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LETTER:

20 YEARS OF LTER SLOVENIA

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1. SHORT HISTORY

In 2003, Long-Term Ecosystem Research (LTER) was launched as European research network aiming to identify drivers of ecosystem change across European environmental and economic gradients. With promising long-term interdisciplinary research, the European LTER also developed the concept of Long-Term Socio-Ecological Research (LTSER) by including LTER research sites and broader LTSER platforms (https://www.ilter.network/).

In the same year, the Slovenian LTER network was established and officially presented and accepted at the meeting of the global network of International Long-Term Ecological Research (ILTER), in Seattle, USA (September 18-23, 2003). At that time, the Slovenian node was established as a consortium of six research institutions and recognized by Ministry of the Environment and Spatial Planning, Environmental Agency of the Republic of Slovenia.

The first Slovenian LTER consortium was formed by six research institutions, with the Karst Research Institute ZRC SAZU as promoter and headquarters of the Slovenian node:

- Scientific Research Centre of the Slovenian Academy of Sciences and Aarts (ZRC SAZU) and four of its institutes (Karst Research Institute, Jovan Hadži Institute of Biology, Institute of Anthropological and Spatial Studies, and Anton Melik Geographical Institute);
- National Institute of Biology;
- University of Primorska, Science and Research Centre of Koper, Institute for Biodiversity Studies;
- University of Ljubljana, Biotechnical Faculty, Department of Biology, Chair of Ecology and Chair of Zoology;
- University of Maribor, Faculty of Natural Sciences and Mathematics, Department of Biology, Chair of Geobotanics;
- Notranjska Museum Postojna, Biological Department.

The Slovenian consortium approved the participation of three most representative research platforms to provide data for the European network: Kras or Karst in English, Karst in the Ljubljanica river basin and the Alpine karst (Figure 1).

The mission of LTER Slovenia was to establish a network of sites that would enable Slovenian scientists to address ecological issues on broad spatial and temporal scale in an interdisciplinary manner. In addition, the national network was aiming to create a legacy of well-designed and documented experiments and observations for future generations of society. The first national LTER sites included both terrestrial and aquatic ecosystems, with comparisons made between different biomes at the national level and among different geographical areas at the international level. The core areas of research within the national network were defined as: i) patterns and

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controls of ecosystem primary productivity; ii) the role of biodiversity in ecosystem structure and functioning; iii) patterns and frequency of ecosystem disturbance; iv) impacts of climate change on ecosystem structure and functioning; v) interactions at the interface between managed and natural ecosystems; and vi) defining criteria for ecosystem management and conservation.

In 2005, the special issue of international karstological journal *Acta Carsologica* was devoted to the presentation of the national LTER sites of the Pivka intermittent lakes in the karst area of the Ljubljanica river basin (Mulec et al., 2005).

The selection of sites was based on the fulfillment of several criteria according to the LTER implementation strategy, namely the existence of a critical scientific mass, a commitment to sharing the data obtained and its long-term management, the involvement of a higher level institution with evidence of its commitment, institutional longevity or security of the site for the future, as well as adequate infrastructure and logistics and an existing knowledge base (e.g. availability of long-term databases and the necessary research tools: networking, database management, geographic information systems and modelling).

The Slovenian node was regularly represented at all LTER, later eLTER and ILTER meetings abroad by its national representatives, Dr. Tanja Pipan and Dr. Janez Mulec.

Shortly after Slovenia became one of the member countries of ILTER Network, the Program Director for Long-Term Ecological Research (LTER), Division of Environmental Biology, National Science Foundation, Dr. Henry Gholz, visited the Slovenian consortium in September 12-14, 2004. The main outcome of this visit was the organization of the international workshop on "Long-Term Ecological Studies in Karst" one year later (October 20 - 24, 2006). The workshop was supported by the National Science Foundation, the Slovenian Research Agency and the Scientific Research Centre of the Slovenian Academy of Sciences and Arts and was attended by 37 participants from 22 research institutions from Slovenia and the USA (Culver & Pipan 2006).

The workshop, held at the Karst Research Institute ZRC-SAZU in Postojna, Slovenia, brought together karst

