Examination the health state with instrumental measurements and the diversity of sessile oak stands in Zemplén mountains

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Abstract: Researching the naturalness of forests has been becoming more and more pronounced in Hungary, since the forest's ecosystems are also concerned by the biosphere crisis, that is a global degradation of the biotic environment. This deterioration could be observed not only through the decrease of the extention of the forests, but also through the altering of their structures.

FAKOPP 3D Acoustic Tomograph have been used and coenological surveys have been carried out in 3 different layers. The examinations have been accomplished in sessile oak stands of the Zemplén Mountains, within 5 different age groups. According to the results of the instrumental measurements – except the youngest age group – the highest value of the rottenness is located in the closest layer to the topsoil, then upwards on the trunk it shows decreasing tendency. Among the stands the 80 years old age group proved to be the healthiest, while the 20 years old group had the worst values. Based on the Shannon and Simpson diversity, the most diverse age group in the ground layer is the 60 years old group, while in the canopy is the 80 years old group. The rottenness measured in the younger stands concerned the higher parts of the trunks and it has presumably evolved because of the frost cracks. The diversity values of the shrub and the ground layer followed the same tendency.

Keywords: sessile oak, Zemplén Mountains, FAKOPP 3D Acoustic Tomograph, health state

Introduction

The reactions of the living world could be totally different within various dimensions causing the biggest difficulty for the climate research. In the interest of achieving more and more accurate prognosis of temporal and spatial changes, numerous researches are needed (Walther et al. 2002, Parmesan & Yohe 2003, Root et al. 2003, Parmesan 2006).

According to several studies the climate zones will give the most sensitive reaction (e.g. Risser 1995). Besides the increasing temperature, the alteration of the actually observed and predicted precipitation is the most hazardous for the ecosystems of the Carpathian Basin (Czóbel et al. 2010). However the responses of the ecosystems to these changes have been slightly explored so far (Czóbel et al. 2008).

According to the scientists besides the rising temperature the presence of drought periods are becoming more often. These periods are considered to be serious threats because of the deterioration of the health state of the stands during those periods which could lead to thinning or to even entire destruction (Csóka et al., 2007; Csóka et al., 2009). Some prognosis predict the shrinkage of the optimal climate range (niche) of sessile oak, according to Czúcz et al. (2013) the extent of this progression could be 80-100% by 2050.

Sessile oak forests cover approximately 160 000 hectares in Hungary, since not only the climatic conditions, but also the natural resources are suitable for them. This is the reason for the huge distribution of forests dominated by sessile oak. The continental xero- and mezophilic oak forests extend around the plains following the border of the Hungarian Mid-Mountains. The typically shallow topsoil of the Central Mountains and the often extremely drought regions are no longer favourable for closed-canopy stands, since the minimumfactor of these associations is the water (Mátyás et al. 1997). Parallel to the drought periods the desvastation of the dominant tree species had been also observed, among those the deterioration of sessile oak (*Quercus petraea*) has seriously appeared. The reason of its decay has been investigated by many researchers as Igmándy et al. (1985), Jakucs et al. (1988) and

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Berki (1991, 1995). Eventually, Vajna (1989, 1990) assigned a reason to this rather complex issue. According to Vajna the primal responsible for the oak's destruction could be the years with drought weather conditions when the parasitic fungi and the herbivorous insects have occurred in large quantities on those trees which were weakened due to the lack of water. Afterwards, it was observed that in those stands where the climate is pushing the limits of the tolerability of the stands, weakening of the vitality of the tree species is typical (Mészáros et al. 2012).

We have used FAKOPP 3D Acoustic Tomograph that is an instrument to determine the extent of the deterioration in tree trunks, developed in Hungary. This instrument measures the speed of sound propagation in the tree matter, since rotten and healthy tissues conduct sound differently. The theory behind this measurement is that sound propagates better in healthy tree tissue than in the decaying material. Every species has its optimal value; the deviation from that - in this case the decreasing of the value - refers to the rot inside of the trunk. The wood decay is caused by the white-rot and the brown-rot fungi; out of them the latter is the responsible for the decomposition of the cellulose content of the wood as well as for the propagation of the sound. Measurements in case of living trees are typically conducted in parks for the purpose of landscape architecture (Divós et al. 2005, Divós et al. 2008, Molnár 2011).

