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ECOLOGICAL STRUCTURE OF BEECH AND CONIFEROUS/BEECH MOUNTAIN CLIMAX FOREST STANDS OF UKRAINIAN CARPATHIANS

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According to the age classes, middle-aged forest stands predominate in the mountan forests of the Carpathians (46.2), overmature stands occupy 6.9% (62 thousand ha). According to the recent inventory, about 85 thousand hectares of climax old-growth forests are identified, including climax virgin forests that occupy about 54 thousand hectares which are uneven-aged. For their identification, a population matrix with a division into age groups is suggested, taking into account the age condition of the edificator. There are 6 age groups: pre-generative – juvenile-immature, virginal; generative – young generative, middle-aged, mature and old generative. In terms of the number of uneven-aged beech and coniferous/beech stands, the adequate cenopopulations of beech is dominated. The age spectra of fir and spruce, sycamore maple, ash-tree are generally non-stabilized or fragmentary. On average, on 1 ha of elementary demographic cenopopulation of beech and coniferous/beech stands on the generative generation there are 174-235 beech individuals, 42-52 – fir, 5-16 – spruce, 5-10 – sycamore and ash-tree, respectively.Half of the timber stock (50-60%) is over-mature, and 25% is in mature age condition. In climax cenosis, it can be recommended to conduct a uniform or non-uniform selection felling system. Introduction of population paradigm in forest synecology opens up a new opportunity to divide stands into age generations and treat them as a set of cenopopulations of key species for old-growth forests and virgin forests.

Keywords: typology; population; structure; beech stand; coniferous/beech stand.

Introduction

About eleven basic formations of edificators have been developed in the phylogenesis process in the mountainous conditions of the Ukrainian Carpathians: *Picea abies*, *Abies alba*, *Fagus sylvatica*, *Quercus robur*, *Quercus petraea*, *Pinus silvestris*, *Alnus glutinosae*, *Alnus incana*, *Pinus mughus*, *Alnus viridis*, *Juniperus sibirica*. In quaternary period their genesis was closely connected with the development of the natural landscapes of Central Europe, and during the last millennium a modern structure of forest vegetation was formed and partially changed depending on the climatic conditions of the region (Kalinovich, 2003; Stoyko, 1985). During this period, subformational and typological-cenotic structure of the forest cover was formed in the different high-altitude climatic zones of the southwestern and northeastern macroslopes of the Carpathians within the locally differentiated soil-water-geochemical conditions of the trophotope. In the last two centuries there have been large-scale changes in the structure of stands as a result of human economic activity, which has disrupted the stability of mountain forests and the performance of their ecological functions (Golubets, 2012; Parpan, Parpan & Hudyma, 2016; Tretiak & Chernevyj, 2015). The changes involved primarily the stand which is an object of management and, in the forest ecosystem, ensures its functioning (Golubets, 2007; Krynytskyi, 2012).

The purpose of this publication is to analyze the typological structure of mountain ecosystems at the level of the subformation as an integral evolutionary natural historical process for the formation of forest cover in the mountains, as well as the analysis of the cenopopulation structure of climax beech and coniferous/beech stands of different ages according to silvicultural and taxonomic, and population-ecological methodological principles (Volosyanchuk, Protsia & Kahala, 2015; Markiv, 1982).

Material and methods

The principles of silvicultural and ecological typology are used in the research: forest formation and subformation, coordination grid (Golubets, 2007, 2012), type of forest conditions, type of forest and type of stand (Vorobiev, 1967; Gerushinsky, 1996; Parpan, Parpan & Hudyma, 2016; Stoyko, 1985; Cherniavskyi, Krynytskyj & Parpan, 2011).

The age structure of the stands was identified according to the age groups adopted in forest science (Pogrebnyak, 1963) and the proposed population-ecology approach (Smirnova, 2011) which uses the periodization of ontogeny (age status) of the edificator (Rabotnov, 1964). This periodization was elaborated in detail for key species such as *Quercus robur* (Smirnova, 1994, 2004), *Fagus sylvatica* (Chistyakova & Parpan, 1991), *Picea abies* (Parpan, 1993),

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Abies alba (Markiv, 1982; Molotkova, 1968) and implemented in relevant scientific papers (Smirnova, 1994, 1998, 2004; Parpan, 2014; Smirnova & Chistyakova, 1980; Chistyakova & Parpan, 1991).

