Investigation of forest management effects on site conditions, regeneration and understory (NKFIH PD_17, PD123811)

Final report

Flóra Tinya

22. 01. 2021.

In the project, I studied the effect of commercial and conservation-oriented forestry treatments on the forest site, woody regeneration, and understory vegetetion, in the framework of two field experiments. The planned field samplings and data analyses have been implemented. 3 first-author papers were published, the fourth is submitted. My results give scientific evidences that continuous cover foresty (by gap-cutting) is applicable to regenerate commercial forests and besides, it helps to preserve forest biodiversity. Gap-cutting is a useful tool for conservation-oriented management, as well, to enhance the compositional and structural heterogeneity of homogeneous forest stand.

Field work

All field surveys were carried out according to the Work Plan. Microclimate, soil, regeneration, and understory vegetation were sampled every year, thus, currently we have seven-year long datasets in the Pilis Experiment (that started in 2014), and 3-4-year long datasets in the Garáb Experiment. In both experiment, measurements will continue, thus, besides the publications of the intital results, our data will contribute to long-term analyses. Only the sampling of the planted herbs in the Pilis was finished because the number of measurable individuals became too low. Additional understory and regeneration samplings were carried out in the Pilis in 2018 and 2020 (with light and soil moisture measurements), in order to obtain spatially more detailed information about the responses to the treatments.

Data analysis

All types of the collected data have been processed. In the Pilis Experiment, the response of microclimate, regeneration, and understory vegetation was published. In the Garáb Project, basic analysis of the data was done, however the regeneration responses were slow. We continue the data collection for some years to obtain enought strong results for publication.

In the Work Plan, we scheduled additional analyses based on our previous study (Őrs-Erdő Project), concerning the stand structural drivers of the regeneration and multi-taxon forest biodiversity. These analyses and publications have been also done.

In 2019, we joined to a COST Action (Biodiversity of Temperate Forest Taxa Orienting Management Sustainability by Unifying Perspectives, BOTTOMS-UP, CA 18207, https://www.bottoms-up.eu/en/) with our two experiments. I participate in the Action as a Working Group leader. Our WG studies the effect of management on biodiversity based on multi-taxon experiments, at continental level. As first task, we set up a network of experiments, thus our projects have been inserted to a European context. Being a participant and coordinator of the network enable us to up-scale our scientific experiences gained from our experiments to a higher, international level by doing common analyses with other similar experimental studies in the future.

Publications

As planned in the Proposal, four papers were submitted to international, Q1 journals, with my first authorship. Three of them have been published (drivers of regeneration based on the Őrs-Erdő Project – Tinya et al. 2019a, D1; understory response in the Pilis – Tinya et al. 2019b, D2; regeneration response in the Pilis – Tinya et al. 2020a, D1), one is submitted (Tinya et al., D1). Publication about the planted herbs in Pilis, and the regeneration in Garáb is planned for the near future.

I am co-author in three papers written by colleagues (initial microclimatic response – Kovács et al. 2018a, D2; 4-year microclimatic response – Kovács et al. 2020, D1; multi-taxon biodiversity response – Elek et al. 2018, D1). In Elek et al. (2018), NKFIH was represented in the Acknowledgement, but we missed to mention the number of the PD. One more publication (Aszalós et al.) is before submission about the six-year response of the understory vegetation.

According to our plans, our results were presented on international congresses (Ódor et al. 2018a, b, and 2020a, Kovács et al. 2020b, Tinya et al. 2018a), on national conferences (Kovács et al. 2018b, Ódor et al. 2018c, Tinya et al. 2018b, c), and for the Hungarian forestry profession via a presentation and a paper (Kovács and Tinya 2018, Ódor et al. 2020b). For the conservation practitioners, we planned to show our results on the 13rd Hungarian Conservation Biological Conference in 2020, but the event (and some other international and Hungarian congresses) was postponed because of the pandemic. If these conferences will be held in 2021, we plan to present our results on them. We published paper for the broad public, as well (Tinya 2020). Our bilingual (Hungarian–English) website (https://piliskiserlet.ecolres.hu/) offers information about our Pilis Project both for the scientific community (all of our publications are available there) and for the broad public.

