Carinthia II

Nature Tech

Part 3

Published since 1811
215th Year of Carinthia

Volume 2

Issue 1

2025 Verlag des Naturwissenschaftlichen Vereins für Kärnten

BioDivTech Lab – conceptualizing a new research infrastructure for biodiversity monitoring

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ABSTRACT

With the advent of new technological capabilities for recording and monitoring biodiversity, the requirements for research infrastructure are changing. Currently, Carinthia University of Applied Sciences (CUAS) is developing testing facilities designed to enable synchronized biodiversity assessment at various scales in the medium term. This major investment is supported by the Austrian Research Promotion Agency, FFG, and is scheduled to become fully operational in the coming years. The facilities comprise several components, including the SKS research site at Metschacher Moos, stationary measurement and observation networks, a mobile biodiversity laboratory, and laboratory and computational resources at CUAS. These infrastructure components are utilized by researchers and students at CUAS and are also intended to be made available to collaborating scientific institutions and companies.

KEYWORDS

- Biodiversity monitoring
- Infrastructure
- Test site
- Outdoor lab

BioDivTech Lab – Eine Forschungsinfrastruktur für das Monitoring von Biodiversität

ZUSAMMENFASSUNG

Mit den neuen technischen Möglichkeiten für die Erfassung und das Monitoring von Biodiversität verändern sich die Anforderungen an Forschungsinfrastrukturen. Derzeit entwickelt die FH Kärnten (FH) eine Versuchsanlage, die mittelfristig eine synchrone Erfassung von Biodiversität auf unterschiedlichen Maßstabs-Ebenen ermöglichen soll. Die Groß-Investition ist wird von der FFG unterstützt und soll in den kommenden Jahren in vollem Umfang in Betrieb genommen werden. Die Infrastruktur besteht aus mehreren Komponenten, darunter das SKS-Forschungsgelände am Metschacher Moos, stationäre Mess- und Beobachtungsnetze, ein mobiles Biodiversitätslabor sowie Labor- und Rechenkapazitäten an der FH. Die Infrastrukturen werden von den Forschenden und Studierenden der FH genutzt und sollen darüber hinaus auch anderen wissenschaftlichen Einrichtungen und Unternehmen zur Verfügung stehen.

INTRODUCTION

The decline of biodiversity necessitates immediate action to halt further losses, as emphasized in international frameworks such as the Kunming-Montreal Global Biodiversity Framework of the Convention on Biological Diversity (CBD) and European biodiversity policies. Effective conservation measures require robust evidence on biodiversity and ecosystem services, driving the need for efficient and technology-based monitoring systems [1].

Technological advances in fields like sensor technology, robotics, data science, and molecular biology are revolutionizing biodiversity research by enhancing efficiency, data quality, and reproducibility [2]. Further, artificial intelligence opens up extensive new possibilities for biodiversity assessment and monitoring [3]. This shift demands new approaches to research infrastructure, emphasizing collaboration and shared use. To address these evolving needs, Carinthia University of Applied Sciences (CUAS) is establishing the Interdisciplinary Centre for Ecosystem Services and Biodiversity (I.C.E.B.). I.C.E.B. shall operate a modular research infrastructure laboratory, the BioDivTech Lab, designed to advance biodiversity monitoring technologies.

CONSIDERATIONS FOR THE R&D INFRASTRUCTURE

The BioDivTech Lab is designed to address recent demands in research and teaching. Its modular architecture supports flexibility and collaboration while promoting open data principles. The infrastructure's primary goal is the development

and testing of technologies for synchronous multiscale monitoring of biodiversity and ecosystems. It combines fixed, mobile, and computational components into a cohesive system, enabling holistic assessments of diversity across landscape, species, and genetic levels. This approach, as illustrated in Figure 1, establishes a solid basis for tackling the complexities of biodiversity monitoring.

