BEeS
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LifeWatch ERIC · hcmr ΕΛΚΕΘΕ · iMBBC ΙΘΑΒΒΥΚ

Session: Biodiversity Observatory: Smart Systems for a Living Planet Revolutionising Biodiversity Monitoring with Automation

2 July 2025 | 11:30-13:00

Challenges in automation of monitoring and modeling in karst forest ecosystems

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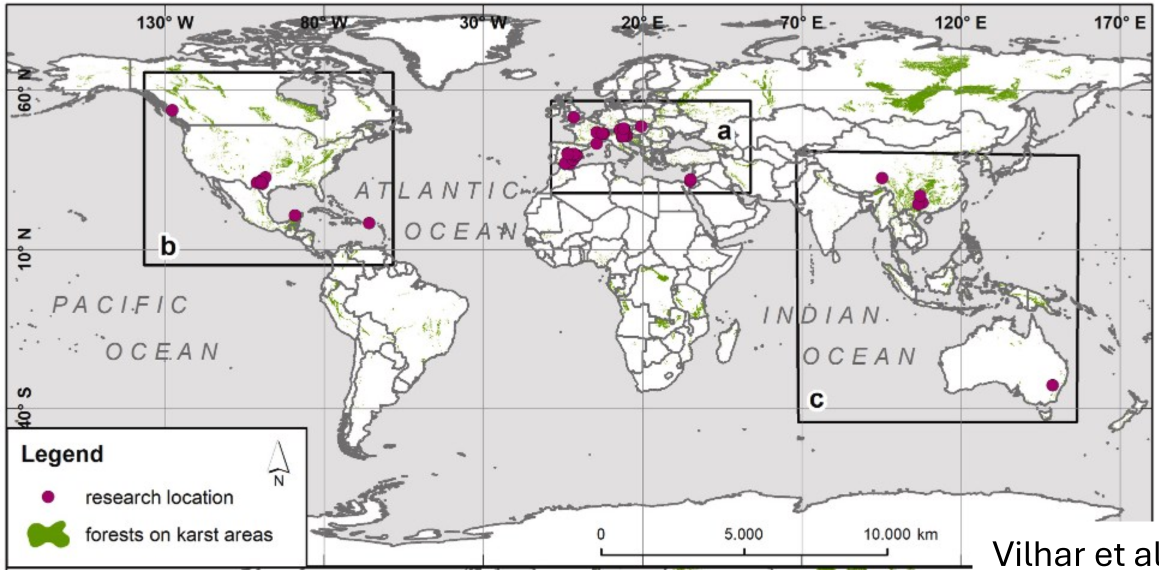
Objectives

- **Forested karst landscapes** are **highly sensitive** to **climate change, pollution, and biodiversity loss** due to their hydrological complexity, high geological porosity, and heterogeneous surface and vegetation structures
- **Monitoring and modeling** these areas face **challenges** such as vertical stratification (from plot level to aquifer), disturbance-induced canopy gaps, and fragmented land cover
- **Integrated ecohydrogeological approaches** are **vital** for understanding and managing these critical zones

What is karst?

- **Karst** -> underground drainage systems, sinkholes, caves, and disappearing streams
- Formed by the **dissolution of limestone and dolomite**
- **Water is the main driver of karstification**, resulting in dynamic and heterogeneous hydrological processes .
- Globally, karst covers about 15% of land surface and supplies a significant portion of the world's drinking water



Vilhar et al. (2022)

