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DIVERSITY ANALYSIS OF MIXED FOREST PLANT COMMUNITIES FROM THE STÂNIŞOAREI MOUNTAINS (ORIENTAL CARPATHIANS)

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Abstract: The studied mixed forest communities belong to two association – *Leucanthemo waldsteinii-Fagetum* (Soó 1964) Täuber 1987 and *Pulmonario rubrae-Fagetum* (Soó 1964) Täuber 1987 are well represented on the south-western slopes of the Stânişoara Mountains (Oriental Carpathians), which was the studied area. This paper is a comparison of the diversity of the two forest formations. Diversity was assessed through species richness, Shannon index, evenness, SHE analysis and rank-abundance models. The most divers communities of the association *Leucanthemo waldsteinii-Fagetum* were identified from Hangu –Runcu forest road, Buhalniţa –Varniţa forest road, Buhalniţa – forest road, Hangu valley basis and the Frasin Hill – slope inferior 1/3. For the association *Pulmonario rubrae-Fagetum*, the most divers communities were identified from Potoci, the Frasin Hill, and Buhalniţa – end of Prislop forest road. Regarding their diversity, the associations are generally alike, except for their species richness (greater in *Pulmonario rubrae-Fagetum*) and evenness (greater in *Leucanthemo waldsteinii-Fagetum*), that cancel each other and consequently proved to be ecologically insignificant with regard to the overall diversity. For both associations, the low evenness values decreased the high species richness values, and vice-versa. The communities of both associations fit the log-normal species abundance model, which, in ecological terms, means that few species are dominant while all the others have similar low abundance values. The observed diversity resemblance of the studied associations is supported by their commune ecological characteristics, such as habitat, bioforms, floristic elements, and ecological indices.

Introduction

This paper presents the diversity of two mixed forest associations of the Class Cl. *Querco-Fagetea* Br.-Bl. et Vlieger in Vlieger 1937 – *Leucanthemo waldsteinii-Fagetum* (Soó 1964) Täuber 1987 and *Pulmonario rubrae-Fagetum* (Soó 1964) Täuber 1987 – from the Stânişoarei Mountains (Oriental Carpathians). Both associations belong to the Order *Fagetalia sylvaticae* Pawl. in Pawl. et Wallich 1928, Alliance *Symphyto-Fagion* Vida 1963, Suballiance. *Symphyto-Fagenion* Boşcaiu et al. 1982. These plant communities are important due to their high productivity. From this point of view, these forests are the second most productive ones (unpublished data). This feature is partly the result of the community diversity. In addition, divers communities are generally more resilient to habitat disturbance [16].

Materials and Methods

The studied area, which is the left side of Izvoru Muntelui-Bicaz reservoir, is 136 km^2 and represents the south-western slopes of the Stânişoara Mountains from the Oriental Carpathians [18].

For the identification of plant associations, we used phytosociological research methods according to the Central-European school [1]. Our results were compared with the syntaxonomic Romanian and foreign literature: Coldea (1991), Oberdorfer (1994), Pott (1992, 1995), Mucina (1997), Sanda et al. (2001) etc. [4, 11, 12, 13, 14].

Diversity was represented through species richness (S), Shannon Index (H) and Shannon evenness (Es). The Shannon index formula is $\mathbf{H = - \Sigma\ p_i \ln p_i}$ where p_i – decimal fraction of i^{th} species abundance [5, 16]. Using the value of H, one can calculate the species abundance equitability, or evenness, which reveals how different is the studied community, compared to an ideal equitable community. The evenness formula is **E=H/Hmax** (Es value is between 0 – 1)

where Hmax =ln(S) or the value of H calculated with the same number of species, but equal p_i values [5, 16]. Another way to assess diversity was by performing the SHE analysis (SHE: S = species richness, H = Shannon index diversity, E = evenness). This technique allows the independent and yet simultaneous evaluation of the species richness and evenness contributions to the community diversity [2, 8, 9, 10]. The diversity measures used in SHE analysis are the above-mentioned S and H together with Buzas and Gibson's evenness – E. This time E was calculated with the equation $\mathbf{E = e^H/S}$ ($0<E\leq1$) where e is the natural logarithm base. The advantage of this formula is that H can be decomposed as the sum of ln(S)+ln(E) (e^H=S E so H=ln(S)+ln(E)). Further more, because $E\leq1$, ln(E) will be a negative number. Therefore, H diversity equals its maximum value, ln(S), less the amount of evenness, ln(E) [15].

