ANALYSIS OF BIODIVERSITY REGARDING STRUCTURAL AND PHYTOCOENOLOGICAL ASPECT IN "OLD GROWTH BEECH FOREST OF HUMOSU" RESERVATION

CĂTĂLIN-CONSTATIN ROIBU, CEZAR TOMESCU, ALEXEI SAVIN and MARIUS MIRON-ONCIUL

University „Ştefan cel Mare", Suceava, str. Universităţii, nr. 13, Suceava, 720229, Romania

Received March 24, 2008

This paper's purpose was structural and phytocoenological diversity distinguishability. In the first part it was revealed structural diversity in both horizontal and vertical level for diameter of breast height, height and dead wood's thick end diameter indexes, using Shannon and Simpson parameters. Structural diversity distinguishability allowed identification of sample plot minimum dimension. Thus, repeated simulations of Shannon, Gini and Camino indexes revealed a stabilisation of their values for areas of 2500 m^2 (for Shannon parameter) and of 500 m^2 (for Gini parameter). The diversity analysis, from a phytocoenological point of view, allowed Geranio robertianae-Fagetum association identification, which is represented by "nude beech stands".

Key words: Structural diversity; Natural forest; Phytocoenoses.

INTRODUCTION

In the last decade, diversity has become one of the most popular themes in the discussions regarding durable development. Still, maintaining forest ecosystems diversity was required long time ago, being increased especially by Rio declaration and renewed at Lisbon conference in 1998[16].

Structural diversity measurement is important for revealing stand feature evolution [23]. Oliver and Larson quoted by[23] indicate that growing models variety is associated with structural diversity. Large diversity is connected to stands with different species of trees of various sizes (Boungiorno, quoted by[23]). Some authors[1,15] agree that stand structure is a biodiversity important component. Kimmins[14] considers that structural diversity can indicate most part of specific diversity for forest ecosystems.

The most suited methods for mathematic description and diversity quantification are those based on parameters[24]. Structural diversity indexes gained large acceptance in sylviculture as quantitative measure of species diversity[23]. For a long time, parameters Clark-Evens and Shannon were most used indexes for horizontal distribution characterization.[16,20,24] Lately, after many researches, there were calculated more indexes which describe either the difference between diameters, height and volume or complex parameters regarding structural diversity components[17,23] Jaehne, 1997 – quoted by[24].

In our country first concerns about quantifying structural diversity were connected with expressing stands organisation rate through the agency of Shannon–Wiever index[14]. Analysis of stands regeneration mode, allowed identifying treatments that respond to all ecologic, conservation and biodiversity improvement requirements at every level[12,18] thus, the best treatment would be single tree selection system and the worst one would be clear cuttings. For setting off natural forest structural diversity were compared more structural diversity indexes distinguishing that Gini parameter has higher relcatlessness[6,20]. Using diversity indexes, Avăcăriţei[2] remarked structural diversity reduction in relation to stands consistence abatement, meaning that structural diversity is appreciably decreased in relation to number and regeneration cutting intensity.

Structural diversity analysis enables revealing biodiversity small part, therefore is advisable a stand characterization, also from phytocoenological point of view. Geranio Robertianae-Fagetum association phytocoenoses were studied in our country by many authors, being presented under different names which keep a synonymy degree like: *Fagetum subcarpato-moldavicum* Burduja, Mihai and Sârbu 1974, *Fagetum carpaticum* Klika 1927 collinum Matuszk. 1958, *Fagetum moldavicum* Bârcă 1973, *Dryopterido carthusianae-Fagetum*[3,7]. In Moldavia the association was also studied in forest Ghindăoani-Tupilați, in Dealul Mare – Hârlău reservation and in Runc forest[3]. Phytocoenose of this association were researched and described in 1994 by T. Chifu and N. Ştefan[7] under the name of *Dryopteridio carthusianae-Fagetum*[3,7], being identified in plane fields or slightly inclined around Dragomirna and Mitocaşi villages from Suceava county.