In order to create a complete picture of the stands investigating sessile oak individuals within the given stands are not sufficient; surveying the species pool and the structure are required too.

Since the forestry with the various forest management practices has great influence on the species composition, on the structure and on the processes of forest dynamics (Rubio et al. 1999, Bengtsson et al. 2000). Species needs to adapt to the regularly disturbances which affect them, and to the situation that their habitat have been continuously narrowing or fragmenting. The generalist species are better able to comply with these changing conditions rather than the specialist species of the forest ecosystems (Hermy et al. 1999). The herbaceous taxa play an important role in the diversity of forests, as they take part in the carbon storage and nutrient supply; moreover have a great impact on the primary production (Whigham 2004). In addition these species are proved to be appropriate indicators of the environmental changes because of their relative quick life cycle (Standovár et al. 2006). The different types of disturbance have direct or indirect influences on the species composition and on the structure of the given layers (Brunet et al. 1996, Decocq et al. 2004, 2005, Van Calster et al. 2008, von Oheimb & Härdtl 2009). The development state of the canopy and the ground layer has direct effect on the amount of light reaching to the latter layer, so that on the species composition and their coverage ratio in forest floor (Barbier et al. 2008, Tinya et al. 2009).

The following aims are set during the research:

What is the degree of the rottenness of the selected age groups of sessile oak in different layers?

How the Shannon and the Simpson diversity indices vary in the layers of the investigated age groups?

Could it be possible to observe some tendency during the analysis of the results of the instrumental measurements and the diversity values?

Materials and methods

The examinations have been carried out in the stands of sessile oak in Zemplén Mountains. In order to obtain data from every development state of the forest five age groups have been marked out. The age groups have set out in every 20 years, thus 20, 40, 60, 80 and 100 years old stands have been examined (Table 1.). The areas of all age groups are part of the Natura 2000 network.

With the purpose of collecting representative data corresponding areas have been determined according to standard parameters. These parameters are the followings: the elevation

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Table 1. The selected subcompartments containing the age groups

Age groups	Subcompartments
20	Nagyhuta 109 A
40	Nagyhuta 109 B
60	Komlóska 53 D
80	Makkoshotyka 15 A
100	Háromhuta 101 D

(~400m), the relief (~15°), the southern exposure, furthermore the sessile oak (*Quercus petraea*) as the dominant tree species (minimum 70% of the canopy). The detailed descriptions of the given subcompartment have been provided by the local competent foresty.

In each selected subcompartment two 20×20 m quadrats have been selected in the way that the sample trees were the closest sessile oak trees to the corner of the quadrats and the closest sessile oak tree to the middle point. Therefore 5 sample trees have been investigated in each quadrats and 10 specimens in each age groups. The trunk diameter at breast height (DBH) (1,3 m) was measured at every sample trees, furthermore the presence of the frost crack was recorded. To determine the health state of the age groups FAKOPP 3D Acoustic Tomograph has been applied. The evaluation of data has been made by computers, that besides the measurements of the tree takes the species into consideration.

During the field measurements specifically developed detectors have been installed on the trees horizontally. In the younger stands 6 detectors have been used because of the small diameter of the trunks, while in the older stands 8 detectors have been applied. In order to receive accurate measurements of the degree of the decay and its evolution between the layers the trunks have been examined in total at 5 different heights above the soil surface (40 cm, 80 cm, 120 cm, 160 cm, 200 cm). The place of the first detector of every layer have been painted on the trunks to achieve repeatable measurements. The investigations have been carried out in the spring of 2015. In all 50 sessile oak trees have been measured regarding the health state of all 5 layers in each case. The collected data accordingly to this method has been quantified with the FAKOPP software and statistically evaluated with the Microsoft Office Excel. While the software expresses the degree of the rottenness in percentage, it is important to evaluate the stem diameter of each age groups.

