FINAL REPORT

Novel aspects of the ecosystem engineering effects of woody plants

Csaba Tölgyesi
Department of Ecology, University of Szeged, Szeged

Project ID: NKFIH PD132131
Period: 01/12/2019 – 30/11/2022

Output summary

This 3-year post-doctoral project aimed to reveal some little known ecological effects of woody species in two independent work packages (WPs). All research activities described in the Research Plan were performed, although Covid and some other administrative obstacles led to a nearly 1-year delay in WP2. I used that 'free time' to put more effort into generalizing the findings of WP1 and to publish two loosely related studies. Thus, compared to the planned 2 Q1 papers for each WP, I could publish 4 papers from WP1 (2 D1, 1 Q1 and one more in Hungarian) and 2 papers (both D1) from the extra topics as first author. WP2 has so far yielded one submitted paper (under review in a D1 paper; see Appendix). I could also publish as co-author 13 more papers in peer-reviewed journals. The cumulative impact factor of papers with the project ID included reached 88.8. Findings of the WPs were presented in three national conferences, namely the Hungarian Ecological Congress (conference talk), Hungarian Conservation Biology Conference (plenary talk), and the 13th "Advances in Research on the Flora and Vegetation of the Carpato-Pannonian Region" International Conference (oral presentation), and in one international conference, the European Congress of Conservation Biology, Prague (conference talk).

Detailed report

WP 1 – *Effects of woody species on deeper soil layers*

In sandy drylands of Hungary we confirmed that patches of woody vegetation reduce microclimatic extremes, sustain a moister topsoil and somewhat better soil conditions compared to adjacent grassy vegetation. This is in accordance with many other studies describing the environmental effects of trees in mixed woody-grassy ecosystems. However, we also scrutinized deep soil moisture dynamics to understand possible effects on groundwater recharge. We found that grassy vegetation utilizes only the top approx. 40 cm of the soil for moisture, while the moisture content of deeper layers remains stable throughout the year; that is, precipitation needs to recharge the topsoil to reach field capacity and any precipitation afterwards can contribute to the recharge of the groundwater. In contrast; woody vegetation desiccates deeper layers; therefore deep percolation is substantially hindered under trees. We studied this effect in three forest types (pine, poplar and *Robinia*) differing in their annual canopy life-time. Pine (*Pinus nigra* and *P. sylvestris*) is evergreen, having constant canopy cover and therefore precipitation interception throughout the year and a longer transpiration period than deciduous species. Poplar (*Populus alba* and *P.* x *canescens*) and *Robinia pseudoacacia* are deciduous. The former flushes leaves earlier and sheds them later then the latter, thus poplar is expected to have a more pronounced effect on the annual soil moisture than *Robinia*. Our findings clearly confirmed the expectations. From the winter equilibrium, pine started to deviate first by showing drier soil below 80 cm than poplar, *Robinia* and the grassland. Poplar started to deplete deep soil moisture reserves a month later and *Robina* one more month later. By summer, all forest types created a thick, completely desiccated layer below the topsoil. This started to recharge in autumn, however recharging in pine had been complete only by the middle of winter. Thus, the most detrimental effects on soil moisture were found for pine, while the concerning is *Robinia* (Tölgyesi et al. 2020).

Our findings highlight that any further afforestation, especially if performed with pine, further aggravates water scarcity in our sandy regions. This is in stark contrast with the current national climate strategy and forestry traditions. Thus, we need to revisit all these; as the desiccation of these regions is an ongoing natural disaster, affecting both nature and the livelihood of people. We communicated our findings on multiple channels beside the scientific paper, including presentations in various events for stakeholders, interested local people, NGOs and so on, and broadcasted the message in online media. Not unexpectedly, we received many attacks from foresters in Hungarian journals, such as Erdészeti Lapok, although the scientific solidity of our findings could not be questioned.

