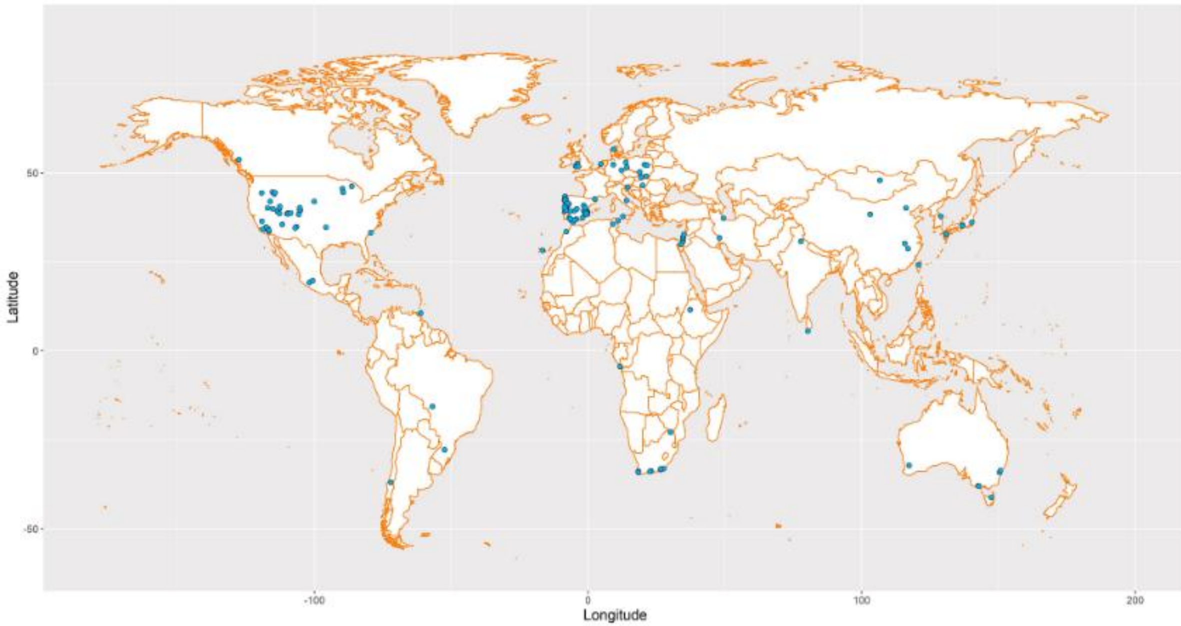
SANDY SOILS
THE GLOBAL CONFERENCE ON SANDY SOILS
Perth, Western Australia | July 21 - 24 2025

# Severity, Extent, and Persistence of Soil Water Repellency in Sandy Soils Under Different Vegetation Cover

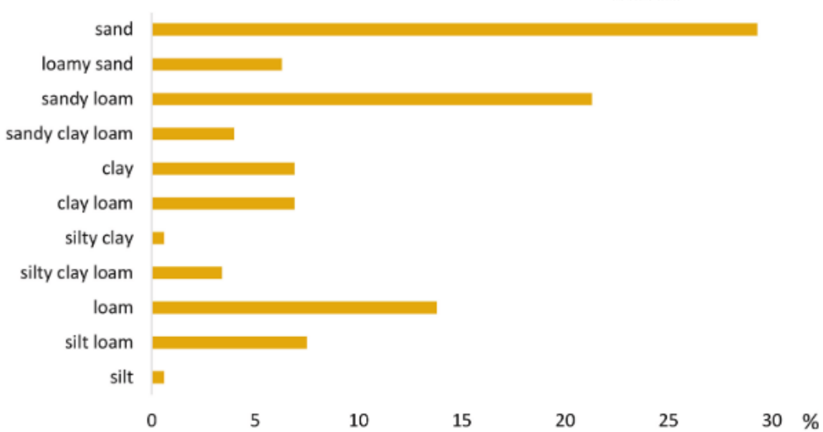
Edyta Hewelke
Institute of Environmental Engineering
WARSAW UNIVERSITY OF LIFE SCIENCES

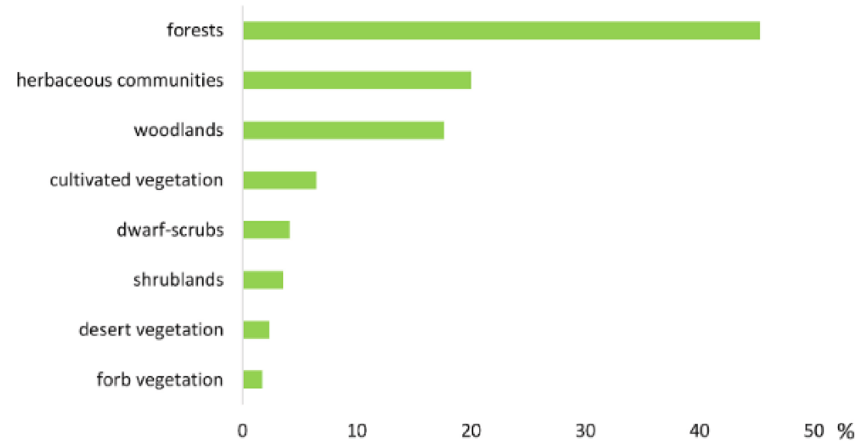
1816 SGGW
WARSAW
UNIVERSITY
OF LIFE SCIENCES

# Numerous studies from diverse Earth's biomes have confirmed that soil water repellency (SWR) is strongly linked to the type of plant cover