The coenological surveys have been carried out in 20×20 meters quadrats in the way that the canopy, the shrub layer and the ground layer have been examined separately. At first each species in the quadrats have been recorded, then the cover-abundance values have been estimated in percentage, moreover the closeness of the canopy layer has been estimated too (Veperdi 2008).

The Shannon and the Simpson diversity values have been calculated by the Microsoft Office Excel, based on the field data (Tóthmérész 2002).

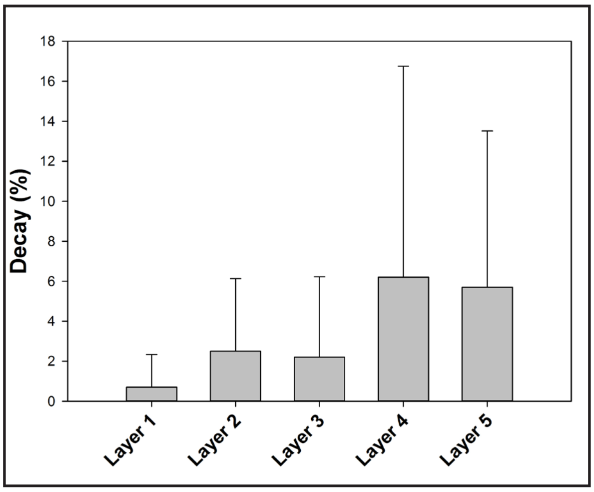
The levels of the significance of the examined layers within certain age groups and between certain age groups have been checked with the T-test during the statistical analysis. T-test has been used to determine the significance level between certain layers during the calculating of the two diversity indices.

Results

The results of the health state examination

Within the 20 years old group the degree of decay has been increased in higher and higher layers (Fig 1). The layer 4 (160 cm) had the

Figure 1. State of wood-decay in the measured layers (0.4 - 2 m). 20 year-old sessile oak stand (Zemplén Mountains, 2015).



worst health state. The rot part of this cross-section is 6.2%, which is considered to be high regarding that it is the youngest stand. In the 5th layer the average value of deterioration was 5.7%. The upper two layers had the biggest standard deviation value too; in the 4th layer it was 10.55 and the 5th layer had the value of 7.82%. Presumably it could be interpreted as the most of the specimens had appropriate health state, regularly these specimens were entirely healthy or had only 1-2% of decay in case of both layers. However two sample trees have badly damaged and the consequence of this they possessed bigger destruction. In the 4th layer the two extreme values of decay were 11% and 34%, while in the 5th layer these values were 11% and 24%.

In the first three layers the degree of degradation and the values of standard deviation had lower values too. In most cases some specimens had low decay values varying from 0 to 3%. In case of the 6th specimen the degree of deterioration in the 2nd and the 3rd layers was 11%; the 5th sample tree had higher value (5%) in the 1st and 2nd layers.

Within the 40 years old group the average and the standard deviation values seemed to be less unsteady (Fig 2). The degree of decay was the smallest in the two layers closest to the soil surface, while in the upper three layers had bigger deterioration. The latter layers had similar decay value; the 5th layer had the lowest with 1.8% and the 3rd layer had the highest with 2.2%. Low average values have belonged to low standard deviation values. Among some specimens the highest decomposition value was 8% that is considered to be corresponding regarding the age of the stand. Compare to this the first two layers had even lower deterioration. In the cross-section of these layers 0.8% of decay has measured equally. The values of standard deviation were also lower than in case of the upper 3 layers. The 3rd sample tree had the worst health state, 4 of its layers had higher decomposition value than 6%. Besides this higher deterioration values have been measured than 7% with the 6th and 7th specimens. Within this age group decay have not been detected in 64% of the examined layers.