In the framework of the BOTTOMS-UP COST Action, a report describing the network of European experiments was written (Tinya et al. 2020b), we plan to publish it as a paper in 2021. The network makes possible for us to involve our experiments into international publications in the future.

Scientific results

Őrs-Erdő Project – Drivers of forest biodiversity and regeneration

Based on our results, the main drivers of multi-taxon forest biodiversity are stand structure and tree species composition (shrub density, tree size, tree species richness, and proportion of Scots pine, oak, and beech in the overstory). Microclimate – that is also determined by the canopy and shrub layers – shows significant relationship with numerous taxa, as well. Forest site, landscape, and land-use history are much weaker predictors (Tinya et al., *submitted*). Detailed analysis of the regeneration revealed that saplings are also driven by the current forest stands (tree species richness, light, proportion of beech in the overstory, diameter heterogeneity of the trees, and large trees, Tinya et al., 2019b).

Consequently, the most important drivers of forest biodiversity are such environmental variables that are under direct control of the actual silvicultural management. Ensuring the structural and compositional heterogeneity of forests is a robust tool for conservation multi-taxon forest biodiversity.

Pilis and Garáb Experiments

I summarize our results along the three questions deliberated in the proposal.

1. How will the light, microclimate and soil conditions change after the treatments?

In the Pilis Experiment, shortly after the interventions, strong treatment effects were observed for the microclimate and litter variables, whereas soil characteristics remained similar. The increase in light was the highest in the clear-cuts and intermediate in the gaps (Fig.1.a, Tinya et al. 2019a). Air and soil temperature and vapour pressure deficit were the highest in the clear-cuts. Increase in soil moisture (Fig. 1.b), litter pH and litter moisture was significant in the gaps and to a smaller extent, in the clear-cuts (Kovács et al. 2018).

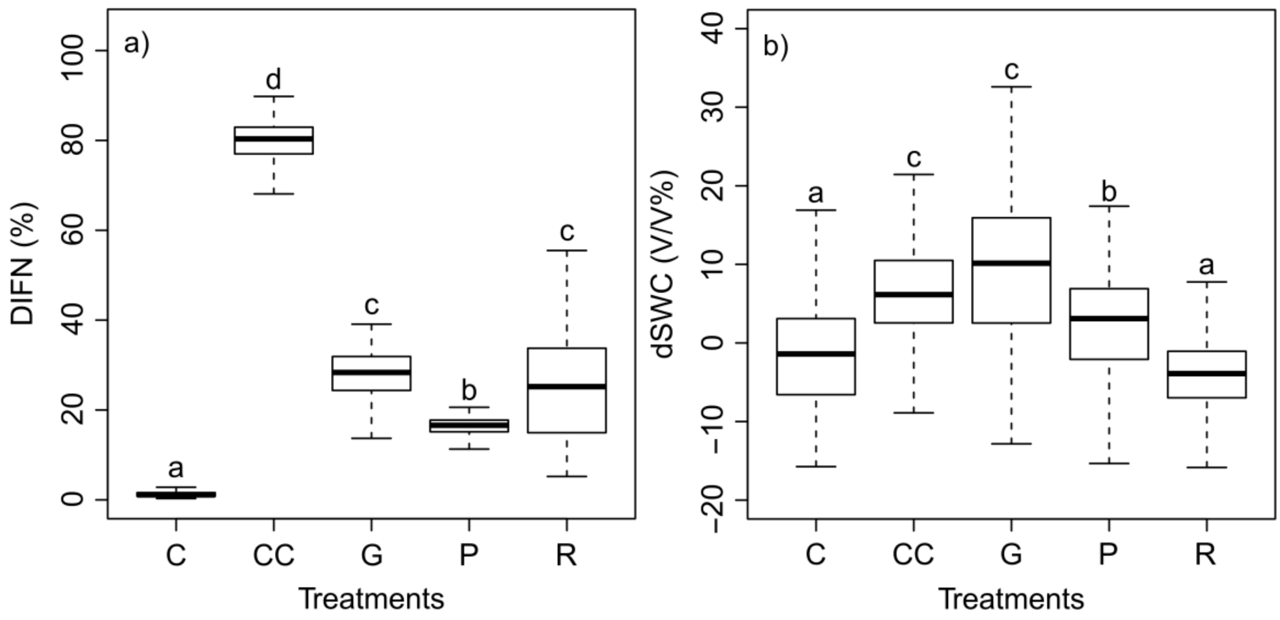

Fig. 1. Relative diffuse light (a) and relative soil water content (b) in the different treatments of the Pilis Experiment. C = control, CC = clear-cutting, G = gap-cutting, P = preparation cutting, R = retention tree group. Different letters mean significant differences ($P < 0.05$). Outliers are not shown (Tinya et al. 2019a).