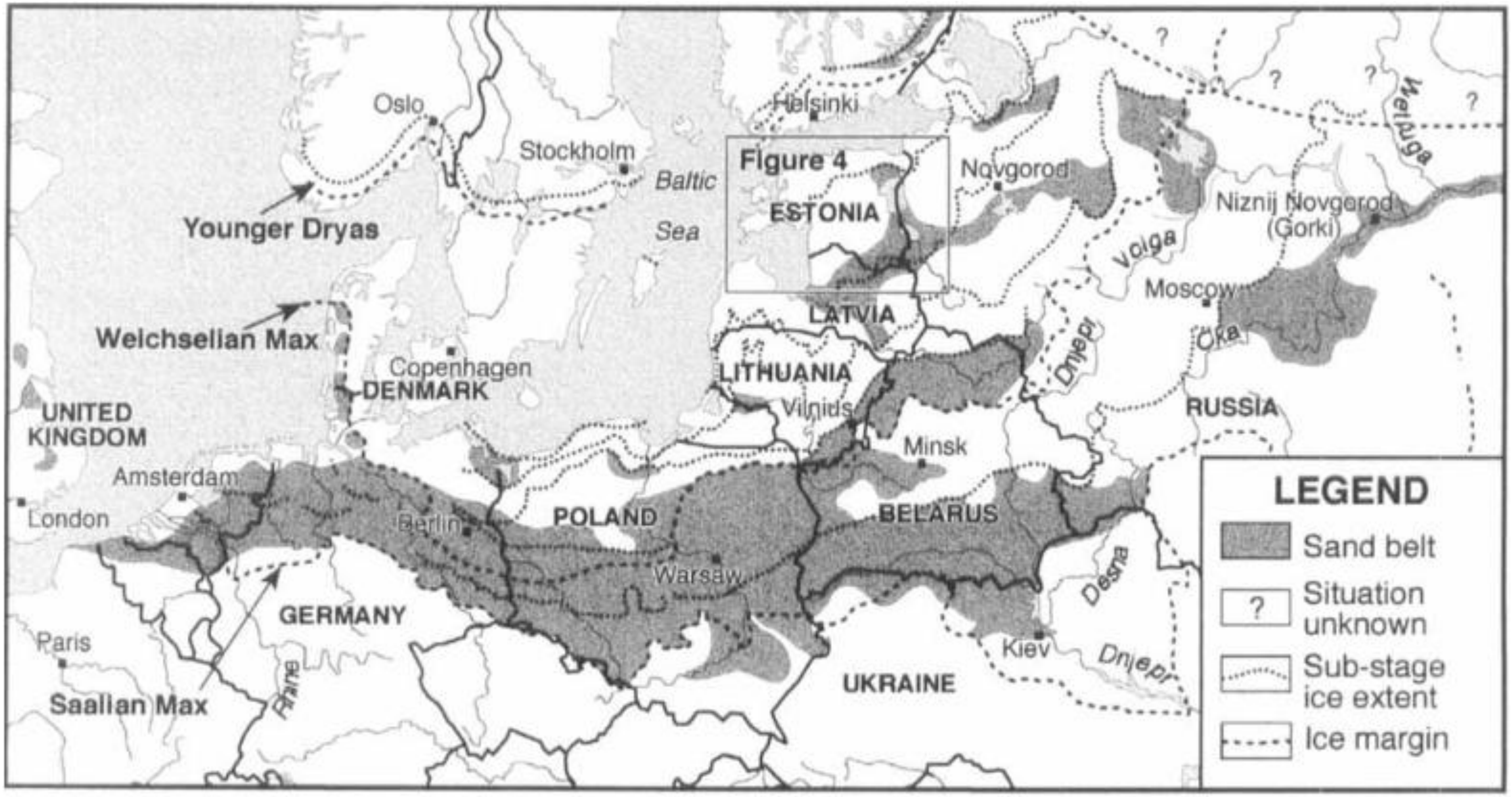



Popović, Z., & Cerdà, A. (2023). Soil water repellency and plant cover: A state-of-knowledge review. Catena, 229, 107213.



# The quality of Polish soils is among the lowest in Europe




The warm temperate climate (Cfb), 545 mm, 7.8 ºC.

Zeeberg, J. 1998. The European sand belt in eastern Europe-and comparison of Late Glacial dune orientation with GCM simulation results. *Boreas*, 27(2), 127-139.

## Whether resigning from agricultural production on sandy soil and the uncontrolled succession of a pine stand can significantly influence the shaping of hydrophysical properties of soil?

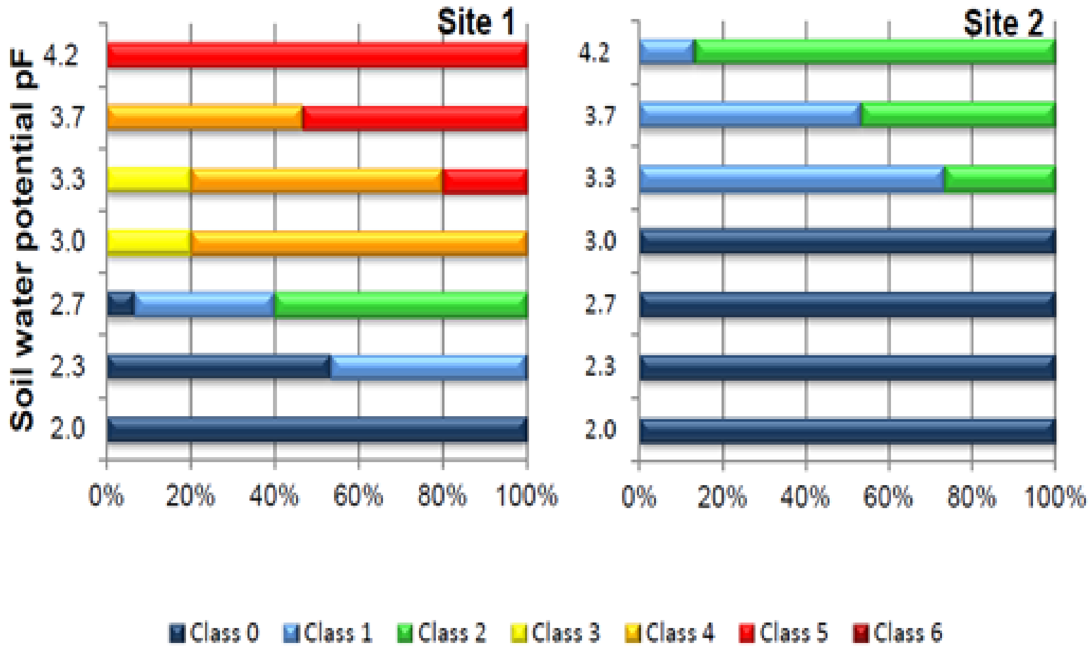


Hewelke, E. (2019). Influence of Abandoning Agricultural Land Use on Hydrophysical Properties of Sandy Soil. *Water*, 11(3), 525.