The distribution of species abundance in each plant community, as another diversity measure, was compared to different theoretical models: geometric, log series, log-normal and "broken-stick". Species abundance equitability increases from the geometric series to the "broken-stick" one [16]. For computation, we used the Abundance Curve Calculator by James A. Danoff-Burg, and performed the chi-square goodness of fit test.

For the diversity measures statistical description, we calculated the measures of the central tendency, variability, and the confidence interval of the mean with 95% probability [7]. The significance of the differences between the diversities of the associations was tested with the Mann-Whithney test [6].

Results and Discussions

The mixed forest communities belong to two association: *Leucanthemo waldsteinii-Fagetum* (Soó 1964) Täuber 1987 and *Pulmonario rubrae-Fagetum* (Soó 1964) Täuber 1987. The most dominant species of both associations were *Fagus sylvatica* and *Abies alba*. The characteristic species are *Leucanthemum waldsteinii*, for the fist association, and *Pulmonaria rubra*, for the second one [3, 17].

The plant communities of the Ass. *Leucanthemo waldsteinii-Fagetum* were identified in the following locations: 1 - Buhalnița forest road, 2 – Frasin Hill – slope inferior 1/3, 3 - Hangu – forest road, 4 - Buhalnița Varnița forest road, 5 - Hangu –Runcu forest road, 6 - Hangu – valley basis, 7 – Potoci, forest road, 8 - Buhalnița, Varnița forest road, 9 - Hangu valley basis.

Diversity measures analysis (Tab. 1, Fig. 1) shows that the relevee 5 had the highest H value (1,562), comprised 25 species and represented 48,5% of an ideal community with maximum diversity for the same number of species. Relevees 4, 1, 9, 8, 2, 6 had the diversity between 1 – 0,5. Relevees 3 and 7 were the least divers ones (H= 0,36 and 0,114, respectively). Regarding the species richness some communities with low H values had more identified species than communities with high H values. For instance, relevee 6 was the second species rich one (22 species) while the H value was low (0,545). On the other hand, relevees 2 and 9 are the least species rich ones (9 species each) and, yet, their H values were close to the average.

This fact is explained by the SHE analysis result (Fig. 1) – the high diversity given by species richness is lowered by the small value of the Buzas and Gibson's evenness. For example, relevee 6 had the evenness approximately as low as the relevees 7, and represented 17,6 % of a community with the same number of species and maximum diversity. Conversely, relevees 2 and 9, which were the least species rich ones, had high evenness values.

Among diversity measures, the fraction ln(E)/ln(S) is the least variable one (Fig. 1), which generally indicates a balance between species richness and evenness at association level.

The concordance between species abundance distribution and the log-normal series is statistically significant (Tab. 2). All the probabilities are 1 or very close to 1. This situation means that the studied plant communities include few dominant species and many less-dominant ones.

Table 1: Diversity measures of Ass. *Leucanthemo waldsteinii-Fagetum*

Relevee	H	Es	E	S	ln(E)	ln(S)	ln(E)/ln(S)
1	0,803	0,284	0,131308	17	-2,03021	2,833213	-0,71658
2	0,688	0,313	0,221081	9	-1,50922	2,197225	-0,68688
3	0,36	0,15	0,130303	11	-2,0379	2,397895	-0,84987
4	0,86	0,298	0,131287	18	-2,03037	2,890372	-0,70246
5	1,562	0,485	0,190734	25	-1,65688	3,218876	-0,51474
6	0,545	0,176	0,078391	22	-2,54604	3,091042	-0,82368
7	0,114	0,043	0,080054	14	-2,52506	2,639057	-0,9568
8	0,576	0,208	0,111182	16	-2,19659	2,772589	-0,79225
9	0,71	0,323	0,225999	9	-1,48722	2,197225	-0,67687

Legend: H – Shannon index, Es – Shannon evenness, E – Buzas and Gibson's evenness, S – species richness

