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THE VARIATION ON TYPES OF MICROHABITATS ON TREES IN A NATURAL FOREST - "IZVOARELE NEREI" NATURAL RESERVE - CASE STUDY

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Abstract

The aim of the paper is to highlight the variation of the frequency and types of microhabitats on trees, in a natural beech forest, depending on different stand characteristics and site condition. The research was carried out in the "Izvoarele Nerei" Nature Reserve from Caras-Severin County, Romania, the previously announced aim being achieved by fulfilling objectives such as: identifying the types of microhabitats on trees (according classification from specialty literature) on altitudinal levels, establishing the influence of altitude on the frequency of microhabitats, identification of other stand characteristics and site conditions having an influence on the frequency of microhabitats on trees. The research was carried out on four altitudinal levels (800, 1000, 1200 and 1350 m), trees characteristics determination and microhabitats identification being carried out in sample areas of 2500 m^2, two on each altitudinal level. The most frequent microhabitats were: branch rot hole (length >= 5 cm), cracks and scars (length >= 100 cm), root buttress cavities (length >= 5 cm), epiphytic lichens (coverage > 25 %), root buttress cavities (length >= 10 cm), branch rot hole (length >= 10 cm).

Key words: *biodiversity, beech forest, rot hole, buttress cavities.*

INTRODUCTION

The importance of research in virgin forests has been highlighted countless times by the possibility of applying the results obtained in the management of cultivated forests. Studying the correlations between the structure and dynamics of virgin forests, but also the links between species and environmental factors can lead to finding new solutions to improve regeneration techniques and the composition of forest stands. Research into virgin forests should be seen as a tool for understanding the processes and interactions between different species. This method can be used to obtain information that can be used in forestry close to nature. (Schuck et al., 1994).

The first research on ecosystems began in the second half of the 19th century. The favourite research topics at the time were freshwater biocenoses. Research on forest ecology began later, thanks to Russian forester Morosow. (Schuck et al., 1994)

Research in the natural forests of central and south-eastern Europe has been strongly influenced by Leibundgut. According to him, the problems and aims of research in virgin forests should focus on the following issues:

• processes and dynamics of different forest communities;
• the stability of forest stands in different stages of development against environmental factors;
• the influence of regeneration on the development and aging processes of the forest stand;
• the appearance and causes of the successions. (Schuck et al., 1994).

A rather little researched aspect in Europe, but especially in Romania, is that of tree-related microhabitats (hereafter TreMs), (Bütler et al., 2013) - these having a special importance in forest habitats, recent studies highlighting their use as a proxy for local taxonomic diversity (Larrieu et al., 2014b; Kraus et al., 2016; Larrieu et al., 2018).

Current research at European level in the field imposes a new paradigm: maintaining and improving the biodiversity of forest ecosystems, not only by creating reserves, but also by increasing the biodiversity of managed forests.

Tree microhabitats are important for the complexity of forest habitats, whose structural diversity enriches them, thus creating conditions for increasing biodiversity. In general, for the existence of most of the microhabitats identified so far, large trees (especially large diameters) are needed, but also an adequate density of these large trees. (Larrieu et al., 2014a).

This study should be considered as one of the first to provide quantitative data on microhabitat densities for Romania, along with other studies (Tomescu et al., 2004; Tomescu et al., 2008; Turcu, 2012). The research is complementary to that of other studies already published for other forests, types and biogeographical regions in France and Europe (Bouget et al., 2013; 2014; Larrieu et al., 2014b; Winter et al., 2015).

In the literature there is a very varied terminology regarding the definition of forests with a high degree of naturalness, without this terminology always being used in a unitary way. Thus, based on the literature, the most frequently used terms that define the forests mentioned above were searched. These terms are: ancient forest, natural forest, old-growth forest, primary forest, primeval forest, relict forest, untouched forest, virgin forest. Based on the definitions published in various scientific papers, they have been translated and explained.

Since there is already a long tradition in the study of natural forests (Tomescu et al., 2004; Tomescu et al., 2008; Turcu, 2012), this study proposes to complete this research with aspects on TreMs.

The hypothesis of the research that was the basis of this study is that the types of microhabitats in the “Izvoarele Nerei” Nature Reserve vary with the characteristics of the forest stands (plot description) and with the specific forest site.