# Assessment of Soil Water Repellency (SWR) and critical thresold of soil moisture content for repellency for Site1 forest, Site 2 arable use

| WDPT * | Site 1 | Site 2 |
|---|---|---|
| Median (s) | 17700 | 90 |
| Average (s) | 17760 | 123 |
| Max (s) | 19200 | 284 |
| Min (s) | 16080 | 38 |
| Range (s) | 3120 | 246 |

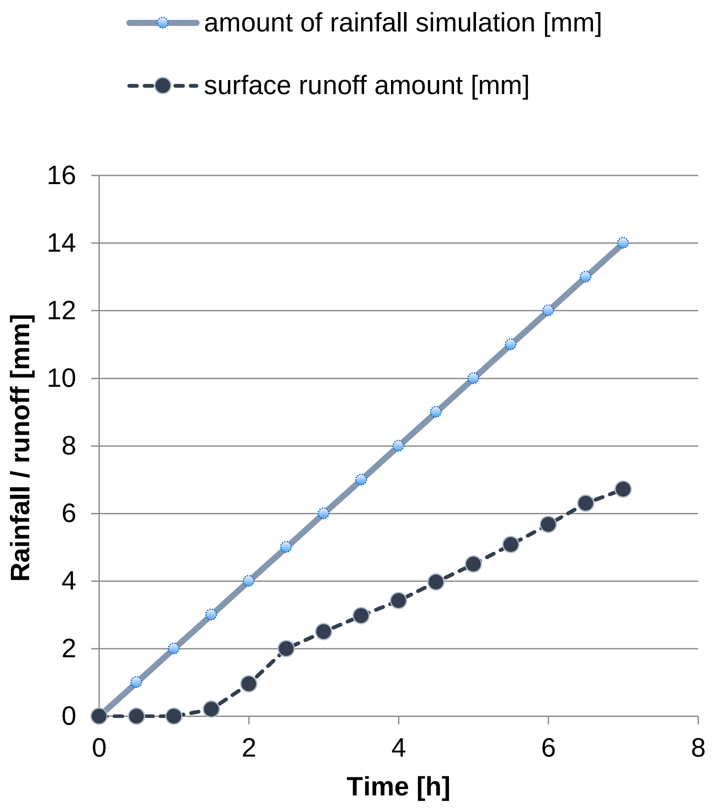
Value of the potential SWR



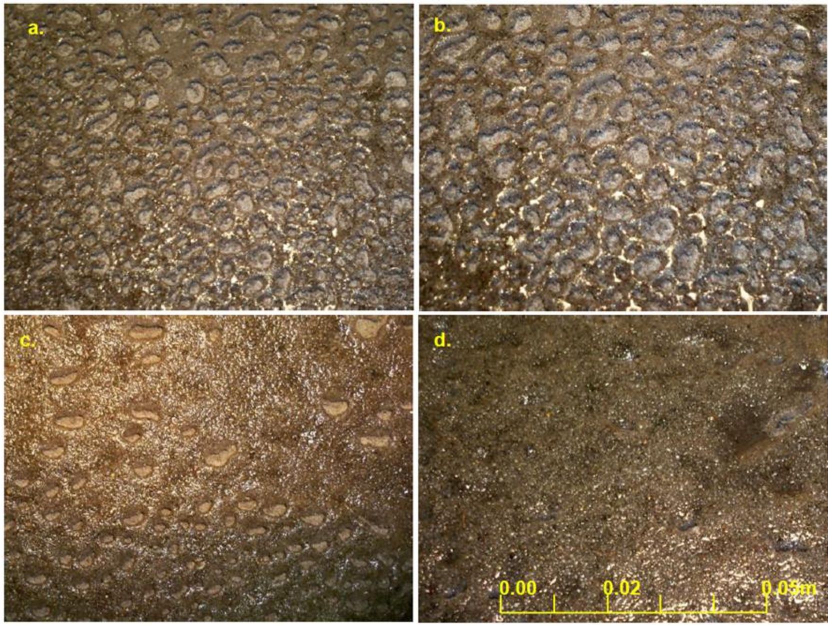

Soil water repellency, in terms of WDPT classes, of the A horizons of Site 1 and Site 2, as a function of soil water potential in terms of pF.

* acc. Dekker, L.W., Jungerius, P.D. 1990. Water repellency in the dunes with special reference to The Netherlands. Catena, 18, 173–183

# Surface Runoff in Soil under Forest Use S1

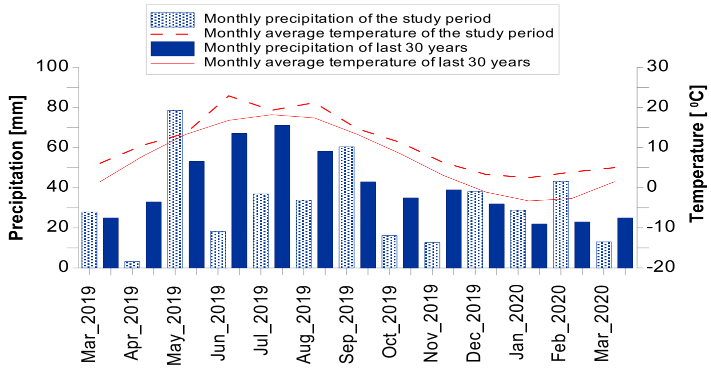


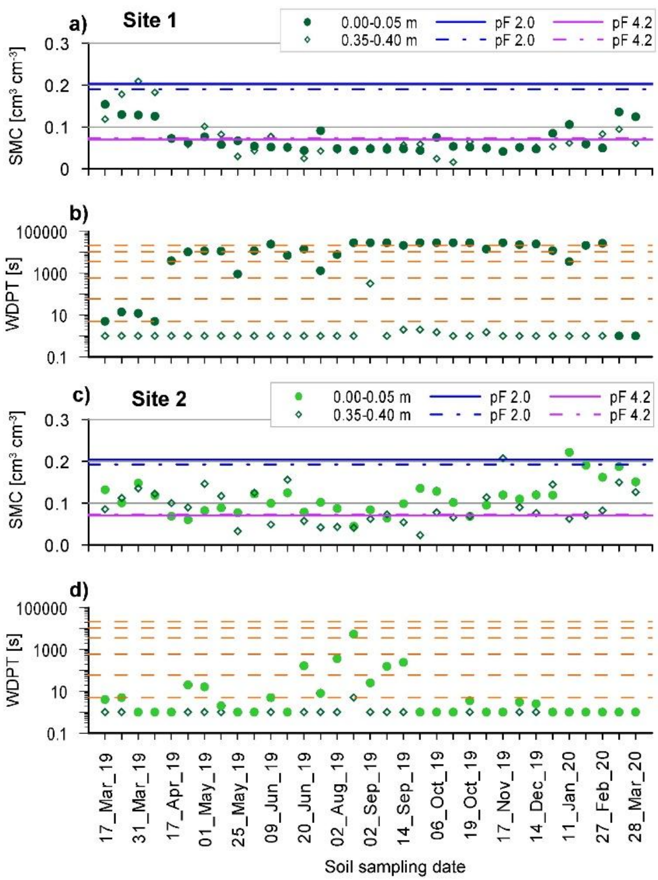

Course of rainfall and surface runoff caused by soil water repellency (Site 1).