Example of a disappearing stream at the same location

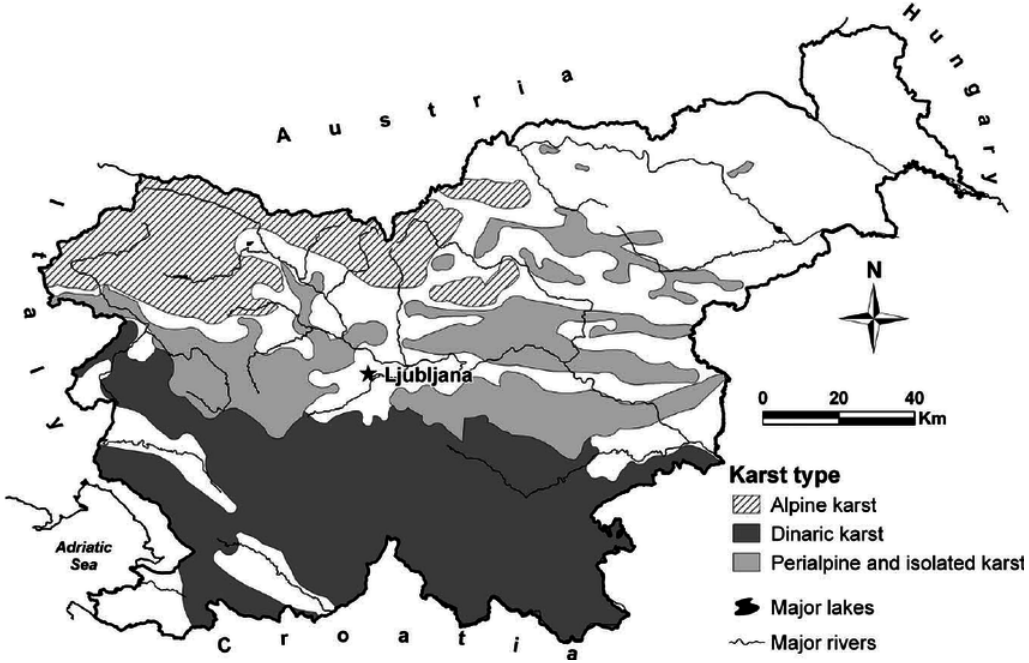
November 2021

November 2024

Foto: Šercer S.

