DIVERSITY, REGULATION AND RELIABILITY – FINE-SCALE FUNCTIONAL ORGANIZATION IN VEGETATION

Final report of NKFI (OTKA) K 105608 research grant
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Introduction

In this project we explored fine-scale spatial and temporal patterns of functional (biomass and soil respiration) and structural (alpha and beta diversity) characteristics in plant communities linking these patterns to potential environmental drivers. Fine-scale approach (with resolution close to the size of plant individuals and with few meters extent) were chosen because we were interested in self-organized emergent community characteristics determined mainly by biotic interactions. We had a special focus on the reliability of community characteristics (i.e the spatial and temporal invariance or consistency of coenostate variables). In our view a plant community stand was considered as a patchwork of interacting meta-communities characterized with convergent or divergent (symmetric/asymmetric) local features due to interactions and similarity of locally self-organized processes.

For exploring biotic drivers of functional patterns, vegetation data were collected at the same scales from the same sampling units (plant cover data and presence/absence data). In some analyses we used plant traits (plant height, plant diameter, specific leaf area (SLA), seed mass (SM), clonal attributes, root architecture). Our study sites were distributed over Hungary at 15 sites (Ásotthalom, Battonya, Bugac, Csévharaszt, Dinnyés, Esztergom, Fülöpháza, Gönyű, Kunpeszér, Magyarszombatfa, Mórahalom, Nagyrákos, Szalafő, Tiszaalpár and Vácrátót). We used alternative sampling designs (transects and grids) and sampled a wide range of natural grasslands including open and closed sand grasslands, mesic loess grasslands and wet meadows. Disturbed or recovering grasslands from the same habitats were sampled as well.

Abbreviations of measured characteristics: soil respiration (Rs), soil temperature (Ts), soil moisture (SWC), above ground biomass (AGB), normalized difference vegetation index (NDVI).

Main Scientific Results

In this report we follow the structure of our original research plan [publications marked by numbers].

Objective #1 *Developing methods for linking fine-scale functional patterns with vegetation structure*

Alternative sampling designs were tested with different extent (from 1m to 80m), resolution (5x5cm to 1x1m) and spatial arrangement (grids, transects and random plots). Results showed that optimum sample sizes and optimum scaling parameters varied between communities but also within-community [**2, 3, 11**]. Final protocols were selected to be applicable in comparative studies at wide range of conditions:

a, At patch scale we used **small circular transects**: 15m long with 75 evenly spaced sampling positions (20cm distance). At each point Rs, Ts, SWC, NDVI, AGB and species cover were detected. The presence/absence patterns of plant species were recorded as well along the same circle (n=300 5x5cm units and n=150 10x10 cm units).

b, At stand scale we used:

b1, **60m biomass transects:** with 31 evenly spaced 50x50cm sampling units (2m distances). AGB was measured together with species cover.

b2, **60x80m grid**: 78 sampling positions (10m distances) used for assessing spatiotemporal patterns. At each point Rs, N_2O flux, soil organic carbon, total soil nitrogen, Ts, SWC, AGB and species cover were detected.

b3, **large circular transects:** 52m long with contiguous 5x5cm units, presence of species were detected in microquadrats. For assessing spatial invariance (spatial reliability), we developed a new method where these transects were re-sampled with moving windows statistics [**8, 13**].

Sampling campaigns were repeated over 5 years and from March to October to represent interannual and seasonal variability.

Objective #2 *Evaluating functional, structural and environmental patterns in the context of reliability*

2.1. Fine-scale spatial variability of soil respiration - interaction with abiotic drivers

Using small circular transects we explored the seasonal and interannual variability of fine scale spatial patterns of Rs and its main drivers (Ts and SWC) in a semiarid sandy pasture. Repeated sampling campaigns revealed high variability in the spatial structure of these variables. Ranges of the spatial autocorrelation varied between 0 and 3.6 m for Rs, 0 and 3 m for SWC and 0 and 2.9 m for Ts. Structural variances were larger than 50% in most cases (and even larger than 75% in few cases) indicating moderate to strong spatial dependence for all of the three variables. Spatial dependence between SWC and Rs (analyzed by cross-variograms) was mostly positive with higher strength during periods of water stress. Ts-Rs spatial correlation was mostly negative and it became generally weaker at higher SWC (similarly to SWC-Rs) [**3**]. These results show that fine-scale functional patterns are very dynamic and can change within a few days with environmental stresses. Drought conditions led to stronger spatial dependency of the Rs-SWC patterns as well as to larger variability of these variables. In contrast, wet soil conditions led to poor spatial dependency and disappearance of spatial structures. Patch size of Rs depended negatively on transect average SWC. Increasing stress induces more pronounced spatial heterogeneity with increasing grain size (and decreasing spatial reliability.

