Review on Agriculture and Rural Development 2025 vol. 14 (1-2) ISSN 2677-0792
DOI: 10.14232/rard.2025.1-2.14-22

MEASURING MICROCLIMATE REGULATION EFFECTS OF FOREST- STEPPE HABITAT IN CENTRAL HUNGARY

Gabriella Hajagos[1]*, Eszter Tormáné Kovács[2], Csaba Vadász[3]

[1]Doctoral School of Environmental Science, Hungarian University of Agriculture and Life Sciences, Gödöllő, HUNGARY
[2]Department of Nature Conservation and Landscape Management, Institute for Wildlife Management and Nature Conservation, Hungarian University of Agriculture and Life Sciences, Gödöllő, HUNGARY
[3]Kiskunsági National Park Directorate, Kecskemét, Hungary

*corresponding author: hajagos@gmail.com

Abstract: This pilot study focused on the microclimate regulating effects of different vegetation types of forest-steppe habitat. Between April and December 2023, soil moisture at a depth of 10, 40 and 80 cm was measured at 3-3 sample plots alongside two natural forest edges. Between September and November 2023, air temperature and relative air humidity were recorded at 7 predefined vegetation types of sandy forest-steppe habitat (4 plots/type, 7 types/site, 3 sites, 84 plots in total). Relative soil and air humidity data was analysed with descriptive statistics, while one-way ANOVA was run for air temperature data. Our results show that the inner parts of the forests and forest edges were characterised with significantly higher soil humidity in each soil layer, compared to woodless grasslands. Furthermore, more moderate temperature is present in woody vegetation types compared to grasslands outside of forests. Significant minimum and maximum temperature-raising effects were also observed. No significant differences were detected between locations and vegetation types in air humidity, but methodological changes are necessary in the future. During the study period, microclimate of woody vegetation types was more balanced, compared to grasslands outside forests. Plots at woody vegetation types were characterised by a better soil moisture supply and a significant air temperature regulating effect, which gave a more balanced air temperature as the minimum and maximum values were more attenuated but did not influence the seasonal mean value.

Keywords: microclimate-regulation, forest-steppe, air temperature, soil humidity

1. Introduction

Ecosystem services are goods and services that ecosystems provide to humans (MEA 2005). When ecosystems function well, they can offer various benefits that satisfy certain needs of people, thereby contributing to human well-being (Kovács et al. 2014).

There are several approaches to categorise ecosystem services, usually with one of the categories assigned to regulating services (MEA 2003, http1) such as microclimate-regulation. The microclimate can be considered as the set of climatic factors (e.g. air temperature, air humidity, soil moisture) that can be measured in the lower layer of the atmosphere at different scales (e.g. landscape, local) (Koncz et al. 2021). The microclimate plays an important role in the habitat selection of species, shaping species composition and species-richness (Inouye 2008, Süle & Körmöczi 2017). Also, various economic and social groups of the human society have expressed its usefulness (Fejes et al. 2022).

DOI: 10.14232/rard.2025.1-2.14-22

The forest-steppe is an independent climatic zone characterised by transitional vegetation between closed forests and grasslands, thereby composed by grassland-forest mosaics (Molnár & Kun 2000). Among the forest habitat types present in Hungary, the extent of the forest-steppe forests has decreased the most in the last century (Bartha 2001). Nowadays we can only encounter such habitats in isolated, smaller patches (Molnár & Kun 2000). One of the most species-rich forest-steppes of Hungary is the Peszér-forest (Doronicum Szolgáltató Kft. 2015).