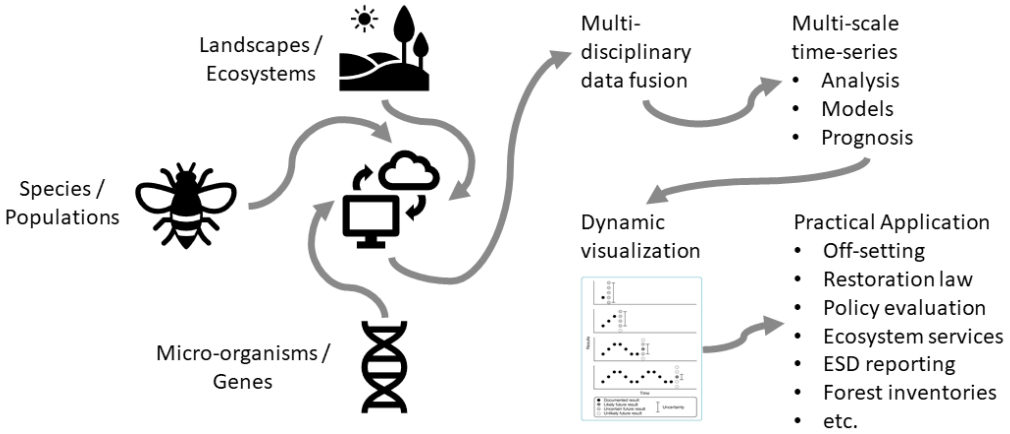

Fig. 1

Figure 1: Operation of the planned infrastructure. With the new infrastructure, the potential for synchronized detection and processing of biodiversity signals across three different scales (microorganisms/genes, species/populations, landscapes/ecosystems) will be developed and tested. The practical applications of these technologies are diverse, ranging from off-setting and restoration to policy and measure evaluation, as well as sustainability reporting. (Source: own figure, dynamic visualization: [3])

Abbildung 1: *Einsatz der geplanten Infrastruktur. Mit der neuen Infrastruktur sollen die Möglichkeiten für eine synchrone Erfassung und Verarbeitung von Biodiversitäts-Signalen auf drei unterschiedlichen Maßstabsebenen (Mikroorganismen/Gene, Arten/Populationen, Landschaften/Ökosysteme) entwickelt und getestet werden. Die praktischen Anwendungsfelder der Technologien sind weit gestreut: Sie reichen von Off-setting, Renaturierungen, Evaluierung von Maßnahmen und Politiken bis hin zu Nachhaltigkeits-Reporting. (Quelle: eigene Abbildung, dynamic visualization: [3])*

CONCEPT OF THE INFRASTRUCTURE

The infrastructure consists of four modules, each fulfilling specific functions while integrating seamlessly into the broader system. These modules are installed at different locations to optimize their utility. This requires a major investment supported by the Austrian Research Promotion Agency, FFG. Currently, the infrastructure is being configured, with operations set to begin in 2026. The infrastructure is composed of numerous elements that interact, as depicted in Figure 2.

Module M1: Long-term Field Research Lab

This module encompasses permanent infrastructure located at the Metschach Experimental and Test Site (hereafter "Metschach"), a restored 14-hectare former moorland area in Carinthia owned by the Bank of Carinthia Foundation, SKS. Metschach provides a long-term data series on vegetative succession (1990–2019), serving as a reference for research and teaching [5]. Additional fixed components are planned for sites such as those used in the BiodiverCITY Villach initiative. A three-component module is planned:

- C1.1 Biotic and abiotic measuring and sensor network. This module includes devices for automated long-term collection of field data.
- C1.2 Biotic reference data kits for calibration. The database allows for the management of all samples and digital evidence of species (e.g., a spectrogram) at the site as documentation.
- C1.3 Semi-stationary field lab (research station, container). The research container provides the basic technical infrastructure for fieldwork on-site.

Module M2: Short-term and Mid-term Multi-site Lab

This module ensures the R&D infrastructure can be deployed at various locations and in different ecosystems. A multi-purpose off-road vehicle equipped with mobile devices is the cornerstone of this module. The infrastructure supports species and population studies as well as remote and close-range sensing. The vehicle is designed for specific research sites and as transport to additional locations. The module will consist of three components:

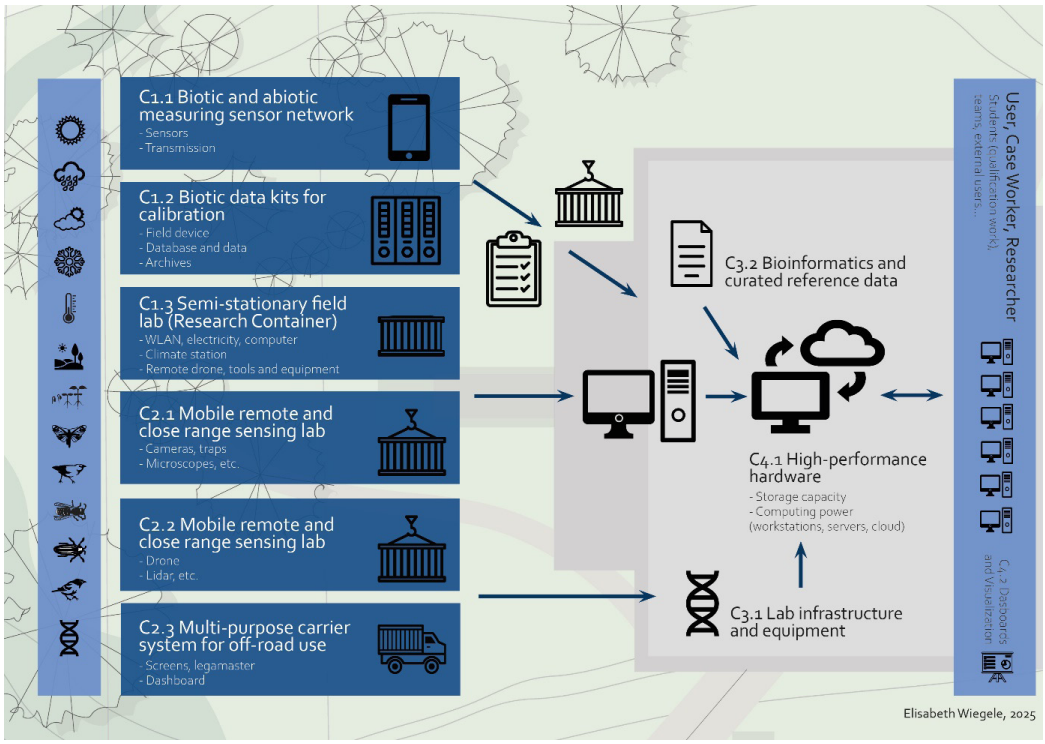

Fig. 2

Figure 2:
Functional interaction of the components. The new infrastructure is designed to enable the entire workflow from field data collection through processing and analysis to visualization. Both fixed installations and mobile devices (such as the "Biodiversity Truck") are used for field data collection. (Source: own figure)

Abbildung 2:
Funktionelles Zusammenspiel der Komponenten. Die neue Infrastruktur soll den gesamten Workflow von der Erfassung im Gelände über die Prozessierung und Auswertung bis hin zur Visualisierung ermöglichen. Bei der Geländeerfassung kommen fix installierte Geräte ebenso wie mobile Geräte ("Biodiversity Truck") zum Einsatz. (Quelle: eigene Abbildung)

- C2.1 Mobile biodiversity lab for all-purpose use. The mobile lab allows for various assessments and analyses directly in the field.
- C2.2 Mobile remote and close-range sensing lab. This is a mobile base for operations in the field of earth observation and remote sensing.
- C2.3 Multi-purpose carrier system for off-road use. The vehicle can transport equipment and gear directly to the deployment site for various missions.

Module M3: Molecular Biology Lab

The existing biomedical laboratory at the CUAS campus in Klagenfurt will be expanded to enhance molecular and microbiological analysis capabilities. This lab will facilitate the identification and detection of organisms, including from bulk sample and eDNA analysis, using cutting-edge tools such as automated nucleic acid extraction, PCR, and next-generation sequencing (NGS). It will consist of two components:

- C3.1 Lab infrastructure and equipment. The operational molecular biology lab is expanded with the latest technologies.
- C3.2 Long-term sample storage and calibration kit. This module primarily involves acquiring storage facilities for genetic samples (deep freezing) for comparison purposes.

Module M4: Data Integration and Analysis Lab

Situated at the CUAS campus in Villach, this module manages the vast volumes of data generated by technology-based biodiversity research. With advanced storage and computational capacities, the Data Integration and Analysis Lab supports data preprocessing, integration, and analysis across spatiotemporal scales. The lab enables big data analysis using a data lake and data warehouse, facilitating insights into biodiversity and ecosystem services. The module will consist of two components:

- C4.1 High-performance hardware for data integration and analysis. Existing computing and storage capacities are significantly expanded.
- C4.2 Dashboards and dynamic visualization tools. Displays and presentation options for various applications are created.

CONCLUSION AND FURTHER PERSPECTIVES

The development of the BioDivTech Lab represents an ambitious initiative to establish a comprehensive research infrastructure tailored to address the challenges of biodiversity monitoring. While this article provides a brief outline of the project, many technical specifications are still under development. The goal is to create an infrastructure capable of driving impactful research and teaching over the next decade. Collaboration with partners from academic institutions, government agencies, companies, and startups will be essential to fully realize its potential.

ACKNOWLEDGMENTS

The procurement of the infrastructure is supported by the Austrian Research Promotion Agency (FFG, F&E-Infrastrukturförderung) in the frame of the project *BioDivTech Lab: Interdisciplinary R&D infrastructure for time synchronous multiscale monitoring of biodiversity and ecosystems*. The development of the I.C.E.B. is supported by the *Privatstiftung Kärntner Sparkasse*.

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I.C.E.B.: Interdisciplinary Centre for Ecosystem Services and Biodiversity

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