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DOCTORAL SCHOOL OF ENVIRONMENTAL SCIENCES

FOREST DYNAMICS ASSESSMENT OF NATURAL OLD-GROWTH FORESTS IN RELATION TO CLIMATIC EXPOSURE

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1. Background and objectives of the work

The increasing trends and prospects of global climate change are one of the greatest challenges facing humanity. The climate crisis affects all sectors of society and is manifested in all regions, posing an increasing threat to the security of future generations (Field et al. 2014, IPCC 2014, 2019). Climate has a decisive influence on species behaviour and therefore also affects ecosystem processes (Lindner et al. 2010, Liang et al. 2017, Petersson et al. 2019). Climate exposure is defined by the IPCC as "the type and extent of external influences and climatic changes that occur on the system under study" (IPCC 2001). Diversity, which refers to the diversity of habitat structure elements and successional processes in addition to species diversity, plays a significant role in the stability of ecosystems (Keith & Peterken 1996). The sensitivity and life history of community is reflected in population processes. One of the major challenges of nature conservation today is to maintain the biodiversity of habitats in the face of climate change, increasingly fragile ecosystems in a highly anthropogenic environment. It also has the task of helping natural habitats to adapt and keeping successional processes in natural way as it is possible (Milad et al. 2011). These efforts are very hard by the degradation of the landscape and the unstoppable spread of alien species (Opdam & Dirk 2004, Langmaier & Lapin 2020).

Using analyses of measured meteorological data series and CO2 emission scenarios and using global and regional climate models can produce predictions for the future. These projections can provide insights into the type and magnitude of changes expected at the regional level and the areas most vulnerable to climate change (Dobor et al. 2015, 2016, Kern et al. 2019). They can also help develop more effective methods for conservation, for example, to promote the functioning, natural processes and adaptation of species and natural systems. In the case of forests, we can expect changes in the dominance and mixture tree species and in the intensity of their production.

Understanding the responses of different forest types and tree species to climate change is made possible by research focused on natural processes, with the best settings being unmanaged habitats that are functioning well after abandonment (Sabatini et al. 2020). The specificity of forest reserves is that their core areas have not been managed for decades, so their functioning is determined by natural forest dynamics, allowing us to gain insights into: the after-effects of past management, the characteristics of the natural forest landscape and the relationships between forest structural elements and species/species groups. The national forest reserves are decades of abandoned stands, many of them old-growth forests of high conservation value, which are home to a number of highly protected species. The main objectives of the Forest Reserve Programme are to ensure the conservation of selected forests and to understand forest dynamics. The Forest Reserve Programme's Long-Term Surveys (ER-HTV) are based on the designation of a fixed sampling point network and a condition assessment. The baseline surveys and the re-surveys, which are repeated at certain intervals, are carried out according to a standardised protocol (Horváth, 2012).

Objectives:

1. to describe recent and projected climatic exposures in the study areas/forest reserves.

2. to develop, test and evaluate a method for re-survey and data processing of long-term studies of forest reserve research.

3. To solve problems encountered in re-survey as a quality control and to present the methods used.

4. To describe changes in tree stand structure of different forest types and to evaluate them from a forest/population dynamics perspective.

5. to assess the (potential) effects of climatic exposure.

2. Material and method

Areas studied

As sampling sites for my research topic, I have chosen forest reserves where former surveys have already been carried out according to the ER-HTV protocol. The forest reserve research team repeated the data collection in the core areas of six forest reserves, which were Hidegvíz-völgy, Szalafő, Nagy-Istrázsa-hegy, Várhegy, Kecskés-galya and Kékes forest reserves, taking into account the previous survey. In the selection of sampling points, I considered the concept of climatic exposure study, therefore the data were taken from mountain and hill stands of mesic forest types like; beech and hornbeam-sessile oak, and dry forest types; turkey oak- sesslie oak and downy-oak. A total of 233 sampling points were resurveyed.