2.2. Cross-site comparative analyses of grassland soil CO_2 efflux - context dependent effects of biotic and abiotic drivers

Based on the same standard sampling protocol we further explored these relationships by 77 measurement campaigns at 8 contrasting grassland sites. We sampled open sandy grasslands with low soil carbon and water content, closed sandy grasslands with high soil carbon content, closed sandy grasslands with high soil water content and closed loess grasslands with high biomass. We found that spatial pattern of Rs was dependent on SWC, but in a highly complex way [**2**]. Relationship between the autocorrelation length of Rs and soil moisture varied and was conditioned by the combination of other factors (average Ts, spatially structured variability of Ts and total sample variance of Rs). For example, negative correlation between SWC and range of Rs did not exist at low Ts when Ts became the main limiting and driving factor of the spatial structure of Rs [**2**]. Our results suggest the existence of specific types of emergent functional patterns related to some threshold values of driving variables (mainly soil moisture, soil temperature and structural vegetation characteristics). The contrasting soil conditions and vegetation structures of these grasslands enabled us to put our results into the context of land use and climate change. Relationships found between Rs, SWC and Ts suggest that grasslands with good soil and proper management have substantial acclimation capacity to climatic variability. However, if drying process occurs with simultaneous loss of soil organic matter due to inappropriate management, the coupling of these variables may diminish or cease completely. This aspect needs further verification comparing successional (regenerating), degraded and natural communities.

2.3. Changing spatial reliability of vegetation structure during degradation and succession.

Our cross-site studies suggested the potential importance of vegetation structures in controlling functional patterns. Therefore, we performed an independent study exploring how vegetation structure change during succession and degradation. Abandoned agricultural fields of various ages and mature natural grasslands were analyzed (three series, sampled by large circular transects in Hungary, Romania and Slovenia). For quantifying spatial reliability, we calculated the relative variance (CV%) of repeated estimates of alpha and beta diversity (from moving window statistics). Our results suggest increasing fine-scale coexistence of species and convergence of metacommunities to similar local assemblages in succession [**10, 12, 18**]. We performed similar analyses for exploring degradation series. One data set represented a grazing gradient in cattle pastures at Transylvanian Lowland, Romania. Another data set was collected in Western Hungary, in 6 wet meadows colonized by different amount of the invasive Solidago gigantea. Using the same sampling protocol and the same analyses, in degradation we found divergence of metacommunities (i.e. decreasing reliability) with increasing level of grazing pressure and with increasing abundance of invasive plant species [**9, 10, 18, 19**]. The increasing spatial stability (convergence) in regenerating communities and the decreasing spatial stability (divergence) due to degradation seem to be general and robust trends (**Fig. 1**). In contrast, there are grasslands adapted to natural disturbances (e.g. to small mammal disturbances) with no detectable degradation [**7**].

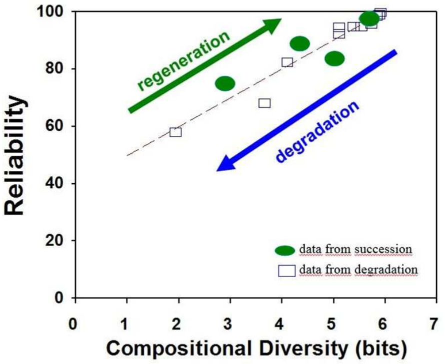
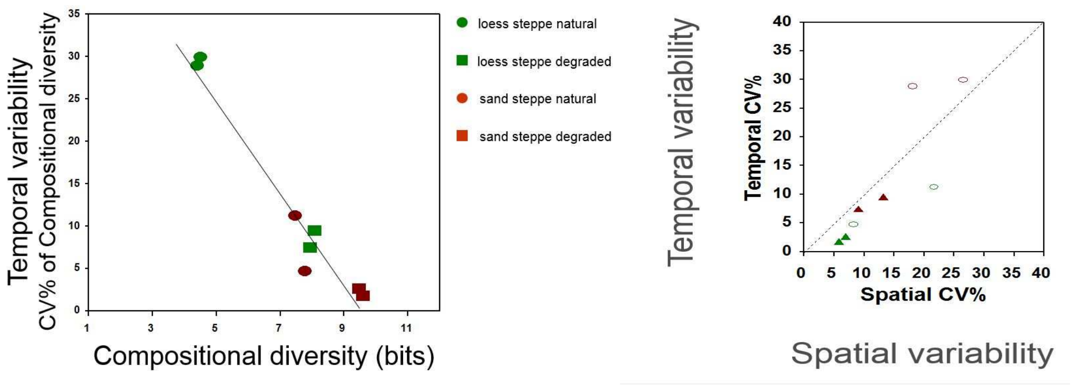


Figure 1. Reliability trends in succession and degradation (each point represent a vegetation stand). (Publications: 9, 10, 12, 18, 19)

2.4. Can grassland stability be inferred from fine-scale spatial patterns? - Relationship between spatial and temporal reliability

Using monitoring data sampled by large circular transects from 8 grassland sites (natural and slightly degraded sand and loess grasslands) we compared spatial and temporal patterns. Spatial reliability was estimated by moving windows statistics as in the previous paragraph. Temporal reliability was expressed by the temporal CV% of diversity sampled over time in the sample windows. Five times higher relative interannual variability was found in more arid and more degraded sites (**Fig. 2a**). Spatial reliability in the initial year showed positive correlation with temporal reliability during the next 5-6 years period (**Fig. 2b**). Our results imply that diversity and structural complexity are important sources of adaptive behaviour of vegetation and future dynamic behaviour of grasslands can be predicted from snapshot assessments [**10, 18, 19, 20**].