A spatial area is chosen as elementary ecological (cenopopulation) unit on which all age generations are concentrated within the subcompartment, the type of water catchment site and the type of forest, calculated by the empiric method. This cenopopulation is called the minimal demographic unit (EDO), which covers an area of about 1 hectare (Parpan, 1993).

Based on the correlation between age, height and diameter of beech, fir and spruce, with the predominance of the diameter interval, we proposed a population matrix for uneven-aged coniferous/beech and beech stands according to the Forestry Age Group (Pogrebnyak, 1963) and the biological age status (Parpan, 1993) (Table 1).

Table 1. Population matrix of structure of climax beech and coniferous/beech stands

Generation*	Intervals			Age group	Age state
	A, years	D, cm	H, m		
1/jim	10-40	до 6	0,1-2,5	Young growth	Juvenile and mature
2/v_1	41-80	8-12	4-14	Pole-stage stand	Virginal
3/g_1	81-120	16-28	16-25	Middle-aged	Young generative
4/g_2	121-160	32-48	25-40	Ripening	Middle-aged generative
5/g_3	161-200	52-64	32-40	Mature	Mature generative
6/g_3s	201-260 (360)	68-120	30-35	Overmature	Old generative

* Note: jim – juvenile and mature; v_1 – virginal; g_1 – young generative; g_2 – middle-aged generative; g_3 – mature generative; g_3 s – old generative.

Results and discussion

Typological structure. Formation of spruce forests in the Carpathian forest cover occupies 36.2 %, fir – 18.6%, beech – 42.6 %. Accordingly, in their structure, there are 5, 4 and 5 subformations, respectively (Table 2).

Table 2. The subformation structure of mountain forest ecosystems of the Ukrainian Carpathians (within the boundaries of the State forestry agency land, thousand hectares)

№ p/p	Basic forest subformations	Macroslope		Carpathians	
		northeast, thousand /ha	southwest thousand /ha	thousand /ha	%
Spruce formation		268.3	101.3	396.6	36.2
1.	Unmixed Spruce	80.5	16.2	96.7	9.5
2.	Cedar/Fir	4.9	0.3	5.2	0.5
3.	Beech/Fir	10.1	14.3	24.5	2.4
4.	Spruce/Fir	10.5	1.2	11.7	1.1
5.	Beech/Spruce/Fir	162.3	69.3	231.6	22.7
Fir formation		168.9	21.8	189.7	18.6
6.	Oak/Fir	3.2	0.0	3.2	0.3
7.	Hornbeam/Beech/Fir	6.7	0.3	7.0	0.7
8.	Beech/Fir	18.9	3.3	22.2	2.2
9.	Beech/Spruce/Fir and Spruce/Beech/Fir	139.2	18.2	157.4	15.4
Beech formation		114.5	316.4	430.9	42.2
10.	Unmixed Beech	10.4	188.3	198.7	19.4
11.	Hornbeam/Beech and Rocky Oak/Beech	4.3	79.1	83.3	8.2
12.	Fir/Beech and Hornbeam/Fir/Beech	30.0	12.3	42.3	4.1
13.	Spruce/Beech and Spruce/Fir/Beech	69.8	30.8	100.7	9.9
14.	Sycamore maple/Beech	0.0	5.9	6.0	0.6
Other forest formations		12.1	19.5	31.6	3.1
Area of forest subformations of the Ukrainian Carpathians		562.9	459.0	1021.8	100.0

Of most ecological-resource and stabilizing importance are the edificator formations: *Picea abies*, *Fagus sylvatica*, *Abies alba*, which account for 97 % of the area of the mountain forests. In their structure, the corresponding forest types and types of stands are highlighted.

The structure of forest stands by age groups. Due to the coupes-type felling system over the last two centuries, modern forest stand successional system has been formed in the forest cover of the Carpathians, these stands being identified by six age groups (Table 3).

Table 3. Age groups of forest-forming species in functional categories of forests of the Ukrainian Carpathians (within the boundaries of the State forestry agency land, thousand hectares)

Age groups	Functional categories of forests *				Total	
	1	2	3	4	га	%
Seedling stage	10.7	5.5	13.3	37.9	67.4	7.5
Sapling stage	16.4	4.2	20.9	51.1	92.6	10.3
Middle-aged	81.7	42.8	135.5	154.1	414.1	46.2
Ripening	20.8	9.5	25.1	70.8	126.2	14.1
Mature	18.0	8.8	36.2	70.2	133.2	14.9
Overmature	12.7	2.7	21.3	25.3	62.0	6.9
Total	160.3	73.5	252.3	409.4	895.5	100

* Note: 1) nature conservation; 2) recreation; 3) protecting; 4) exploitable.