Estimating the climatic exposure of forest reserves

The climatic exposure of forest reserves was assessed using 30-year averages of mean temperature, precipitation sum and forest drought index (Führer et al. 2011, 2018), highlighting the reference period 1951-1980, 1991-2020 (including baseline and re-surveys), and estimating the expected exposure for the period 2071-2100. Meteorological data were retrieved from FORESEE (Open Database FOR ClimatE Change-Related Impact Sudies in CEntral Europa) free-access database with 1/6° × 1/6° grid resolution (Dobor et al. 2015). Climate data were retrieved from the database from the 1950s to 2100 for cells covering the area of selected forest reserves. To retrieve data for the future period 2020-2100, I selected the Aladin-Arpege, Hirham5-Echam5 and Regcm3-Echam5 climate models. The MTCLIM microclimate simulation model was used to further refine the regional climate models for field conditions.

The tree structure surveys

Standard data collection for the tree stand structure and lying deadwood survey was carried out according to the standardized protocol of the Long-term Forest Reserve Program Surveys (ER-HTV). During the survey, the exact location of individuals was recorded, which is their distance and angle from the centre of the sampling point (MVP). The survey was double-combined sampling, i.e., we recorded trees above 5 cm diameter at breast height within the 250 m2 sample area and those outside the sample area (but included in the sample according to the Bitterilch-method). Thin trees (<25.23cm d130) were evaluated according to the sample circle sampling, and thick trees (>25.23 d130) according to the Bitterlich-method. The re-survey of tree species was also a quality assurance of the data; problematic cases and errors were encountered during field recording and data entry, which provided an opportunity to develop quality control and error correction procedures. I applied a trunk reconstruction procedure for those specimens that were missed in the baseline survey or difficult to measure becouse of trunk problems. I calculated the annual growth of tree species and shrubs (or species groups in the case of a small number of samples) per forest reserve and forest type over the period between surveys, based on the diameter of the trees recorded.

Aspects of data analysis and statistical methods

For the structural and population dynamics assessment of the tree population, the basic parameters used were stem number per hectare (N - number of trees per hectare), basal area (G - m2/ha) and tree-volume (V - m3/ha). The samples are complementary, so the stem number, basal area and tree-volume per hectare were calculated additively by summing the shares of the sampled trees. Forest dynamics variables were calculated using parameters of regeneration, growth, mortality and decay, taking into account the time between surveys. Data were analysed for tree stand structure and forest dynamics variables and their relationship with climatic exposure, statistical analysis was performed in R environment. Principal Component Analysis (PCA) was used to explore the relationship between the tree stand structural variables. I used a statistical t-test to compare the changes in tree stand structural variables between the first and second survey. I treated the mesic and dry forest types as separate groups (the PCA results separated these two groups most clearly), and the significance levels and p-values are summarized in tables. I divided the surveyed individuals into different groups according to their growth form (character) and their role in the stand. The forest dynamics variables of the species groups were compared using the Kolmogorov-Szmirnov non-parametric statistical test. The test was used to compare the differences in the distributions of variables for the forest types mesic and dry, including beech, hornbeam-sessile oak, turkey oak-sssile oak and downy-oak. A general linear model was used to investigate the possible effect of climatic exposure as an independent variable on changes in stand structure variables and forest dynamics variables as dependent variables, again grouping the mesic and dry types separately.