a,

b,

Figure 2. Relationship between spatial and temporal variability of diversity in grasslands (each point represent a vegetation stand). (Publications: 10, 18, 19, 20)

2.5. Within-stand variability of above ground biomass

Stand scale homogeneity (spatial reliability) of above ground productivity of vegetation was assessed by 60m biomass transects in various grasslands (58 transects sampled in open and closed sand grasslands, mesic steppe meadows on loess, wet meadows and ruderal assemblages from abandoned agricultural fields). Spatial variability of biomass was expressed by the coefficient of variation of spatial replicates sampled along the transect. Considering the spatial variability of biomass in natural grasslands, negative relationship was found between spatial CV% and the mean values of biomass (**Fig. 3**). Similar trend appeared in regenerating transitional communities (old fields) but the biomass was spatially more variable [**14, 17**].

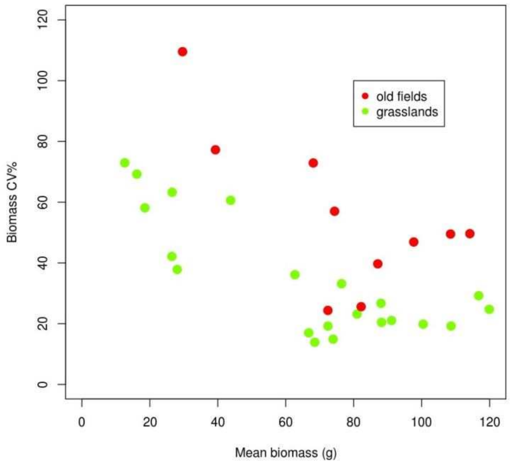


Figure 3. Relationship between biomass CV% and mean biomass. (Publications: 14, 17)

Objective #3 *Assessing mechanisms from functional patterns – a deductive approach*

3.1. Evidence of unimodal relationship between productivity and species richness – global versus local scale patterns

We had the opportunity to join to an international collaboration (30 sites in 19 countries and 6 continents) for testing the classic humped-back model (HBM) between productivity and species richness. Based on a worldwide coordinated survey, using extremely large local sample sizes (n=64, 1x1m plots,) and careful consideration of sampling conditions, our data supported the HBM model [**4**]. This study offered some important conclusions that were relevant to our OTKA project. First: the consistency of results depends on the range of site productivities sampled and the classic HBM appears only at broad productivity range. Second: the relationship was a „constraint type" suggesting multiple additional factors limiting species richness at given productivity levels. Furthermore, we learnt that these global and regional scale relationships reflect some overall near-equilibrium patterns more relevant for evolutionary interpretation. Therefore, we decided to change our methodology focusing on regulation instead of regressions. For exploring regulatory relationships we extended our spatial analyses with temporal replicates.

3.2. Assessing temporal variability of spatial functional patterns – pattern regulation

We studied the temporal variability of grassland CO_2 flux and biomass spatial patterns over 4 years under varying environmental conditions in a semiarid grassland near Bugac. Soil respiration and biomass were monitored 9 times (representing also seasonal variability). The sampling scheme was the 60x80m grid sampled at two sites with contrasting management (grazed vs. mowed). Data analysis was based on variography and kriging. Altitude (slightly undulating micro-relief, with 1-2 m differences) showed strong spatial correlation to the abiotic co-variates, soil moisture and temperature, with a consequent correlation with soil respiration and above-ground biomass[**1**]. We concluded that in grasslands minor topographical differences are important in the formation and regeneration of functional patterns at stand scale. The temporal variability of the signs (positive or negative) of the autocorrelations found between these spatial patterns suggest a complex interaction network of studied variables regulating these patterns. The patterns were more variable in drought years, while under well-watered conditions we detected higher stability (higher reliability) and also homogeneity. Grazing potentially created increased heterogeneity and regulation of the patterns, while mowing appeared to have had a homogenizing effect resulting in a lesser degree of pattern regulation [**1**].

3.3. Model fits reflect pattern regulation

Analyzing the fine-scale functional patterns of soil respiration, soil moisture and soil temperature by geostatistics (77 small circular transects), we found that model fits (i.e. detectability of spatial patterns) depend on specific conditions (vegetation closure in combination with large Rs and SWC values, as well as low variability of Ts and Rs). Our results show a shift from homogeneity and dominance of biotic processes to an increased heterogeneity and abiotic regulation in drought prone ecosystems under decreasing soil moisture [**2**].

3.4. Linking functional patterns to vegetation characteristics

In case of 60m biomass transects, when biomass and diversity were analyzed separately, we found negative relationships between spatial CV% and mean values at both characteristics. Wet meadows and loess steppe meadows showed the highest spatial reliability of diversity and as well as the highest spatial reliability of biomass. However, we did not found relationships between mean diversity and the spatial reliability of biomass at stand scale (**Fig. 4a**) [**14**]. Similar relationships were assessed at patch scale using small circular transects. Data were collected from the same type of grasslands as for the 60m long transects (172 transects sampled at 15 sites from different seasons (March to November) and different years (2013-2017). According to our hypothesis, the highest functional reliability is expected in spatially well-organized plant communities with high structural complexity (high beta diversity) at fine scale. Our results have supported this hypothesis: we found lower CV% of soil respiration in vegetation communities with higher beta diversity (higher structural complexity) at vegetation patch scale (**Fig. 4b**) [**15, 16**].