Most massive deforestation in the Carpathians took place in the 1950s and 1960s, when logging was carried out in all functional categories of forests. As a consequence, middle-aged forest stands are prevailing age groups in the current forest cover - 46.2 %. Young stands account for 17.8 % of the area, ripening and mature age groups – 14.1% and 14.9 %, respectively. Overmature stands occupy only 6.9 %, or 62 thousand hectares. In terms of the age structure, the modern Carpathian forest stands are generally divided, by convention, into even-aged and uneven-aged (Krynytsky, 2012; Tsurik, 1974). In the context of structure, uneven-aged forest stands are less studied than other ones.

According to origin, level of preservation, the rate of natural cycle development and anthropogenic influence in a modern forest cover of the Carpathians, it is proposed to distinguish:virgin forests; natural (old-growth) forests on the site of virgin forests; natural-artificial forests with permanent human intervention and artificial (culture) with constant economic activity (Parpan, 2014). According to the identification of old-growth forests and virgin forests in the Ukrainian Carpathians as of the late 2016, the forests subordinated to the State forestry agency contain about 85 thousand hectares of old-growth forests, including about 54 thousand hectares of virgin forests (Parpan, Parpan & Hudyma, 2016; Parpan & Chystiakova, 1990).

The impact of forest management and the forest stands formed by the age groups are critically evaluated in the manual "Close-to-nature forestry and multifunctional forest management in the Carpathian region of Ukraine and Slovakia", which is the result of joint intellectual work by Uk-

rainian and Slovak forest scientists and practitioners (Parpan, 2014). The manual and modern publications offer general positive principles for the introduction of a close-to-nature forestry and the possibility of its use in the Ukrainian Carpathians (Chernevyj, 2006; Cherniavskyi, Krynytskyj & Parpan, 2011).

We analyzed the age structure of the all-aged coniferous-beech and beech stands, which can serve as identification criteria and models for selection felling and re-forming of stands into complex mixed cenoses within forest types in spatially different watersheds.

Population structure of uneven-aged coniferous/beech and beech stands. The population structure of edificator species has common variants of ontogenesis, self-maintenance, distribution by age groups (generations) and specific for fir and spruce. An analysis was carried out for four forest types on 50 hectare trial plots, of which 34 belong to old-growth forests, and 16 to climax virgin forests. In connection with a significant amount of research material, averaged data, for better perception, on the number and productivity of cenopopulations according to forest types, age periods and age groups are given (Table 4, Table 5).

In all types of forest, the coenopopulation of beech is complete, the cenopopulation of fir and especially spruce in coniferous-beech types is fragmentary (gappy). In the generative period, the number of reproductive individuals of the beech varies from 174 to 235 specimens /ha and is sufficient to reproduce the juvenile generation. For sub-edificator species – fir and spruce- they are are not enough. The reserve stock of cenopopulations is the number of pregenerative individuals (virgin and juvenile-immature age group). It is also characteristic that the number of individuals of the virgin age for all species cenopopulations in coniferous-beech and beech stands is not enough, while the number for the juvenile-immature group, especially beech, is sufficient. For fir and spruce, special regulatory measures should be introduced to promote natural regeneration. From the standpoint of the population ecology, the juvenile-immature generation will be analyzed in more detail in later publications.

Table 4. The number of cenopopulations (specimen / ha) of tree species in the age groups of uneven-aged Coniferous/Beech and Beech stands (mean values)

Code, amount of samples	Coeno-population *	Generative period					Pre-generative period	
		Age groups (generation) *						
		6	5	4	3	Σ	2	1
P_3-SF-BE 9 samples (old-aged)	Fg.s	60	50	42	83	235	96	6,377
	Ab.al	1	6	12	17	42	15	733
	P.ab	-	2	5	11	18	18	144
	A.ps	-	2	6	8	16	3	4,557
P_3-S-BE 13 samples (old-aged)	Fg.s	39	37	53	85	214	153	1,090
	Ab.al	8	11	15	18	52	116	1,992
	P.ab	-	-	1	4	5	7	185
OK_3-BE 12 samples (old-aged)	Fg.s	35	37	36	121	224	326	12,206
	Ab.al	1	1	2	2	8	1	2,467
	P.ab	-	1	1	1	6	1	2,858
OK_{2-3}-BE 16 samples (virgin forests)	Fg.s	56	48	29	41	174	105	21,240
	Ab.al	3	3	2	2	10	-	6,458
	Fr.ex	4	1	-	-	5	-	3,725

* Note: 1- juvenile and mature (young growth); 2- virginal; 3- young generative; 4 – middle-aged generative; 5 – mature generative; 6 – old generative; Fg.s – beech, Ab.al – fir, P.ab – spruce, A.ps – sycamore, Fr.ex – ash tree.