There are some studies that focus on measuring microclimatic factors (soil humidity, air temperature, air humidity) of similar habitats in the Kiskunság (Unyi-Buzetzky 2014, Bolla 2017, Süle 2022, Khanh et al. 2024), also in other regions (Anenkhonov et al. 2015, Milosevic et al. 2020, Süle et al. 2020). Bolla (2017) installed measuring stations to measure the hourly soil moisture in four soil layers (between 0-100 cm) in forest and grassland habitats. When using the TDR hand-held measuring instrument, the thickness of the soil layer that can be tested varies, while some measuring devices reach deeper soil layers (up to 1.5 m) (Unyi-Buzetzky 2014, Bolla 2017), Süle's (2022) measurements only reached a depth of 7-8 cm. We also have several methods for measuring air temperature and air humidity (Loksa 2004), one of which is the use of data measured by meteorological stations (Bolla 2017). In addition, it is also possible to use installed loggers, which usually collect data periodically (Ódor 2015, Kovács 2018, Stofa 2021). Manual measuring instruments and data loggers allow us to measure at several sampling points covering a larger area, on the other hand, the advantage of measuring stations (including meteorological stations) is that they provide us with year-round data, but with a smaller coverage in space.

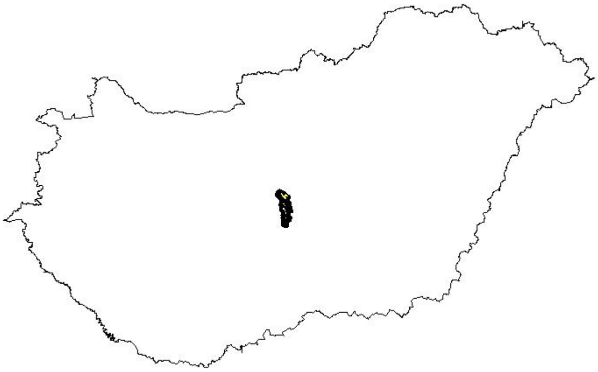
The main objective of our pilot study was to characterise the microclimate regulating effect of different types of forest-steppe vegetation. The temporal patterns of soil moisture, air temperature and air humidity were assessed in the research area during the study period.

2. Materials and methods

2.1. Study sites

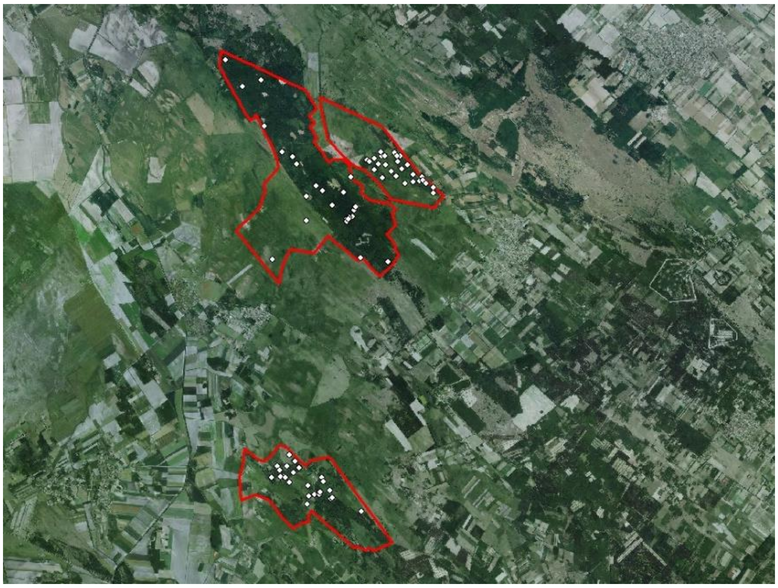
The study was carried out at three sites (Peszér-forest, Szalag-forest and Adacs-forest) in the Kiskunság, Central Hungary (*Figure 1*). The study area is charaterized with broad-leaved forest-steppe (dominated by Quercus robur, Populus x canescens), closed shrublands (dominated by Crataegus monogyna, Prunus spinosa, Juniperus communis) and woodless grasslands on sand soils (dominated by Festuca rupicola, Chrysopogon gryllus), alltogether forming a habitat complex with high nature conservation value. Soil moisture data were recorded at one site, while air temperature and air humidity data were recorded at all three sites (*Figure 2*). All three sites are representatives of forest-steppe on sand, differing from each other only in landscape history.