The aim of the paper is to highlight the differences regarding the frequency of microhabitats by their types in “Izvoarele Nerei” Nature Reserve and the influence of tree characteristics and the conditions of the forest site on microhabitats. The goal was achieved by fulfilling the following objectives:

1. Identifying the types of TreMs on altitudinal levels;
2. Establishing a link between altitude and the frequency of some TreMs;
3. Identify other characteristics of the forest stand and the forest site on the frequency and types of TreMs.

MATERIALS AND METHODS

The research is located in the “Izvoarele Nerei” Nature Reserve, in the southwest of Romania, on the territory of Caraş-Severin County, within the Nera Forest District and from the point of view of the local administration within the Prigor commune. The location of the Reserve at the Romanian level is shown in Figure 1a.

Currently, the Reserve is included in the Semenic - Cheile Caraşului National Park, occupying its southeastern part and also constituting one of the wildest areas of the Park (Figure 1b).

The “Izvoarele Nerei” reservate is located from a geographical point of view between the coordinates 45°5′ - 45°10′ north latitude and 22°2′30′′ - 22°6′40′′ east longitude; Regarding the forest management, the reserve is located within the Nera Forest District, managed by the Caras-Severin Forestry Department and belongs to the production units II Nergana and III Nergăniţa.

The reservate occupies a total area of 5028.0 ha, included in the upper basins of the rivers Nergana (Bănieş) and Nergăniţa. According to OM 552/2003, GEO 57/2007 regarding the regime of protected natural areas, conservation of natural habitats, of wild flora and fauna, approved with modifications and completions by Law no. 49/2011, the strictly protected areas, included in the type of functional category T1 -excluding any kind of forestry interventions, are found in the following development units:

• U.P. II Nergana: parcells 19, 20, 24, 25, 28, 29, 31-33, 52-14, total 2930.0 ha

• U.P. III Nergăniţa: parcells 6-63, total 1956.0 ha

It was installed 8 plots in the natural forest ("Izvoarele Nerei" Nature Reserve), with an area of 0.25 hectares (2500 m^2) each, distributed respectively 2 on 4 altitude levels: 800, 1000, 1200 and 1350 m (Figure 1).