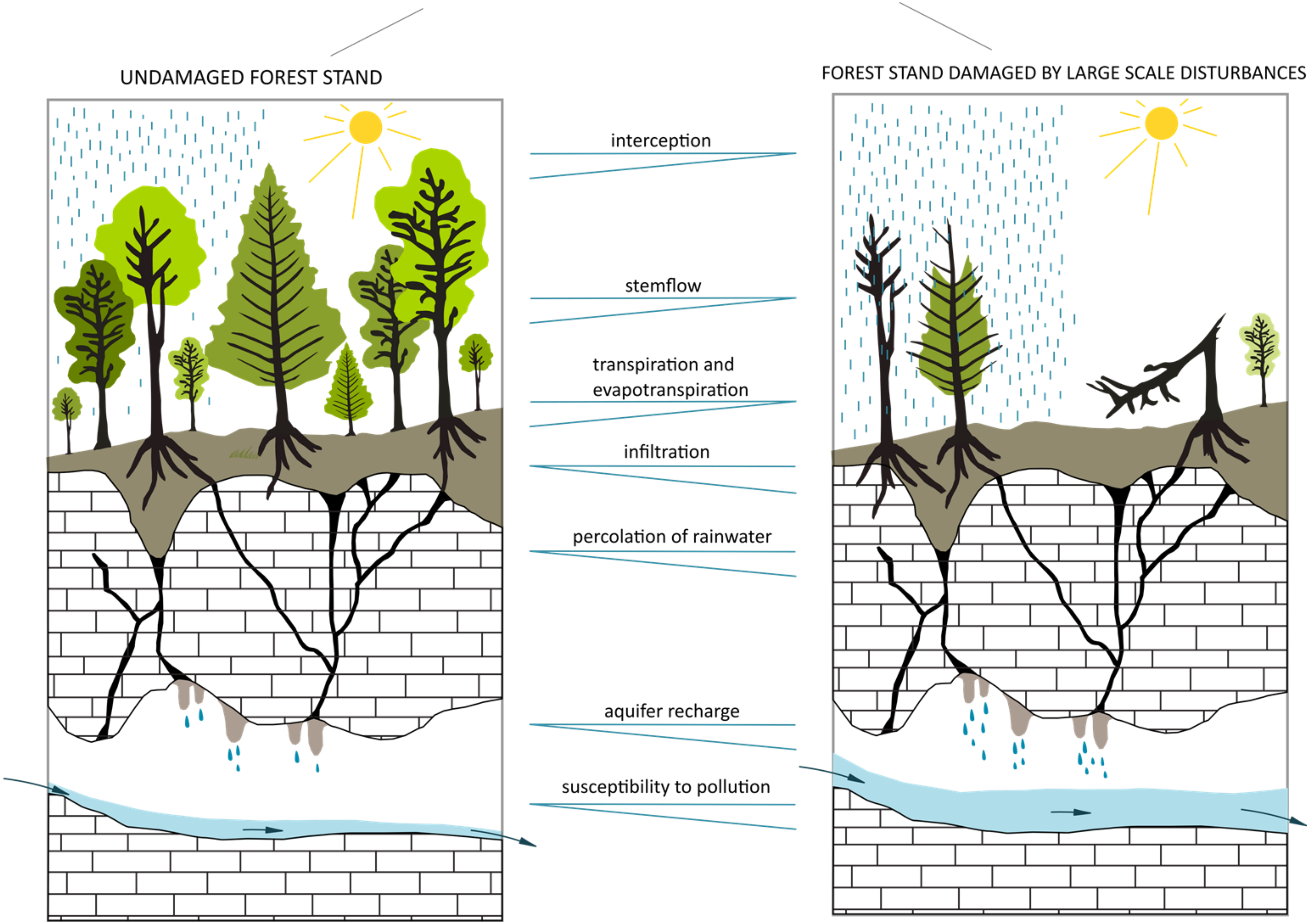
Karst in Slovenia

- Karst covers **44-49% of Slovenia**, with forests overlaying most of these areas
- The Dinaric Mountains or Dinaric Alps host extensive fir-beech forests, crucial for biodiversity and water resources
- Recent **large-scale disturbances** (ice storms, bark beetle outbreaks, forest fires, windthrow) have significantly **impacted forest structure and hydrology**
- **Karst** vs. **Karst plateau**



Komac and Urbanc (2012)

KARST HYDROLOGICAL PROCESSES



Vilhar et al. (2022)

Intergrated Monitoring Approach

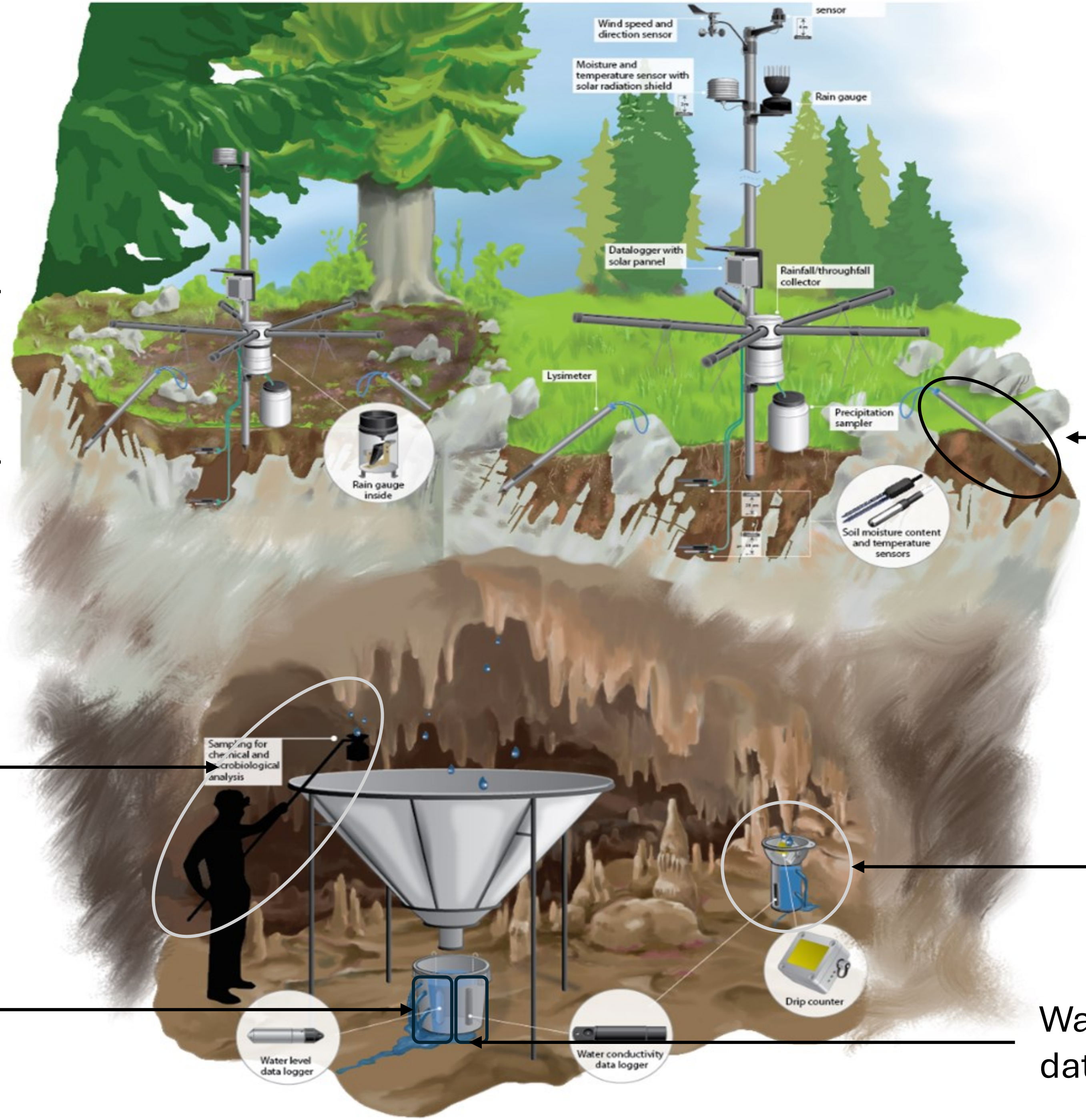
- The **integrated ecohydrogeological approach** in Slovenia combines:
  - **Surface monitoring** (precipitation, canopy interception, soil moisture, temperature)
  - **Subsurface monitoring** (cave drips, water discharge, temperature, electrical conductivity)
- **Strategic site selection**
- **Remote sensing** (scaling and context)
- Customized lysimeters and multi-inlet rain techniques