MATERIAL AND METHOD

For fulfilling the objectives proposed in this paper, in 2005, there was placed one permanent sample plot of one hectare. The sample plot is placed in the „ Humosu old growth beech forest" reservation located in Hîrlău Forest District at an altitude of 455 m, with the coordinates 47°30'02'' Northing, and 26°43'27'' Easting.

Geomorphologically speaking, the sample plot is located on a wavy slope with a 12 degree declination. The main type of soil is luvosol, the annual average temperature being 7,9°C and the rainfall multiannual average being about 534 mm[22].

The installing of the sample area has been done according to the well known methodology for studying forest ecosystems trough structural profiles[11,4,5]. The position of trees and deadwood has been computed with the total station (±0.05m precision). For each tree with diameter at breast height higher then 4cm we measured the next characteristics: diameter at breast height, height, crown length, social position, crown form, crown diameter, Cartesian coordinates (x,y).

For the structural diversity emphasis, there were calculated more specific indexes revealed in the first Table.

Under floristic aspect, species nomenclature, bioformes and floristic elements were adopted according to the paper "Flora ilustrată a României – Pteridophyta et Spermatophyta"[9]. The paper "Flora şi vegetația Moldovei – România"[8] was used in order to talk about the vegetation aspect. Ecological indexes were established according to the paper as "Indicator values of vascular plants in Central Europe"[10]. In the field were located seven phytocoenoses surveys, according to the methodology adopted by Romanian school of phytocoenology, using Phytocoenology Schools from Zürich-Montpellier. There was elaborated an association phytocoenological table using filed data along with characteristic species grouping of different

Table 1

Applied diversity index and formulas

Shannon index of diversity (Shannon, 1948)	$SH=-\sum_{i}^{k} p_i \ln p_i$	k – number of species (categories) p_i – relative abundance of the ith species (categories)
Simpson index of diversity (Simpson, 1949)	$SI=\sum_{i}^{k} (p_i)^2$	k - number of species (categories) p_i – relative abundance of the i-th species (categories)
Camino index (Comino, 1976)	$H=\dfrac{\sum_{i=1}^{k} n_{\%i}}{\sum_{i=1}^{k} n_{\%i}-\sum_{i=1}^{k} v_{\%i}}$	$n_{\%i}$ – cumulate tree number on diameter category $v_{\%i}$ – cumulate volume of trees on diameter category k – number of dbh classes
Gini index (Gini, 1912)	–	area between Lorentz curve and diagonal of the chart

cenotaxon. This beech stands' floristic composition is more meager than other types of beech stands. There were analysed bioformes spectrum, floristic elements and ecological indexes by Ellenberg. The overall image of natural beech stand biodiversity and productivity was underlined by analysing two soil profiles in different relief conditions.

RESULT AND DISCUSSION

Structural diversity characterization

To see which one of the proposed indexes is more suited for revealing structural diversity in table two, there are presented its values for diameter of breast height, height and thick end diameter indexes. These were chosen for underlining structural diversity both in horizontal and vertical level.

Table 2

Structural organization degree

Structural diversity index	Calculation parameter		
	Dbh	**Height**	**Thick end diameter of dead wood**
Simpson Index (SI)	0.100	0.118	0.078
Shannon index (SH)	**2.715**	**2.258**	**2.699**
Shannon maxim value	3.135	2.565	2.833
Camino index (H)	**1.853**	–	–
Gini index (G)	0.629	–	–

By processing the data we find that analyzed trees contribute to a better ecosystem structure in relation with diameter of breast height than with vertical level. Shannon index values show that the analyzed stand has a structural diversity close to the maximum one for all analyzed parameters. This aspect can be explained by the fact that the analyzed stand is in its last development regeneration phase. The study of deadwood structural diversity is important because it makes up microhabitat for different producers categories, consumers and especially for decomposers. In consent to those above,[13] says that structural diversity can indicate, for forest ecosystems, most part of the specific diversity. Analyzing the data emerges that Gini index is the most representative for structural diversity characterization. Stands' sorting according to this coefficient presents itself from heterogeneousness to homogeneousness (simplification)[6]. In the studied case we have a diversified stand for both live and dead trees.

