroda. TPN a człowiek, T. 2, Biologia, Editor Kownacki, A., Kraków-Zakopane, 62–73. In Polish
- Działuk, A., Chybicki, I., Gout, R., Mączka, T., Fleischer, P., Konrad, H., Curtu, A. L., Sofletea, N., Valadon, A. (2014). *No reduction in genetic diversity of Swiss stone pine (Pinus cembra L.) in Tatra Mountains despite high fragmentation and small population size*. Cons. Gen., 15, 1433-1445, DOI 10.1007/s1059.
- Gensiruk S. A., Bondar V. S. 1973. *Lisovi resursy Ukrainy, i'h ohorona i vykorystannja [Forest resources of Ukraine, their protection and use]*. Kyiv: "Naukova dumka". 528 s.
- Global Biodiversity Information Facility. [online] <https://www.gbif.org/> [dostęp: 21.05.2019].
- Holeksa, J., Szwagrzyk, J. (2012). *9420. Górski bór limbowo-świerkowy (Pino cembrae-Piceetum) [Mountain limb-spruce forest]*. Monitoring siedlisk przyrodniczych. Przewodnik metodyczny. Część III. Editor Mróz., W., Publisher: GIOŚ, Warszawa, 328–338, ISBN 978-83-61227-76-2. In Polish
- Kozikowski A., 1914: *Limba (Pinus cembra L.) u źródeł Łomnicy. 2. Analiza przyrostu*. Sylwan 32, 6.: 218-221.

- Li M.-H., Yang, J. (2004). *Effects of microsite on growth of Pinus cembra in the subalpine zone of the Austrian Alps*. Ann. For. Sci. 61, 319–325, DOI 10.1051/forest:2004025
- Mróz W. (red.) 2012. Monitoring siedlisk przyrodniczych. Przewodnik metodyczny. Część III. GIOŚ, Warszawa.
- Pawłowski, B. 1977. Skład i budowa zbiorowisk roślinnych oraz metody ich badania (Composition and structure of plant communities and methods of their studies) [in Polish]. – In: Szafer, W. Zarzycki, K. (Eds.): Szata roślinna Polski, Vol. I: 237–279. PWN, Warszawa.
- Rymarowicz L. 1995. Rezerwat limbowy na Jajku Perehińskim w Gorganach // Płaj: almanach karpacki. — Wiosna. — S. 81 — 93.
- Smagljuk K. K. 1972. Aborygenni hvojni lisoutvorjuvachi [Aboriginal coniferous forest formers]. Uzhgorod, vydavnytvo "Karpaty". 112 s. In Ukrainian
- Środoń, A. (1936). Rozmieszczenie limby w polskich Karpatach i jej ochrona. Ochrona Przyrody. Rocz. 16. Krakow, 22–42.
- Stojko, S. M., Tretyak, P. R., Bojchuk, I. I. (1999). *Sosna kedrova (Pinus cembra L.) na verhnij mezhi lisu v G'org'anah: horologija, ekologija, fenologija* [Swiss stone pine (Pinus cembra L.) on the Upper Forest Line in the Gorgany range: Chorology, Ecology, Phenology.]. Nauk. visnyk UkrDLTU: Doslidzhennja, ohorona ta zbagachennja bioriznomanittja [Science Bulletin of the UkrDLTU: Exploration, Protection and Enrichment of Biodiversity], 9.9, 173–179. In Ukrainian
- Szafer W., 1914: Limba (*Pinus cembra* L.) u źródeł Łomnicy. 1. Rozsiedlenie na podstawie materyałów zebranych przez Pp. J. Kosinę i A. Stachnika. Sylwan 32, 6.: 212-217.
- Tasjenkevych, L. O., Mel'nyk, V. I., Sirenko, O. G. (2009). *Sosna kedrova (sosna kedrova jevropejs'ka) Pinus cembra L.* Chervona knyga Ukrai'ny. Roslynnyj svit [Swiss stone pine (European pine cedar) Pinus cembra L. The Red Book of Ukraine. Vegetable world]. Editor. Diduh, Ja. P., Publisher: Globalkonsaltyng, Kiyv, Ukraine, 45, ISBN 978-966-97059-0-7. In Ukrainian
- Tretiak P. (1998a). Zmiany w składzie gatunkowym lasów w Gorganach. Roczniki Bieszczadzkie, T. 7: 327–334.
- Tretiak P. (red.) 1998b. Istorija Osmolods'koi' pushhi [History of Osmoloda Forest]. Lwiv. 145 p. In Ukrainian
- Tretiak P., Bojczuk I. (1997). *Antropogeniczne i naturalne przemiany lasów w Gorganach*. Roczniki Bieszczadzkie, T. 6: 177–183.
- Tretyak P. Cherevyy J. (2013). *Przyrost drzew starszego wieku w lasach karpackiej części zlewni Dniestru* [Increase of old age trees in forest of the Carpathian part of the Dniester river basin]. Roczniki Bieszczadzkie. T. 21, 184–200.
- Tretyak P., Cherevyy Yu. (2018). The grow of trees of the Carpathian Forests (in the basin of the Dniester River). Lviv. Publishing House of Lviv Polytechnic National University. 202 p. Doi: 10.23939/book.growth.2018
- Tretyak, P., Pozynych, I., Sawycka, A. *Generalized phytocenon of Pino cembrae-Piceetum association in the region of the Eastern Carpathians (Ukraine)* [online] (<http://ekontsh.civicua.org/syntaxons/Pino%20cembrae-Piceetum.html>) [dostęp: 28.05.2018].
- Ulber, M., Gugerli, F., Bozic, G. (2004). *EUFORGEN. Technical Guidelines for genetic conservation and use for Swiss stone pine (Pinus cembra)*. Publisher: International Plant Genetic Resources Institute, Rome, Italy. [online] (<http://www.lbg.lasy.gov.pl/documents/20597836/28594685/Pinus+cembra.pdf>) [dostęp: 28.05.2018].
- Zięba A, Różański W., Szwagrzyk J. 2018. Syntaxonomy of relic Swiss stone pine (*Pinus cembra*) forests in the Tatra Mountains. Tuexenia 38: 155–176. DOI: 10.14471/2018.38.004