Seeing that our findings cannot be accepted by the main stakeholder group, foresters, we prepared a Hungarian paper, in which we made a thorough review of Hungarian results in the topic, and highlighted that many earlier local-scale studies also emphasized the potential desiccating effects of trees and their contribution to the desiccation of our sandy regions. We also found many studies that argue against them, so we assessed their validity and highlighted which findings are scientifically backed up while which ones are not. Eventually, we concluded that the desiccating effect is unquestionable. The strength of this effect relative to other contributors of desiccation is difficult to tell, but unfortunately it is increasing. However, to have an eventually constructive message, we outlined the benefit of accepting that trees can create negative water balance in our climate. Floodplains receive a higher water input than they consume by evapotranspiration; thus, it is a plausible solution to shift the focus of afforestation (and tree-based climate mitigation in the national climate strategy) from sandy drylands to floodplains. We propose a realistic framework on how to perform this and how to make stakeholders interested in this endeavour in the published paper (Tölgyesi et al. 2021).

Moving from our regional scale difficulties to tackle climate change with forests to a global scale, we also saw a fundamental unsolved problem. Misplaced afforestation is common globally but the root of the problem seemed to come from the global awareness disparity of alternative ecosystem types for climate change mitigation. In many regions globally, grasslands and wetlands can capture and store carbon more efficiently and more safely (e.g. in the soil, away from the reach of wildfires). To call scientific attention to this 'grassland blindness', we prepred a perspective paper in Restoration Ecology (Tölgyesi et al. 2022a).

As a planned part of WP1, we also scrutinized the effects of trees on the moisture dynamics of fine-textured soils to supplement findings on sandy soils. Here we found a different pattern. Infiltration rate is slower in finer-grained soils than in coarse-grained ones (i.e. sandy soils); therefore a higher proportion can return to the atmosphere due to prolonged exposure to solar radiation and absorption by grasses than in sandy soils. Trees on fine-grained soils are also important contributors to moisture loss through transpiration, but their canopy shade efficiently offsets the increased potential evaporation, leading to, by and large, an overall neutral effects on moisture regime compared to grassy habitats. Therefore, our restrictions for tree planting are not as strict for finer-grained soils as for sandy soils; establishing forest patches in these landscape or maintaining wood-pasture physiognomy, i.e. grassland with scattered trees, are not so problematic from the perspective of regional water regime (Tölgyesi et al. 2023). It is another question, though, that tree mortality and general forest vitality show a decreasing trend and will continue to decrease according to projected climate change scenarios in most lowlands of Hungary with fine-grained soil.

Publications:

- Tölgyesi, C., Török, P., Hábenczyus, A. A., Bátori, Z., Valkó, O., Deák, B., Tóthmérész, B., Erdős, L., Kelemen, A. (2020). Underground deserts below fertility islands? Woody species desiccate lower soil layers in sandy drylands. Ecography, 43(6), 848-859. IF: 6.8 (D1); Independent citations: 17.

- Tölgyesi, C., Bátori, Z., Deák, B., Erdős, L., Hábenczyus, A. A., Kukla, L. S., Török, P., Valkó, O., Kelemen, A. (2021). A homokfásítás alkonya és az ártérfásítás hajnala. Természetvédelmi Közlemények, 27, 126-144. [in Hungarian with English abstract]
- Tölgyesi, C., Buisson, E., Helm, A., Temperton, V. M., & Török, P. (2022a). Urgent need for updating the slogan of global climate actions from "tree planting" to "restore native vegetation". Restoration Ecology, 30(3), e13594. IF: 4.2; Independent citations: 5
- Tölgyesi, C., Hábenczyus, A. A., Kelemen, A., Török, P., Valkó, O., Deák, B., Erdős, L., Tóth, B., Csikós, N., Bátori, Z. (2023). How to not trade water for carbon with tree planting in water-limited temperate biomes? Science of the Total Environment, 856, 158960. IF: 10.8.

WP2 – Effects of woody plants on understory herb layer communities in wood-pastures

Wood-pastures are among the most ancient land use forms. If managed in a traditional way, they can maintain higher species diversity for many taxa than either open grassland or closed canopy forest. Despite their high conservation value, they are declining all over Europe due to an inadequate representation in agricultural subsidies and the overall undervaluation of their trees by both policy makers and land users.