Distinguishing structural diversity is very important for establishing a minimum sample range in forest inventorying. In this acceptation, initial sample plot was divided in more rectangular patterns of 100 m^2, 400 m^2, 625 m^2, 2500 m^2 and 5000 m^2. Shannon, Camino and Gini indexes were calculated for each new sample plot. For diameter of breast height we monitories indexes variation in relation with the plot dimension (Fig. 1).

From the upper diagram we can see a stabilization of structural diversity indexes variation in relation to sample plot area, starting from 2500 m^2. Stands homogeneity and heterogeneity, both determined by Gini index, can be revealed by inventories in sample plot areas of 500 m^2. This aspect confirms, on one hand, researches about samples plot areas[11], and, on the other hand, argues their dimension also from structural diversity distinguishability point of view.

For explaining stand's higher productivity (almost 1050 m^3 ha^{-1}) and floristic diversity were analyzed two soil samples (Table 3).

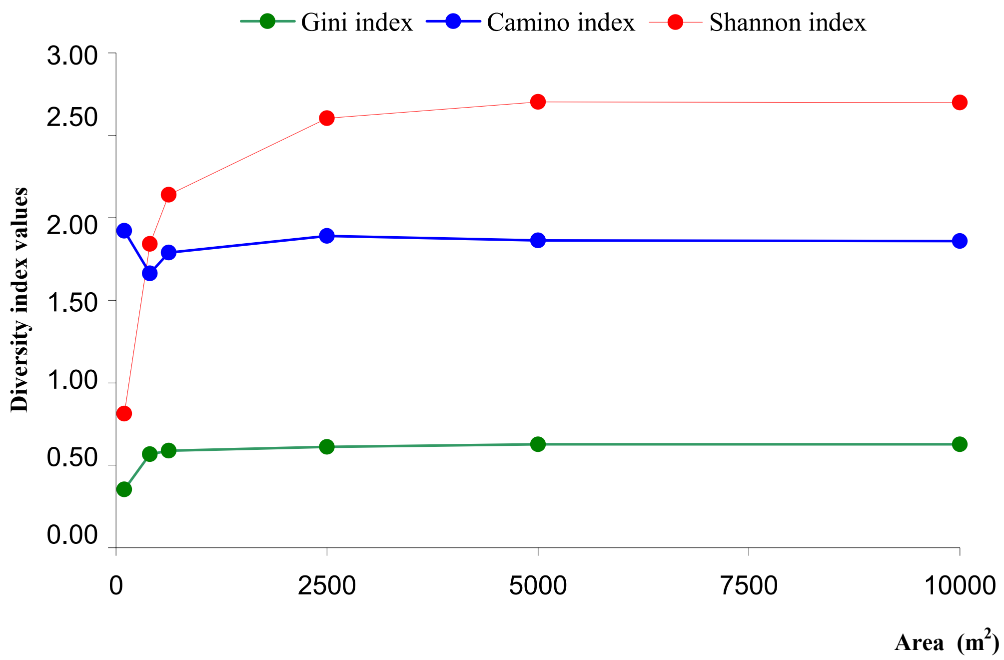

Fig. 1. The variation of the structural indexes in report with area.

Table 3

Soil units' granulometric composition from profile

Profile	Horizon	Thickness (cm)	pH	Brutish sand (%)	Fine sand (%)	Dust I+II (%)	Colloidal clay (%)	Fine clay (%)
1	Ao	0-10	4.26	1.41	50.47	26.78	21.48	32.17
	El	10-33	4.05	1.27	52.55	28.38	17.66	30.09
	E/B	33-47	4.34	1.02	46.91	27.18	24.89	38.90
	Btw	47-101	4.24	0.14	44.19	28.84	26.83	41.55
	B/C	101-140	5.16	0.19	45.32	27.13	27.36	41.86
	Ck	Sub 140	7.84	0.09	77.27	11.27	11.37	16.53
2	Ao	0-6	4.70	0.37	40.97	40.48	18.18	38.38
	Elw	6-28	3.96	2.81	42.29	37.80	17.10	36.03
	E/BW	25-45	4.91	1.71	36.67	39.85	21.77	42.01
	BtW	45-80	5.20	1.03	33.67	41.66	23.64	45.17
	B/C	80-100	5.28	1.90	32.91	45.11	20.08	43.26