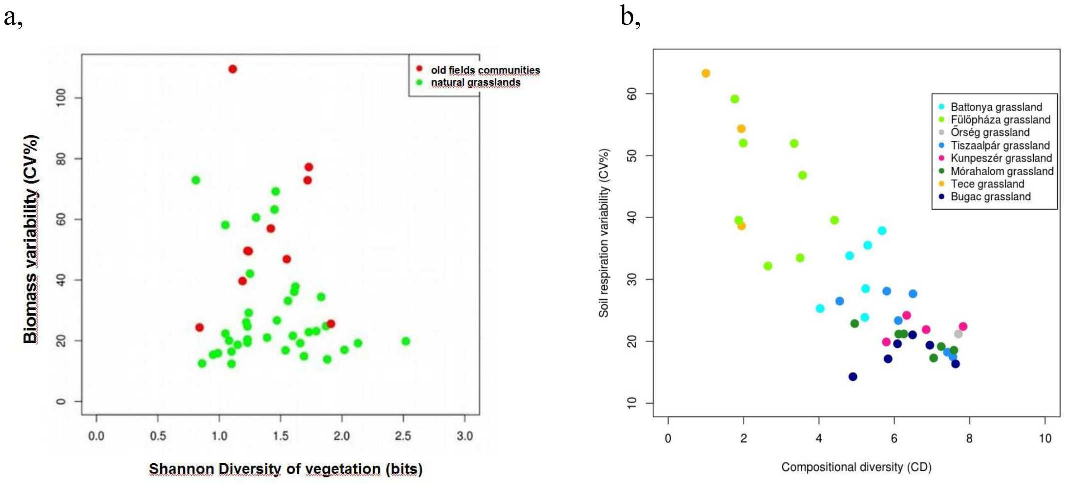


Figure 4. Relationship between functional reliability and vegetation diversity a, Biomass CV% and stand scale diversity b, Patch-scale soil respiration and compositional diversity. (Publications 14, 15, 16)

3.5. Exploring mechanisms affecting reliability of vegetation patterns

Dominance and diversity is often negatively related in plant communities. We tested this relationship in a wide range of successional plant communities and found that only a small portion of species acts as strong biotic filter [**5**]. Our results showed that spatial patterns and associations between dominants and subordinates vary with dynamical states (stable or transitional) and environmental conditions. Using hierarchical approach, we showed that the spatial functional organization of subordinate species affected by the spatial organization of dominant grass matrix in an abandoned mountain meadow. We found that trait-based assembly rules are consistent within habitats but may vary from community to community indicating that heterogeneous landscapes might support multiple processes of coexistence [**6**]. Changing biotic filters due to changing patterns of dominant species modulate the contribution of subordinate species to functional patterns and to the reliability of ecosystem services.

Problems

Due to unfavorable weather conditions and some technical problems (with our field instruments) we needed an additional field season to finish our field measurements. Therefore we asked and received permission for extending our study period with one additional year until 31 December 2017.

Publications

Since the start of the project 49 publications have been published (with NKFI/OTKA support ackowledged). We published 7 papers in ISI journals, 2 paper in Hungarian journals, 2 plenary talks, and 38 other presentations (posters or lectures).

The total **IF** of these publications is **51,329**
The number of **independent citations** received by the publications of this OTKA grant is **143**.

Publications cited in the project report

[1] Szilvia Fóti , János Balogh , Marianna Papp , Péter Koncz , Dóra Hidy , Zsolt Csintalan , Péter Kertész , Sándor Bartha , Zita Zimmermann , Marianna Biró , László Hováth , Erik Molnár , Albert Szaniszló , Krisztina Kristóf , Györgyi Kampfl , Zoltán Nagy: *Temporal variability of CO2 and N2O flux spatial patterns at a mowed and a grazed grassland*, **Ecosystems** Online first: p. &. (2017) https://doi.org/10.1007/s10021-017-0138-8, 2017

[2] Szilvia Fóti, János Balogh, Michael Herbst, Marianna Papp, Péter Koncz, Sándor Bartha, Zita Zimmermann, Cecília Komoly, Gábor Szabó, Katalin Margóczi, Manuel Acosta, Zoltán Nagy: *Meta-analysis of grassland soil CO2 efflux spatial variability as a result of interacting environmental factors at field scale.*, **Catena** 143: 78-89., 2016

[3] Fóti Szilvia, Balogh János, Nagy Zoltán, Herbst Michael, Pintér Krisztina, Péli Evelin, Koncz Péter, Bartha Sándor: *Soil moisture induced changes on fine-scale spatial pattern of soil respiration in a semi-arid sandy grassland*, **Geoderma** 213: 245-254., 2014