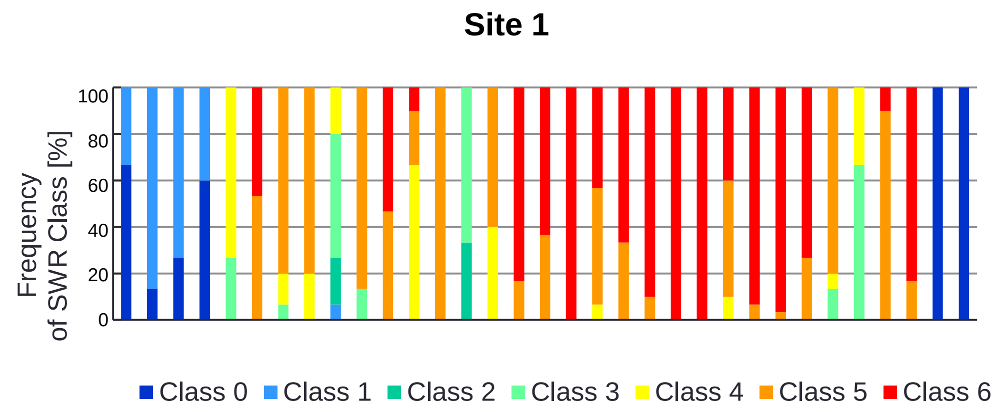


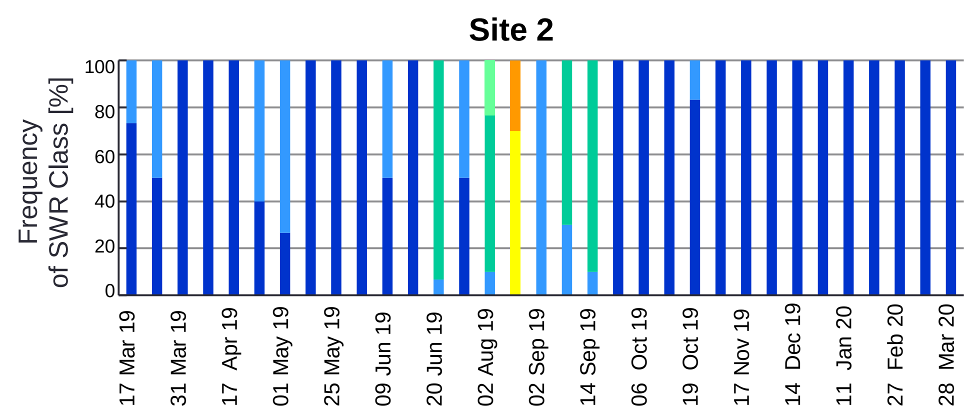

Visualization of wetted surface area over time during simulated rainfall, Site 1: (a) after 1 h; (b) after 2 h; (c) after 4 h; and (d) after 7 h.

# Soil moisture content and repellency resolution time series 2019



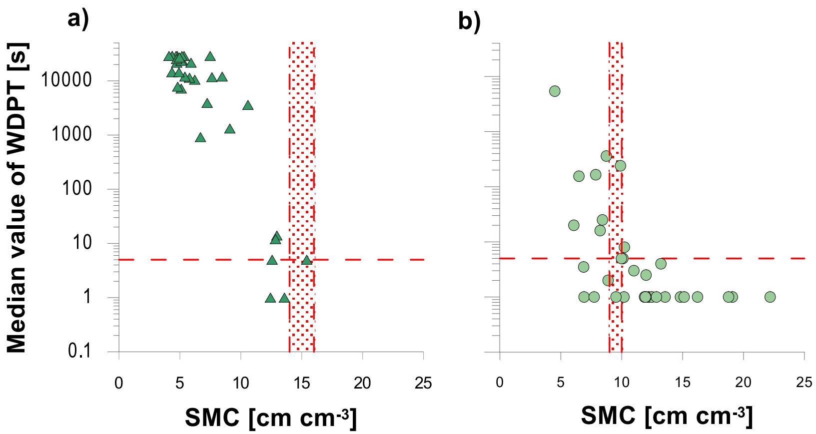




Hewelke, E., Gozdowski, D., Korc, M., Małuszyńska, I., Górska, E. B., Sas, W., & Mielnik, L. (2022). Influence of soil moisture on hydrophobicity and water sorptivity of sandy soil no longer under agricultural use. *Catena*, 208, 105780.

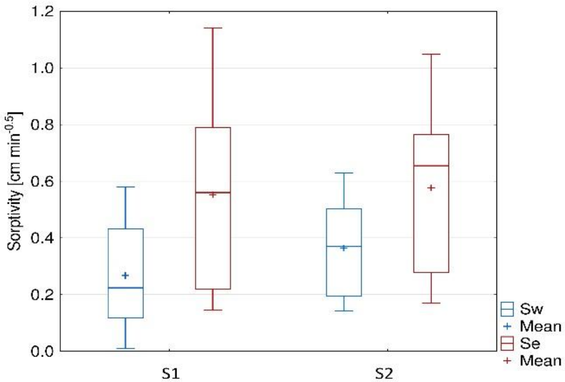
# Effect of soil moisture on water repellency

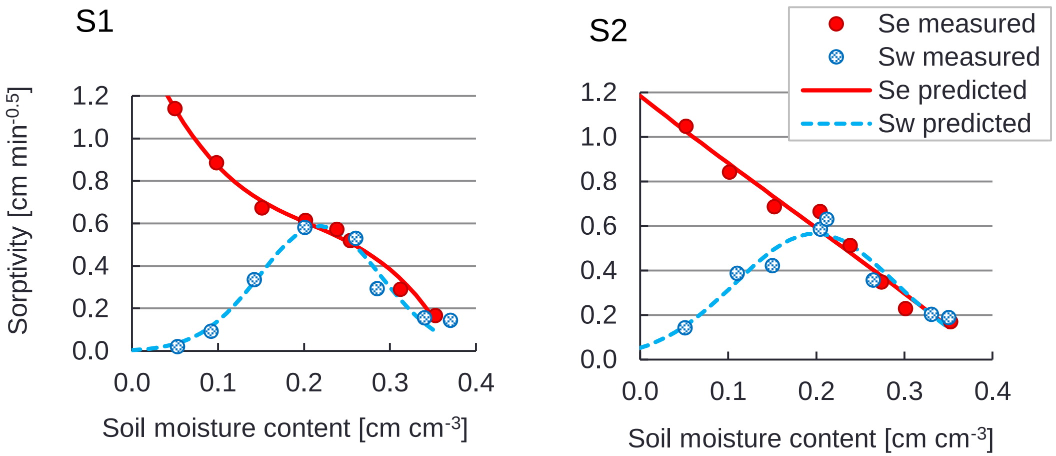



Relationship between soil hydrophobicity expressed as a median value of the WDPT test and mean soil moisture content (SMC) for: a) the pine stand site, S1, and b) land site under extensive arable use, S2 (n = 33) plotted against the critical SMC threshold (vertical red dashed lines), 5 s - horizontal red dashed lines – separate wettable class from repellent.