Analyzing on the whole those two stationary situations, we can say that this uneven age beech stand is placed in optimum soil and stationary conditions. The soil is profound, being formed on a sedimentary deposit (sandy clay) with a very high content of carbonates (over 5%). The rather brutish texture of parent material caused a brutish to moderate soil texture. According to granulometric analysis (Table 3), in any horizon the colloidal clay content does not excelled 30%, and soils are moderately textured differentially (*Idt=1,2–1,4*). As a result, the texture is clayey-sandy in superior horizons (illuviated by clay) and clayish, at the most, in *Bt* eluvial horizon. So, even if in the superior horizons we can see a marked reduction in base and a higher acidity (pH between 4.0 and 5.0), in overall the soil has a high fertility especially for good internal drainage and for helpful aerial and hydric regime. It is well known that the beech, along other species (durmast oak, linden, acacia, aspen), needs a loose soil, with medium or brutish texture[19]. There's not to neglect the carbonilyc substratum which raises pH value up to 7 in inferior horizons, raising soil's total troficity. We can say that edaphic factor, soil's texture, has a very important role regarding these unique beech stands longevity and vigor.

Phytocoenological analyze

It was adopted the following vegetal association:

Class QUERCO-FAGETEA Br.
Order Fagetalia sylvaticae Pawlowski
Alliance Symphyto cordati-Fagion
Sub-alliance: Epipactido-Fagenion

From the phytocoenoses structural and specific analysis, according to adopted typology, we can see that they fit in **Geranio robertianae-Fagetum** association[3,8,9]. As association inferior cenotaxon, the analysed phytocoenoses fit in the sub-association **fagetosum**[7,8] which has the following synonymy: *Dryopterido carthusianae-Fagetum tipicum*[7], *Dryopterido carthusianae-Fagetum fagetosum*, *lectotypus*[3]. This sub-association is represented actually by "nude beech stand", which grow on high plateaus and slight slopes, with a uniform and poor floristic composition, with no differential species.

Floristic and phytocoenoses composition – These phytocoenoses reveals a stratification of phyto-indivuals airy parts, at arborescent level differentiating, often, canopies multi-stage. In the arborescent layer constitution prevails Fagus sylvatica, along which can appear rare *Tilia cordata, Fagus orientalis* or *Fagus × taurica* specimen. The arborescent layer covering is relatively good and varies between 75 and 95%.

Regeneration layer covers maximum 50% and consists mainly in small beech sapling and rarely in large beech sapling.

The studied phytocoenoses have a very low floristic diversity. Among the association characteristic species appear many typical species to cenotaxon of association upper order, so we identified: one characteristic specie to sub-alliance *Epipactido-Fagenion* (3.03%), one typical specie to sub-alliance *Galio schultesii-Carpinenion* (3.03%), two characteristic species to sub-alliance *Aro orientalis-Carpinenion* (6.06%), 8 typical species to the *Fagetalia sylvaticae* (24.24%) order and 5 characteristic species to *Querco-Fagetea* (15.15%) class, all distinctive species of different cenotaxon belonging to *Querco-Fagetea* class representing 78.79% of total identified species from sample plot. Along these appear 7 characteristic species to *Galio-Urticetea* class, most probably favored by human and animal pressure.

