BIODIVERSITY RECOVERY IN THE SALT MARSHES OF MORAVIAN PANNONIA

ASSESSMENT OF HETEROGENEITY AND CLIMATE VULNERABILITY

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LIFE IN SALT MARSHES

LIFE project (2023-2029) focused on **restoration and protection of 506 ha of wetlands** (10 sites), **including 20 ha of endangered salt marshes** in South Moravia

HOW?

- Restore and stabilise wetlands (target habitat **inland salt meadows**)
- Reduce water pollution and optimise the water regime
- Strengthen the populations of target species
- Develop new plans for site management and management
- Transfer knowledge and experience at national and European level

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HETEROGENEITY

Currently, most of the area is dominated by undesirable species. By the end of the project, habitat heterogeneity is expected to increase by up to 50% through invasive species reduction and management (grazing, mowing). Spectral indices and field data will be used to track vegetation health, biomass and the presence of water, and annual analysis will ensure effective management.

METHODS

PlanetScope data was acquired in 2023 with 8 spectral bands (Blue to NIR). The data (GSD of 3.7 to 4.2 m) was processed to remove cloud cover and filtered based on valid data availability → 41-90 images per site.

Spectral indices

- NDVI
- TVI
- CIre
- SIPI
- EBIwhite
- EBIyellow
- NDWI

Temporal statistics

- mean
- std dev
- 95th pctl.
- 5th pctl.
- sum
- month of peak index value
- the number of peaks in the timeline

Shannon entropy
Measures the diversity or uncertainty in a dataset by quantifying how evenly the elements are distributed - in this case, higher values indicate greater species or habitat diversity. The indices were standardised to enable site comparison, and entropy was calculated using a 3×3 pixel sliding window to prioritise vascular plants and maintain high spatial resolution.

LIMITATIONS

This **approach cannot distinguish between surface types**, therefore, high heterogeneity may reflect the presence of invasive species rather than biodiversity. Inter-annual variability and environmental factors may affect index values, which limits long-term comparability. Although widely used, the suitability of Shannon entropy for this study requires further validation.

RESULTS & DISCUSSION

Higher entropy values, indicating **greater heterogeneity, were observed around the pools and along the linear vegetation**.

- significant difference in the spatiotemporal spectral expression of the adjacent LULC classes (e.g. reedbed-pond, grassland-linear vegetation, etc.).

However, this highlights the method's limitation in distinguishing between 'good' and 'bad' heterogeneity, for which the inclusion of LULC information is required for accurate interpretation.
Conversely, **the lowest entropy values were found in large areas of reeds and permanent grassland**, which cover a significant portion of the project sites.
Further development will require to focus on trends, as absolute values alone are not as meaningful without long-term monitoring, as well as in-situ data.