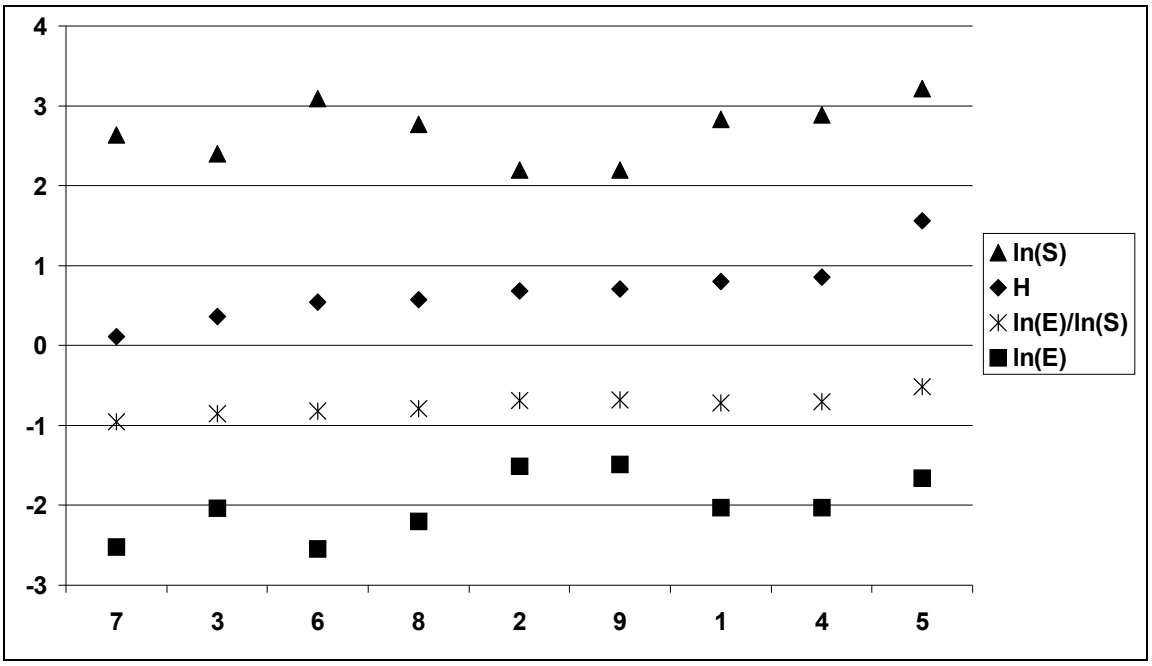

Fig. 1: SHE analysis of Ass. *Leucanthemo waldsteinii-Fagetum* (1 – 6 – relevees in H ascending order, H – Sahnnon index, Es – Shannon evenness, E – Buzas and Gibson's evenness, S – species richness)

Table 2: Goodness of fit of the species observed rank-abundance distribution to the lognormal theoretical distribution for Ass. *Leucanthemo waldsteinii-Fagetum* and *Pulmonario rubrae-Fagetum*

Leucanthemo waldsteinii-Fagetum			*Pulmonario rubrae-Fagetum*		
Relevee	χ^2	P	Relevee	χ^2	P
1	0,08036	1	1	0,101104	1
2	2,49E-14	1	2	0,101104	1
3	0,031773	1	3	0,163311	1
4	0,045658	1	4	0,537631	0,999991
5	0,540918	0,99999	5	0,217402	1
6	0,212596	1	6	0,085929	1
7	0,045254	1	7	0,0745	1
8	0,017808	1	8	0,271664	1
9	0,035598		9	0,582069	0,999986

Legend: (χ^2 – chi-square value, P – probability). If P>0,05 then the observed distribution fits the theoretical one

Diversity measures mean values represent diversity of the association as a whole (Tab. 3). Thus, at this level, the H value is 0,690±0,307, the Es value is 0,374±0,099, the E value is 0,144±0,042, and the average number of species is 15,666±4,279 (Tab. 3).