Table 4

As. *Geranio robertianae-Fagetum*

Bioform	Floristic elements	Sample plot number	1	2	3	4	5	6	7	K
		Altitude (m)	450	450	440	440	470	470	440	
		Orientation	SE	E	SE	E	S	NE	S	
		Wavy slope (declination degree)	5	10	3	10	5	10	2	
		Tree vegetation cover (%)	80	90	90	75	75	80	95	
		Shrubs vegetation cover (%)	15	10	10	50	1	5	10	
		Herbal vegetation cover (%)	2	1	15	30	1	3	10	
		Sample plot area (m^2)	1000	1000	1000	1000	1000	1000	1000	
		Number of species	13	5	14	16	5	8	10	
		Epipactido-Fagenion								
G.	Eur.	*Cephalanthera damasonium*	+	-	-	-	-	-	-	I
		Galio schultesii-Carpinenion								
Ph.	Eur.	*Tilia cordata*	-	-	-	-	-	-	1	I
Ph.	Eur.	*Tilia cordata (juv.)*	-	-	-	-	-	-	1	I
		Aro orientalis-Carpinenion								
Ph.	Pont.-balc.	*Fagus x taurica*	-	-	-	-	+	+	-	II
Ph.	Pont.-balc.	*Fagus orientalis*	+	-	+	+	-	-	+	III
		Fagetalia sylvaticae								
H.	Circ.	*Carex sylvatica*	-	+	-	-	-	-	-	I
H.	Circ.	*Dryopteris carthusiana*	+	-	+	1	-	-	-	III
H.	Euras.	*Epilobium montanum*	-	-	-	-	-	+	-	I
Ph.	Centr.-eur.-atl.	*Fagus sylvatica*	4	5	5	4	4	4	4	V
Ph.	Centr.-eur.-atl.	*Fagus sylvatica (juv)*	2	2	2	3	+	1	1	V
G.	Euras.	*Galium odoratum*	-	-	+	+	-	-	-	II
H.	Circ.	*Milium effusum*	-	-	+	-	-	-	-	I
H.	Euras.	*Salvia glutinosa*	-	-	1	-	-	-	-	I
H.	Euras.	*Sanicula europaea*	-	-	-	+	-	-	-	I
		Alnion incanae et Alno-Fraxinetalia s.l.								
H.	Euras.	*Cardamine amara*	-	-	+	+	-	-	-	II
H.	Circ.	*Cardamine pratensis*	-	-	-	-	-	+	+	II
H.	Subatl.-submedit.	*Carex pendula*	-	-	-	+	-	-	-	I
H.	Circ.	*Carex remota*	+	-	-	1	-	-	+	III
G.	Euras.-medit	*Circaea lutetiana*	+	-	1	+	-	-	-	III
T.	Euras.	*Impatiens noli-tangere*	+	-	1	2	-	1	2	IV
Ph.	Eur.	*Sambucus nigra*	+	-	-	-	-	-	-	I
Ch.	Euras.	*Solanum dulcamara*	-	-	-	-	+	-	-	I
H.	Eur.	*Stellaria nemorum*	-	-	-	-	+	-	-	I
		Querco-Fagetea								
H.	Cosm.	*Athyrium filix-femina*	-	-	+	+	-	-	+	III
H.	Euras.	*Brachypodium sylvaticum*	-	-	-	1	-	-	-	I
H.	Euras.	*Dryopteris filix-mas*	+	-	-	-	-	-	-	I
H.	Eur.	*Mycelis muralis*	-	-	+	-	-	-	-	I
G.	Circ.	*Neottia nidus-avis*	+	+	+	-	-	-	-	III
		Galio-Urticetea s.l.								
Ht.-H.	Euras.	*Alliaria petiolata*	-	-	-	-	-	-	+	I
H.	Centr.eur.atl.medit.	*Atropa belladonna*	+	-	-	-	-	-	-	I
T.	Circ.	*Galium aparine*	+	+	+	+	+	+	+	V
T.	Euras.	*Lapsana communis ssp. communis*	-	-	-	+	-	-	-	I
H.	Circ.	*Poa nemoralis*	-	-	-	+	-	-	-	I
H.	Euras.	*Taraxacum officinale*	-	-	-	-	-	+	-	I
H.	Cosm.	*Urtica dioica*	+	+	1	1	-	+	1	V

Note: Place and date of surveys: 1-7 – *Fagetum Secular* Humosu – Hârlău, jud Iași (24.05.2007).

Bioformes spectrum (Figure 2) – The analysis of bioformes spectrum shows the prevail of hemicryptophytes (H) with 57.58%, followed by phanerophytes (Ph), with 15.15%. They give the largest proportion of phytocoenoses phytomass volume. The geophytes (G) are relatively well represented. They have 12, 12% from all identified species. The geophytes have a maximum growing season in spring and summer time. Therophytes (T) have 9.09% off al species. Hemiterophytes (Ht) and camephytes (Ch) are represented by one species.