3. Presentation of results

In the selected forest reserves, the FAI and the frequency of dry years increased in all cases until 2020, resulting in a forest-climate zone change at Várhegy and Kecskés-galya. Although the change in the 30-year average drought index in the Hidegvíz-völgy and Szalafő, which are located in areas with a wetter and cooler climate, has exceeded that of these reserves, the zone didm't change, and it has occurred to the higher proportion of years with a beech and hornbeam-sessile oak climate category. Comparing the first and second time-windows, the Nagy Istrázsa-hegy can be considered as averagely exposed. The Kékes was found to be the least exposed, with years with favourable weather conditions for the mesic forest types also being much more frequent in the period of 1991-2020. Average temperatures increased the most (1.5°C) at Szalafő, while the other reserves increased by 0.8-0.9°C. Average precipitation totals have changed less for Szalafő, Kékes and Hidegvíz-völgy, while at Nagy Istrázsa-hegy it has already decreased spectacularly by 40 mm compared to the first time window (611.23mm>>>570.51mm). There are discrepancies and uncertainties in the regional climate models' estimates for the future, which are mainly reflected in the precipitation data. If we look to the end of the century using our models, we can see an extraordinary increase in the climatic exposure of forest reserves compared to the first and second periods. In the period of 2071-2100, several forest-climate zone changes are expected to occur at each of these sites. The most exposed of the reserves is the Nagy Istrázsa-hegy, with a drought index increasing by 5-6 values, and the number of years with turkey-oak and forest-steppe is also high. The smallest change in the drought index, but still almost 0.9-1, is expected for the Hidegvíz-völgy and the Szalafő, which are also affected by the forest-climate zone change and whose exposure will increase towards the end of the century.

Based on the principal component analysis of the tree stand structural variables, the sample points of the mesic and dry forest types are well separated in their structural characteristics. In the PCA-12 version of the analysis, the first two component relationships within the multivariate space show that the dominant tree species; beech, sessile oak and downy oak have the strongest significance. There is a strong correlation between the proportions of shrub and downy and turkey oak and the grassland cover is also correlated with the two species. There is also a strong correlation between the upper canopy cover, and the proportion of beech, while sessile-oak is strongly associated with second canopy cover.

A comparative analysis of the changes in forest types shows that beech and other tree species show significant changes in the case of the mesic forest types, while the dry forest types show significant changes in the case of the sessile oak, field maple and other tree species. There are significant differences in closure for all forest types, but significant changes in leveling are observed in the upper canopy level of the mesic forest types. The number of live trees per hectare decreased in the beech and hornbeam-sessile oak forest types between the surveys, while it increased slightly in the dry oak forest types. In the latter case, it is mostly due to the regeneration of mixed species and shrubs. Both types show a decrease in the basal area and tree-volume per hectare, which is more pronounced in the mesic forests. Overall, in these variables, the tree species of the mesic forest types show greater changes, with the most significant changes in basal area of beech and other species. The amount of fallen trees increased in all forest types, but not significantly. Changes in stand structural characteristics between two surveys do not show a significant dependence on climatic exposure. The analysis shows that only the development of the grassland level of the mesic forest types has a weaker but significant dependence on climatic exposure.

To study the population dynamics of tree species, I have developed a framework for categorising tree species according to their life history (phases and turning points). These categories are similar to the variables describing tree stand structure (such as density, proportion and dominance), but I used annual values calculated from aggregated values of tree-historical events to characterise stand and species dynamics. Among the species, the regeneration of cornus and common hazel is outstanding, as well as that of shrub hawthorn species and field maple. In the case of shrubs, it is important to note that we can't speak in-growth regeneration. Based on the averages of annual growth, it can be said that the most significant changes in the period between the surveys occurred in the stand-forming tree species, with the flowering ash being the most notable among the mixture tree species, but also the shrub species showing a strengthening of the shrub layer. The average annual mortality is highest for common birch, common hazel, and lowest for lime, early maple and turkey oak. Of the main tree species, the average annual mortality is highest and nearly the same for the other component species, except for turkey oak.

My analysis compared the population dynamics of the four forest types. There are significant differences between the forest dynamical variables of the different forest types, especially in the annual regeneration. Regeneration of tree species in the upper canopy level is much higher in the mesic forest types compared to the dry types, but the regeneration rate of shrub species is stronger in the dry forest types. Overall, beech has the lowest variation, with a much higher number of young trees and shrubs in all forest types. There are also significant differences in growth in terms of tree-volume between dry and mesic forests. Also for this forest dynamics variable, the growth of high-growing species is more pronounced. There are differences in mortality trends, but they are significant between hornbeam-sessile oak and turkey oak-sessile oak stands. The annual amount of wood in the decay phase is highest in downy oak stands, but overall this variable shows little difference between forest types.