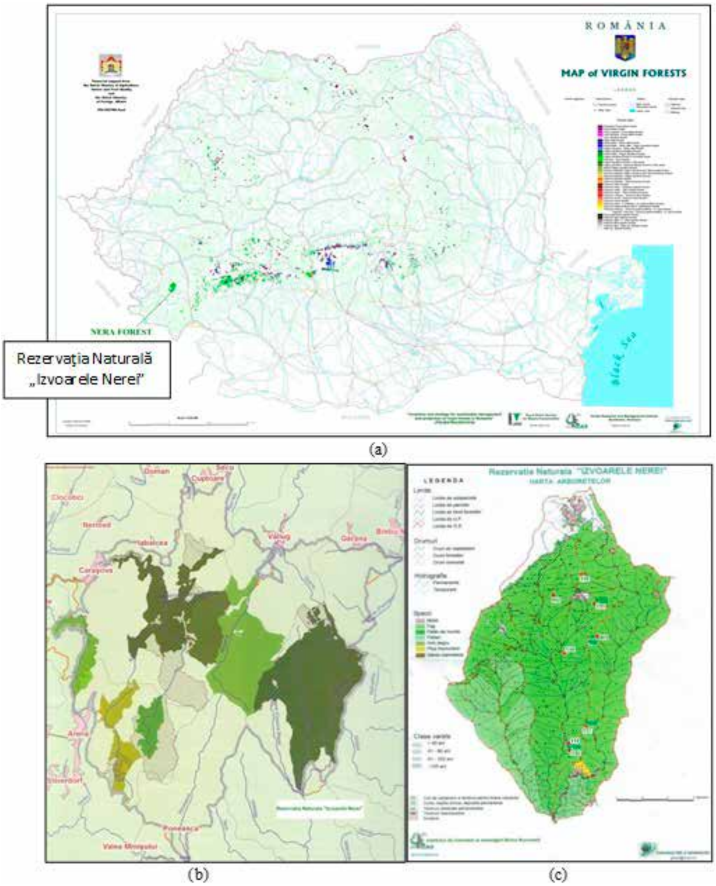


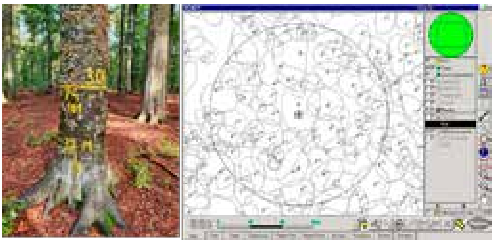
Figure 1. The location of the “Izvoarele Nerei” Nature Reserve and the location of the test areas;
a - map of Romania - Distribution of virgin forests in Romania (after Veen and Biriş, 2004), b - Location of the “Izvoarele Nerei” Nature Reserve within the Semenic National Park - Cheile Caraşului (dark green) (after Bădescu and Vlaicu 2011); c - Map of “Izvoarele Nerei” Nature Reserve and the location of the 8 permanent sample plots of 0.25 ha each (based on Tomescu et al. 2004-2006)

The assessment of the frequency and qualitative characteristics of the TreMs in the natural forest was done in the test areas, the trees were identified and their position was taken with the help of FildMap equipment, the diameters were measured using a forest calliper, the heights of the trees were measured with the help of Vertex III equipment.

Regarding the presence and frequency of microhabitats, the classification proposed by the European Forestry Institute (EFI) through the Integrate + project (www.integrateplus.org) and materialized in the Catalogue of tree microhabitats (Kraus et al., 2016).

For the correct inventory and characterization of the microhabitats encountered on each tree, a specific terrain sheet was elaborated. Although the inventory and description of the microhabitats was carried out on individual trees, the characterization of the presence, respectively the frequency/abundance, was made at the level of the forest stand (and, for an easier use of the results, by reduction per hectare). A relationship was made between the presence/frequency of microhabitats and the presence of thick trees, both in the natural forest, to establish possible correlations.

The research was done in 8 plots with an area of 0.25 hectares (2500 m2) each, distributed respectively 2 by 4 altitudinal levels: 800 m (plots 114 and 116), 1000 m (plots 110 and 112), 1200 m (101 and 102) and 1350 m (plots 118 and 119). These were materialized in the field with the device FieldMap (www.field-map.com) (Figure 2 a, b).



(a) (b)

Figure 2. a - Field materialization of the plot; b - Graphic representation of plot no. 112 measured with FieldMap

The 10 most common types of TreMs at altitude levels were presented. With the help of the t-student statistical test, the hypothesis was tested according to which is a statistical link between groups of certain types of TreMs and altitude. Using the Pearson correlation coefficient, the correlation between the number of TreMs in the groups with the most common microhabitat types and the altitudinal levels at which they were observed was studied. For groups of microhabitats that have the highest correlation between the number of microhabitats and exposition (expressed in sexagesimal degrees to the north) and the slope (expressed in degrees), models of linear statistical links were developed.

RESULTS AND DISCUSSIONS

Types of TreMs in the "Izvoarele Nerei" Nature Reserve

The types of TreMs inventoried in the 8 plots in which the research was conducted are listed in Table 1, being in accordance with the latest classification in the literature, as previously specified in the chapter material and method (Kraus et al., 2016).

Table 1. TreMs frequency. The list refers to the TreMs frequencies within all 8 plots.
The record "Other" refers to 32 TreMs types that present individual frequencies lower than 10