[4] Fraser LH, Pither J, Jentsch A, Sternberg M, Zobel M, Askarizadeh D, Bartha S, Beierkuhnlein C, Bennett JA, Bittel A, Boldgiv B, Boldrini II, Bork E, Brown L, Cabido M, Cahill J, Carlyle CN, Campetella G, Chelli S, Cohen O, Csergo AM, Diaz S, Enrico L, Ensing D, Fidelis A, Fridley JD, Foster B, Garris H, Goheen JR, Henry HAL, Hohn M, Jouri MH, Klironomos J, Koorem K, Lawrence-Lodge R, Long RJ, Manning P, Mitchell R, Moora M, Muller SC, Nabinger C, Naseri K, Overbeck GE, Palmer TM, Parsons S, Pesek M, Pillar VD, Pringle RM, Roccaforte K, Schmidt A, Shang ZH, Stahlmann R, Stotz GC, Sugiyama S, Szentes S, Thompson D, Tungalag R, Undrakhbold S, van Rooyen M, Wellstein C, Wilson JB, Zupo T.: *Worldwide evidence of a unimodal relationship between productivity and plant species richness*, **Science** 349:(6245) 302-305., 2015

[5] Bartha Sándor, Szentes Szilárd, Horváth András, Házi Judit, Zimmermann Zita, Molnár Csaba, Dancza István, Margóczi Katalin, Pál Róbert, Purger Dragica, Schmidt Dávid, Óvári Miklós, Komoly Cecília, Sutyinszki Zsuzsanna, Szabó Gábor, Csathó András István, Juhász Melinda, Penksza Károly,

Molnár Zsolt: *Impact of midsuccessional dominant species on the diversity and progress of succession in regenerating temperate grasslands*, **Applied Vegetation Science** 17: 201-213, 2014

[6] Camilla Wellstein, Giandiego Campetella, Francesco Spada, Stefano Chelli, Ladislav Mucina, Roberto Canullo, Sandor Bartha: *Contextdependent assembly rules and the role of dominating grasses in semi-natural abandoned sub-mediterranean grasslands*, **Agriculture, Ecosystems and Environment** 182: 113-122, 2014

[7] Zita Zimmermann, Gábor Szabó, András István Csathó, Judit Sallainé Kapocsi, Szilárd Szentes, Melinda Juhász, Judit Házi, Cecília Komoly, Klára Virágh, Zsuzsanna Harkányiné Székely, Zsuzsanna Sutyinszki, Sándor Bartha: *The impact of the lesser blind mole rat [Nannospalax (superspecies leucodon)] on the species composition and diversity of a loess steppe in Hungary,* **Applied Ecology and Environmental Research** 12(2): 591-602., 2014

[8] Bartha Sándor, Zimmermann Zita, Szabó Gábor, Szentes Szilárd, Virágh Klára, Csathó András István: *A magyar földikutya (Nannospalax hungaricus) növényzetre gyakorolt hatásának mikrocönológiai monitorozása a Tompapusztai löszgyepben (2011–2014).,* **Crisicum** 9: 21-35., 2016

[9] Kun Róbert, Szépligeti Mátyás, Malatinszky Ákos, Virágh Klára, Szentirmai István, Bartha Sándor: *Egy inváziós faj, a Solidago gigantea Aiton által kolonizált mocsárrétek diverzitása és Fajkompozíciós koordináltsága*, **Botanikai Közlemények** 101(1-2): 65-77., 2014

[10] Bartha Sándor: *Understanding vegetation succession process in habitat and vegetation restoration and rehabilitation.* (IAVS symp.), In: Mucina, L., Price, J.N. & Kalwij, J.M. (eds.), Biodiversity and vegetation: patterns, processes, conservation, 2014 pp. 25-26. Kwongan Foundation, Perth, AU, ISBN 978-0-958, 2014 (plenary lecture)

[11] Campetella, G, Canullo, R., Mucina, L., Kertész, M., Ruprecht, E., Penksza, K., Chelli, S., Csathó, A.I., Zimmermann, Z., Komoly, C., Szabó, G., Házi, J., Besnyői, V., Koncz, P., Čarni, A., Paušić, A., Juvan, N., Wellstein, C., Szépligeti, M., Csete, S., Kun, R. & Bartha, S.: *Solving the conflict between intensive and extensive approaches: transect based sampling design for comparative studies on fine scale plant community organization*., In: Mucina, L., Price, J.N. & Kalwij, J.M. (eds.), Biodiversity and vegetation: patterns, processes, conservation, p. 76. Kwongan Foundation, Perth, AU., ISBN 978-0-958476, 2014

[12] Bartha, S., Ruprecht, E., Szabó, A., Zimmermann, Z., Komoly, C., Szabó, G., Paušić, A., Juvan, N. & Čarni, A: *Reliability and coherence of diversity patterns in plant community succession*, In: Mucina, L., Price, J.N. & Kalwij, J.M. (eds.), Biodiversity and vegetation: patterns, processes, conservation, p. 219. Kwongan Foundation, Perth, AU., ISBN 978-0-95847, 2014