Among the tree dynamics variables, I investigated the dependence of annual regeneration and mortality on climatic exposure for the above-mentioned tree species groups (upper-, lower-canopy-, and shrub and shrub species). However, the dependence on climatic exposure was not significant for any of the groups.

4. Conclusions and proposals

Several studies on the estimation of climatic exposure have demonstrated the importance and the determining role of site microclimatic conditions and soil factors in the species composition of forest stands (Léesque et al. 2016, Árvai et al. 2018, Bose et al. 2020, Weigel et al. 2023). However, the available meteorological data series do not adequately reflect the specific microclimatic conditions of the terrain. The data can be further refined by using a microclimate simulation model, MTCLIM (Thornton & Running et al, 2000), but as the model was developed for high mountain conditions, it does not provide an estimate the fine scale that fits well with the scale of the 50x50m sampling point network of the Forest Reserves. For this reason, the values of the Forest Drought Index (Führer et al. 2011, 2018) were applied to the area of forest reserves and not to the sampling points, which representing different forest types. When analysing the predictions, the estimating rainfall and its distribution is difficult due to the variability of this parameter. Measured weather data from the FORESEE meteorological database show an increase in climatic exposure in all forest reserve areas compared to the base period. Taking into account the weather trends of the last decades is expected to increase by the end of the century, as supported by regional climate model estimates (Kjellstro et al. 2011, Räisänen et al. 2016, Dosio et al. 2020). This future trend is expected to lead to higher average temperatures, less precipitation and an increase in the frequency of dry forest-climate years based on FAI values.

The set of variables under study can be divided into two groups: the structural tree population variables and the population dynamic variables. From the preliminary data evaluation, it is evident that the stand-structural characteristics of the forest types are separated into dry and mesic forest types, and therefore further analyses of the variable groups were carried out from this point of view. The variables showing the greatest variation between surveys are the sum of the basal area of the mesic forest types, the proportion of beech and other species, and the proportion of other species in the dry forest. The dependence of the variables on climatic exposure is not significant.

I have developed a new framework for population biological assessment. The Central European approach to forest dynamics is based primarily on models of forest cycle phases rather than on population biological models of tree individuals. When describing the intrinsic drivers of forest dynamics, the dynamics of living and dead trees are usually investigated and evaluated separately (Vrska et al 2015; Huber et al 2020; Meyer et al 2021; Woods et al 2021). However, tree population dynamics are closely related to mortality events. The framework I propose is an appropriate approach to fill this gap. Because of the ecological role of dead trees, I propose the introduction of a new parameter; the assessment of lying dead trees and the monitoring of their condition change (Szegleti et al 2023). I have prepared the population dynamics assessment from this approach in terms of life history stages and events of tree individuals. There are significant differences in the annual values of population dynamics between the different tree species traits (upper canopy species, lower canopy species, shrub species) of the forest types, with a significant difference between downy oaks and other forest types. Among the population dynamics variables, I investigated the dependence of regeneration and mortality on climatic exposure by these tree species groups. Similar to the tree stand structure variables, these variables did not show a significant dependence on climatic exposure.