In case of the 60 years old group the so far experienced trend has changed. Instead of the former linear growing values of decomposition, some layers are located through a curve in the way that a decrease could be seen until the 3rd layer which is followed by an increase until the 5th layer (Fig 3). The average value of deterioration could be divided into two groups: the 1st, 2nd and 5th layer possess the 3 highest values, while the health state of the 3rd and 4th layers considered to be better (0.5% and 1.1%). This stand had the lowest degree of decomposition among the 5 age groups. The health state has been experienced to be equal between the layers as well as with the standard deviation values. The standard deviation values varied within a narrow range from 2.29% to

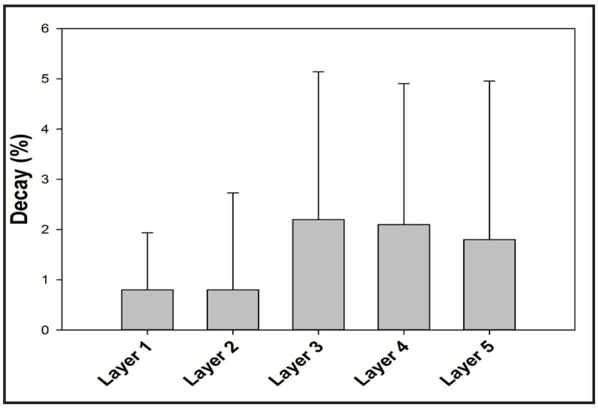


Figure 2. State of wood-decay in the measured layers (0.4 - 2 m). 40 year-old sessile oak stand (Zemplén Mountains, 2015).

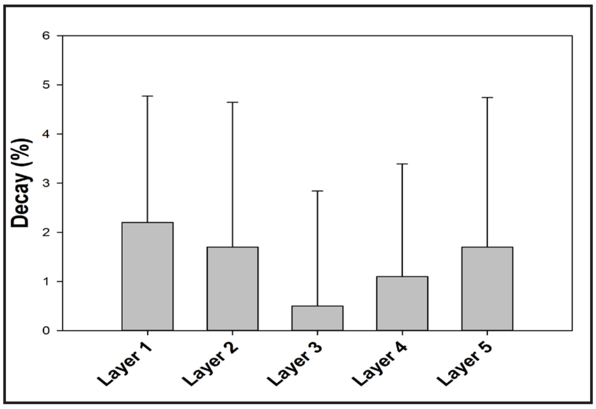


Figure 3. State of wood-decay in the measured layers (0.4 - 2 m). 60 year-old sessile oak stand (Zemplén Mountains, 2015).

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3.04%. The two thirds of the investigated layers of the stand were totally healthy, 22% showed 0-5% of damage, 12% seemed to have bigger than 5% of decomposition so that the highest decay value was 10%. Among the 10 sample trees there was only one which had all of the 5 measured layers entirely healthy. There were 5 specimens with one damaged layer, 2 specimens with 2 deteriorated layers and with the rest 2 specimens there were 3 and 4 decayed layers, respectively.

The trend of the 80 years old group has changed dramatically so that it became the opposite as we experienced in the 20 and 40 years old group. From the first layer – measured at 40 cm height – continuous reduction can be seen towards the 5th layer located at 200 cm height (Fig 4). The closest layer to the soil surface showed higher degree of deterioration (with the average of 4.1%). Even though among the 10 specimens 7 were entirely healthy in this layer, 2 had the decomposition of 3%, but the rot of the 5th specimen had been measured 35%. Better health state had been experienced in the 2nd layer, since its decay was only 1%. Altogether 2 specimens presented deteriorated health state, in one case the rot of the cross-section reached 8%, while the other specimen had 2% of decay. From the 3rd layer decomposition could be hardly experienced, the 3rd layer had 0.6% and the 5th layer had only 0.2%. For the latter ones the highest value of decay was 3% and the 73.3% of the layers were totally healthy. The standard deviation was the highest (6.75%) in the first layer, while the other layers showed far lower standard deviation values (1.97% és 2.81%).