Figure 1.: Location of the study area within Hungary



Source: own editing

Figure 2.: Location of the three study sites and sampling plots



Source: own editing

2.2. Data gathering

2.2.1. Relative soil humidity

Between April and December 2023, soil moisture was measured at 3-3 plots alongside two natural forest edges. When selecting the sampling points, the main

DOI: 10.14232/rard.2025.1-2.14-22

aim was to characterise the transition from closed forest to open grassland via three points: 1) the inner part of the forest (20 meters away from the edge), 2) forest edge, 39 grasslands outside of the forest (20-30 meters away from the forest edge).

Decagon loggers and sensors were used for measuring relative soil humidity (hereinafter: RSH). Sensors were installed at 10, 40, and 80 cm depth in the case of open grasslands and forest edges, and at 80 cm depth in the case of inner parts of forests. Soil humidity data were recorded in 15 minutes intervals.

2.2.2. Air temperature and relative air humidity

Between September and November 2023, air temperatures (hereinafter: AT) and relative air humidity (hereinafter: RAH) were measured at randomly selected plots representing 7 predefined structural types of the sand forest-steppe habitat complex (4 plots/type, 7 types/site, 3 sites, 84 plots in total). The vegetation types were the following:

- woodless sand grassland outside of forest (hereinafter: grassland)
- woodless clearings in forests on sand soil (clearing)
- solitaire shrub outside of forests (solitaire shrub)
- shrubland with closed canopy (closed shrubland)
- forest with low canopy closure (open forest)
- closed forest with no significant shrub layer (closed forest without shrub layer)
- closed forest with significant shrub layer (closed forest with shrub layer)

Xiaomi Mi Temperature and Humidity Monitor devices were applied. In woodless vegetation types, the devices were installed to a wooden post at 1 meter height with southern orientation, while in the rest of the vegetation types devices were attached to the tree trunk or hung on a shrub at 1 meter height with northern orientation. This way, maximal shading by woody vegetation, therefore maximal differences compared to woodless grassland were recorded. In order to be able to detect subtle changes in microclimate, the devices measured the current temperature and humidity conditions every minute, and saved the average of the measured data in every 10 minutes.

2.3. Data analysis

For characterising RSH, the following descriptive statistics were calculated: maximum, minimum, average for each month and for the whole study period. Due to unbalanced study design (no data were recorded at 10 and 40 cm depth at inner parts of forests, and failure of one of the sensors) it was not possible to run statistical tests on this dataset. For quantifying the length of water deficient period throughout the study period, the number of months during the vegetation period (from April till October) with RSH less than 10% and less than 20% were calculated.

DOI: 10.14232/rard.2025.1-2.14-22

For AT, one-way ANOVA was run for seasonal minimum, seasonal maximum and seasonal average temperatures (separately). For post-hoc testing, Tukey-tests were run.

For RAH, descriptive statistics were calculated: maximum, minimum, average for each month and for the whole study period.

3. Results

3.1. Soil moisture

RSH varied across months, sites, and soil layers (*Table 1*). In the case of woodless grasslands, independently from soil layers and sites, average RSH (calculated for the whole study period) varied in a narrow range between 13.3% and 17.6%, indicating that all the soil layers were considerably dry throughout the study period.

In the case of forest edges more expressed differences were revealed, as average RSH (calculated for the whole study period) varied between 14.1% and 32.2%. In the case of forest edges, the lowest soil layer was relatively wet (29.2%-32.2%) and the upper two layers were characterised with less balanced range (with the lowest monthly average RSH and the highest monthly average RSH throughout the study period ranging between 5.9% and 19.3% and between 22.4% and 27.4%).

In the case of inner parts of forest, RSH of the lowest soil layer varied in a range between 28.1% and 38.1%, indicating that this layer was characterised with favorable conditions throughout the study period.