We already showed that if the soil is not sandy, trees in wood-pastures are unlikely to cause a severe negative water balance. However, the main concern about wood-pasture trees is more likely their suppressive effect on forage yield. Due to the interactive effect of grazers and trees on herbage yield, this effect can be tested by grazing exclusion. To this end, we established 1 m x 1 m grazing exclusion sites in four wood-pastures under tree canopies (ten in each wood-pasture) and in adjacent open pastures sites (ten in each wood-pasture) and measured herbage production and herbage quality (nitrogen content) inside and next to the excluded sites. We also measured site conditions (soil texture, humus and nitrogen content and soil moisture) in five locations of each wood-pasture habitat (open pasture sites and under scattered trees) to understand how the environmental effects of trees drive the responses of the herb layer, and also to identify *a priori* site differences between the studied habitats. We also performed all measurements in adjacent closed canopy woodland sites, as they are considered the original, natural type of vegetation, from which wood-pastures were created centuries ago. We measured soil moisture on the sites with a hand-held soil moisture meter but for the other soil parameters we collected samples and planned to have them analysed in a dedicated soil laboratory. Unfortunately, due to Covid lockdown and institutional procurement difficulties, we received the results of the analysis almost one year after sending them to the lab, which delayed analysis and paper preparations. We do not have a published paper yet but a submitted manuscript, which is under review in Agriculture, Ecosystems and Environment (D1, IF: 6.6, Appendix); therefore, I provide a more detailed description of the findings of WP2 (although only main statistical results are shared) than for WP1, where all findings can be found in the publications.

We found no difference in the soil texture among the habitats (open pasture, scattered trees and adjacent woodland sites; Fig. 1), which we confirmed for the top 0-10 cm and for the 20-30 cm deeper layer using permutational multivariate ANOVA. The predictors were the habitat type and depth, and the dependent variables were the proportions of sand, silt and clay in the soil (habitat type: $F=0.44$, $R2=0.008$, $p=0.700$; depth: $F=1.83$, $R2=0.016$, $p=0.154$). Soil organic carbon (humus) content was uniform among the studied habitats both in the top 10 cm layer (linear mixed-effects models, $Chi^2=2.22$, $p=0.330$; Fig. 2A) and at 20-30 cm ($Chi^2=1.65$, $p=0.439$; Fig. 2B). Wood-pasture trees accumulated considerable amounts of nitrogen in the soil ($Chi^2=8.55$, $p=0.014$ at 0-10 cm and $Chi^2=7.05$, $p=0.029$ at 20-30 cm; Fig. 2C-D). This was not an *a priori* soil heterogeneity, as open pastures and adjacent woodlands did not differ in soil nitrogen content. The excess nitrogen may have come from increased livestock activity under the trees and nutrient trapping by the trees (from airborne particle deposition and by absorbing nutrients with roots extending beyond the surface projection of the canopy). Soil moisture was uniform in spring ($Chi^2=3.10$, $p=0.212$; Fig. 2E), indicating a lack of *a priori* differences in water regime, but in summer the topsoil under the trees got drier than beyond ($Chi^2=26.51$, $p<0.001$; Fig. 2F).

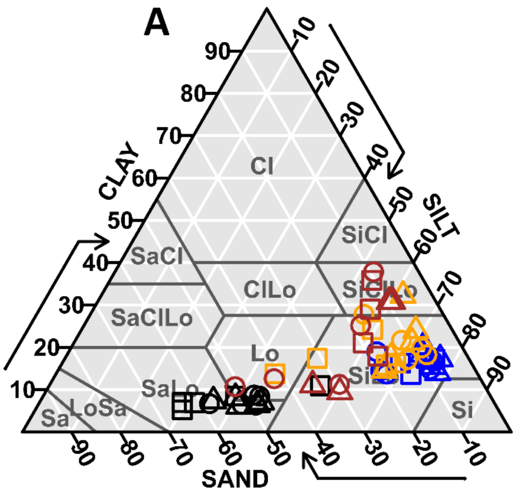

Figure 1 Texture of the topsoil (0-10 cm; A) and deeper layers (20-30 cm; B) in Central European wood-pasture landscapes. Triangle: open grassland, circle: stand-alone trees, square: adjacent closed-canopy forest; colours identify the wood-pastures, black: Bixad, blue: Cserépfalu, red: Mercheasa, golden: Erdőbénye. Split zones in the plot space correspond to USDA soil texture classification categories; Sa: sand, Si: silt, Lo: loam, Cl: clay.