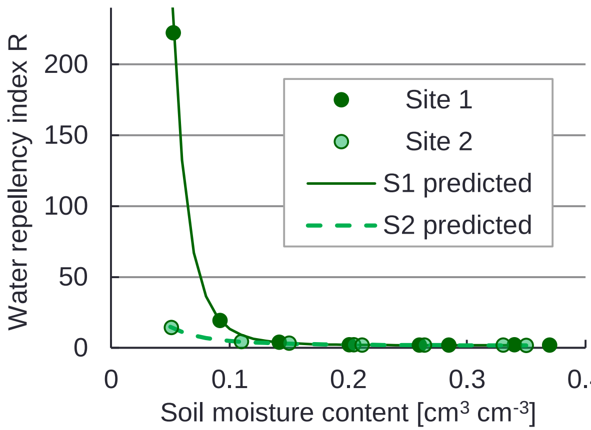
Some authors report that among others, SWR is one of the main soil properties that can serve to be a good indicator of soil quality (Jordán et al., 2013; Kraemer et al., 2019, Cervera-Mata et al., 2021).

# Effect of soil moisture content on water sorptivity




Soil infiltration using the microinfiltrometer method:
water sorptivity (Sw) and ethanol sorptivity (Se) against the background of soil moisture content measured for the 0–0.05 m layer in the S1 forest and S2 arable site.




Graphical representation of the correlation between the water repellency index (R) and soil moisture content of the topsoil leyer at two study sites: S1 – pine stand site; S2 - extensive arable land site.

For the modelling of soil-plant-atmosphere processes, familiarity with soil water sorption, which is dependent on SWR, is important (Orfánus et al., 2008)

# Humic substances extracted from soil material collected at different dates of 2019 and chemical analyses

Total organic carbon content and properties of humic substances: content of humic (HA) and fulvic (FA) acid, HA/FA ratio, and humification degree (HD)

| location | sampling term | TOC g kg$^{-1}$ | HA g kg$^{-1}$ | FA g kg$^{-1}$ | HA/FA | HD |
|---|---|---|---|---|---|---|
| site 1 (forest) | 12.V.2019 | 19.1 | 3.1 | 2.4 | 1.30 | 32.78 |
| | 2.VIII.2019 | 18.2 | 2.8 | 2.3 | 1.23 | 31.85 |
| | 7.IX.2019 | 19.3 | 3.4 | 2.5 | 1.38 | 34.22 |
| | 19.X.2019 | 16.2 | 3.2 | 2.6 | 1.24 | 39.91 |
| | 14.XII.2019 | 22.8 | 4.1 | 2.9 | 1.42 | 33.52 |
| | Average* | 19.1[a] | 3.3[a] | 2.5[a] | 1.31[a] | 34.45[a] |
| site 2 (arable) | 12.V.2019 | 11.7 | 1.8 | 1.7 | 1.11 | 33.19 |
| | 2.VIII.2019 | 16.2 | 3.4 | 2.4 | 1.40 | 39.03 |
| | 7.IX.2019 | 20.9 | 4.2 | 2.5 | 1.65 | 34.04 |
| | 19.X.2019 | 16.5 | 4.0 | 2.7 | 1.48 | 44.10 |
| | 14.XII.2019 | 18.4 | 5.0 | 2.8 | 1.82 | 44.22 |
| | Average* | 16.8[a] | 3.7[a] | 2.4[a] | 1.49[a] | 38.91[a] |

Elemental composition and internal oxidation (ω) of the ash free humic acid extracted from soil material

| location | sampling date | ash % | C atomic % | H atomic % | N atomic % | O atomic % | H/C | O/C | ω |
|---|---|---|---|---|---|---|---|---|---|
| site1 (forest) | 12.V | 3.68 | 34.52 | 38.60 | 1.71 | 25.16 | 1.12 | 0.73 | 0.49 |
| | 2.VIII | 2.95 | 33.96 | 38.90 | 1.82 | 25.31 | 1.15 | 0.75 | 0.51 |
| | 7.IX | 3.33 | 32.44 | 39.84 | 1.76 | 25.95 | 1.23 | 0.80 | 0.53 |
| | 19.X | 2.20 | 33.59 | 40.24 | 1.88 | 24.30 | 1.20 | 0.72 | 0.42 |
| | 14.XII | 2.86 | 33.63 | 39.53 | 1.81 | 25.03 | 1.18 | 0.74 | 0.47 |
| | average* | 3.00[a] | 33.63[a] | 39.42[a] | 1.80[a] | 25.15[a] | 1.17[a] | 0.75[a] | 0.48[a] |
| site 2 (arable) | 12.V | 2.63 | 32.33 | 40.92 | 1.82 | 24.92 | 1.27 | 0.77 | 0.45 |
| | 2.VIII | 2.48 | 33.17 | 40.12 | 1.76 | 24.95 | 1.21 | 0.75 | 0.45 |
| | 7.IX | 5.84 | 31.60 | 36.44 | 1.67 | 30.29 | 1.15 | 0.96 | 0.92 |
| | 19.V | 2.18 | 32.77 | 40.26 | 1.75 | 25.22 | 1.23 | 0.77 | 0.47 |
| | 14.XII | 3.58 | 32.80 | 39.02 | 1.72 | 26.47 | 1.19 | 0.81 | 0.58 |
| | average* | 3.34[a] | 32.53[a] | 39.35[a] | 1.75[a] | 26.37[a] | 1.21[a] | 0.81[a] | 0.57[a] |

Mielnik, L., Hewelke, E., Weber, J., Oktaba, L., Jonczak, J., & Podlasiński, M. 2021. Changes in the soil hydrophobicity and structure of humic substances in sandy soil taken out of cultivation. *Agriculture, Ecosystems & Environment*, 319, 107554.