Table 1.: Monthly average of relative soil humidity (%) fom April till December

Plot	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	min	max	avg
Site 1, grassland, 10 cm	25.0	22.2	13.4	11.5	13.7	8.2	10.4	25.4	26.4	8.2	26.4	17.4
Site 1, grassland, 40 cm	25.7	24.7	21.2	13.6	9.5	7.5	6.8	19.2	26.3	6.8	26.3	17.2
Site 1, grassland, 80 cm	18.9	18.6	16.0	10.8	8.6	7.2	6.1	13.4	20.0	6.1	20.0	13.3
Site 1, forest edge, 10 cm	26.7	25.1	20.1	16.8	16.0	13.2	13.9	25.0	27.4	13.2	27.4	20.4
Site 1, forest edge, 40 cm	24.5	24.2	23.3	22.1	21.3	20.2	19.3	19.7	25.3	19.3	25.3	22.2
Site 1, forest edge 80 cm	33.7	33.9	33.9	33.7	33.0	31.3	29.4	29.0	32.3	29.0	33.9	32.2
Site 1, forest, 80 cm	38.1	38.0	37.6	37.0	36.2	34.3	32.9	33.0	37.7	32.9	38.1	36.1
Site 2, grassland, 10 cm	22.8	16.3	6.4	6.9	8.1	-	-	-	-	-	-	-
Site 2, grassland, 40 cm	23.8	22.5	13.8	13.3	15.5	9.6	11.6	24.0	24.3	9.6	24.3	17.6
Site 2, grassland, 80 cm	20.9	19.9	8.1	5.5	5.4	5.1	5.6	17.5	22.4	5.1	22.4	12.3
Site 2, forest edge, 10 cm	26.2	23.7	14.8	13.1	14.9	12.6	15.4	25.8	27.2	12.6	27.2	19.3
Site 2, forest edge, 40 cm	22.1	21.4	13.3	8.1	6.3	5.9	6.1	20.2	23.6	5.9	23.6	14.1
Site 2, forest edge 80 cm	33.4	33.1	30.2	26.6	26.0	25.6	25.5	28.4	33.9	25.5	33.9	29.2
Site 2, forest, 80 cm	33.8	33.7	32.0	29.0	28.5	28.4	28.1	30.4	32.6	28.1	33.8	30.7

Source: own calculation

The number of months thoroughout the vegetation season, characerised with severly water deficiency (RSH less than 10%), and number of months thoroughout the vegetation characterised with limited (suboptimal) water supply (RSH less than 20%) ranged between 0-5, 0-7, respectively (*Table 2*).

DOI: 10.14232/rard.2025.1-2.14-22

Table 2.: Number of months thoroughout the vegetation season, with RSH less than 10% and RSH less than 20%.

Plot	RSH<10%	RSH<20%
Site 1, grassland, 10 cm	1	5
Site 1, grassland, 40 cm	3	4
Site 1, grassland, 80 cm	3	7
Site 1, forest edge, 10 cm	0	4
Site 1, forest edge, 40 cm	0	1
Site 1, forest edge 80 cm	0	0
Site 1, forest, 80 cm	0	0
Site 2, grassland, 10 cm	-	-
Site 2, grassland, 40 cm	1	5
Site 2, grassland, 80 cm	5	6
Site 2, forest edge, 10 cm	0	5
Site 2, forest edge, 40 cm	4	5
Site 2, forest edge 80 cm	0	0
Site 2, forest, 80 cm	0	0

Source: own calculation

3.2. Air temperature

Seasonal maximum, minimum and average temperatures for the seven vegetation types are indicated in *Table 3*. Seasonal minimum temperature, seasonal maximum temperature and seasonal average temperature significantly varied across vegetation types (df=73, F=8.8982, p<0.01; df= 73, F=16.2478, p<0.01; df=73, F=2.5662, p=0.02, respectively). Vegetation type had significant effect on the seasonal range of temperature (df=73, F=23.1128, p<0.01).