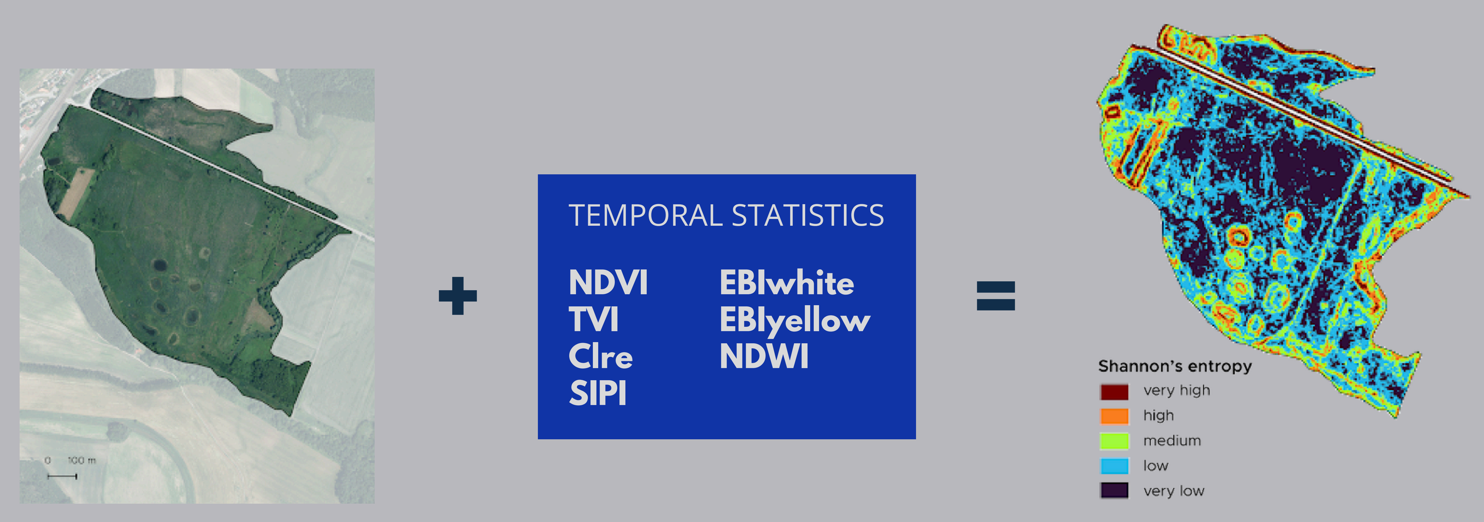

Fig. 1: Overivew of heterogeneity analysis steps

← **Fig. 2:** Drone images of 8/10 project sites (2024)

Moravian Pannonia in Czechia

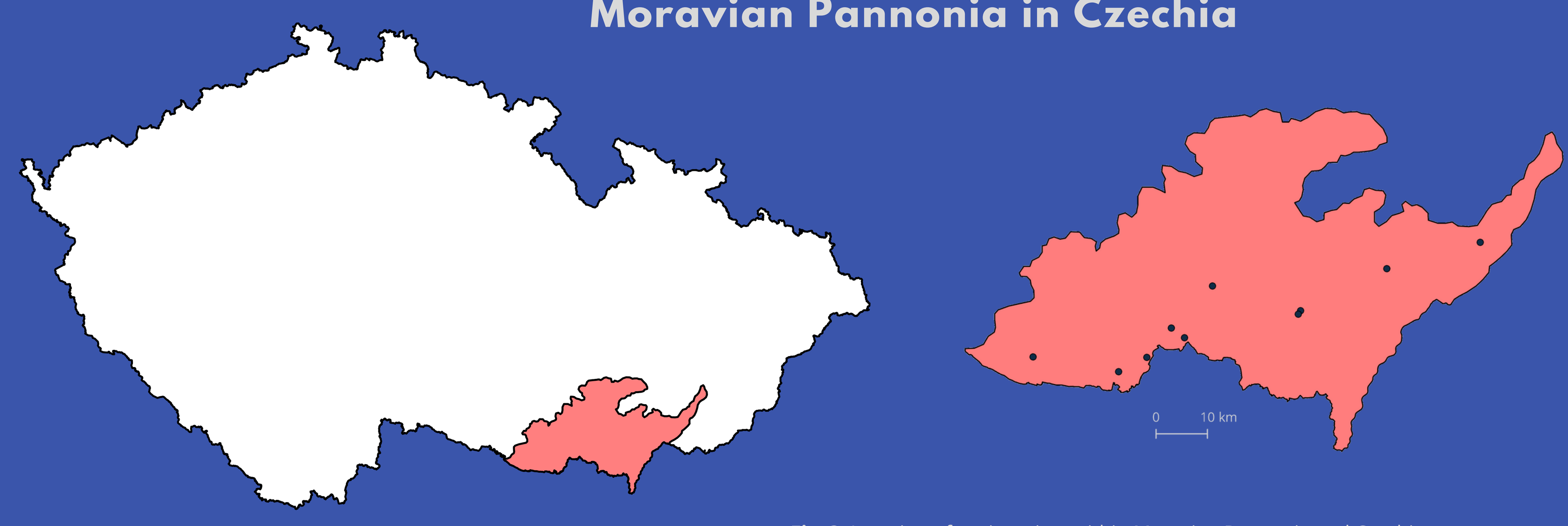

Fig. 3: Location of project sites within Moravian Pannonia and Czechia

CLIMATE CHANGE VULNERABILITY

We adopt the IPCC's definition of **vulnerability as the degree to which a system can be disrupted or irreversibly damaged by climate change.** This is influenced by three key components:

- **Exposure** is the extent to which the system is exposed to climatic fluctuations,
- **Sensitivity** reflects the extent to which an ecosystem responds to climate change,
- **Adaptive capacity** determines how well a system can mitigate or adapt to these changes.

METHODS

Vulnerability = Exposure + Sensitivity - Adaptive capacity

The indicators are ranked on a scale of 1-5 and the resulting values are assessed within a 30 m cell grid. Sub-vulnerability was calculated separately for selected climate stressors: **Rising mean air temperature (AT), heatwaves (HW), drought (D), floods (F) (river + flash).** Total vulnerability is determined by the max sub-vulnerability value.

Exposure indicators
These are derived from meteorological data (1984–2023): daily mean temperatures (AT), maximum temperature extremes (HW), and precipitation trends (F). Drought exposure was assessed using the SPEI.