After this immediate response of microclimate to treatments, in the next years, only weak trends were observable in the values of the microclimate variables, which means that the climatic recovery time is far longer (Kovács et al. 2020).

In the Garáb Experiment, range of air temperature and humidity proved to be slightly broader in gaps than in the closed stand, while mean and variance of the canopy openness was significantly higher in the gaps.

2. What kind of differences will be detectable between the treatments in the abundance and diversity of the natural regeneration and in the development of individual (natural and planted) tree seedlings? How will the different characteristic tree species of the investigated mixed oak forests respond to the treatments?

Despite the continuous seed availability, closed forests do not ensure proper conditions for regeneration, presumably due to low light availability and modest soil moisture. Survival was low, and height growth was almost zero for every species.

Compared to the closed forest, the applied treatments did not increase the species number of the regeneration significantly. Survival of the saplings increased in every treatment, but there was no significant difference in this measure between the differently treated sites.

In general, regeneration proved to be most successful in the clear-cuts and gaps. Despite the higher irradiance, most of the species did not grow better in the clear-cuts than in the gaps. It can be explained by its harsh conditions compared to the balanced microclimate of the gaps. Maximal increment of the shade-tolerant species was observable in gaps, while growth of *Quercus petraea* (sessile oak) was the largest in the clear-cuts.

In preparation cuts, the success of regeneration was moderate, due to the intermediate light and soil moisture conditions. Number of acorns was large, however, height growth of the saplings was weak. Growth of hornbeam and beech was significantly larger than in the control, but oaks and common ash could not grow in these sites.

Conditions of the retention tree groups (moderately increased light, relatively high temperature, and sparse vegetation) favoured the establishment of some woody species of forest edges and xerothermic forests. However, the low soil moisture precluded the growth of the saplings. Thus, retention tree groups are not the localities of successful stand regeneration, however, they can still contribute to it, e.g. via seed scattering, and by providing habitat for admixing species, thereby increasing forest biodiversity (Tinya et al. 2020a).