Variable influences and conditions go to changes in forest structural properties and population processes of tree species, which can vary between forest reserves (Vrška et al 2015; Meyer et al 2021). When analysing variables, it is important to consider, for example, the after-effects of past forest management. A detailed forest history of the reserves would be very much needed for a multidisciplinary analysis of forest dynamics. In the case of Várhegy, the current forest structure is influenced by the stand's origin and the oak mortality that occurred a few decades ago. These factors lead to the thinning of the oak stands on the Várhegy, and the composition of the new growth filling the gaps is also influenced by several factors. The same can be said for the Hidegvíz-völgy, where the decline and mortality of spruce trees causes change in the proportion of the population. In Szalafő, the process observed is a gradual decline of pioneer tree species and an increase in forest closure and density, which leads to a change in species composition from herbaceous to canopy level. The success of tree species regeneration depends to a large extent on the wild games. The significance of this is best illustrated by the example of the Nagy Istrázsa-hegy, which is the only one of the forest reserves studied to have a fenced core area. Thanks to game exclusion, the new growth level is hardly affected by the consumption of herbivorous big game. In contrast, in the light- and xeric oaks of the Kecskés-galya, the new growth is under enormous pressure from game. These thicketed forests are a favourite daytime resting place for wildlife, and even in winter, large game groups still retreat to these areas in the southern part of Beech-mountain. Overall, in addition to climatic effects, it is worth taking into account the specific characteristics of the sample areas and other abiotic and biotic effects on the population, as well as habitat characteristics.

5. New scientific results

I calculated the values and changes in Forest Drought Index (FAI) for the six forest reserve areas, which I examined over three selected time windows (1951-1980, 1991-2020, 2071-2100). This was used to estimate the change that has already occurred compared to the baseline period, and the climatic exposure expected by the end of the century. I have presented the most important changes that have occurred and are expected to occur in the future in the climatic conditions of forest reserves, which I have also assessed by forest-climate class. My analyses confirmed that all forest reserves have experienced an increase in climatic exposure, with an increase in average annual temperature, a decrease in precipitation, a decrease in years with a mild climate and an increase in FAI. The highest exposure to date has occurred in the case of the Szalafő forest reserve, with the least exposure in the Kékes forestreserve. As these trends increase, a deterioration of one or two degrees in the forest climate zones is expected in all cases by the end of the century. In the future, the Hidegvíz-völgy is expected to be the least exposed forest reserve, while the climatic exposure of the Nagy Istrázsa-hegy will increase the most.

Based on the experience of the re-surveys and a literature review, I developed a methodological framework for evaluating population biological processes. The concept of the new framework is to monitor the entire life cycle of trees from regeneration through growth and mortality to complete decay, i.e. it includes the stages and turning points in the life and mortality history of trees. The new perspective is unique in that it takes the dynamics of living and dead trees together. I have used this new approach to evaluate the data. Based on the results, I have proposed improvements to the ER-HTV survey protocol and an evaluation of the re-survey data from a population biology perspective.

The field re-survey was carried out in terms of quality control of the previous former survey, so new procedures were used to correct any errors that occurred. I developed a reconstruction method to replace the diameter of missed or incorrectly recorded individuals. This avoids data loss and allows for correction. Further suggestions for quality control have been summarised and presented, which will help in the long-term study of forest reserves in the future.

I evaluated the relationships and changes in tree stand structural variables between the two surveys by dry and mesic forest types. My results showed that there were several significant changes in the mesic forest types; the most significant changes were in the sum of the basal area per hectare, the proportion of beech and the proportion of other tree species. For dry forest types, the change in the mixture of other tree species is significant.

I evaluated the trends and differences in population biological variables by comparative analysis of four forest types and different species groups. The analysis showed significant differences mainly between regeneration, growth and mortality processes of tree species groups of dry forest types (downy-oak and turkeyoak-sessile-oak) and mesic forest types (beech and hornbeam-sessile oak). The dependence of population biological variables on forest type was also investigated and presented. In this case, aggregate regeneration and upper canopy mortality showed the strongest significance for the mesic forest type, and lower canopy regeneration and shrub regeneration and shrub mortality for the dry forest type.

Finally, I examined the dependence of stand structure and population biology variables (regeneration and mortality of tree species groups) on climatic exposure, which suggests that these variables are not sensitive indicators of climatic exposure. However, their relationship should be investigated with more detailed climatic data sets, measurements and the inclusion of several factors.