Sensitivity indicators
Habitats were classified to achieve finer granularity. Experts in botany, zoology and environmental science then assigned each habitat a sensitivity score (1-5) based on its response to climate stressors.

Adaptive capacity indicators

- Spectral heterogeneity (*Shannon entropy*)
- Biodiversity (*species richness*)
- Habitat quality (*ecological expert scores*)

Additional indicators specific to climate stressors:

- **Land Surface Temperature** (*LST*): Landsat 5, 8/9; 1984-2023; 30 m, mean, 90th pctl. → trend line/slope
- **Surface Moisture**: Landsat 5, 8/9; 1984-2023 JJA, OPTRAM model; 0-100% water saturation
- **Floodplain Classification**: floodplain data (Q5, Q20, Q100, Q500)
- **Flash Flood Modeling**: runoff simulation; 5mm/h for 24 hours on 5m DSM

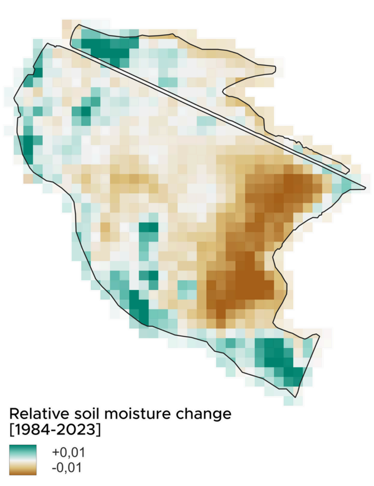

Fig. 4: Soil moisture change

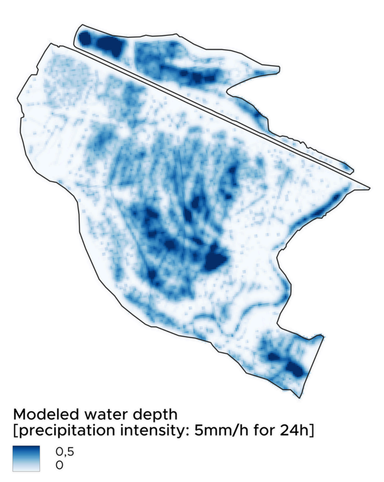

Fig. 5: Water depth map

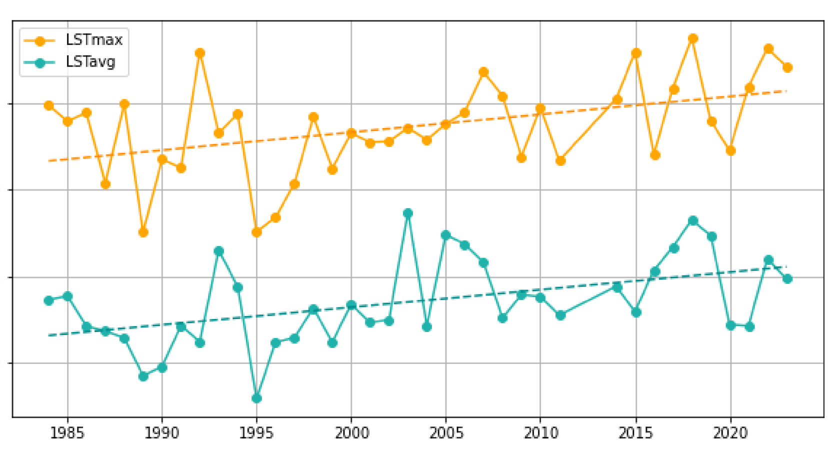

Fig. 6: LST (avg; max=average above 90Q) change

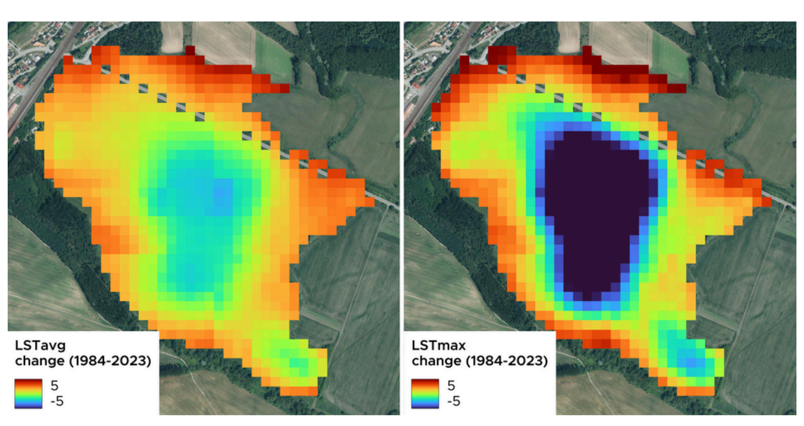

Fig. 7: LST change - visual

RESULTS & DISCUSSION

Over the 40-year reference period (1984-2023):