[13] Bartha Sándor, Zimmermann Zita, Csete Sándor, Házi Judit, Szépligeti Mátyás, Komoly Cecília, Kun Róbert, Csathó András István, Szabó Gábor: *Structural reliability – a new index for measuring naturalness of grasslands,* „Sustainable development in the Carpathian basin III" Conference., Gödöllő, 2016.03.17-18. Abstracts p. 35., 2016

[14] Szabó Gábor, Zimmermann Zita, Andraž Čarni, Csathó András István, Házi Judit, Kálmán Nikoletta, Komoly Cecília, Kun Róber, Margóczi Katalin, Mojzes Andrea, Szépligeti Mátyás, Bartha Sándor: *Diverzitás és biomassza-produkció megbízhatóságának vizsgálata hazai gyeptársulásokban*, MBT XXX. Vándorgyűlés: összefoglalók: 2017. február 17-18, Budapest, p. 34., 2017

[15] Zimmermann Zita, Szabó Gábor, Fóti Szilvia, Balogh János, Andraž Čarni, Csathó András István, Margóczi Katalin, Bartha Sándor*: A talajlégzés térbeli variációja, mint a működés megbízhatóságának egy lehetséges indikátora*, MBT XXX. Vándorgyűlés: összefoglalók: 2017. február 17-18, Budapest, p. 33., 2017

[16] Zita Zimmermann, Gábor Szabó, Szilvia Fóti, János Balogh, Andraž Čarni, András István Csathó, Katalin Margóczi, Sándor Bartha: *Spatial variation of soil respiration, as a potential indicator of functional reliability in grasslands*, The 60th IAVS Annual Symposium: Vegetation patterns in natural and cultural landscapes, Palermo, Italy – Abstract Book. p 373., 2017

[17] Gábor Szabó, Zita Zimmermann, Andraž Čarni, András István Csathó, Judit Házi, Nikoletta Kálmán, Cecília Komoly, Róbert Kun, Katalin Margóczi, Andrea Mojzes, Mátyás Szépligeti, Sándor Bartha: *Diversity and reliability of biomass production in different grassland types in Hungary,* The 60th IAVS Annual Symposium: Vegetation patterns in natural and cultural landscapes, Palermo, Italy – Abstract Book. p. 323, 2017

[18] Bartha Sándor, Zimmermann Zita, Szépligeti Mátyás, Kun Róbert, Csete Sándor, Komoly Cecília, Házi Judit, Szentes Szilárd, Vadász Besnyői Vera, Bódis Judit, Ruprecht Eszter, Szabó Anna, Virágh Klára, Kun András, Csathó András István, Penksza Károly, Szabó Gábor: *Szimmetriák a növénytársulások szerkezetében*, BOTANIKAI KÖZLEMÉNYEK 104:(2) pp. 251-252. (2017), 2017

[19] Bartha Sándor: *Növénytársulások stabilitásának és megbízhatóságának mikrocönológiai háttere - kompozícionális diverzitás, heterogenitás, léptékfüggés*, MBT XXX. Vándorgyűlés: összefoglalók: 2017. február 17-18, Budapest, p. 31., 2017

[20] Sándor Bartha, Klára Virágh, Cecília Komoly: *Can grassland stability be inferred from fine-scale spatial patterns?,* In: 10th EDG meeting, "When theory meets practice: Conservation and restoration of grasslands. 24-31 May 2013, Zamosc, Poland (lecture), 2013

Other publications supported by NKFI(OTKA) K105608

[21] Bartha Sándor, Zimmermann Zita, Házi Judit, Juhász Melinda, Komoly Cecília, Szabó Gábor, Horváth András, Molnár Zsolt: *Are Hungarian sand grasslands threatened by climate and landuse changes?*, In: Zimmermann Z, Szabó G (eds.): Grassland management and nature conservation – Conference proceedings, 25th-26th Febr. 2013, Budapest, Hungary, p. 10. (Plenary lecture), 2013

[22] Sándor Bartha, Szilvia Fóti: *Percolation networks of dominant grasses drive diversity and assembly of subordinates in semiarid sand steppes.,* 56th IAVS Symposium, June 26-30, 2013, Tartu, Estonia (lecture), 2013

[23] Bartha Sándor: *Reliability of diversity patterns – a new approach for indicating naturalness and degradation in grasslands*, In: „Sustainable development in the Carpathian basin" International conference, 21-23. November 2013., Budapest (lecture), 2013

[24] Bartha Sándor, Fóti Szilvia, Balogh János, Biró Mariann, Margóczi Katalin, Csete Sándor, Zimmermann Zita, Szabó Gábor, Házi Judit, Juhász Melinda, Csathó András István, Péli Evelin, Horváth András és Nagy Zoltán: *Hogyan vizsgálható a vegetációszerveződés finom térléptékű szabályozottsága?,* MBT Botanikai Szakosztály előadóülése, Budapest, 2013. 04.08 (lecture), 2013