6. List of scientific publications

In a foreign language, non impact factor journal:

1.Szegleti Zs., Czóbel Sz., Zimmermann Z., Horváth F.(2019): How do Central-European forest stands respond to climate change – Review, Columella, Journal of Agricultural and Environmental Sciences Szent István University Press Gödöllő

In a foreign-language, impact-factor journal

1.Szegleti, Zsófia & Vig, Ákos & Ortmann-Ajkai, Adrienne & Szabó, Gábor & Zimmermann, Zita & Horvath, Ferenc. (2023). Repeated stand structure inventory dataset in long abandoned deciduous forest reserves in Hungary. Data in Brief. 47. 108929. 10.1016/j.dib.2023.108929

Domestic edition

1.Szegleti Zsófia, Csicsek Gábor, Szabó Gábor, Zimmermann Zita, Bölöni János, Horváth Ferenc (2017): Erdőtermészetesség szempontú értékelési módszer a Pannon életföldrajzi régió Natura 2000 erdőtípusainak szerkezet és funkció monitorozása alapján. TERMÉSZETVÉDELMI KÖZLEMÉNYEK, 23. pp. 100-117. ISSN 1216-4585v

2.Falvai Dominika, Baltazár Tivadar, Szegleti Zsófia és Czóbel Szilárd (2020): *Picea abies* és *Pinus mugo* fafajok egészségi állapotának vizsgálata a Wechsel-hegység természetközeli erdőállományaiban. Természetvédelmi Közlemények 26: 16–27. https://doi.org/10.20332/tvk-jnatconserv.2020.26.16

3.Horváth Ferenc, Bíró Attila, Csicsek Gábor, Demeter László, Lipka Borbála, Papp Mónika, Szegleti Zsófia, Vig Ákos Kornél (2021): Fényi-erdő - egy erdőrezervátum jelölt. Erdészeti Lapok 156(02): 47-50.

4.Horváth Ferenc, Csicsek Gábor, Papp Mónika, Szegleti Zsófia, Vig Ákos Kornél (2021): Az újszentmargitai Tilos-erdő Erdőrezervátum. Erdészeti Lapok 156(03): 87-89.

Conference publications

Hungarian abstract

1.Szabó Gábor, Szegleti Zsófia, Zimmermann Zita, Penksza Károly: Botanikai, természetvédelmi és gyepgazdálkodási vizsgálatok Balatonfelvidéki szarvasmarha-legelőkönIV. Fenntartható fejlődés a Kárpátmedencében" konferencia, Hódmezővásárhely, 2019, Absztraktkötet, 74p.

2.Szegleti Zsófia, Szabó Gábor, Zimmermann Zita, Penksza Károly: A természetvédelmi kezelés hatásai a dinnyési-fertő szikes gyepjeire, IV. Fenntartható fejlődés a Kárpátmedencében" konferencia, Hódmezővásárhely, 2019 Absztraktkötet 79p.

3.Szegleti Zsófia, Szabó Gábor, Zimmeremann Zita, Vig Ákos Kornél: A Nivegy-völgy és környezetének élőhely-térképezése és védett értékeinek felmérése, IV. Fenntartható fejlődés a Kárpátmedencében" konferencia, Hódmezővásárhely, 2019 Absztraktkötet 80p.

4.Zimmermann Zita, Szegleti Zsófia, Szabó Gábor: A nyugati földikutya [Nannospalax (superspecies leucodon)] túrásainak hatása a tompapusztai löszgyep vegetációjára IV. Fenntartható fejlődés a Kárpátmedencében" konferencia, Hódmezővásárhely, 2019 Absztraktkötet, 86p.

5.Szabó Gábor, Pápay Gergely, Szegleti Zsófia, Péter Norbert, Penksza Károly: Festuca vaginata és Festuca pseudovaginata dominálta nyílt homokpusztagyepek biomassza-vizsgálatai. In: Tinya Flóra (szerk.): 12. Magyar Ökológus Kongresszus – Előadások és poszterek összefoglalói, p. 200.