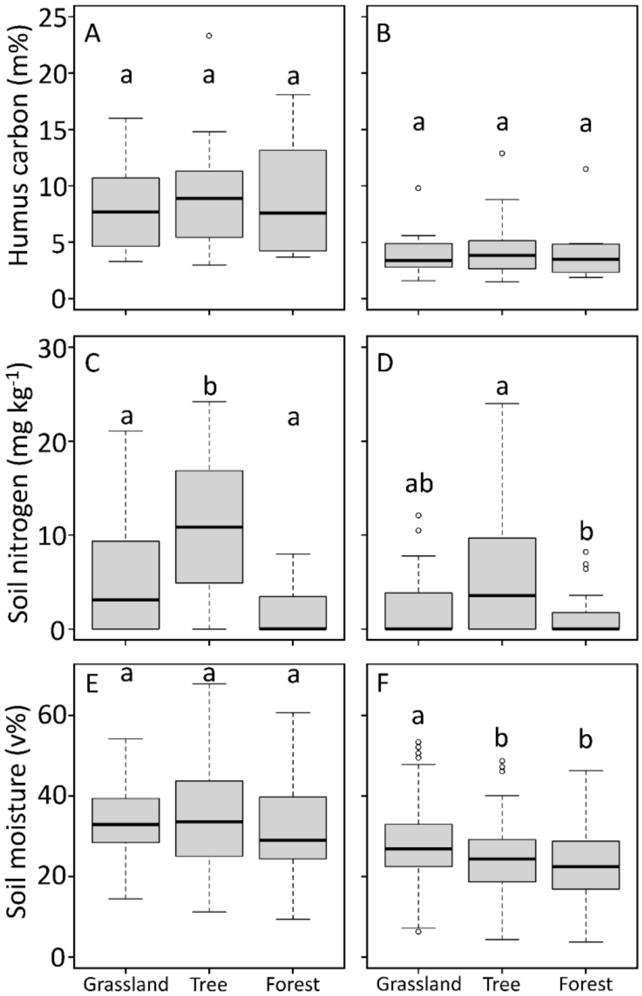

Figure 2 Soil carbon and plant available nitrogen content in the upper 0-10 cm layer (A and C) and below at 20-30 cm (B and D), and soil moisture content in the upper 0-10 cm layer in spring (E) and summer (F) in the studied habitats. Different lowercase letters identify significantly differences groups ($p<0.05$).

The above described effects of trees, supplemented with reduced light availability, resulted in a net negative impact on herbaceous biomass production both in spring (Chi^2=38.82, p<0.001; Fig. 3A) and summer (Chi^2=77.67, p<0.001; Fig. 3B). The increased soil nitrogen content under the trees could be utilized in spring and resulted in higher herbage nitrogen content (Chi^2=3.96, p=0.047; Fig 4A). Conversely, in summer the high soil nitrogen content was not reflected in the herbage as we found higher values in the open pasture sites (Chi^2=6.41, p=0.011; Fig. 4B).

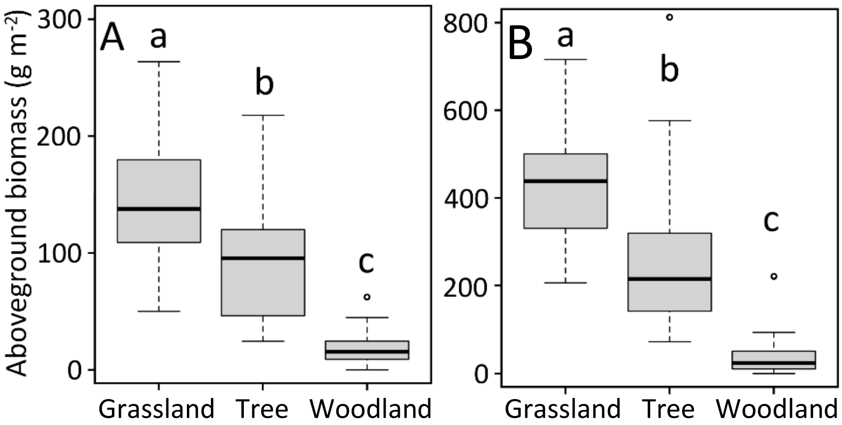

Figure 3 Herb layer biomass in the studied habitats. Different lowercase letters identify significantly different groups (p<0.05). A: spring, B: summer.