# Spectroscopic analyses, 2019

The percentage of characteristic structures in the synchronous scan spectra of the examined HA and ratios of fluorescence intensity at given wavelength

| sampling date | location | PLF% | FLF% | HLF% | $IF_{375}/IF_{495}$ |
|---|---|---|---|---|---|
| 12.V | site 1 | 5.9 | 19.8 | 46.6 | 0.60 |
| | site 2 | 0.9 | 18.6 | 54.6 | 0.45 |
| 2.VIII | site 1 | 2.6 | 21.2 | 46.5 | 0.69 |
| | site 2 | 1.6 | 20.5 | 50.4 | 0.57 |
| 14.XII | site 1 | 3.4 | 21.9 | 44.7 | 0.78 |
| | site 2 | 1.7 | 20.5 | 50.2 | 0.57 |

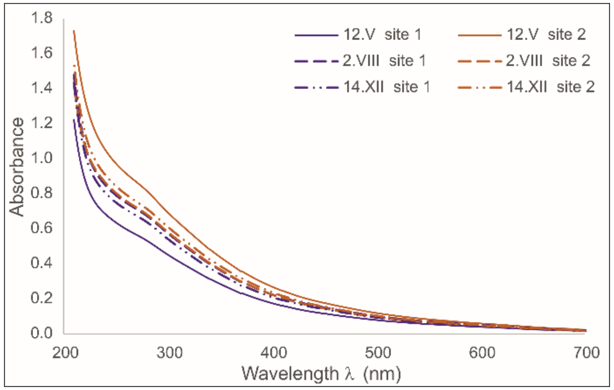
The percentage of characteristic structures in the examined HA and their relationships

| sampling date | location | P1 % | P2 % | P3 % | P4 % | P1/P3 | P1/P4 |
|---|---|---|---|---|---|---|---|
| 12.V | site 1 | 17.83 | 4.36 | 10.39 | 5.48 | 1.72 | 3.25 |
| | site 2 | 14.47 | 4.13 | 11.62 | 8.10 | 1.25 | 1.79 |
| 2.VIII | site 1 | 18.32 | 4.55 | 9.68 | 5.17 | 1.89 | 3.54 |
| | site 2 | 16.89 | 4.46 | 10.54 | 6.18 | 1.60 | 2.74 |
| 14.XII | site 1 | 18.73 | 4.79 | 7.45 | 4.72 | 2.51 | 3.97 |
| | site 2 | 17.51 | 4.41 | 10.35 | 4.88 | 1.69 | 3.59 |

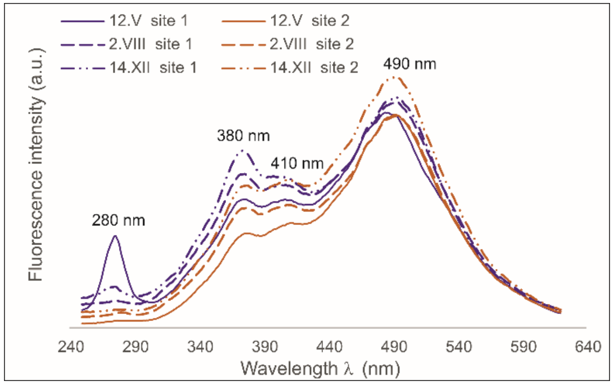
Fluorescence indexes of examined HA

| sampling date | location | **HIX** | $f_4/f_5$ | **$\sum Fl_{465}/A_{465}$** |
|---|---|---|---|---|
| 12.V | site 1 | **14.5** | 0.74 | **479** |
| | site 2 | **57.8** | 0.70 | **638** |
| 2.VIII | site 1 | **37.7** | 0.78 | **774** |
| | site 2 | **28.5** | 0.74 | **971** |
| 14.XII | site 1 | **29.4** | 0.80 | **742** |
| | site 2 | **46.1** | 0.75 | **887** |

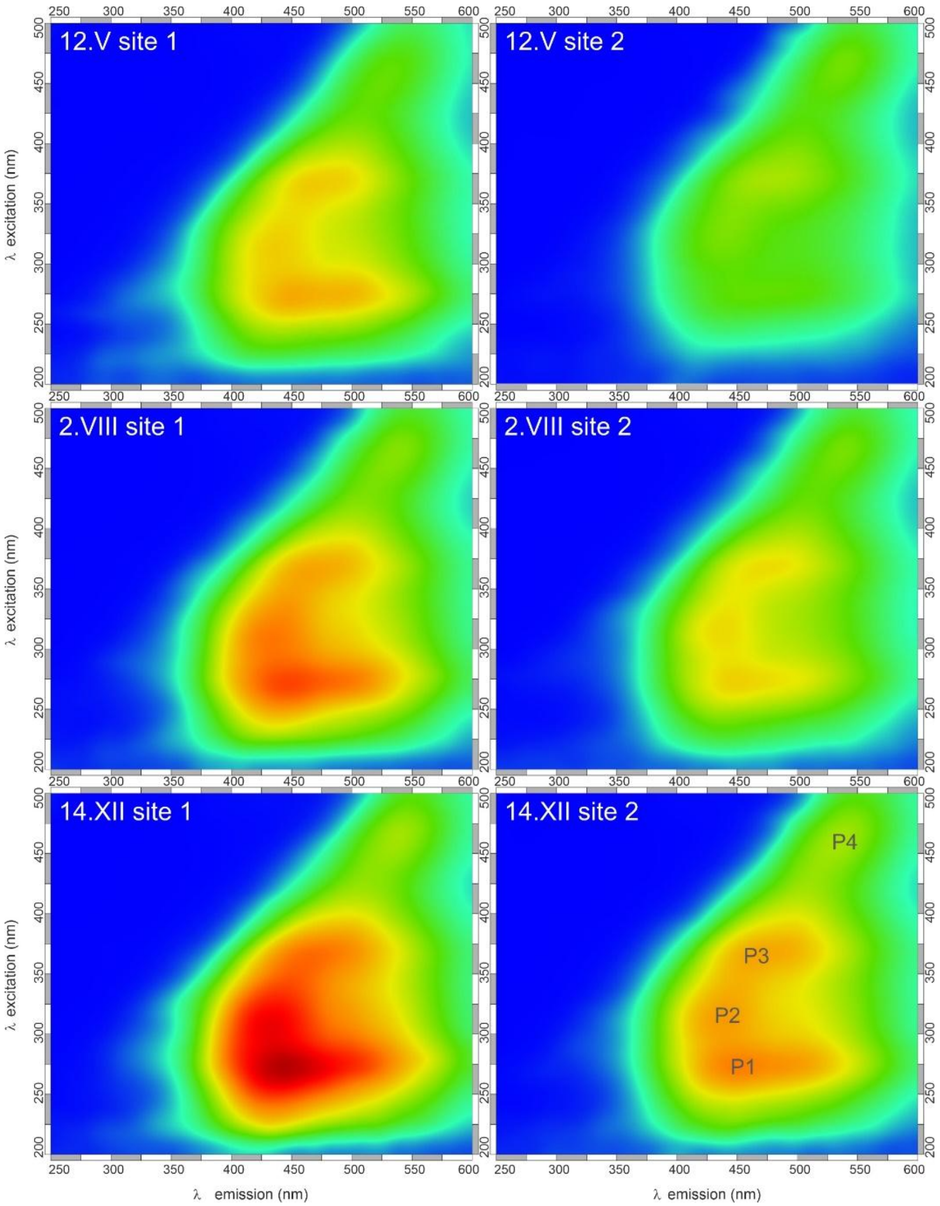
# Fluorescence properties of HA extracted from soil material collected at different terms