Table 5. The productivity of cenopopulations (m^3/ ha) of tree species in the age groups of the uneven-aged Coniferous/Beech and Beech stands (mean values)

Code, amount of samples	Coeno-population *	Age groups (generation) *						
		6	5	4	3	2	Σ	%
P_3-SF-BR 9 samples (old-aged)	Fg.s	218.6	78.4	24.4	10.4	3.1	335.0	71.0
	Ab.al	3.6	33.3	17.7	7.0	0.5	61.9	13.1
	P.ab	-	10.2	32.5	9.7	3.1	54.3	11.5
	A.ps	-	1.8	13.1	5.6	0.4	20.9	4.4
P_3-S-BE13 samples (old-aged)	Fg.s	148.6	73.7	46.4	19.9	6.3	294.9	81.0
	Ab.al	29.9	15.8	11,2	4.5	4.0	65.4	18.0
	P.ab	-	0.6	1.0	1.5	0.4	3.5	1,0
OK_3-BE 12 samples (old-aged)	Fg.s	253.2	106.0	33.1	28.0	12.9	433.3	96.4
	Ab.al	1.1	3.2	3.6	1.4	-	9.3	2.0
	P.ab	-	0.6	5.6	0.2	0.4	6.8	1.6
OK_{2-3}-BE 16 samples virgin forests	Fg.s	330.8	142.1	38.5	20.5	7.8	539.7	98.5
	Ab.al	1.2	3.9	0.7	0.2	-	6.0	1.1
	Fr.ex	2.0	0.2	-	-	-	2.2	0.5

* Note: see Table 4 for designations.

A brief analysis of the productivity of the cenopopulations indicates its features in coniferous/beech and beech uneven-aged stands. In coniferous-beech cenoses, a beech population of type P_3-SF-BE accounts for 71 % of the stock; fir – 13,1%; spruce – 11 %, and in type P_3-S-BE – 81 %, 18% and 1 %, respectively. In monodominant beech forests, the cenopopulation of beech is predominant and to amounts to 96.4-98.5 % of the stock. The distribution of the stock over the age groups is such that almost half of it is concentrated in the overmature (old generative post vegetative) generation (P_3-SF-BE – 47 %; P_3-S-BE – 49 %; OK_2-BE – 56-61 %). In the mature generative stand, the volume of timber amounts to 24-26 %; in middle-aged – 17-18 %; in young generative – 4-7 %, and in virginal – 1.5-3.0 %. For selective regulation from the standpoint of rejuvenating the cenopopulation, it is necessary to use predominantly overmature and mature age groups of beech, and, more rarely, fir and spruce.

Therefore, coniferous/beech and beech uneven-aged stands of the Carpathians include all age generations with the dominance in the number of the pre-generative generation, and in terms of productivity – the generative generation. They need to be identified as old-growth forests and virgin forest ecosystems. Only old-growth stands underwent insignificant anthropogenic impact, and the virgin forests emerged and develop naturally through the action of only natural elements and events without significant human intervention (Parpan, 1993). Both groups of forest stands are need of preservation and protection.

Conclusions

According to the age classes, middle-aged forest stands predominate in the mountain forests of the Carpathians (46.2 %), overmature stands occupy 6.9 % (62 thousand ha). According to the inventory, about 85 thousand hectares of old-growth forests are identified, including virgin forests that occupy about 54 thousand hectares (Volosyanchuk, Protsia & Kahala, 2015). According to the age structure, as shown in this publication, they are uneven-aged. For their identification, a population matrix with a division into age

groups is proposed taking into account the age condition of the edificator. There are six age groups: pre-generative – juvenile-immature, virginal; generative – young generative, middle-aged, mature and old generative. In terms of the number of uneven aged coniferous-beech and beech stands, the complete cenopopulation of beech is dominated. The age spectra of fir and spruce, sycamore maple, ash-tree, and elm are generally non-stabilized, or fragmentary. On average, on one hectare in all-aged coniferous-beech and beech stands on the generative generation there are 174-235 beech individuals, 42-52 – fir, 5-16 spruce, 5-10 – sycamore and ash-tree. Half of the timber stock (50-60 %) is over-mature, and 25 % is in mature age condition. In uneven-aged stands, a uniform or non-uniform selection felling system can be recommended. The introduction of population paradigm in forest synecology opens up a new opportunity to divide stands into age generations and treat them as a set of cenopopulations of key species for old-growth forests and virgin forests.