The phytogeographic spectrum (Figure 3) – The phytogeographic elements spectrum is dominated by the Eurasiatic element (Euras. – 33.71%), followed by the circumpolaric (Circ. – 24.24%) and the European (Eur. – 15.15%). The European elements have together 60.60% from the total amount of species.

The spectrum of the ecological indexes (Figure 4) – This spectrum reveals the general preferences of the vegetal species as well as the characteristics of the stations these phytocoenoses occupy, thus: regarding the preferences of the species for light, the most of the percentage is hold by the shadow (L) – semi-shadow species (L4), category formed in its majority by species of the estival herbal rug, around which there are a lot of species, more developed towards the spectrum middle, namely scyaphilous (L5) and sub-heliophilus species; regarding the species preferences for temperature, the greatest percentage is held by the mesotherm species (T5) followed by the amphitolerant ones (Tx); with respect to the species continentalism (K), the greatest percentage is held by the intermediary category between the oceanic and sub-oceanic climate (K3); regarding the species preferences for the soil humidity (F), it was stated that mezoxerophite species have the best representation (F5); from the point of view of the tolerance towards the soil reaction (R), there is a majority of amfitolerant species (Rx) and a relatively large percentage of the neutrophilous ones (R7), that constitute the basis of a relatively narrow nucleus of species; regarding the species preferences for the quantity of azotus accessible in the soil (N), the best represented categories are the mezonitrophilus – nitrophilus (N6), mezonitrophilus (N5) şi nitrophilus (N7), and also the eurinitrophilus ones (Rx).

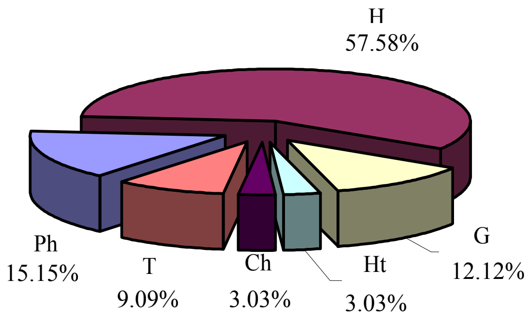

Fig. 2. Bioformes spectrum of as. *Geranio robertianae-Fagetum*.

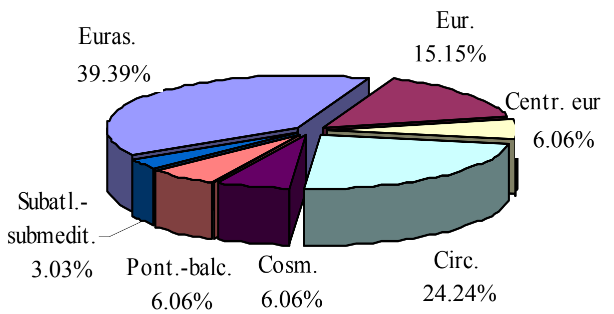

Fig. 3. Phytogeographic elements spectrum of as. *Geranio robertianae-Fagetum*.

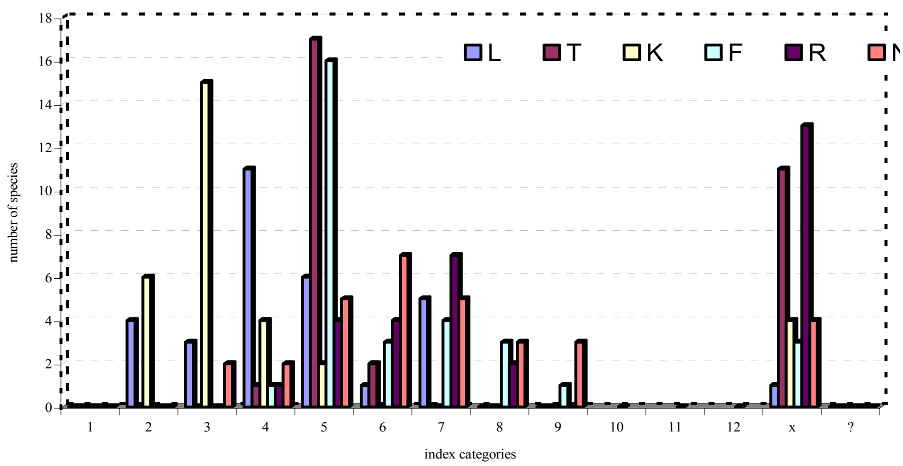

Fig. 4. The ecological indexes spectrum for as. *Geranio robertianae-Fagetum*.