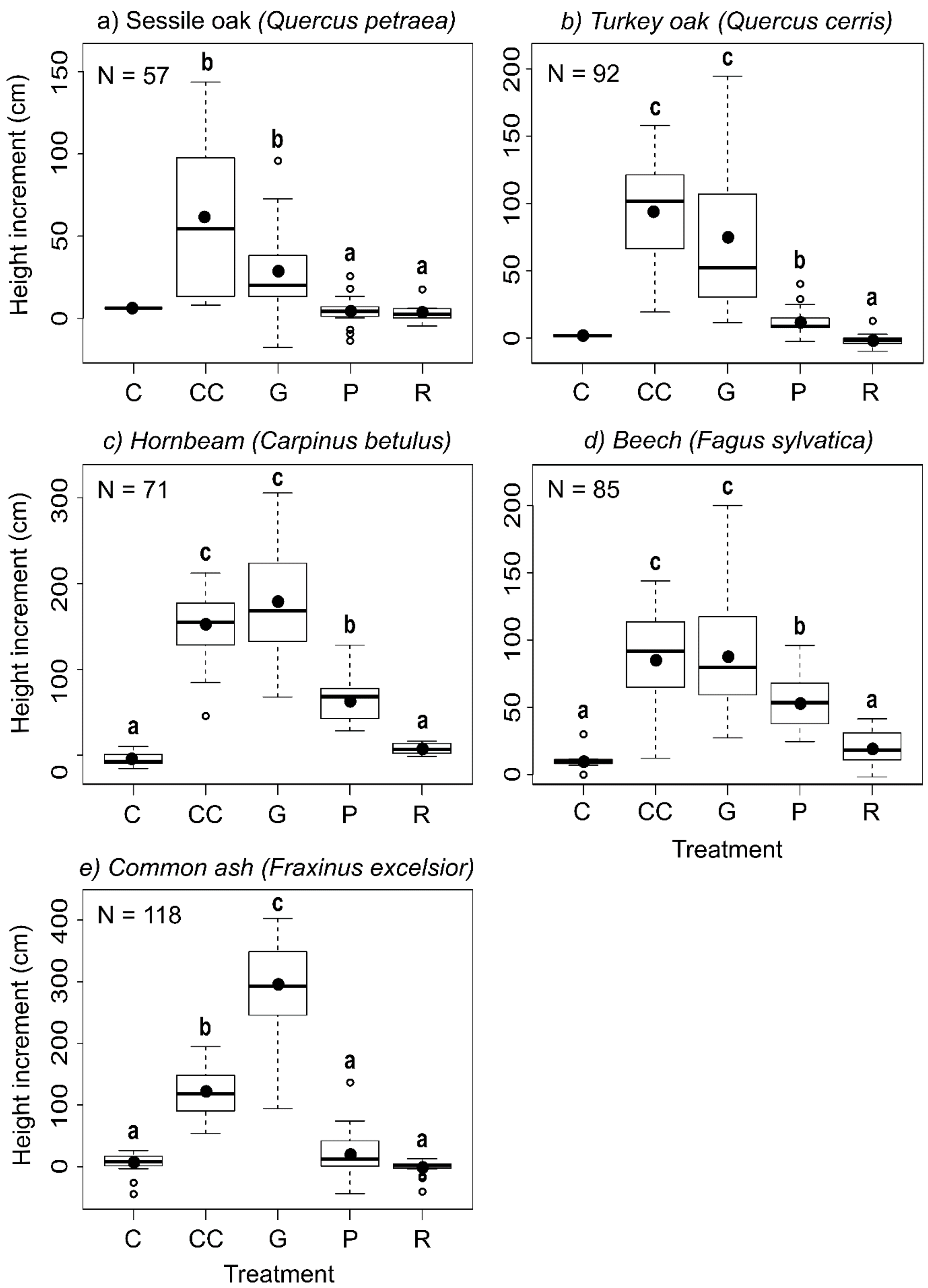

Fig. 2. Height growth of the planted tree saplings in the Pilis Experiment, between the first and the fourth year, in the different treatments (C = control, CC = clear-cutting, G = gap-cutting, P = preparation cutting, R = retention tree group) (Tinya et al. 2020a). Black dots represent the mean values. Dissimilar letters mean significant differences between the treatments ($P < 0.05$).

Based on the initial results of the Garáb Experiment, there are continuous trends in the response of saplings to gaps, but the differences are weak, yet. Congruent to our hypotheses, saplings are slightly larger in the gaps, and admixing species (*Acer campestre*, and especially *Sorbus domestica*) show stronger growth response in gaps than *Quercus petraea*.

3. How will the abundance and composition of the understory vegetation and the individual growth of typical forest herbs change due to the treatments?

Species richness, cover, and height of the understory were significantly higher in the treated sites than in the controls. Besides, also the composition and heterogeneity of the understory differed between the treatments and the control (Tinya et al. 2019a).

In uncut sites, the low irradiance and soil moisture values resulted in low understory species richness, cover, and height, and homogeneous species composition.