Table 3.: Seasonal maximum, minimum, average temperatures and the seasonal range of temperature (°C)

	Sesonal minimum	Seasonal maximum	Seasonal average	Seasonal range
grassland	-9.7 ± 1.9 a	34.4 ± 2.3 a	11.3 ± 1.2 abc	44.1 ± 3.0
clearing	-7.2 ± 2.0 b	35.6 ± 0.9 a	12.5 ± 0.9 abc	42.8 ± 1.9
solitaire shrub	-8.2 ±1.4 ab	33.4 ± 1.5 ac	11.4 ± 0.5 ab	41.6 ± 1.7
closed shrubland	-7.1 ± 1.0 b	32.2 ± 2.1 bc	11.3 ± 0.9 ac	39.4 ±2.3
open forest	-7.5 ± 1.8 b	31.8 ± 1.3 bc	11.3 ± 1.3 abc	39.3 ± 2.2
closed forest without shrub layer	-5.5 ± 0.8 bc	30.0 ± 1.1 bcd	11.9 ± 0.4 abc	35.5 ± 1.6
closed forest with shrub layer	-5.9 ± 1.2 b	30.9 ± 1.3 bcd	11.7 ± 0.9 abc	36.8 ± 1.5

Source: own calculation

3.3. Relative air humidity

Regarding the air humidity we assume that the device cover caused an artifact in the results since no significant differences were detected between locations and vegetation types. Therefore methodological changes are necessary in the future.

4. Discussion

In the case of forests (at 80 cm depth) more favourable (more humid, less arid) soil moisture conditions were revealed, compared to grasslands. Forest edges were characterized with a transitional level of soil humidity, with expressed variablitiy within layers and sites. In the case of grasslands, all the three soil layers were completely dry during the hottest (and driest) part of the year with soil humidity being present as dead water (i.e. humidity non-accessible for plants). It is well known that soil humidity can decrease via two processes: evaporation and transpiration. Evaporation is enhanced by more open (less shading) vegetation (Erdős et al. 2018), while transpiration – as a rule of thumb – is increasing with increasing phytomass (Szabó et al. 2012). Considering the fact that soils inside forests were more humid than the ones at the other two parts (forest edges and woodless grasslands) despite the bigger phytomass, it can be hypothesised that evaporation can play a more significant role in water loss than transpiration on the hot and considerably dry climate being present at the study area. Also, we hypothesise that woody vegetation prevented the soil from extreme water loss, even in the hot season. The results of Bolla (2017) show the opposite, and several sources emphasize the negative water balance of the lowland forests too (Szabó et al. 2012, Mátyás et al. 2018). Our results can be explained by the fact that some tree species of our sandy forests (e.g. Populus ssp., Quesrcus ssp.) directly reach the groundwater level and utilise the water from here (Gácsi 1998, Gőbölös 2002). The treeless habitats are independent of the groundwater (Tölgyesi et al. 2021). Nevertheless, to derive more solid relationship between vegetation structure and soil humidity, much larger number of repetition is needed.

Considering air temperature, all the investigated woody vegetation types except for solitaire shrubs had significant regulating effect, resulting in lower seasonal maximum and higher seasonal minimum temperatures, compared to woodless grasslands, which is in line with the findings of other studies in the same region (e.g. Süle et al. 2020, Khanh et al. 2024). Interestingly – and to the contrary of our a priori hypothesis – there was no significant difference in seasonal average temperature during the three-month long study period. The seasonal range of temperature showed a clear relationship between vegetation types and microclimate regulation: types with more dendromass (and with larger leaf surface) resulted in a less range of temperature, i.e. in a more balance microclimate. The cooling effect of woody vegetation has already been demonstrated, which is due to the fact that it enhances the cooling properties of evaporation (Luyssaert et al. 2018). Compared to woodless grasslands the canopy of trees also moderates the cooling at night (Tölgyesi et al. 2018). As our pilot study was carried out exclusively during the autumn months, a much more detailed and differentiated picture could be obtained in the future with a study covering the whole year.

The above measurements showed a differentiated picture of soil moisture and air temperature heterogeneity that characterises the forest-steppe habitat complex. The results showed significant differences in the microclimate regulating effect of particular woody vegetation types in the study area.