STRESZCZENIE

Wyjawiono, że w obszarze Gorgany lasy, w których występuje *Pinus cembra*, zajmują powierzchnię około 5054 ha. Jest to prawie jedna szóstą całkowitej powierzchni takich lasów na świecie. Nasze badania analityczne opierają się na danych dotyczących inwentaryzacji lasów na początku XXI wieku. Badania prowadzono na podstawie własnej bazy danych wszystkich działek leśnych, w których rosła *Pinus cembra*. Następnie przeprowadzono procedury analityczne przy użyciu SQL-technologii dla zapytań specjalizowanych. Struktura powierzchni została obliczona według klas wiekowych i kategorii siedlisk. Zwłaszcza znaleziono na łącznej powierzchni 3173 ha takie drzewostany, które mają ponad 100 lat. Największe obszary leśne, w których rosną limby, znajdowały się zasadniczo w górnej części najwyższych pasm górskich. Zdecydowana większość starszych drzewostanów, które zawierają limby, rośnie na wysokości 1000 - 1600 m.n.p.m. Te lasy są pozostałościami lasów naturalnych. Znaczna większość ich rośnie na stromych zboczach 16 - 35 stopni, dla których charakterystyczne są oligo-mezotroficzne warunki glebowe. Oryginalna analiza polegała na wyizolowaniu powierzchni drzewostanów z różnymi częściami w ich objętości drzew *Pinus cembra*. Dokonano tego, biorąc pod uwagę wskaźniki uczestnictwa gatunkowego w składzie drzewostanów (części dziesiętne). Podsumowano, że ponad 1,5 tys. ha zajmują drzewostany, w objętości których udział drzew *Pinus cembra* stanowi jedną lub dwie dziesiąte, oraz w wypadku więcej dziesiątych - prawie 175 ha. Badania fitosocjologiczne wykazały, że lasy te można uznać za należące do zespołu *Pino cembrae-Piceetum*.

SUMMARY

In the Gorgany range, the forest stands, with *Pinus cembra* occupy a total area almost 5,054 ha. It is almost one-sixth of the total area of such forests in the world. Our analytical research is based on forest inventory data at the beginning of the 21st century. To explore them, a database of all plots of forests, in which *Pinus cembra* grew, was created. Subsequently, the analytical procedures by using SQL subject-specific query technologies were performed. The structure of the surface area was calculated according to stand age classes and habitat categories. Among them, such forest stands, of more than 100 years old, on a total area of 3,173 ha were found. The largest forest areas, in which Swiss stone pines grow, were located regularly on the upper part of the highest mountain ranges. The overwhelming majority of old-age stands, with the Swiss stone pine trees grow within the altitude of 1000 - 1600 m a.s.l. These forests are the remains of natural forests. A significant majority of these forests grow on steep slopes of 16 - 35 degrees, where oligo-mesotrophic soil conditions are characteristic. The original analysis was to isolate the surfaces of the stands with different parts in their volume of *Pinus cembra* trees. This was done taking into account participation indicators (decimal parts). It was concluded that over 1,500 ha occupy the stands, in the volume of which the *Pinus cembra* trees constitutes one or two tenths and more tenths - almost 175 ha. Phytosociology studies have shown that these forests can be considered as belonging to the association *Pino cembrae-Piceetum*.