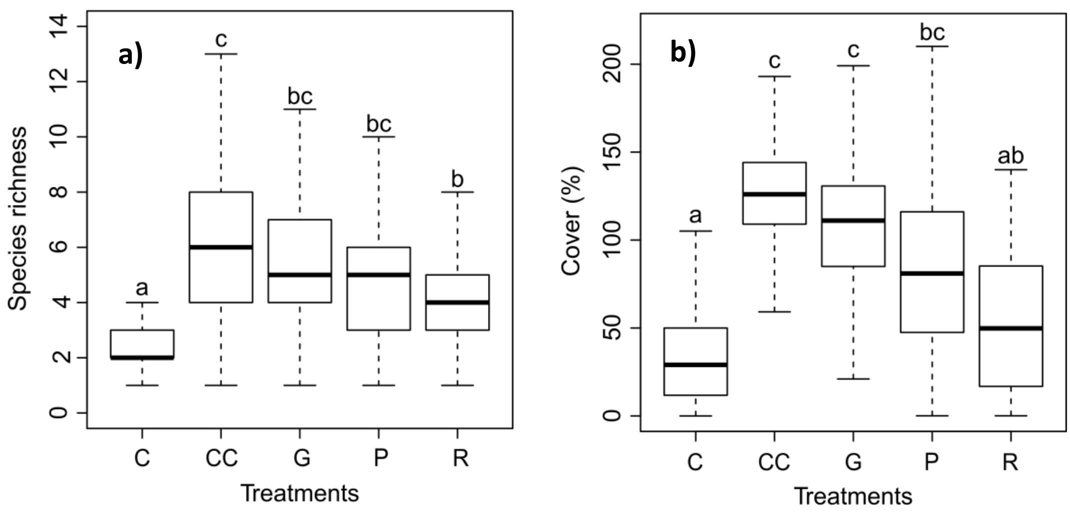

Fig. 3. Understory species richness (a) and cover (b) in the different treatments, on the level of 0.5 m × 0.5 quadrats. C = control, CC = clear-cutting, G = gap-cutting, P = preparation cutting, R = retention tree group. Different letters mean significant differences (P<0.05). Outliers are not shown (Tinya et al. 2019a).

Species richness, cover, and height of the understory were high in the clear-cuts and gaps. In the clear-cuts, higher species richness was mainly caused by the occurrence of non-forest (ruderal and meadow) species. Species composition changed substantially, it lost its original forest character. Annual weeds had high abundance two years after the interventions, but later they were outplaced by perennial herbs. After six years, in game-exclosure areas, woody regeneration displaced the herbs. Contrary to clear-cuts, in the gaps, light-flexible forest species became abundant, and not non-forest species. These species may occur also in the natural gaps established during the small forest cycle. Therefore we conclude that gap-cutting is more apt for preserving forest understory than clear-cutting.

In preparation cuts, understory changes were moderate, some open-forest species have spread. In the retention tree groups, presumably because of the low soil moisture the cover and height of the understory did not differ from the control. At the same time, new, forest edge or non-forest species caused a higher species richness. However their abundance was low, thus the overall composition of the forest understory did not changed considerably.

Size parameters of planted herbs (*Corydalis solida* and *Cardamine bulbifera*) in the gaps differed from those in the uncut controls. The strength of the treatment effects was different depending on the time since the interventions: In the case of *Corydalis*, increased height and leaf area was observable in the gaps in the fourth and fifth year after the interventions. *Cardamine* showed significant treatment effect 1–2 years after the interventions, and then these effects vanished.

Conclusions

Final cutting in the rotation forestry systems (here represented by the clear-cuts) produces too open conditions in an oak-hornbeam forest. Vegetation of clear-cuts is not analogous with the understory of any stage of the natural stand dynamics. Meanwhile, in the mature stage of these systems, the homogeneous, closed canopy favours only shade-tolerant species.

Our results provide evidences that oak-hornbeam forests can be regenerated not only by rotation forestry, but also by continuous cover forestry (CCF). Fine-scale forestry treatments like gap-cutting maintain long-term forest continuity, and by creating a more complex stand structure, they provide buffered, but heterogeneous microsite conditions for the saplings. However, two subjects have to be regarded during CCF: felling should be carried out in the first subsequent year after a masting to ensure there are enough acorns on the sites. Furthermore, if management's priority is to regenerate sessile oak, shade-tolerant competitor species (primarily hornbeam) must be restrained.

The environmental conditions in the gaps of our experiments may be similar to those of natural gaps, thus, besides their economic role, they may be a means to recover the near-natural state of the understory vegetation. Local increase in the abundance of light-flexible forest species fits into the natural dynamics of these forests, while in the uncut parts of the stand, the dominance of shade-tolerant species remains. Gaps promote the natural regeneration of admixing tree species, as well, thus they are useful tool of conservation-oriented management to enhance the compositional and structural heterogeneity and thereby the biodiversity of the forests.