Table 3: Descriptive statistics of diversity measures of Ass. *Leucanthemo waldsteinii-Fagetum*

Statistic	H	Es	E	S
Count	9	9	9	9
Mean	0,690889	0,253333	0,144482	15,66667
Median	0,688	0,284	0,131287	16
Range	1,448	0,442	0,147608	16
Minimum	0,114	0,043	0,078391	9
Maximum	1,562	0,485	0,225999	25
Sample Variance	0,159643	0,015997	0,003104	31
Standard Deviation	0,399554	0,126477	0,055709	5,567764
Standard Error	0,133185	0,042159	0,01857	1,855921
Confidence Level(95,0%)	0,307125	0,097219	0,042822	4,279765

Legend: H – Sahnnon index, Es – Shannon evenness, E – Buzas and Gibson's evenness, S – species richness

Association *Pulmonario rubrae-Fagetum* plant communities were identified from 1 – Frasin Hill, 2 - Buhalnița, end of Prislop forest road, 3 - Hangu –Audia valley, 4 –Frasin Hill, 5 – Piciorul Vânăt forest road, 6 - Potoci, forest road, 7 –Frasin Hill, 8 - Potoci, 9 – Potoci.

The analysis of the diversity measures (Tab. 4, Fig. 2) shows that relevees 9, 2, and 1 had the highest H values (greater than 0,8), included 29, 20, and 20 species respectively and represented more than 25% of a maximum diversity community with the same number of species.

Table 4: Diversity measures of Ass. *Pulmonario rubrae-Fagetum*

Relevee	H	Es	E	S	ln(E)	ln(S)	ln(E)/ln(S)
1	0,838	0,28	0,115587	20	-2,15773	2,995732	-0,72027
2	0,838	0,28	0,115587	20	-2,15773	2,995732	-0,72027
3	0,666	0,23	0,108135	18	-2,22437	2,890372	-0,76958
4	0,773	0,235	0,080232	27	-2,52284	3,295837	-0,76546
5	0,427	0,127	0,05285	29	-2,9403	3,367296	-0,87319
6	0,182	0,059	0,054528	22	-2,90904	3,091042	-0,94112
7	0,165	0,055	0,05897	20	-2,83073	2,995732	-0,94492
8	0,574	0,176	0,068283	26	-2,6841	3,258097	-0,82382
9	0,897	0,266	0,08456	29	-2,4703	3,367296	-0,73361

Legend: H – Sahnnon index, Es – Shannon evenness, E – Buzas and Gibson's evenness, S – species richness

According to the SHE analysis, other plant communities that contained 20 or more species, such as relevees 4, 8, 6, 7 and especially 5 (29 species), proved to be less diverse because their low Buzas and Gibson's evenness, which, as mentioned before, decrease the value of the Shannon diversity index (Fig. 2).

At association level, there is an obvious equilibrium between species richness and evenness, across the plant communities (fig. 2 – ln(E)/ln(S) slightly varied across relevees).

In all communities, the distribution of species abundance significantly fitted the log-normal model (Tab. 2). This means that the mixed forest communities are dominated by a few species while the rest of them are rarer.

At the association scale, the medium values of the diversity measures are the followings: the Shannon index value is 0,59±0,215, the Es value is 0,189±0,069, the E value is 0,082±0,019, and the species richness is 23,444±3,308 (Tab. 5).