Acknowledgements

This study was supported by ÚNKP-23-3 New National Excellence Programme, Reserach Scholarship for PhD Students.

References

Anenkhonov O. A., Korolyuk A. Y., Sandanov D. V., Liu H., Zverev A. A., Guo, D. (2015). Soil-moisture conditions indicated by field-layer plants help identify vulnerable forests in the forest-steppe of semi-arid Southern Siberia. Ecological Indicators, 57, 196-207.

Bartha D. (2001): Veszélyeztetett erdőtársulások Magyarországon. WWF füzetek, 18, 35 p.

Bolla B. (2017): Hidrológiai vizsgálatok a Kiskunsági Nemzeti Park működési területén lévő erdőállományok természetvédelmi kezeléséhez (Doctoral dissertation, Soproni Egyetem), 127 p.

Doronicum Szolgáltató Kft. (2015): Natura 2000 fenntartási terv; A Peszéri-erdő (HUKN20002) kiemelt jelentőségű természetmegőrzési terület. Felsőcsatár, 150 p.

Erdős L., Ambarlı D., Anenkhonov O. A., Bátori Z., Cserhalmi D., Kiss M., Kröel-Dulay Gy., Liu H., Magnes M., Molnár Zs., Naqinezhad A., Semenishchenkov Y. A., Tölgyesi Cs., Török P. (2018): The edge of two worlds: A new review and synthesis on Eurasian forest-steppes. Applied Vegetation Science, 21(3): 345-362. https://doi.org/10.1111/avsc.12382

Fejes Zs., Kovács E., Hajagos G., Vadász Cs. (2022): A Peszéri-erdő természeti értékelemeinek megítélése a főbb érintett csoportok körében. Természetvédelmi Közlemények, 28: 29-47. https://doi.org/10.20332/tvk-jnatconserv.2022.28.29

Gácsi Z. (1998): Adatok az alföldi erdők és a talajvíz kapcsolatához III. Erdészeti Lapok, 133(5): 158-159.

Gőbölös A. (2002): A „vízhiányos" erdőgazdálkodás kérdései a Duna-Tisza közi homokhátton. Hidrológiai Közlöny, 82(6): 324–326.

Inouye D.W. (2008): Effects of climate change on phenology, frost damage, and floral abundance of montane wildflowers. Ecology, 89: 353-362. https://doi.org/10.1890/06-2128.1

Khanh H. V., Süle G., Kovács B., Erdős L. (2024). Strong differences in microclimate among the habitats of a forest-steppe ecosystem. Időjárás (Quaterly Journal of the HungaroMet Hungarian Meterological Service), 128(1) 1-26.

Koncz P., Horváth L., Somogyi Z., Kottek P., Weidinger T., Ács F., Popp J. (2021): A tűzifatermelés, az éghajlat- és a mikroklíma-szabályozás, mint ökoszisztéma szolgáltatás értékelése – Az ökoszisztéma állapottól a ténylegesen igénybe vett ökoszisztéma-szolgáltatás értékelésig. A közösségi jelentőségű természeti értékek hosszú távú megőrzését és fejlesztését, valamint az EU biológiai sokféleség stratégia 2020 célkitűzéseinek hazai szintű megvalósítását megalapozó stratégiai vizsgálatok projekt, Ökoszisztéma-szolgáltatások projektelem. Budapest, Agrárminisztérium, Budapest, 191 p.

DOI: 10.14232/rard.2025.1-2.14-22

Kovács E., Kelemen E., Czúcz B. (2014): A természettől a jóllétig: az ökoszisztéma szolgáltatások természet- és társadalomtudományi meghatározottsága. In: Ökoszisztéma szolgáltatások: A természet- és társadalomtudományok metszéspontjában. Szent István Egyetem, Környezet- és Tájgazdálkodási Intézet; Environmental Social Science Research Group (ESSRG), Gödöllő-Budapest, 2014. pp. 15-34.