UV–Vis spectra

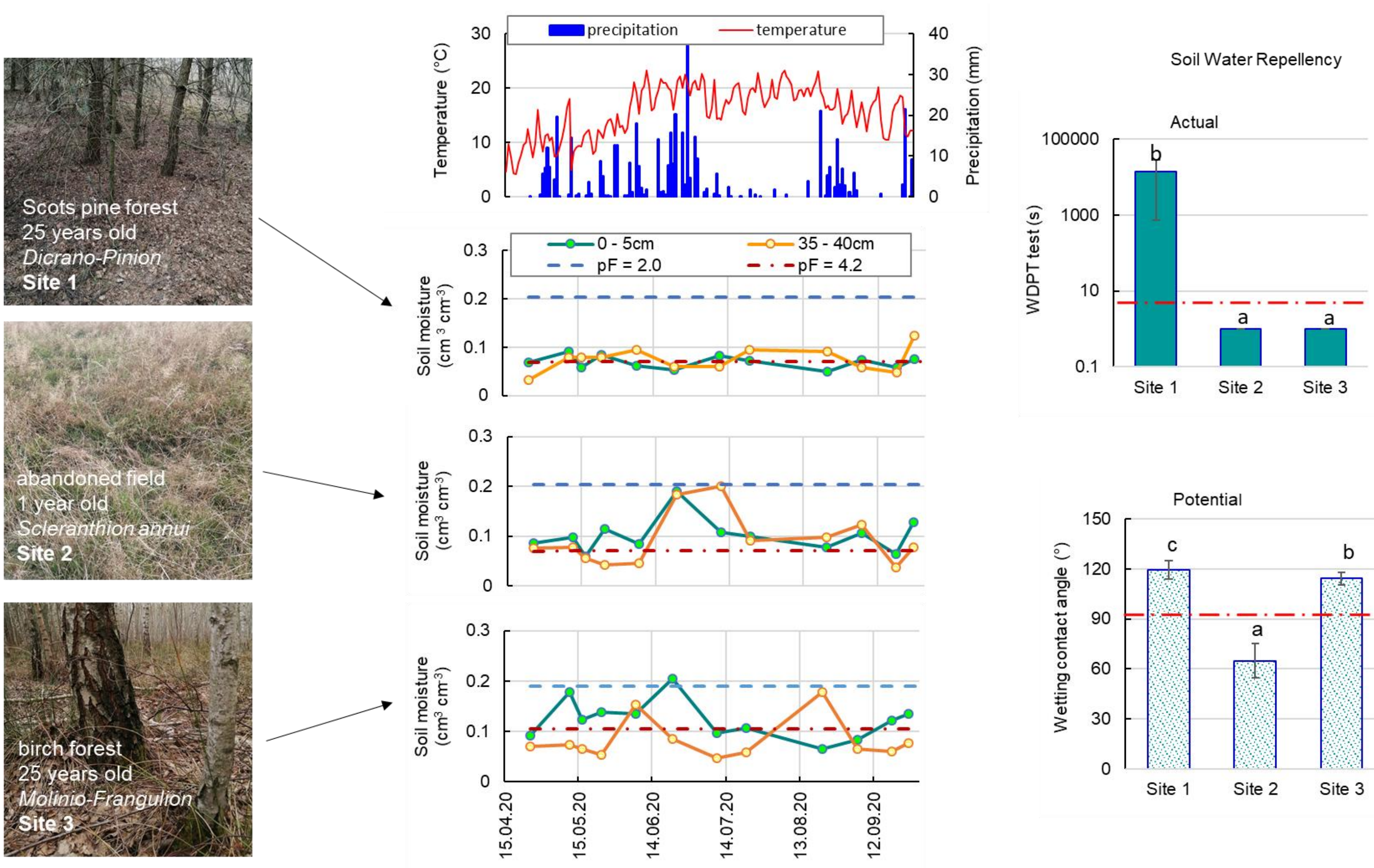



Fluorescence synchronous scan spectra




Fluorescence 3-D spectra (EEM)

# Does Spontaneous Secondary Succession Contribute to the Drying of the Topsoil?



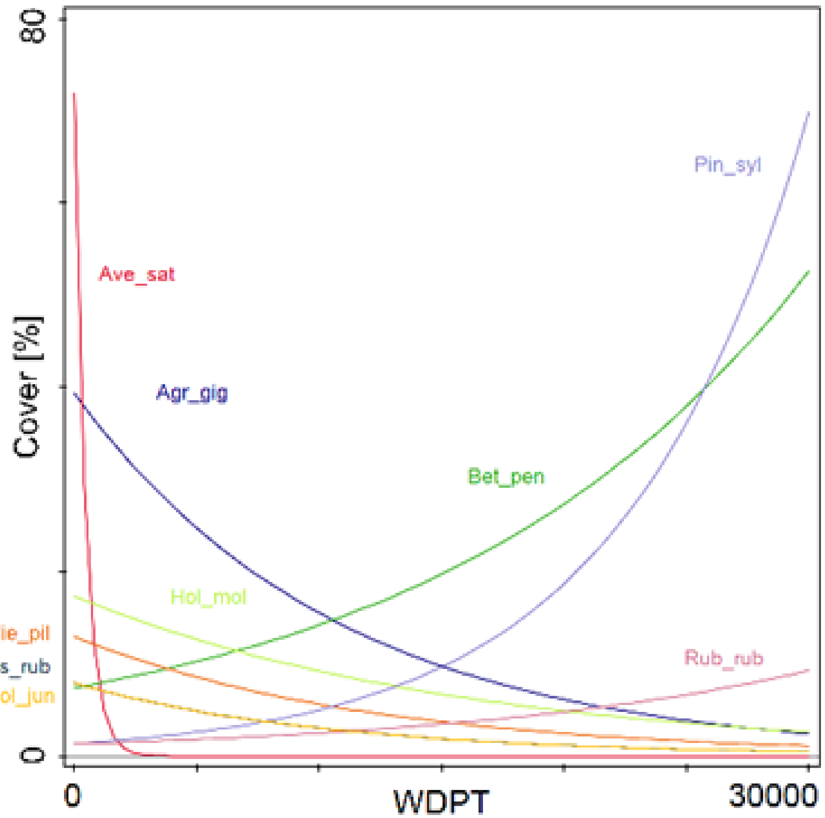

Hewelke, E., Zaniewski, P. T., Zaniewska, E., Papierowska, E., Gozdowski, D., Łachacz, A., & Górska, E. B. (2023). Does spontaneous secondary succession contribute to the drying of the topsoil?. *Forests*, *14*(2), 356.