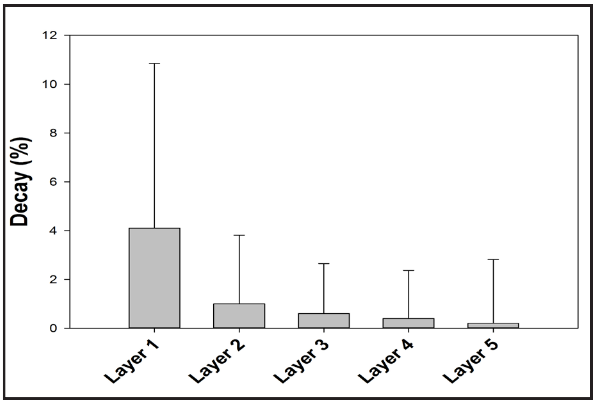

Figure 4. State of wood-decay in the measured layers (0.4 - 2 m). 80 year-old sessile oak stand (Zemplén Mountains, 2015).

The 100 years old group followed the same trend that we formerly used to experience with the 80 years old group (Fig 5). The lowest layer possessed the worst health state; the degree of decomposition decreased linearly towards the 5th layer. The standard deviation values have been observed to be high in the first 2 layers (8.46% and 5.86%). Compared to them the upper 3 layers had less fluctuation and the standard deviation values varied from 1.78 to 2.65. Within this group 3 sessile oak tree with worse health state have been measured too. Within certain age groups the examined layers showed no significant deviation. Compare to that the layers of the second youngest age group (40 years) and the layers of the two oldest age groups (80 and 100 years) indicated statistically proved significant deviation ($p<0.05$). In case of the age groups are evaluated separately, the value of the rottenness expressed by the software in percentage is suitable for comparing certain layers

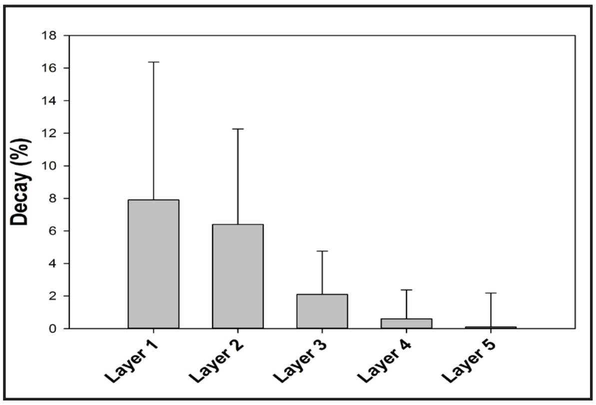

Figure 5. State of wood-decay in the measured layers (0.4 - 2 m). 100 year-old sessile oak stand (Zemplén Mountains, 2015).

or sample trees, evaluating the presented trends among them. However, comparing the age groups with this method is not possible because there is appreciable difference among the trunk diameters which concerns the extension of the rottenness.

The Figure 6. shows the values of the rottenness of the examined age groups in percentage and in cm2. The Exponential growth (single, 2-parameters) had the most strictly, significant

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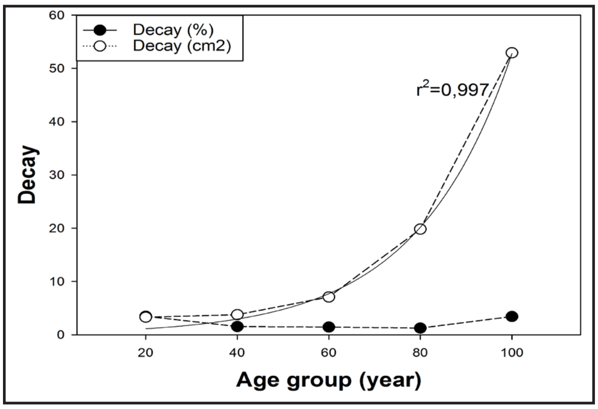

Figure 6. The rottenness of certain age groups expressed in percentage and in layer's extensions

(p<0.001) correlation among the rottenness based on the layer's extension, expressed in cm^2.