Kovács B. (2018): Az erdei mikroklíma vizsgálata gazdasági erdőkben (Doctoral dissertation, Eötvös Loránd Tudományegyetem Természettudományi Kar Biológia Doktori Iskola), 139 p.

Loksa G. (2004): Meteorológia a tájökológia szolgálatában. Tájökológiai Lapok, 2(2): 195-199. https://doi.org/10.56617/tl.4593

Luyssaert S., Marie G., Valade A. et al. (2018): Trade-offs in using European forests to meet climate objectives. Nature 562, 259–262. https://doi.org/10.1038/s41586-018-0577-1

Mátyás C., Berki I., Bidló A., Csóka G., Czimber K., Führer E., Gálos B., Gribovszki Z., Illés G., Hirka A., Somogyi Z. (2018): Sustainability of forest cover under climate change on the temperate-continental xeric limits. Forests, 9(8): 489. https://doi.org/10.3390/f9080489

MEA - Millennium Ecosystem Assessment (2003): Ecosystems and Human Well-being: A Framework for Assessment. Island Press, Washington DC, 245 p.

MEA - Millennium Ecosystem Assessment (2005): Ecosystems and Human Well-Being: Current State and Trends. Island Press, Washington DC, 563 p.

Milosevic D., Dunjić J., Stojanović V. (2020). Investigating micrometeorological differences between saline steppe, forest-steppe and forest environments in northern Serbia during a clear and sunny autumn day. Geographica Pannonica, 24(3). https://doi.org/10.5937/gp24-25885

Molnár Z. & Kun A. (2000): Alföldi erdőssztyepp-maradványok Magyarországon. WWF füzetek, 15, 55 p.

Ódor P. (2015): A biodiverzitást meghatározó környezeti változók vizsgálata az őrségi erdőkben, 2(2), MTA Ökológiai Kutatóközpont, Tihany, 66 p.

Stofa K. (2021): Mikroklíma mérések és módszertan fejlesztés a Harkai-kúp hőmérsékleti viszonyainak példáján (Doctoral dissertation, Soproni Egyetem),

Süle G., Körmöczi L. (2017): Vegetáció foltmintázat és mikroklíma mintázat kapcsolata erdőssztyepp élőhelyen. pp. 28-34. In: XIII. Kárpát-medencei Környezettudományi Konferencia. (szerk: Szigyártó I. L.; Szikszai A.), Ábel Kiadó. Kolozsvár, Románia.

Süle G. E. (2022): Homoki erdőssztyepp határzónáinak funkcionális szerveződése a mikroklimatikus mintázatok és a domborzat alapján (Doctoral dissertation, Magyar Agrár-és Élettudományi Egyetem), 105 p.

Süle G., Balogh J., Fóti S., Gecse B., Körmöczi L. (2020). Fine-scale microclimate pattern in forest-steppe habitat. Forests, 11(10), 1078. https://doi.org/10.3390/f11101078

Szabó A., Kiss K., Gribovszki Z., Tóth T. (2012): Erdők hatása a talaj és altalaj sóforgalmára, valamint a talajvíz szintjére. Agrokémia és Talajtan, 61(1): 195-209. https://doi.org/10.1556/agrokem.60.2012.1.14

Tölgyesi C., Valkó O., Deák B., Kelemen A., Bragina T. M., Gallé R., Erdős L., Bátori Z. (2018): Tree–herb co-existence and community assembly in natural forest-steppe transitions. Plant Ecology & Diversity, 11(4): 465-477. https://doi.org/10.1080/17550874.2018.1544674

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. https://doi.org/10.20332/tvk-jnatconserv.2021.27.126

Unyi-Buzetzky B. (2014): Talajnedvesség mérések nedvességdinamikai vizsgálatokhoz a Duna-Tisza közén= Soil moisture monitoring between the Danube and the Tisza river. GRADUS, 1(2): 81-87.

Electronic references:

http1: https//cices.eu/ ESMERALDA: http://esmeralda-project.eu/ (2024.04.30.)