References

Burrascano, S., Ódor, P., Paillet, Y., De Andrade, R., B.,Dörfler, I., Janssen, P., Lõhmus, A., Müller, J., Nagel, T., Nascimbene, J., Penner, J., Remm, L., Sitzia, T., Storch, I., Tinya, F., Ujházyová, M. (2020): BOTTOMS-UP: Biodiversity Of Temperate forest Taxa to Orient Management Sustainability by Unifying Perspectives. In: Abruscato, S., Joa, B., Winkel, G.: Governing and managing forests for multiple ecosystem services across the globe. February 26–28, 2020 Bonn, Germany. Book of Abstracts. European Forest Institute, Bonn, pp. 110–111.

Elek, Z., Kovács, B., Aszalós, R., Boros, G., Samu, F., Tinya, F., Ódor, P. (2018): Taxon-specific responses to different forestry treatments in a temperate forest. SCIENTIFIC REPORTS 8: 16990. https://doi.org/10.1038/s41598-018-35159-z

Kovács, B., Tinya, F. (2018): Különböző erdészeti beavatkozások termőhelyre, biodiverzitásra és felújulásra gyakorolt hatásai. Beszámoló a Pilis Üzemmód Kísérlet eredményeiről. Session of the Local Group of Visegrád, National Forestry Association, Budapest.

Kovács, B., Tinya, F., Guba, E., Németh Cs., Sass, V., Bidló, A., Ódor, P. (2018a): The short-term effects of experimental forestry treatments on site conditions in an oak-hornbeam forest. FORESTS 9: 406. https://doi.org/10.3390/f9070406

Kovács, B., Tinya, F., Németh, Cs., Ódor, P. (2018b): Erdészeti beavatkozások mikroklímára gyakorolt hatásainak kísérletes vizsgálata a Pilisben. In: 11. Magyar Ökológus Kongresszus. Absztraktkötet. Magyar Ökológusok Tudományos Egyesülete, Nyíregyháza, p. 49.

Kovács, B., Tinya, F., Németh, Cs., Ódor, P. (2020a): Unfolding the effects of different forestry treatments on microclimate in oak forests: results of a 4-year experiment. ECOLOGICAL APPLICATIONS 30: e02043. https://doi.org/10.1002/eap.2043

Kovács, B., Tinya, F., Németh, Cs., Ódor, P. (2020b): The effects of different silvicultural treatments on microclimate in oak-dominated forests: results of a 4-year experiment. In: Abruscato, S., Joa, B., Winkel, G.: Governing and managing forests for multiple ecosystem services across the globe. February 26–28, 2020 Bonn, Germany. Book of Abstracts. European Forest Institute, Bonn, pp. 110-111.

Ódor, P., Aszalós, R., Bidló, A., Boros, G., Csépányi, P., Elek, Z., Horváth, Cs. V., Kovács, B., Németh, Cs., Soltész, Z., Samu, F., Sass, V., Tinya, F., Tóth, B. (2020a): The effect of forestry treatments on forest site, biodiversity and regeneration: the Pilis Forestry Systems Experiment. In: Abruscato, S., Joa, B., Winkel, G.: Governing and managing forests for multiple ecosystem services across the globe. February 26-28, 2020 Bonn, Germany. Book of Abstracts. European Forest Institute, Bonn, pp. 67–68.

Ódor, P., Aszalós, R., Bidló, A., Boros, G., Elek, Z., Kovács, B., Samu, F., Sass, V., Tinya, F., Tóth, B., Vadas, Á. (2018b): Effects of forestry treatments on forest site, biodiversity and regeneration In: Mázsa, K. (ed.): 5th Forum Carpaticum: Adapting to Environmental and Social Risk in the Carpathian Mountain Region. MTA Ökológiai Kutatóközpont, Tihany, pp. 100-101.

Ódor, P., Aszalós, R., Boros, G., Elek, Z., Kovács, B., Samu, F., Sass, V., Tinya, F., Tóth, B., Vadas, Á. (2018c): Erdészeti fahasználatok termőhelyre, biodiverzitásra és felújulásra gyakorolt hatásának kísérletes vizsgálata. In: 11. Magyar Ökológus Kongresszus. Absztraktkötet. Magyar Ökológusok Tudományos Egyesülete, Nyíregyháza, p. 60.