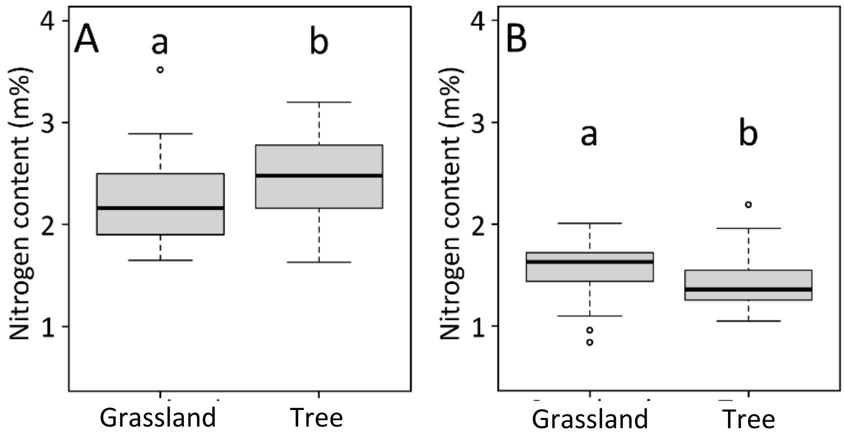

Figure 4 Nitrogen content of the aboveground herb layer biomass in the studied habitats in spring (A) and summer (B). Different lowercase letters identify significantly different groups (p<0.05).

Our findings confirmed a suppressive effect of trees under their canopy. However, to tell the overall effect of trees in an entire wood-pasture, we need to scale up the effect. For this we mapped the studied wood-pastures and estimated their total tree coverage. It remained below 10%, which is typical for traditional Central-European wood-pastures. We then estimated overall wood-pasture herbage yield in the presence of trees and also without them (using only open pasture biomass data). We found that the loss of biomass due to the presence of trees is below 3%. This is small but is it small enough to be acceptable for land users and policy makers? Shading by wood-pasture trees reportedly causes an up to 10% of milk yield in dairy cows compared to cows kept without any shade in summer. Thus, the loss of 3% biomass is clearly offset by the ecosystem services of trees. We concluded that there is a clear trade-off between shade provision and herbage production in wood-pastures, but the effects of the former prevails, so trees have no net economical drawback. Scattered trees in wood-pastures should be protected for maintaining biodiversity, supporting animal husbandry and also, as a recently recognized ecosystem service, for capturing and storing atmospheric carbon. We recommended that tree-based climate mitigation strategies should recognize the potential in the protection of mature and the planting of new trees in wood-pastures (see also the Appendix).

Extra studies

Due to the 'free time' left by delayed soil analysis, I could focus on two formerly unpublished datasets during the project period. In the first one we compared restoration success in meadow-steppe grasslands restored and later managed with different methods. Restoration methods included one of spontaneous recovery, sowing low-diversity seed mixture, and restoration through perennial crop. Regarding management, half of the sites was mowed and the other half grazed; all in a balanced design. We found that there are clear differences among the restoration methods regarding the recovery of species and functional trait composition in mowed sites. The best approach turned out to be the spontaneous recovery owing to the low dispersal limitation, while the other two methods allowed for a more moderate recovery rate. Grazing blurred the differences among the initial restoration methods and brought up the two lagging ones to the level of mowed spontaneous sites or even beyond. We suggested that the beneficial effect of grazing is related to the increased functional redundancy of grazed sites. We concluded that post-restoration management is crucial for long—term restoration success and grazing brings better prospects than mowing, especially when the target community shows a high level of functional redundancy (Tölgyesi et al. 2022b).