TreMs Code	TreMs type	Frequency of TreMs	Frequency (%)
CV31	Branch hole ø ≥ 5 cm	635	14.96
IN32	Cracks and scars Length ≥ 100 cm; width > 1 cm; depth > 10 cm	377	8.88
GR11	Root buttress cavities ø ≥ 5 cm	359	8.46
EP32	Epiphytic foliose and fruticose lichens, coverage > 25 %	247	5.82
GR12	Root buttress cavities ø ≥ 10 cm	229	5.39
CV32	Branch hole ø ≥ 10 cm	199	4.69
GR31	Cancerous growth, ø > 20 cm	170	4.01
BA11	Bark shelter, width > 1 cm; depth > 10 cm; height > 10 cm	148	3.49
BA12	Bark pocket, width > 1 cm; depth > 10 cm; height > 10 cm	132	3.11
CV33	Hollow branch, ø ≥ 10 cm	111	2.61
CV44	Dendrotelms and water-filled holes ø ≥ 15 cm/crown	93	2.19
DE13	Dead branches and limbs ø 10–20 cm, not sun-exposed	92	2.17
CV12	Woodpecker cavities ø = 5–6 cm	89	2.10
BA21	Coarse bark	81	1.91
EP12	Perennial polypores, ø > 10 cm	80	1.88
CV23	Trunk and mould cavities ø ≥ 10 cm	71	1.67
DE11	Dead branches and limbs ø 10–20 cm, sun-exposed	66	1.55
IN31	Cracks and scars Length ≥ 30 cm; width > 1 cm; depth > 10 cm	61	1.44
IN11	Bark loss 25- 600 cm^2, decay stage < 3	53	1.25
CV14	Woodpecker cavities ø ≥ 10 cm feeding hole)	46	1.08

CV24	Trunk and mould cavities ø ≥ 30 cm	46	1.08
CV15	Woodpecker "flute " / cavity string	44	1.04
EP13	Woodpecker cavities ø ≥ 10 cm feeding hole)	44	1.04
IN12	Bark loss > 600 cm^2, decay stage < 3	30	0.71
DE12	Dead branches and limbs ø > 20 cm, sun exposed	25	0.59
EP31	Epiphytic bryophyte coverage > 25 %	25	0.59
GR13	Trunk cleavage length ≥ 30 cm	21	0.49
GR22	Water sprout	21	0.49
OT11	Sap flow > 50 cm	19	0.45
CV13	Woodpecker cavities ø > 10 cm	11	0.26
IN14	Bark loss > 600 cm^2, decay stage = 3	11	0.26
EP11	Annual polypores, ø > 5cm	10	0.24
Others	Other TreMs	599	14.11

Based on the graphs presented below, the main four microhabitats for each altitudinal level were selected (Figure 3). The first four most numerous microhabitats identified on each altitudinal level were also tracked within the other altitudinal levels.

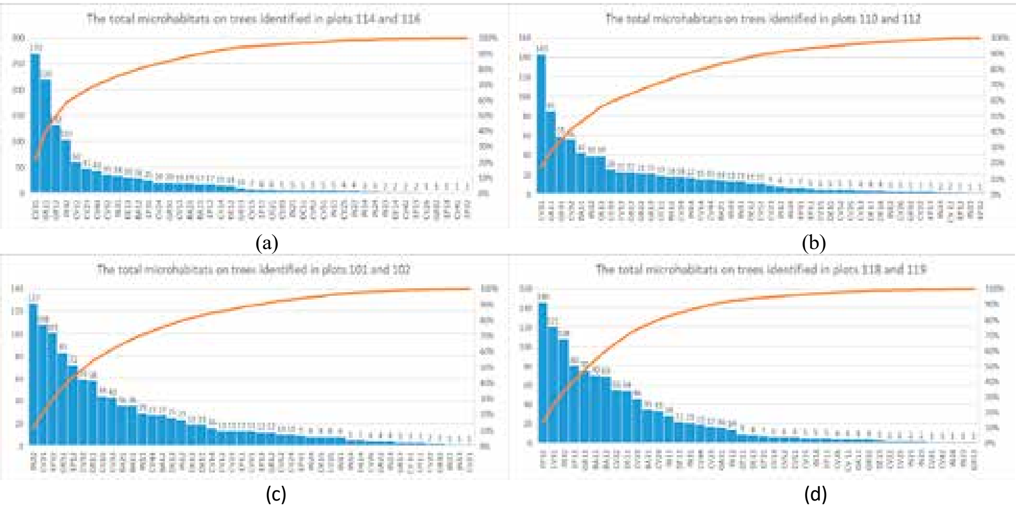


Figure 3. Total number of microhabitats by their types in the plots (a - 800 m altitude level; b - 1000 m altitude level; c - 1200 m altitude level; d - 1350 altitude level)

Thus, the most common microhabitat in the studied sample areas was CV31, with an almost double number of microhabitats compared to those of type IN32 and GR11. The following microhabitats encountered, presented in descending order of number are: EP32, GR 12, CV 32, GR 31, EP12 (Table 2).