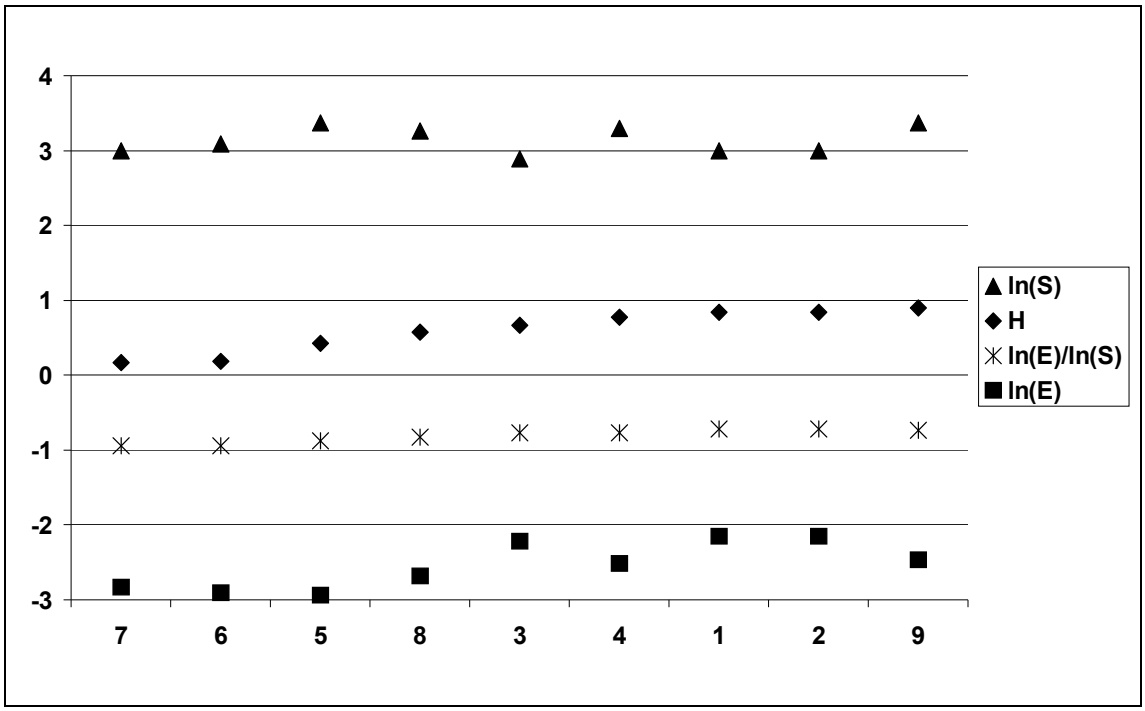

Fig. 2: SHE analysis of Ass. *Pulmonario rubrae-Fagetum* (1 – 6 – relevees in H ascending order, H – Sahnnon index, Es – Shannon evenness, E – Buzas and Gibson's evenness, S – species richness)

Table 5: Descriptive statistics of diversity measures of Ass. *Pulmonario rubrae Fagetum*

Statistic	H	Es	E	S
Count	9	9	9	9
Mean	0,595556	0,189778	0,082081	23,44444
Median	0,666	0,23	0,080232	22
Range	0,732	0,225	0,062737	11
Minimum	0,165	0,055	0,05285	18
Maximum	0,897	0,28	0,115587	29
Sample Variance	0,07877	0,008144	0,000659	18,52778
Standard Deviation	0,28066	0,090244	0,025671	4,304391
Standard Error	0,093553	0,030081	0,008557	1,434797
Confidence Level (95,0%)	0,215734	0,069368	0,019732	3,30865

Legend: H – Sahnnon index, Es – Shannon evenness, E – Buzas and Gibson's evenness, S – species richness

Diversity comparison of the studied associations reveals that, apparently the association *Leucanthemo waldsteinii-Fagetum* is slightly more divers than the association *Pulmonario rubrae-Fagetum* (Tab. 3, Tab. 5). In fact, the differences concerning H and Es at association level were not statistically significant, according to the Mann-Whitney test ($U= 39$, $p>0,05$, for H and $U= 25,5$, $p>0,05$ for Es). The diversity measures, which were significantly different, were the species richness (S) and the Buzas and Gibson's evenness (E). Actually, the Mann-Whitney one-tail test indicates that S of *Pulmonario rubrae-Fagetum* is significantly greater than the S of *Leucanthemo waldsteinii-Fagetum* ($U= 71$, $p<0,05$). Concerning E, the situation is opposite – the E values of *Leucanthemo waldsteinii-Fagetum* are significantly higher than the E values of *Pulmonario rubrae-Fagetum* ($U= 69$, $p<0,05$). Therefore, these differences annul each other and, consequently, they are not sufficient to inflict a significant distinction between the overall diversities of the studied associations.

Hence, the conclusion is that regarding their diversity the associations are similar.

This conclusion is also supported be certain ecological characteristics of the associations. Thus, both of them occur on slopes with similar orientation (predominantly northern) and slope ($7 – 40^o$). The altitude interval, in which the plant communities were identified, was between 710 – 875m. Although, the association *Leucanthemo waldsteinii-Fagetum* exists at lower altitudes (608 – 730m), it makes no significant difference in diversity, compared to *Pulmonario rubrae-Fagetum*.