The second study aimed to disentangle the role of drainage canal banks in mixed agricultural-natural landscape mosaics. We assessed the effect of several canal properties on plant, spider, butterfly, true bug and bird assemblages and also on invasive plant abundance. Studied canal parameters included size (small ditches vs. larger arterial canals), potential habitat type (sandy, saline and fen habitats/substrates), naturalness of the surrounding landscape (agricultural vs. semi-natural), as well as reed abundance and woody species abundance.

It has long been known that drainage canals in agricultural landscapes, although detrimental for the hydrology of native ecosystems, are often the last refuges of native biodiversity. We could also confirm this in our agricultural canals. It was a more interesting finding that canals cutting through semi-natural landscapes concentrated more species than the adjacent habitats, i.e. were biodiversity hot spots (or hot lines) in all landscape types. We explained this with the steep hydrologic gradient of the drainage canal banks, which can enable the coexistence of species with contrasting niches. We found that the species concentrating potential was highest in saline canals, where a salinity gradient is superimposed to the hydrology gradient. Our findings also indicated that canal size had little effect, thus, small ones also deserve our attention. Intermediate amounts of reed and woody vegetation had positive effects on some taxa; thus clearing all reed or woody vegetation during canal management should be avoided.

We also expressed our concern about the attitude of both nature conservation and water resource management authorities to drainage canals. The former looks at canals as enemies and in most restoration activities that involve canalized areas, drainage canals are removed by filling them up. The latter, however, praises canals even during our era of water scarcity and regularly dredges them and clears the vegetation. We proposed a consensus approach, which maintains the canal profiles but obstructs flowing water during restoration and entails lower management intensity (Tölgyesi et al. 2022c).

Publications:

- **Tölgyesi, C.**, Vadász, C., Kun, R., Csathó, A. I., Bátori, Z., Hábenczyus, A., ... & Török, P. (2022b). Post-restoration grassland management overrides the effects of restoration methods in propagule-rich landscapes. Ecological Applications, 32(1), e02463. IF: 6.1 (D1).
- **Tölgyesi, C.**, Torma, A., Bátori, Z., Šeat, J., Popović, M., Gallé, R., Gallé-Szpisjak, N., Erdős, L., Vinkó, T., Kelemen, A., Török, P. (2022c). Turning old foes into new allies—Harnessing drainage canals for biodiversity conservation in a desiccated European lowland region. Journal of Applied Ecology, 59(1), 89-102. IF: 6.9 (D1); independent citations: 3.

Other publications with the project ID included:

1. Erdős, L., Ho, K. V., Bátori, Z., Kröel-Dulay, G., Ónodi, G., **Tölgyesi, C.**, ... & Lengyel, A. (2022). Taxonomic, functional and phylogenetic diversity peaks do not coincide along a compositional gradient in forest-grassland mosaics. Journal of Ecology, in press. https://doi.org/10.1111/1365-2745.14025. IF: 6.4 (D1).
2. Bátori, Z., Gallé, R., Gallé-Szpisjak, N., Császár, P., Nagy, D. D., Lőrinczi, G., Torma, A., **Tölgyesi, C.**, Maák, I.E., Frei, K., Hábenczyus, A.A., Hornung, E. (2022). Topographic depressions provide potential microrefugia for ground-dwelling arthropods. Elem Sci Anth, 10(1), 00084. IF: 4.6 (D1).
3. Hábenczyus, A. A., **Tölgyesi, C.**, Pál, R., Kelemen, A., Aradi, E., Bátori, Z., ... & Török, P. (2022). Increasing abundance of an invasive C4 grass is associated with larger community changes away than at home. Applied Vegetation Science, 25(2), e12659. IF: 3.4 (Q1).
4. Erdős, L., Bede-Fazekas, Á., Bátori, Z., Berg, C., Kröel-Dulay, G., Magnes, M., Sengl, P., **Tölgyesi, C.**, Török, P., Zinnen, J. (2022). Species-based indicators to assess habitat degradation: Comparing the conceptual, methodological, and ecological relationships between hemeroby and naturalness values. Ecological Indicators, 136, 108707. IF: 6.3 (D1).
5. Gallé, R., **Tölgyesi, C.**, Torma, A., Bátori, Z., Lörinczi, G., Szilassi, P., ... & Batáry, P. (2022). Matrix quality and habitat type drive the diversity pattern of forest steppe fragments. Perspectives in Ecology and Conservation, 20(1), 60-68. IF: 5.7 (D1).
6. Szilassi, P., Soóky, A., Bátori, Z., Hábenczyus, A. A., Frei, K., **Tölgyesi, C.**, ... & Csikós, N. (2021). Natura 2000 areas, road, railway, water, and ecological networks may provide pathways for biological invasion: A country scale analysis. Plants, 10(12), 2670. IF: 4.7 (Q1).
7. Török, P., Schmidt, D., Bátori, Z., Aradi, E., Kelemen, A., Hábenczyus, A. A., Cando, P.D., **Tölgyesi, C.**, ... & Sonkoly, J. (2021). Invasion of the North American sand dropseed (Sporobolus cryptandrus)–A new pest in Eurasian sand areas?. Global Ecology and Conservation, 32, e01942. IF: 4.0 (Q1).
8. Bátori, Z., Erdős, L., Gajdács, M., Barta, K., Tobak, Z., & **Tölgyesi, C.** (2021). Managing climate change microrefugia for vascular plants in forested karst landscapes. Forest Ecology and Management, 496, 119446. IF: 4.4 (D1).
9. Erdős, L., Szitár, K., Öllerer, K., Ónodi, G., Kertész, M., Török, P., Baráth, K., **Tölgyesi, C.**, ... & Kröel-Dulay, G. (2021). Oak regeneration at the arid boundary of the temperate deciduous forest biome: insights from a seeding and watering experiment. European Journal of Forest Research, 140(3), 589-601. IF: 3.1 (Q1).
10. Valkó, O., **Tölgyesi, C.**, Kelemen, A., Bátori, Z., Gallé, R., Rádai, Z., ... & Deák, B. (2021). Steppe Marmot (Marmota bobak) as ecosystem engineer in arid steppes. Journal of Arid Environments, 184, 104244. IF: 2.8 (Q2).
11. Bátori, Z., Lőrinczi, G., **Tölgyesi, C.**, Módra, G., Juhász, O., Aguilon, D. J., ... & Maák, I. E. (2020). Karstic microrefugia host functionally specific ant assemblages. Frontiers in Ecology and Evolution, 8, 613738. IF: 4.5 (D1).
12. Aguilon, D. J., Vojtkó, A., **Tölgyesi, C.**, Erdős, L., Kiss, P. J., Lőrinczi, G., ... & Bátori, Z. (2020). Karst environments and disturbance: evaluation of the effects of human activity on grassland and forest naturalness in dolines. Biologia, 75(10), 1529-1535. IF: 1.7 (Q4).
13. Bátori, Z., Kiss, P. J., **Tölgyesi, C.**, Deák, B., Valkó, O., Török, P., ... & Kelemen, A. (2020). River embankments mitigate the loss of grassland biodiversity in agricultural landscapes. River Research and Applications, 36(7), 1160-1170. IF: 2.8 (Q2).
14. Erdős, L., Török, P., Szitár, K., Bátori, Z., **Tölgyesi, C.**, Kiss, P. J., ... & Kröel-Dulay, G. (2020). Beyond the forest-grassland dichotomy: The gradient-like organization of habitats in forest-steppes. Frontiers in Plant Science, 11, 236. IF: 6.6 (D1).

Appendix

Submitted paper of WP2 in the journal Agriculture, Ecosystems and Ecosystems as of 26/12/2022.

em Agriculture, Ecosystems and Environment

Csaba Tölgyesi | Logout

Home Main Menu Submit a Manuscript About Help

Submissions Being Processed for Author

Page: 1 of 1 (1 total submissions)

Results per page 10

Action	Manuscript Number	Title	Initial Date Submitted	Status Date	Current Status
Action Links	AGEE34353	Maintaining scattered trees to boost carbon stock in temperate pastures does not compromise overall pasture quality for the livestock	Oct 11, 2022	Oct 22, 2022	Under Review

Page: 1 of 1 (1 total submissions)

Results per page 10