# Description of the sites surveyed with SWR indicators after prolonged droughts

| No | Date | Vegetation type | Short description of vegetation | Critical θ ($m^3\ m^{-3}$) | Actual θ ($m^3\ m^{-3}$) | WDPT (s) | Repellency Class |
|---|---|---|---|---|---|---|---|
| 1 | 2020 | young birch stand (Molinio-Frangulion) | Woodland: $E_3$: *Betula pendula* agg., $E_2$: *Frangula alnus*, *Sorbus aucuparia*, $E_1$: *Juncus effusus*, *Rubus* sect. *Rubus* | 0.139a ± 0.013 | 0.061ab ± 0.004 | 19080e ± 1867 | Extremely repellent |
| 2 | 2023 | young birch stand (Molinio-Frangulion) | Woodland: $E_3$: *Betula pendula* agg., $E_2$: *Frangula alnus*, $E_1$: *Agrostis gigantea* agg., *Juncus effusus*, *Rubus* sect. *Rubus*, $E_0$: *Brachythecium rutabulum*, *Pleurozium schreberi* | 0.147a ± 0.018 | 0.116d ± 0.036 | 18000de ± 3275 | Extremely repellent |
| 3 | 2020 | young pine forest (Dicrano-Pinion sylvestris) | Woodland: $E_3$: *Pinus sylvestris*, *Betula pendula* agg., $E_2$: *Frangula alnus*, $E_1$: *Agrostis gigantea* agg., *Holcus mollis*, $E_0$: *Hylocomium splendens*, *Pleurozium schreberi* | 0.150a ± 0.017 | 0.031a ± 0.002 | 28800f ± 0 | Extremely repellent |
| 4 | 2023 | young pine forest (Dicrano-Pinion sylvestris) | Woodland: $E_3$: *Pinus sylvestris*, *Betula pendula* agg., $E_1$: *Agrostis gigantea* agg., *Pilosella officinarum*, *Rumex acetosella*, $E_0$: *Dicranum polysetum*, *Pleurozium schreberi* | 0.134a ± 0.023 | 0.070bc ± 0.010 | 17160d ± 3900 | Extremely repellent |
| 5 | 2023 | community with Pilosella officinarum (initial Armerion elongatae) | Initial meadow: $E_1$: *Achillea millefolium*, *Agrostis gigantea* agg., *Arrhenatherum elatius*, *Carex ovalis*, *Festuca rubra*, *Holcus lanatus*, *Hypochoeris radicata*, *Juncus effusus*, *Luzula campestris*, *Pilosella officinarum*, *Rumex acetosella*, $E_0$: *Polytrichum juniperinum*, *Polytrichum piliferum* | 0.130a ± 0.018 | 0.078bc ± 0.017 | 7950b ± 763 | Extremely repellent |
| 6 | 2020 | extensive arable field (Scleranthion annui) | Arable field: $E_1$: *Agrostis gigantea* agg., *Anthoxanthum aristatum*, *Holcus mollis* | 0.138a ± 0.010 | 0.049ab ± 0.003 | 10980c ± 1727 | Extremely repellent |
| 7 | 2023 | extensive arable field (Scleranthion annui) | Arable field: $E_1$: *Agrostis gigantea* agg., *Anthoxanthum aristatum*, *Avena fatua*, *Avena sativa*, *Digitaria ischaemum*, *Holcus mollis*, *Setaria pumila* | 0.127a ± 0.020 | 0.094cd ± 0.021 | 227a ± 27 | Strongly repellent |

$E_3$ – tree layer, $E_2$ – shrub layer, $E_1$ – herb layer, $E_0$ – bryophyte layer

# Relationship between dominant species cover and WDPT in the studied sites near Stanisławów village




Hewelke, E., Zaniewski, P. T., Pędziwiatr, A., Gozdowski, D., & Górska, E. B. (2024). The relations between soil hydrophobicity and vegetation in abandoned arable fields on sandy soil. *Biologia*, 1-9.

# Conclusions, recommendations for practitioner

- In connection with the progressing warming of the climate and the increasing frequency of droughts, it can be assumed that SWR will increasingly strongly affect the hydrophysical properties of soils and mineralization of organic carbon in areas characterized by a warm temperate climate,
- Abandonment of agricultural production on low-productivity sandy soil and its afforestation with pine stands resulted in a significant increase in the potential value of SWR and an increase in CSMC for the occurrence of hydrophobicity. As a consequence, this phenomenon may cause intensive surface runoff of rainwater,
- The critical moisture contents presented in the scientific achievement make it possible to predict the occurrence of SWR,
- Maintaining the moisture content of soil above CSMC is an important criterion for the sustainable use of soils and maintaining their unique ecosystem services.

# Conclusions

- The change in water regime influenced the direction of SOM transformation, but the period of 30 years was not long enough to cause changes in the elemental and/or fractional composition of humic substances. Nevertheless, the modified conditions of SOM transformation resulted in a marked increase in soil hydrophobicity,
- UV-Vis investigation did not show any significant differences in the structure of the analysed HA, however differences in the molar absorptivity at 280 nm ($\varepsilon 280$) pointed to a lower degree of condensation of aromatic structures in the abandoned soil, indicated a lower humification degree of its HA,
- Synchronous scanned spectra indicated the adverse effect of lower moisture in the abandoned soil on the humification processes, which resulted in a lower number of humic-like structures in HA.

# Conclusions

- In forest areas, especially where pine stands dominate, the initial SWR deepens soil drought and is a risk factor where the occurrence of fires is concerned,
- A pine tree stands 170-200 years old significantly increases the water repellency of soil, which can continue to be maintained after atmospheric drought lets up,
- The occurrence of the SWR phenomena differs on a spatial scale based on the severity of the fire in the second, wet year of ecosystem regeneration.
- Statistically significant negative correlations between SWR and SWC were found only in some individual layers, which may indicate new research areas for environmental microbiology. Based on the obtained results, the SWR in forest soil is connected mainly with fungi, not bacteria.

# To sum up…

- Irrespective of the magnitude of climate change, land management demands that mitigation measures be continually adapted to strengthen an ecosystem's resilience to future warming and that risk reduction strategies are refined.
- SWR assessment can be helpful to identify quickly such areas' soils and sustain their ecosystem services under climate change.


Thank you ...