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ПОПУЛЯЦІЙНО-ЕКОЛОГІЧНА СТРУКТУРА БУКОВИХ І ХВОЙНО-БУКОВИХ КЛІМАКСОВИХ ДЕРЕВОСТАНІВ УКРАЇНСЬКИХ КАРПАТ У ЛІСОВОМУ ПОКРИВІ

За класами віку гірських лісів Карпат переважають середньовікові деревостани (46,2%), перестійні займають 6,9% (62 тис. га). За сучасною інвентаризацією виділено близько 85 тис. га клімаксових старовікових лісів, зокрема, близько 54 тис. га клімаксових різновікових пралісів. Для їх ідентифікації запропоновано екологічну матрицю з поділом на вікові групи з урахуванням вікового стану едифікатора. Виділено 6 вікових груп: догенеративна – ювінільно-іматурна і віргінільна; генеративна – молода, середньовікова, стигла і стара (перестійна). За чисельністю в різновікових хвойно-букових і букових деревостанів домінує повночленна ценопопуляція бука. Вікові спектри ялиці та смереки, клена-явора, ясена, ільма, зазвичай, неповночленні або фрагментарні. У середньому на одному гектарі елементарної демографічної клімаксової ценопопуляції букових і хвойно-букових деревостанів на генеративне покоління припадає 174-235 особин бука, 42-52 – ялиці, 5-16 – ялини, 5-10 – клена-явора та ясена звичайного, відповідно. Запас деревини на 50-60% приурочений до перестійних і на 25% – до спілого вікового стану. У клімаксових ценозах доцільно проводити рівномірно або нерівномірно вибіркову систему ру-

бань. Впровадження популяційної парадигми в лісову синекологію відкриває нову можливість членувати деревостани на вікові покоління та трактувати їх для старовікових лісів і пралісів як сукупність ценопопуляцій ключових видів, встановити стратегічну поведінку.

Ключові слова: типологія; популяція; структура; буковий і хвойно-буковий деревостани.

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ПОПУЛЯЦИОННО-ЭКОЛОГИЧЕСКАЯ СТРУКТУРА БУКОВЫХ И ХВОЙНО-БУКОВЫХ КЛИМАКСОВЫХ ДРЕВОСТОЕВ УКРАИНСКИХ КАРПАТ В ЛЕСНОМ ПОКРОВЕ

По классам возраста горных лесов Карпат преобладают средневозрастные древостои (46,2%), перестойные занимают 6,9% (62 тыс. га). По современной инвентаризации выделено около 85 тыс. га климаксовых старовозрастных лесов, в т.ч. около 54 тыс. га климаксовых девственных лесов разновозрастных. Для их идентификации предложена популяционно-экологическая матрица с разделением на возрастные группы с учетом возрастного состояния эдификатора. Выделено 6 возрастных групп: догенеративная – ювинильно-иматурная и виргинильная; генеративная – молодая, средневозрастная, спелая и старая (перестойная). По численности в разновозрастных хвойно-буковых и буковых древостоях доминирует полночленная ценопопуляция бука. Возрастные спектры пихты и ели, клена-явора, ясеня, ильма, как правило, неполночленны или фрагментары. В среднем на одном гектаре элементарной демографической климаксовой ценопопуляции буковых и хвойно-буковых древостоев на генеративное поколение приходится 174-235 особей бука, 42-52 – пихты, 5-16 – ели, 5-10 – клена-явора и ясеня обыкновенного, соответственно. Запас древесины на 50-60% приурочен к перестойному и на 25% – к спелому возрастному состоянию. В климаксовых ценозах целесообразно проводить равномерно или неравномерно выборочную систему рубок. Внедрение популяционной парадигмы в лесную синекологию открывает новую возможность членить древостой на возрастные поколения и трактовать их для старовозрастных и девственных лесов как совокупность ценопопуляций ключевых видов, наметить стратегическое поведение.

Ключевые слова: типология; популяция; структура; буковый и хвойно-буковый древостой.