[25] Szilvia Fóti, J. Balogh, Z. Nagy, M. Herbst, K. Pintér, E. Péli, P. Koncz, S. Bartha: *Soil moisture induced changes on fine-scale spatial pattern of soil respiration in a semi-arid sandy grassland.,* Greenhouse Gas Management in European Land Use Systems, 16-18. September 2013. Antwerp, Belgium (poszter), 2013

[26] Campetella, G., Bartha, S., Chelli, S., Wellstein, C., Cervellini, M. & Canullo, R.: *Is species turnover in the herb layer of old-growth beech forests driven by specific plant traits?,* In: Mucina, L., Price, J.N. & Kalwij, J.M. (eds.), Biodiversity and vegetation: patterns, processes, conservation, p. 75. Kwongan Foundation, Perth, AU., ISBN 978-0-9584, 2014

[27] Szilvia Fóti, János Balogh, Marianna Papp, Zita Zimmermann, Gábor Szabó, Michael Herbst, Marianna Biró, Sándor Bartha, László Horváth, Zoltán Nagy: *Drivers of spatial patterns of physiological and soil parameters at micro- and field scale in a Hungarian sandy grassland*, In: EGU General Assembly 2014. Wien, Ausztria, 2014.04.27-2014.05.02. Paper EGU2014- 13672, 2014

[28] Andraž Čarni, Ruprecht Eszter, Szabó Anna, Zimmermann Zita, Szabó Gábor, Csathó András István, Házi Judit, Komoly Cecília, Andrej Paušić, Nina Juvan, Bartha Sándor: *Diversity, regulation and reliability in vegetation succession,* In: Zimmermann Zita, Szabó Gábor (szerk.): "II. Sustainable development in the Carpathian Basin" international conference" – Book of Abstracts pp. 60-61. (ISBN: 978-963-2, 2014

[29] Zimmermann Zita, Szabó Gábor, Házi Judit, Bartha Sándor: *A biomassza variációja, mint a társulások szervezettségének és funkcionális szempontú természetességének lehetséges indikátora,* In: (Lengyel Szabolcs szerk.) IX. Magyar Természetvédelmi Biológiai Konferencia Absztrakt kötet Szeged, 2014. november 20-23. p. 143-144., 2014

[30] Camilla Wellstein, Anke Jentsch, Stefano Chelli, Giandiego Campetella, Roberto Canullo, Iva Apostolova, Juliette Bloor, Kevin Cianfaglione, Jürgen Dengler, Philipp von Gillhaußen, Behlül Güler, Házi Judit, Komoly Cecília, Jürgen Kreyling, Julien Pottier, Szabó Gábor, Tsvetelina Terziiska, Emin Uğurlu, Zimmermann Zita, Bartha Sándor: *Fine-scale functional organization in grasslands – a microquadrat-based approach to assembly rules.*, . In: Zimmermann Zita, Szabó Gábor (szerk.): "II. Sustainable development in the Carpathian Basin" international conference – Book of Abstracts pp. 68-71. (ISBN: 978-963, 2014

[31] Besnyői Vera, Vadász Csaba, Máté András, Andraž Čarni, Nina Juvan, Csathó András István, Kelemen András, Komoly Cecília, Koncz Péter, Kun Róbert, Molnár Zsolt, Szabó Gábor, Zimmermann Zita, Bartha Sándor: *Diversity and fine-scale spatial organization of microhabitats in species rich natural grasslands*, In: Zimmermann Zita, Szabó Gábor (szerk.): "II. Sustainable development in the Carpathian Basin" international conference – Book of Abstracts pp. 64-67. (ISBN: 978-963-26, 2014

[32] Zimmermann Zita, Szabó Gábor, Házi Judit, Bartha Sándor: *Variation of the biomass can indicate organization and naturalness of the plant communities.*, In: Zimmermann Zita, Szabó Gábor (szerk.): "II. Sustainable development in the Carpathian Basin"pp. 161-162. (ISBN: 978-963- international conference – Book of Abstracts, 2014

[33] Bartha Sándor: *Variability of relative abundances of species in plant communities*, In: Zimmermann Zita, Szabó Gábor (szerk.): "II. Sustainable development in the Carpathian Basin" international conference – Book of Abstracts pp. 62-63. (ISBN: 978-963-26, 2014

[34] Gábor Szabó, Zita Zimmermann, Judit Házi, András István Csathó, Sándor Bartha: *Fine-scale spatial variability of biomass in grasslands as a potential indicator of naturalness and management.,* In: M. Chytrý, D. Zelený, E. Hettenbergerová (eds.) 58th Annual Symposium of International Association for Vegetation Science - Abstracts p.365., 2015

[35] Kun R, Szépligeti M, Szentirmai I, Bartha S.: *Mocsárréti állományok koordináltsága a diverzitás - és biomassza varianciájának tekintetében.*, In: Padisák J. Liker A. StengerKovács Cs. (szerk.) X. MÖK: Veszprém, Absztrakt Kötet, p. 87., 2015

[36] Sándor Bartha, Sándor Csete, Ladislav Mucina, Eszter Ruprecht, Klára Virágh, András Horváth, Anna Szabó, Judit Házi, Zita Zimmermann, Gábor Szabó, András Kun, Zsolt Molnár: *Relationship between diversity components in dry grasslands.*, In: M. Chytrý, D. Zelený, E. Hettenbergerová (eds.) 58th Annual Symposium of International Association for Vegetation Science - Abstracts p.36., 2015