Table 2. The most popular microhabitats that appear on the 4 altitudinal levels

Altitude	CV31	IN32	GR11	EP32	GR12	CV32	GR31	EP12
800	270	103	220	1	132	35	20	17
1000	143	39	85	1	22	56	59	2
1200	108	127	58	101	12	59	83	72
1350	121	108	4	146	75	55	16	80
TOTAL	642	377	367	249	241	205	178	171

As can be seen in the graph below (Figure 4), we cannot talk about an increase or decrease in the total number of microhabitats with altitude.

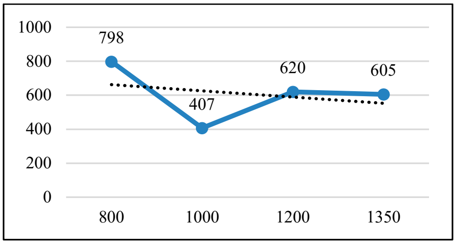


Figure 4. Variation in total number of microhabitats with altitude

However, the number of microhabitats encountered is very high at altitudes below 1000 m, their number decreases to an altitude of 1000 m to increase later and remain almost constant at altitudes of 1200 and 1350 m, respectively.

For two of the microhabitats, which are also the most numerous at the altitudinal level of 800 m, decreases of the number of microhabitats were observed with the increase of the altitude, almost on the entire altitudinal range analyzed; the exception is CV31 microhabitats at an altitude of 1350 m where a slight increase was found.

The number of microhabitats of type GR11 registers a constant decrease on the studied altitudinal range, reaching very small values identified at the altitudinal level of 1350 m (4 microhabitats of this type).

The variation of the number of microhabitats from CV32 and EP32 types is almost complementary to the variation of the types presented above. The number of micro-habitats of the CV32 type increases with the altitude up to 1200 m and registers a slight decrease at the altitude level of 1350 m.

EP 32 type microhabitats were recorded in very small numbers at altitudes of 800 and 1000 m (one microhabitat of this type at each altitude level), but at over 1000 m the increase is constant over the entire altitudinal range studied.

Regarding the other types of microhabitats identified in significant numbers, no relationship was observed between their number and the increase of the altitude.

However, in the case of three of the four types in the above figures (GR12, IN32, EP12) a decrease in the number of microhabitats was observed in the range 800-1000 m, similar to the decrease in the total number of microhabitats identified in this altitudinal range.

In the case of GR31, the increase in the number of microhabitats is constant between 800 and 1200 m, but suddenly decreases above this altitude, proving that the high altitude is not favourable for this type of microhabitat.

Frequency of TreMs and altitude

The relationship between altitude and frequency of TreMs was analyzed using the Pearson correlation coefficient. The Pearson correlation coefficients between the groups of TreMs and the altitudinal levels at which the test surfaces were located (800 m, 1000 m, 1200 m, 1350 m) are shown below:

- r = - 0.745 for the cavity group (CV) - high inverse correlation;
- r = 0.474 for the group of injuries and wounds (IN) - reasonable direct correlation;
- r = 0.929 for the bark group (BA) - very high direct correlation;
- r = 0.954 for the group of crown deadwood (DE) - very high direct correlation;
- r = - 0.974 for the group of in the root buttress cavities (GR) - very high inverse correlation;
- r = 0.903 for the group of fruiting bodies of fungi (EP) - very high direct correlation;
- r = - 0.244 for the group of sap and resin run (OT) - very weak direct correlation.