6.Szabó, Gábor ; Zimmermann, Zita ; Andrea, Catorci ; Csontos, Péter ; Wichmann, Barnabás ; Szentes, Szilárd ; Szegleti, Zsófia ; Penksza, Károly: Cönológiai vizsgálatok nyílt homoki gyepekben. BOTANIKAI KÖZLEMÉNYEK 105 : 1 p. 164 , 1 p. (2018)

7.Horváth Ferenc, Bede-Fazekas Ákos, Csicsek Gábor, Molnár Ábel, Szegleti Zsófia és Demeter László (2019): Milyenek lehettek kocsányos tölgyes őserdőink? Erdőrezervátum-kutatás keményfás ligetekben**,** Biodiverzitásról másképp előadóülés-sorozat IV.

1.2.2. Foreign abstract

1.Zsófia Szegleti, Ferenc Horváth (2018): Climatic exposure of natural upland forest stands: What impact will be expected by the end of 21th century?, 5th Forum Carpaticum Adapting to Environmental and Social Risk in the Carpathian Mountain Region, Eger 15th-18th October 2018, ISBN:978-615-5270-48-2 Book of abstract, 136p

2.Zsófia Szegleti, Ferenc Horváth (2019): Climatic exposure of natural upland forest stands: What impact will be expected by the end of 21th century?, SCCS Europe, 2019, Tihany 15th-18th Augustus 2019

3.Kun, R., Babai, D, Csathó, A. I.3, Erdélyi, A., Hartdégen, J., Lengyel, A., Kálmán, N., Szegleti, Z., Víg, A., Máté, A., Mártonffy, A., Hábenczyus, A. A, Malatinszky, Á., Vadász, C.:

Effects of grassland management elements on diversity and functional state of species rich meadow steppes in the southern great plain region, hungary, 6th Croatian Botanical Symposium, 2019, Book of abstract, 50p.

Conducting a non-qualified professional plan, study or survey as a participant

1.Horváth Ferenc, Csicsek Gábor, Bíró Attila, Demeter László, Lipkai Bori, Neumann Szilvia, Papp Mónika, Szegleti Zsófia, Vig Ákos (2018): A Fényi-erdő Erdőrezervátum alapállapot felmérés: faállomány-szerkezet, újulati és cserjeszint, aljnövényzet a teljes magterületen. Kutatási jelentés, MTA Ökológiai Kutatóközpont, Vácrátót, 61 old.

2.Horváth Ferenc, Csicsek Gábor, Bíró Attila, Demeter László, Lipka Borbála, Neumann Szilvia, Papp Mónika, Szegleti Zsófia, Vig Ákos és Lesku Balázs (2018): Fényi-erdő - Égett kocka 2018-ban, ER Füzetek 1, MTA Ökológiai Kutatóközpont, Tihany, 16 old., DOI: 10.46441/ERF.2018.1

3.Horváth Ferenc, Csicsek Gábor, Lipka Borbála, Neumann Szilvia, Papp Mónika, Szegleti Zsófia, Tihanyi Gábor és Vig Ákos (2019): Az újszentmargitai Tilos-erdő Erdőrezervátum, ER Füzetek 2, Ökológiai Kutatóközpont, Tihany, 16 old.., DOI: 10.46441/ERF.2019.2

4.Szegleti Zsófia, Horváth Ferenc: Beszámoló a Szalafő Erdőrezervátum 2020-as felméréséről Őrségi Nemzeti Park, 2020

5.Horváth Ferenc, Csicsek Gábor, Gyurina Tamás, Neumann Szilvia, Papp Mónika és Szegleti Zsófia: a Baktai-erdő erdőrezervátum (er-24) magterületén erdő+h+á+l+ó létesítése és az egységes botanikai alapfelmérés (anöv) elkészítése 2019-ben,Vácrátót, 2019

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