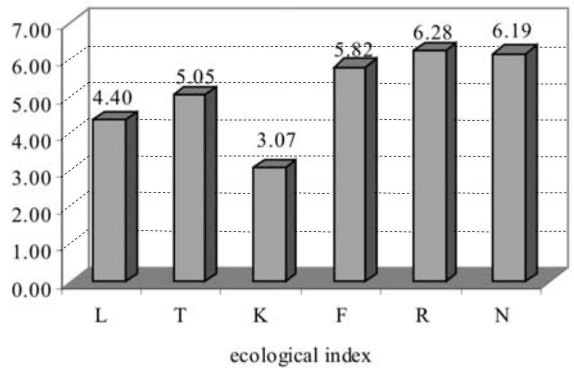

Fig. 5. The average values of the ecological indexes for as. *Geranio robertianae-Fagetum*.

From the analyses of the averages of the ecologic indexes (Figure 5) it can be distinguished: the relatively small value of the light indexes average[4,40] reveals the presence of the scyaphilous and semishadow species, aspect correlated to the canopy big closure degree of these phytocoenoses; the average of the temperature index[5,05] is more raised toward other types of beech stands, fact that indicates the predominant sunny slopes within which these phytocoenoses are located, and also the lower altitude, which determines a better thermal regime; the average of the soil humidity index[5,82], is lower comparative to other types of beech stands, reflecting the presence in a large number of the mezoxerophytuous and some xerophytuous – mezoxerophytuous species; the relatively high soil reaction average[6,28], indicates the presence of the neutrophylus species, based on a majority of amphytolerant species and the neutral reaction soils; the average of the free azot quantity index from the soil is relatively large[6,19], fact correlated with the significant presence of the superior category species of the spectrum.

CONCLUSIONS

In the first part of this research structural diversity was characterized using Shannon, Simpon, Camino and Gini indexes. The results showed that the analyzed trees contribute to better ecosystem structurelessness in report with diameter of breast height than in report with vertical distribution. Shannon parameter values indicate that the analyzed stand shows a structural diversity closed to maximum diversity for all analyzed indexes. Structural diversity indexes calculation for different sample plots allowed minimum area identification for patterns. Thus, for characterizing the studied natural stand from a homogeneity point of view is necessary a sample plot of 500 m^2, and for revealing structural diversity the studied area should be of 2500 m^2.

Studies results, under phytocoenological report but also under bioformes spectrum aspect, floristic elements and ecological indexes by Ellenberg, are similar to other nude beech stands analysis, described and studied in the literature. Ecological indexes spectrum reveals both preferences on the whole of this vegetal species from this stand and stations characteristic.