The microhabitats in the cavity group (CV) show a decrease in number with increasing altitude, the high inverse correlation being related to the more difficult development of fungi and microorganisms that favour them, with increasing altitude. The number of injuries and wounds (IN) does not show a high correlation with the altitude, being rather the product of some events in the life of the natural forest (fillings, wounds caused by animals, etc.). For the bark group (BA) the direct correlation is very high, the number of microhabitats in this group increasing significantly with increasing altitude. A cause of this correlation can be given by the vulnerability to diseases and pests of trees that grow at the upper altitude limit of the area. The same happens in the case of microhabitats from the group of crown deadwood (DE), whose frequency registers a very high direct correlation with the increase of the altitude. The root buttress cavities (GR) are becoming less frequent with increasing altitude (very high inverse correlation), due to the shorter cycle of microorganism colonies on the soil surface at higher and average altitudes of higher annual temperatures. However, the fruiting bodies of fungi (EP) are more frequent with increasing altitude, which is explained only by the increased vulnerability of trees that grow at higher altitudes than the ecological optimum. Sap and resin run (OT) microhabitats are favoured by higher temperatures and longer vegetation seasons, the number of which decreases with increasing altitude, but their frequency correlation with altitude is weak (Fütterer et al., 2017).

Testing statistically using the t-student statistical test, the hypothesis that there is a statistical link between groups of certain types of TreMs and altitude, significant differences were found only between the altitudes minimum and maximum altitudes for microhabitats in the bark group (BA) (Table 3). Therefore, the amplitude of 550 m between the minimum and maximum altitudes in which observations were made, and the high altitude of the last altitudinal level, lead to significant differences in the frequency of microhabitats in the bark group (BA) in the "Izvoarele Nerei" Nature Reserve.

Table 3. T-student statistical test - values of p for testing differences in the number of microhabitats in the bark group (BA) at altitude levels ($p < 0.05$ - significant differences, $p < 0.01$ distinctly significant differences, $p < 0.001$ very significant differences)

Altitudinal level	800	1000	1200	1350
800	1	0.693	0.151	0.038
1000	0.693	1	0.454	0.082
1200	0.151	0.454	1	0.126
1350	0.038	0.082	0.126	1

Stationary conditions and their influence on TreMs

The site conditions have a determined role on the forest habitat, implicitly influencing the formation, development and maintenance of TreMs. Of these, in the analysed surfaces, the soil type and the forest site type are identical in all 8 plots. Stationary conditions such as slope and terrain exposure differ from case to case (Table 4), as does altitude. The latter was a criterion for the design of the research and the location of the test surfaces and was previously analysed in the context of TreMs.

Table 4. Microhabitats on their groups in the plots and some stationary conditions

	Altitude (m)	800		1000		1200		1350	
	Plot no.	114	116	110	112	101	102	118	119
	Cardinal orientation of the slope	V-NV	V-SV	NV	SE	S	V	NV	SV
	Cardinal orientation of the slope (sexagesimal degrees)	67.5	112.5	45	225	180	90	45	135
	Slope (degrees)	30	32.5	27.5	20	17.5	20	10	5
Group of microhabitats (no. of microhabitats per group)	Cavity (CV)	264	228	220	42	152	168	146	111
	Injuries and wounds (IN)	80	57	63	0	48	123	76	85
	Bark (BA)	13	25	33	24	23	69	123	51
	Crown deadwood (DE)	12	18	37	10	24	25	41	26
	Root buttress cavities (GR)	225	145	207	0	31	106	73	13
	Fruiting bodies of fungi (EP)	13	12	0	0	88	67	92	134
	Sap and resin run (OT)	0	0	19	0	0	0	0	0

As can be seen in Table 4, the exposure of the land in the test areas varies between orientations from 450 to 2250 in the N direction, covering half of the possible orientations, from NW to SE. Of the 7 most common groups of TreMs, only 4 of them can talk about a linear relationship between their number and orientation and having a coefficient of determination (R^2) with a reasonable value (Figure 5).

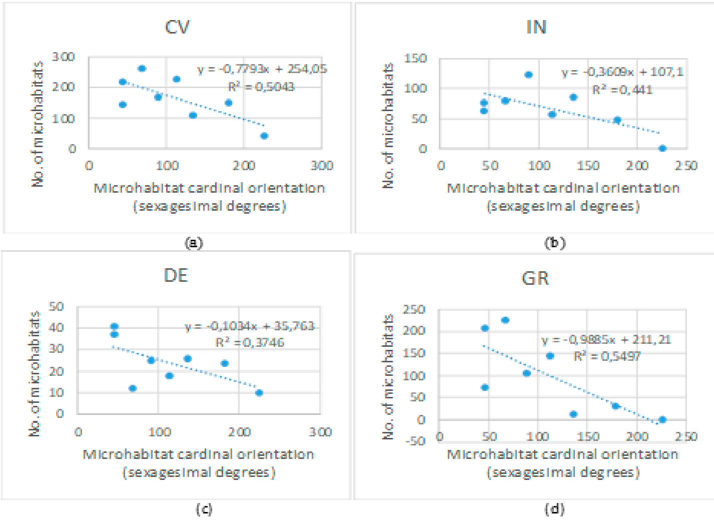


Figure 5. The relationship between the groups of microhabitats and the exposure of the land (a - cavities; b - injuries and wounds; c - crown deadwood; d - root buttress cavities)