Regarding bioforms, floristic elements and ecological indices, the communities of both associations are alike – both are dominated by hemicryptophytes, Eurasian elements, mesophytes, mesothermophilous species and acido-neutrophilous species [3, 17]

A final absolute assessment of the diversity of the studied associations would be that they roughly represent 20 – 25% of the maximum potential diversity.

Conclusions

The plant communities of the association *Leucanthemo waldsteinii-Fagetum* represent approximately 25% of maximum potential diversity and contain approximately 16 species in average per $1000m^2$.

The plant communities of the association *Pulmonario rubrae-Fagetum* represent almost 19% of maximum potential diversity and contain approximately 23 species in average per $1000m^2$.

The difference of diversity between the associations in not statistically significant, except for the species richness (greater in *Pulmonario rubrae-Fagetum*) and evenness (greater in *Leucanthemo waldsteinii-Fagetum*), which in return annul each other and consequently proved to be ecologically insignificant with regard to the overall diversity.

For both associations, there is an obvious balance between species richness and equitability, across plant communities. Generally, that means that low evenness values decreased high species richness values, and vice-versa.

The communities of both associations fit the log-normal species abundance model, which, in ecological terms, means that few species are dominant while all the others have similar low abundance values.

The observed diversity resemblance of the studied associations is supported by their commune ecological characteristics, such as habitat, bioforms, floristic elements, and ecological indices.

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ANALIZA DIVERSITĂȚII COMUNITĂȚILOR VEGETALE DIN UNELE PĂDURI DE AMESTEC DIN MUNȚII STÂNIŞOAREI (CARPAȚII ORIENTALI)

(Rezumat)

Lucrarea de față prezintă analiza diversității fitocenotice a două tipuri de păduri de amestec (foioase – răşinoase) aparținând Cl. *Querco-Fagetea* Br.-Bl. et Vlieger in Vlieger 1937, reunite în asociațiile *Leucanthemo waldsteinii-Fagetum* (Soó 1964) Täuber 1987 şi *Pulmonario rubrae-Fagetum* (Soó 1964) Täuber 1987, Ord. *Fagetalia sylvaticae* Pawl. in Pawl. et Wallich 1928, Al. *Symphyto-Fagion* Vida 1963, Subal. *Symphyto-Fagenion* Boşcaiu et al. 1982. Ambele tipuri de păduri sunt larg răspândite în partea de sud-vest a Munților Stânişoarei (Carpații Orientali), zona luată de noi în studiu. Tabelele fitocenologice, analiza bioformelor, indicilor ecologici şi elementelor floristice, precum şi descrierea fitocenozelor au făcut obiectul unor lucrări publicate anterior, lucrarea de față încercând să compare cele două formațiuni forestiere destul de asemănătoare floristic din punctul de vedere al diversității fitocenotice. Diversitatea a fost apreciată prin bogăția specifică, valoarea indicelui Shannon, a echitabilității, analiza SHE şi distribuția abundențelor speciilor. Pentru asociația *Leucanthemo waldsteinii-Fagetum* comunitățile cele mai diverse au fost identificate la Hangu – drum forestier Runcu, Buhalnița – drum forestier Varnița, Buhalnița – drum forestier, Hangu baza văii şi Dl. Frasinului - 1/3 inferioră. În cazul asociației *Pulmonario rubrae-Fagetum*, valorile cele mai mari ale diversității au fost obținute pentru comunitățile de la Potoci, Dealul Frasinului şi Buhalnița – capătul drumului forestier Prislop. La nivelul asociațiilor, singura diferență semnificativă statistic apare în cazul bogăției specifice (mai mare pentru *Pulmonario rubrae-Fagetum*) şi echitabilității (mai mare pentru *Leucanthemo waldsteinii-Fagetum*) care însă se anulează reciproc, motiv pentru care nu sunt importante din punct de vedere ecologic pentru diversitatea privită în ansamblu. Ambele asociații au o distribuție a acoperirii speciilor ce concordă semnificativ cu modelul logaritmic-normal ceea ce, din punct de vedere ecologic, înseamnă că în general există puține specii foarte abundente şi multe cu abundență mult mai mică. Similaritatea dintre diversitățile celor două asociații este susținută şi de caracteristicile ecologice comune ale acestora, cum ar fi habitatul, bioformele, elementele floristice şi indicii ecologici.