REFERENCES

1. Ambuel, B., Temple, S.A., 1983, *Area-dependent changes in the bird communities and vegetation of southern Wisconsin* Forests. Ecology, **64**: 1057–1068.
2. Avăcăriței, D., 2005, *Cercetări auxologice în arborete de fag aflate în perioada de regenerare,* Teză de doctorat, Universitatea „Ștefan cel Mare” Suceava, 381 p.
3. Burduja, C., Mihai, Gh., Sârbu, I., 1982, *Vegetația rezervației forestiere „Humosu” din Dealul Mare – Hârlău*, Culeg. St. Art. Biol., Grăd. Bot. Iași, **2**; p. 222–225.
4. Cenușă, R., 1986. *Structura și stabilitatea unei păduri naturale de molid din Codrul secular Giumalău*, Revista pădurilor, **4** pp. 185-189.
5. Cenușă, R., 2000, *Cercetări asupra dinamicii structurale a ecosistemelor de pădure de la limita altitudinală de vegetație pentru menținerea echilibrului ecologic*, Referat științific final ICAS. 69 p.
6. Cenușă, R., Popa, C., Teodosiu, M., 2002, Cercetări privind relația structură funcție și evoluția ecosistemelor forestiere naturale din Nordul țării, Analele I.C.A.S., București, nr. **45**, pp. 9-19.
7. Chifu, T., Ștefan, N., 1994, *Recherches phytocenologiques dans les hêtraies collinaires du Plateau de Suceava*, An. șt. Univ. „Al. I. Cuza”, Iași, t. XL, s. II a, Biol. Veget., 71-80.
8. Chifu, T., Mânzu, C., Zamfirescu, O., 2006, *Flora și vegetația Moldovei – România*, Ed. Univ. „Al.I. Cuza” Iași, **vol. I**, 368 p.
9. Ciocârlan, V., 2000, *Flora ilustrată a României – Pteridophyta et Spermatophyta*, Edit. Ceres, București;
10. Ellenberg, H., 1974, *Indicator values of vascular plants in Central Europe*, Scripta Geobotanica, Band **9**, Verlaf Erich Goltze KG, Göttingen.
11. Giurgiu, V., 1979, *Dendrometrie şi auxologie forestieră*, Editura Ceres, Bucureşti, 692 p.
12. Giurgiu, V., 2002, *Biodiversitatea și regenerarea arboretelor*, Bucovina forestieră nr. **2**, I.C.A.S. Câmpulung Moldovenesc, pp. 45-54.
13. Kimmins, J.P., 1997, *Biodiversity and its relationship to ecosystem health and integrity*. For. Chron. **73** pp. 229–232.
14. Leahu, Ș., 1978, *Structura arboretelor și gradul lor de organizare în lumina teoriei informației*, Revista Pădurilor nr. 6, București, pp. 276-281.
15. Macarthur, R.H., Macarthur, J.W. 1961. *On bird species diversity*. Ecology, **42**: 594–598.

16. Neumann, M., Starlinger, F., 2001. *The significance of different indices for stand structure and diversity in forests*. For. Ecol. Manage. **145**, 91–106.
17. Pommerening, A., 2006, *Evaluating structural indices by reversing forest structural analysis*, Forest Ecology and Management **224** (2006) 266–277.
18. Pro Silva, 1993, *Actes du 1-er Congres europeen*, Pro Silva, Besancon, 243 p.
19. Roşu, C., 1997, *Staţiuni forestiere*, Universitatea "Ştefan cel Mare", Suceava, 183p.
20. Lexerød, N., Eid, T., .2006, *An evaluation of different diameter diversity indices based on criteria related to forest management planning*, Forest Ecology and Management **222**, 17–28.
21. Sanda, V., 2002, *Vademecum ceno-structural privind covorul vegetal din România,* Edit. Vergiliu, Bucureşti.
22. Sârbu, A.,et al., 2007, *Arii speciale pentru protecţia şi conservarea plantelor în România*, Ed. Victor B Victor, Bucureşti, 396 p.
23. Staudhammer L., Lemay, V.M., 2001, *Introduction and evaluation of possible indices of stand structural diversity***,** Can. J. For. Res. **31**: 1105–1115.
24. Vorčak, J., Merganic, J., Saniga, M., 2006, *Structural diversity change and regeneration processes of the Norway spruce natural forest in Balbia hora NNR in relation to altitude*, Journal of Forest Science no. **52,** pp. 399-409.
25. Wallnöfer, S., Mucina, L., Gross, V., 1993, *Querco-Fagetea,* in Mucina L., Grabherr G., Wallnöfer S., 1993 – *Die Pflanzengesellschaften Österreichs*, Teil III, *Wälder end Gebüsche,* Edit. Gustav Fischer Verlag, Jena-Stuttgard-New York: 85-236.
26. *** 1952–1976 – *Flora R.P.R. – R.S.R.*, vol. I–XIII, Edit. Acad. R.P.R.–R.S.R., Bucureşti.