The diversity of the canopy

The forestry has the biggest effect on the species composition of the canopy, since the forest managements have also influence on the species pool and on the cover values through the future forestry practices. The natural resources and the climatic factors play an important role in the combination of species, as the possibly dominant species are determined by them.

Table 2. The distribution of the closeness of the canopy in certain age groups

Age groups	Closeness (%)
20	70
40	70
60	70
80	75
100	72,5

The closeness of the canopy of certain age groups are presented in Table 2. Significant deviation is not observed in the closeness among certain age groups, so thus this has no influence on the diversity values.

The 80 years old group had the biggest diversity value from that the other groups lagged behind (Fig 7). The diversity of the 40, 60 and 100 years old stands were similar to each other, compare to them the diversity of the 20 years old group was slightly higher. These differences could predict that the other tree species could not be able to find their essential necessities due to the process of forestation.

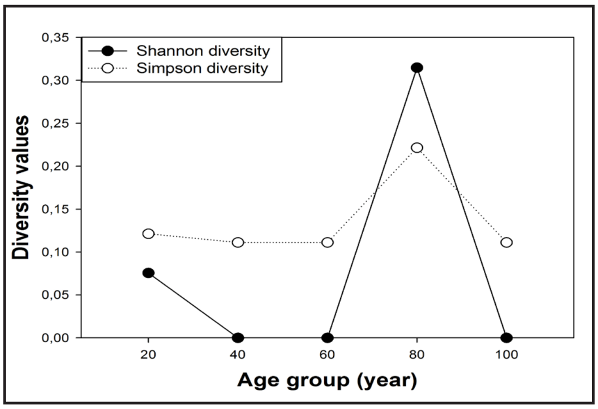

Figure 7. Shannon and Simpson-diversity values in the studied age groups of canopy layer (Zemplén Mountains, 2015).

The biggest distinctions have been realised between the Shannon and Simpson diversity indices in some groups when the canopy had consisted only of sessile oak. This phenomenon could be explained with the shallow topsoil of the Zemplén Mountains and the bad water management of the soils. Within these stands the Shannon index regularly has the value of 0, while the Simpson index has the value of 1.11 (Fig 7).

Based on the different sensitivity of the indices the Simpson diversity had higher values, since this index is rather sensitive for wide range tolerance and abundant species. In the 80 years old group where specialist species have been presented the Shannon index showed the higher value.

The diversity of the shrub layer

Besides the canopy the forestry management practices has strong effect on the combination of species of the shrub layer and its cover values too. The shrub layer has often been deliberately removed, or sometimes the managements of the canopy have such a huge disturbance so that the coverage of some species decreases. Furthermore the ratios within the combination of species could be shifted towards the disturbance tolerant species due to the influence of the disturbances.

In the case of the shrub layer bigger diversity was expected in the younger stands too that statement has seemed to be verified by the

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surveys. Despite the higher species diversity in the younger stands less coverage values have been recorded probably caused by the disturbances.

Within this layer between the two indices have significantly higher difference than in the case of the canopy (Fig 8). Generally the values of

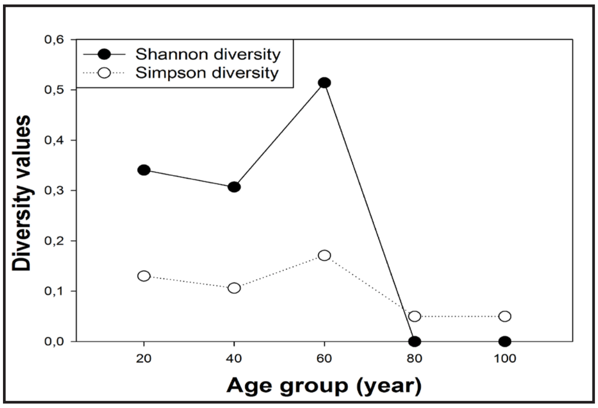

Figure 8. Shannon and Simpson-diversity values in the studied age groups of shrub layer (Zemplén Mountains, 2015).

the Shannon index are two times higher than the value of the Simpson index. Within the shrub layer there are also two groups where only one species has been presented, so that the value of the Shannon diversity is zero like in the former case.