As can be seen, the highest value of the coefficient of determination is recorded in the group of microhabitats such as root buttress cavities (GR). In all cases, however, the highest values are observed on exposures close to N, the frequency of microhabitats decreasing and reaching minimum values on S, SE and SV. Therefore, it is observed that insolation leads to a small number of microhabitats, inhibiting to a certain extent the development of decomposing microorganisms and fungi.

The groups of microhabitats for which the coefficient for determining (R^2) the linear relationship between the number of microhabitats and the slope, has reasonable values, are the cavities (CV), bark (BA), root buttress cavities (GR) and the fruiting bodies of fungi (EP) (Figure 6).

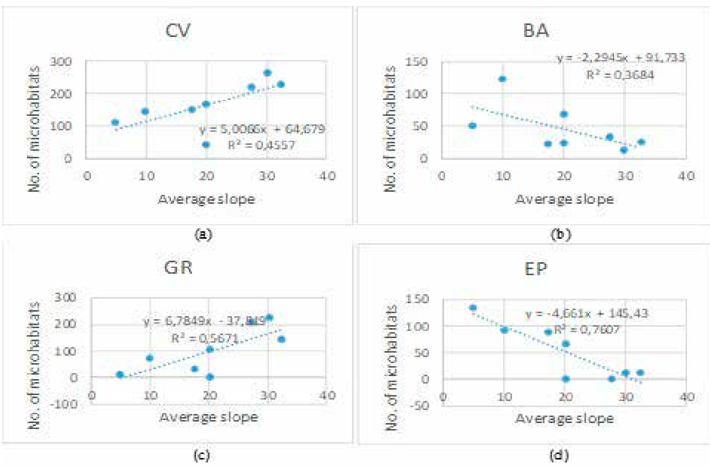


Figure 6. The relationship between the groups of microhabitats and the slope (a - cavities; b - bark; c - root buttress cavities; d - fruiting bodies of fungi)

As can be seen, the increase in the slope causes an increase in the number of microhabitats in the cavity groups (CV) and the root buttress cavities (GR). Increasing the slope causes a decrease in the number of microhabitats in the bark groups (BA) and the fruiting bodies of fungi (EP).

CONCLUSIONS

This paper is one of the first attempts to address this research topic in our country. The main advantage consists in the certain natural value of the stands studied, the stands from Izvoarele Nerei, which have a very high degree of naturalness, and where they can be observed the characteristics and natural processes of beeches in the form least influenced by anthropogenic activities.

The most frequent microhabitats were:
- CV31 - Branch rot hole >= 5 cm;
- IN32 - Cracks and scars L >= 100 cm;
- GR11 - Root buttress cavities >= 5 cm;
- EP32 - Epiphytic lichens, coverage > 25%;
- GR12 - Root buttress cavities >= 10 cm;
- CV32 - Branch rot hole >= 10 cm.

The high amplitude between the extreme altitude levels among those analyzed and the high altitude of the last altitude level led to significant differences in the frequency of microhabitats in the bark group (BA) in the "Izvoarele Nerei" Nature Reserve.

Between the altitude and the frequency of the TreMs, the Pearson correlation coefficient shows that there are high direct or inverse correlations in most of the groups of microhabitats studied.

The highest frequency of microhabitats is recorded on lands with exposures close to N, and the lowest frequency on lands with exposures S, SE and SV.

Increasing the slope causes more injuries to the trunks and root buttress, which over time lead to microhabitats in the group of trunk cavities (CV) and root buttress cavities (GR). Increasing the slope leads to a decrease in the number of microhabitats in the bark groups (BA) and the fruiting bodies of fungi (EP).

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