Foto: Kutnar L.

Multi-inlet rain collector

Meteorological station

Lysimeter



Sampling for chemical and microbiological analysis

Drip container

Water level data logger

Water conductivity data logger

Ravbar et al.

Foto: Kutnar L.

Problems in Karst Monitoring

SURFACE MONITORING

- Heterogeneous vegetation, canopy gaps, and shallow soils
- Complicated scaling plot-level measurements to the aquifer level

Large-scale forest disturbances

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Altered interception, evapotranspiration, soil moisture

↓

Impact on recharge and water quality

SUBSURFACE MONITORING

- Limited access
- Sparse monitoring networks

Complex underground water flow through channels and fissures

↓

Rapid and variable recharge

Solutions and Innovations

- **Continuous**, **event-based monitoring** captures rapid hydrological responses often missed by conventional systems
- **Sensor integration** and **interdisciplinary collaboration** bridge gaps between local measurements and ecosystem-wide modeling
- **Remote sensing**, while promising for upscaling, **requires advanced calibration and adaptation** in densely forested or topographically diverse karst areas

Modeling Challenges and Advances

- **Modeling is constrained by insufficient calibration data** and **oversimplified representations** of complex groundwater flows
- Bridging the gap between plot-scale observations and catchment-scale predictions requires:
  - Long-term data continuity
  - Multi-scale monitoring
  - Advanced numerical and conceptual models (tailored to karst systems)
- Models like **V2Karst simulate groundwater recharge** (climate and land cover) in karst regions

Key Findings and Recommendations

- **Large-scale forest disturbances significantly alter hydrological processes**, especially in karst aquifers where rapid recharge and limited storage increase vulnerability
- **Integrated, multi-scale monitoring and modeling are essential** for effective management and protection of karst ecosystems
- **Future research** should focus on:
  - Improving spatial and temporal representativeness of monitoring networks
  - Enhancing sensor integration and data sharing
  - Developing robust, scalable models for prediction and management

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Thank you!

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Questions?

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