[37] Fóti Szilvia, Balogh János, Michael Herbst, Papp Marianna, Koncz Péter, Bartha Sándor, Zimmermann Zita, Komoly, Cecília, Szabó Gábor, Margóczi Katalin, Manuel Acosta, Nagy Zoltán: *Metaanalízis gyepek talajlégzésének térbeli mint*ázatáról., In: Padisák J. Liker A. Stenger-Kovács Cs. (szerk.) X. MÖK: Veszprém, Absztraktkötet, p. 55., 2015

[38] Bartha S, Zimmermann Z, Szabó G: *A kisemlősök szerepe a füves ökoszisztémák szerveződésében és dinamikájában.*, X. MTBK, Mórahalom 2016.04.1-3. Abstracts, p. 22., 2016 (invited lecture)

[39] Bartha S: *Kisemlős bolygatás, szukcessziós ablakok és béta diverzitás spontán regenerálódó parlagterületeken.*, X. MTBK, Mórahalom 2016.04.1-3. Abstracts, p. 53-54., 2016

[40] Szabó G, Zimmermann Z, Bartha S: *Assessing spatial heterogeneity of biomass production in Hungarian grasslands.,* 13th Eurasian Grassland Conference, Sighisoara, Románia, 2016.09. 20-24. p. 61., 2016

[41] Zimmermann Z, Szabó G, Fóti Sz, Balogh J, Čarni A, Csathó A I, Margóczi K, Bartha S: *Relationship between fine-scale functional and coenological patterns in grasslands in Hungary.,* 13th Eurasian Grassland Conference, Sighisoara, Románia, 2016. 09. 20- 24. p. 76., 2016

[42] Szabó Gábor, Zimmermann Zita, Házi Judit, Bartha Sándor: *Variation of biomass as a potential indicator of organization and naturalness of the plant communities.*, „Sustainable development in the Carpathian basin III" Conference., Gödöllő, 2016.03.17-18. Abstracts p. 73., 2016

[43] Bartha S, Virágh K, Szabó A, Kun A, Zimmermann Z, Szabó G, Ruprecht E: *Miről ismerhető fel egy gyeptársulás leromlásának legkorábbi stádiuma? Egy különlegesen fajgazdag gyeptársulás szerkezetének változásai egy legeltetési gradiens mentén.,* X. MTBK, Mórahalom 2016.04.1-3. Abstracts, p. 54., 2016

[44] Bartha Sándor, Szabó Gábor, Csathó András István, Házi Judit, Kálmán Nikolett, Kun Róbert, Csete Sándor, Komoly Cecília, Mojzes Andrea, Szentes Szilárd, Szépligeti Mátyás, Zimmermann Zita: *Növénytársulások szerveződésének mikrocönológiai léptékű térbeli és időbeli variációja.,* BOTANIKAI KÖZLEMÉNYEK 103:(2) pp. 266-267., 2016

[45] Szabó Gábor, Zimmermann Zita, Andraž Čarni, Csathó András István, Házi Judit, Kálmán Nikolett, Komoly Cecília, Kun Róbert, Margóczi Katalin, Mojzes Andrea, Szépligeti Mátyás, Bartha Sándor: *Biomassza-produkció térbeli variációja különböző gyeptípusokban.*, BOTANIKAI KÖZLEMÉNYEK 103:(2) pp. 263-264., 2016

[46] Zimmermann Zita, Szabó Gábor, Fóti Szilvia, Andraž Čarni, Csathó András, Házi Judit, Margóczi Katalin, Bartha Sándor: *Szünfiziológiai és mikrocönológiai mintázatok összefüggései gyepekben.*, BOTANIKAI KÖZLEMÉNYEK 103:(2) p. 264., 2016

[47] Bartha S, Csete S, Szabó G, Zimmermann Z, Virágh K, Házi J, Kun A, Csathó A I, Komoly C, Molnár Zs: *Stabilizálják-e a társulásokat a finom térléptékű szomszédsági relációk? - néhány hosszútávú (7-20 éves) monitoring vizsgálat tapasztalatai*, XI. Magyar Természetvédelmi Biológiai Konferencia Absztraktkötet. Eger, 2017.11.2-5.p. 45., 2017

[48] Andraž Čarni, Nina Juvan Mastnak, Andrej Paušič, Gábor Szabó, Zita Zimmermann, Sándor Bartha: *Quantifying biotic filter effects in old field succession*, 1st International Conference of Community Ecology: Book of Abstracts. Budapest, 2017.09.28-29. p. 105.,

[49] Szabó G, Zimmermann Z, Carni A, Csathó A I, Házi J, Komoly C, Kun R, Margóczi K, Szépligeti M, Bartha S: *A diverzitás és a biomassza-produkció megbízhatóságának vizsgálata különböző gyeptípusokban*, XI. Magyar Természetvédelmi Biológiai Konferencia Absztraktkötet. Eger, 2017.11.2-5. p. 137., 2017

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