The diversity of the ground layer

In the ground layer of the investigated stands 55 species have been surveyed. The values of the two diversity indices markedly differ from each other, but following the same trend in cases of

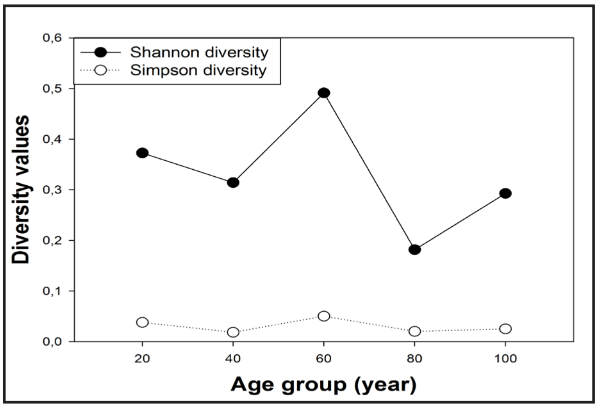

Figure 9. Shannon and Simpson-diversity values in the studied age groups of ground layer (Zemplén Mountains, 2015).

given age groups. The values of the Shannon diversity are always higher, indicating that the examined stands have high diversity, and are seminatural with several protected species. The most commonly appeared dicotyledon species were *Viola sylvestris, Campanula sp.* and *Gallium odoratum*. Because of the shallow topsoil of the examined stands of the Zemplén Mountains relatively low coverage values have been estimated, however this has not affected significantly the number of species (Fig 9).

There are no significant deviation in the case of both indices of the canopy and the shrub layer. On the other hand, in the case of both indices of the canopy and the ground layer indicated significant deviation ($p<0.5$), while among the shrub and the ground layer only the Simpson diversity had significant deviation ($p<0.5$).

Discussion

Our measurements complete the ongoing EVH I status survey since 1988. This survey measures the health state of the stands located in the intersections of the16x16 km grid considering 8 types of damages (game, insect, fungi, abiotic, anthropogenic, fire, other damage, degradation) (Hirka et al 2015).

The expediency of instrumental measurements is confirmed by the fact that accomplishing the measurements not only the accurate pictures of the degree of decomposition is achieved, but also the reasons of decay could be revealed. So thus the responses of the stands due to the extremities in climate parameters could be determined more precisely.

Among the stands the 80 years old age group proved to be the healthiest, while the 20 years old group had the worst values, but the decay of all age groups were less than 5%.

In this examination two facts can be for responsible for the evolution of deterioration. The observed decay in the younger stands that typically concerned the upper layers. The reason of this could be the evolution of the frost cracks since the rottenness and the recorded frost cracks located in the same places. The deterioration of

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these trees could be seen by visual observations too, and they have been extracted during the later thinning. Hence this type of decomposition do not affects the older stands. In those stands the large-scale devastation of the lower layers is typically continuously reducing towards the higher layers. This type of decay concerns the coppice trees, since the trunk of the formerly extracted trees started to decompose that proceeded towards the coppice too.

According to the coenological evaluations and the diversity indices the examined stands have high diversity and are seminatural ones. Despite the fact that the aspect of nature conservation receives bigger and bigger emphasis on the field of forestry, the latter often negatively affects the diversity of some layers. This statement has been verified by the diversity values too. The diversity values of the shrub layer and the ground layer followed the same trend. The shrub layers of low diversity belong to similarly low diversity of ground layer, and this correlation could be observed in case of high diversity too. Presumably, this could be explained with the fact that when the disturbance influenced the shrub layer, it had affected collaterally the ground layer too. Furthermore, the closeness and the density of the canopy directly influence the amount of light reaching to the deeper layers, thus it has an effect on the diversity and on the coverage values too.

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