- **Almost all sites experienced mean air temperature increases >2°C**.
- **Heatwaves exposure** was even more extreme, **with increases exceeding 2.5°C at most sites.**
- **Drought exposure (SPEI) showed a slight to moderate increasing trend**,
- while **flood exposure remained low** due to the location of the sites in one of the driest regions of the Czech Republic (annual precipitation <500 mm, compared to a national average of 600–800 mm).

Adaptive capacity indicators help to mitigate vulnerability by offsetting high levels of exposure and sensitivity.

- **High species richness** (classes 4-5) was found in **8.4% of the study areas,**
- **ecologically valuable habitats in 11.1%,**
- and **high spectral heterogeneity in 13.4%.**

Soil moisture played a key role in **reducing vulnerability to drought**, particularly in floodplain forests and periodically flooded zones. High adaptive capacity (classes 4-5) covered >70% of all sites. **Flash flood resilience was high** (~70%), while vulnerability to river flooding was largely confined to sites within flood zones (Q5-Q500).

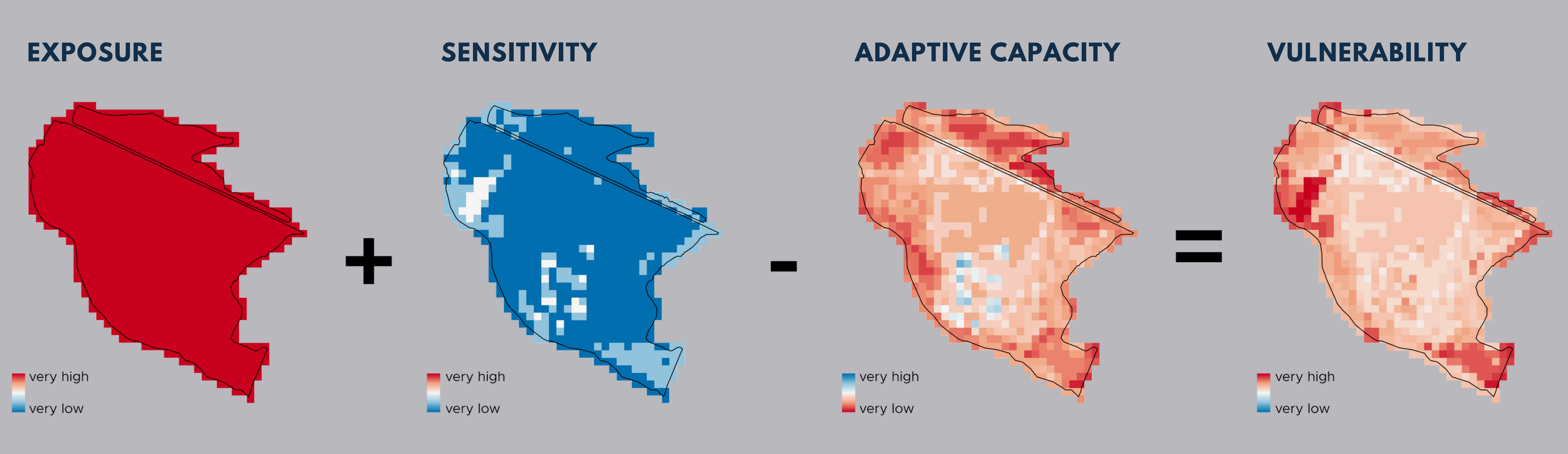

Fig. 8: Example of the vulnerability components evaluation 30m grids (heat waves) for one of the project sites

OVERALL VULNERABILITY PATTERNS

Sub-vulnerabilities were assessed for each site. **Rising mean air temperatures (AT) and heatwaves (HW) had the greatest impact**, particularly on salt marshes, wetlands and some forests. Drought (D) vulnerability was significant, but mitigated by high adaptive capacity. Flood (F) vulnerability remained the lowest, as periodic flooding benefited wetland habitats.
The project aims to reduce the vulnerability in particular by increasing its adaptive capacity, as indicators of exposure and sensitivity are expected to rise.

Overall, **65.4% of the total study area was classified as highly vulnerable, with the highest vulnerability due to rising mean air temperatures (AT).**

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