Ódor, P., Kovács, B., Boros, G., Samu, F., Aszalós, R., Tinya, F., Elek, Z. (2018a): Effects of forestry treatments on forest site conditions and the biodiversity of different organism groups. In: 5th European Congress of Conservation Biology, Jyväskylä, p. 707. https://doi.org/10.17011/conference/eccb2018/107617

Ódor, P., Tinya, F., Kovács, B., Aszalós, R., Bidló, A., Boros, G., Csépányi, P., Elek, Z., Farkas, V., Horváth, Cs. V., Németh, Cs., Soltész, Z., Samu, F., Sass, V., Simon, L., Szenthe, G., Tóth, B., Vadas, Á. (2020b): Különböző erdészeti beavatkozások termőhelyre, biodiverzitásra és felújulásra gyakorolt hatása gyertyános tölgyesekben. Beszámoló egy 5 éve indult erdőökológiai kísérletről. ERDÉSZETI LAPOK 155: 8-12.

Tinya, F.: A folyamatos erdőborítást fenntartó gazdálkodásról. Fát is vágjuk és az erdő is megmaradjon. ÉLET ÉS TUDOMÁNY 2020: 19–21.

Tinya, F., Bidló, A., Dima, B., Király, I., Kovács, B., Kutszegi, G., Lakatos, F., Mag, Zs., Márialigeti, S., Nascimbene, J., Samu, F., Siller, I., Szél, Gy., Ódor, P.: Stand structure and tree species composition are the main drivers of multi-taxon biodiversity in temperate mixed forests, SCIENCE OF THE TOTAL ENVIRONMENT, submitted.

Tinya, F., Kovács, B., Aszalós, R., Ódor, P. (2018b): Erdészeti kezelések aljnövényzetre gyakorolt hatásának kísérletes vizsgálata. In: Molnár, V. A., Sonkoly, J., Takács, A. (eds.): XII. Aktuális Flóra- és Vegetációkutatás a Kárpát-medencében. Program és Összefoglalók. Debreceni Egyetem TTK Növénytani Tanszék, Debrecen, pp. 95-95.

Tinya, F., Kovács, B., Aszalós, R., Tóth, B., Csépányi, P., Németh, Cs., Ódor, P. (2020a): Initial regeneration success of tree species after different forestry treatments in a sessile oak-hornbeam forest. FOREST ECOLOGY AND MANAGEMENT 459: 117810. https://doi.org/10.1016/j.foreco.2019.117810

Tinya, F., Kovács, B., Ódor, P. (2018a): Towards a more nature-based silviculture: effects of experimental forestry treatments on forest regeneration in an oak-hornbeam stand. In: 5th European Congress of Conservation Biology, Jyväskylä, p. 72. https://doi.org/10.17011/conference/eccb2018/107504

Tinya, F., Kovács, B., Ódor, P. (2020b): Description of the existing forest manipulation experiments, COST Action BOTTOMS-UP – Biodiversity of Temperate Forest Taxa Orienting Management Sustainability by Unifying Perspectives, CA18207, Working Group 3, Deliverable 1. Report. https://www.bottoms-up.eu/en/results/working-group-3.html

Tinya, F., Kovács, B., Prättäla, A., Farkas, P., Aszalós, R., Ódor, P. (2019b): Initial understory response to experimental silvicultural treatments in a temperate oak-dominated forest. EUROPEAN JOURNAL OF FOREST RESEARCH 138: 65–77. https://doi.org/10.1007/s10342-018-1154-8

Tinya, F., Márialigeti, S., Bidló, A., Ódor, P. (2018c): A fásszárú újulatot meghatározó környezeti változók vizsgálata őrségi erdőkben. In: 11. Magyar Ökológus Kongresszus. Absztraktkötet. Magyar Ökológusok Tudományos Egyesülete, Nyíregyháza, p. 106.

Tinya. F., Márialigeti, S., Bidló, B., Ódor, P. (2019a): Environmental drivers of the forest regeneration in temperate mixed forests. FOREST ECOLOGY AND MANAGEMENT, 43: 720-728. https://doi.org/10.1016/j.foreco.2018.11.051