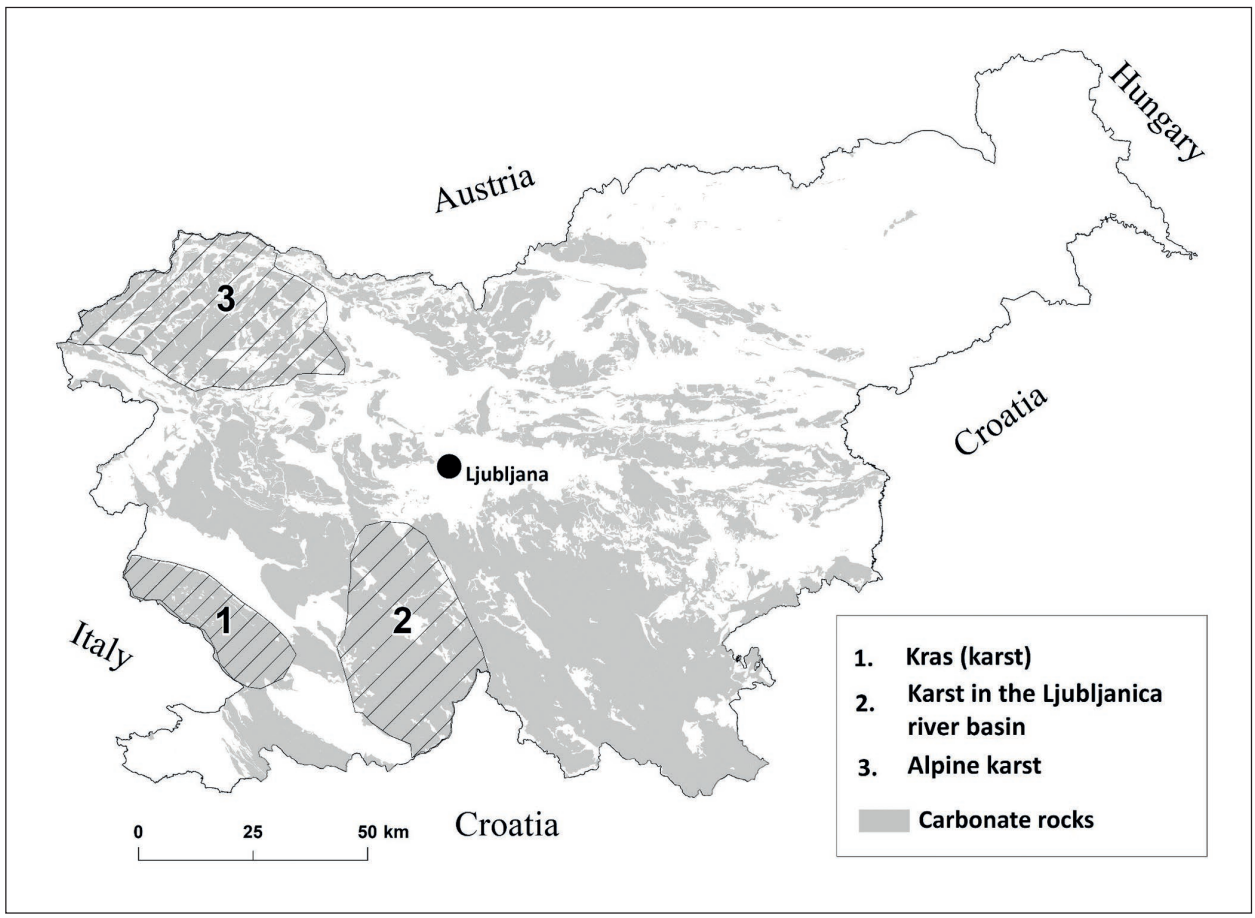

Figure 1: LTER-Slovenia research platforms participating in the European LTER (Carbonate rocks layer source: Gostinčar, 2016)

and ecosystem scientists from Slovenia and the USA to explore common interests in long term studies in the Slovenian karst, focusing on the above and below-ground components of karst (Culver & Pipan, 2006). The main idea of this international workshop was to bring together a strong group of experts to provide a comprehensive understanding of the patterns of karst ecosystems, the role of biodiversity in the structure and functioning of karst ecosystems, and the interactions at the interface between managed and natural ecosystems. The discussions took place within the framework of the International Long-Term Ecological Research (ILTER) Network.

Later, in the 2016 revised Slovenian National Roadmap for Research Infrastructures for the period 2011-2018 (NRRI, 2016), eLTER was included in the priority list of the ESFRI Roadmap 2018 as an "emerging project" with ZRC SAZU as the leading national partner for the preparatory phase of the project (2011-2019). During this period, the framework for the operation of the new research infrastructure was elaborated, including the financial parameters and the assessment of the costs for national participation.

2. NEW ERA OF LTER SLOVENIA

In 2017, Slovenia was one of the 17 countries that signed the "Letter of Political Support" and as leading partner of the consortium, also supported the scientific part of the project. The international level of the eLTER project also marked two periods in its development: the planning phase (2015 - 2019) and the preparatory phase (2019-2021) (NRRI, 2030). Both phases were successfully completed and in 2018 eLTER was included in the ESFRI Roadmap.

Following the international context of the eLTER RI project, LTER Slovenia node was reorganized and a new consortium of research institutions and NGO signed a Memorandum of Understanding:

- Research Centre of the Slovenian Academy of Sciences and Arts (ZRC SAZU);
- National Institute of Biology – Marine Biology Station Piran (NIB-MBP);
- Slovenian Forestry Institute (GIS);
- University of Ljubljana – Biotechnical Faculty (UL BF);
- Škocjan Caves Park Public Service Agency (PSJ);
- Slovenian Museum of Natural History (PMS);
- Society for Cave Biology (Tular Cave Laboratory);
- University of Maribor (UM).

The consortium has established 16 operational eLTER sites (Figure 2; https://lter.zrc-sazu.si/sites-2/) covering four ecosystems: terrestrial, freshwater, forest, and marine. All sites are listed and described in detail in the eLTER DEIMS database (Table 1, Wohner et al., 2019).

LTER Slovenia continued to be very active as a national node and contributed to the eLTER project through the participation of its national representatives in international meetings, to name but a few: Dr. Tanja Pipan, Dr. Magdalena Aljančič and Dr. Matej Blatnik as well as in various international eLTER seminars and research activities by Dr. Tanja Pipan, Dr. Magdalena Aljančič, Dr. Matej Blatnik, Dr. Mitja Prelovšek, and MSc Žan Kafol from Karst Research Institute ZRC SAZU and by Dr. Urša Vilhar and Dr. Mitja Ferlan from the Slovenian Forestry Institute, Dr. Mateja Germ from University of Ljubljana, and Gregor Aljančič from the Society for Cave Biology.

2.1. ELTER TA-RA MOBILITY SCHEME IN SLOVENIA

In 2017, the Karst Research Institute ZRC SAZU hosted a young Romanian researcher, Dr. Sanda Iepure from the "Emil Racovita" Speleological Institute Cluj-Napoca, as part of the second call for proposals for the eLTER Transnational and Remote Access mobility system. The research stay included field and laboratory work (https://lter.zrc-sazu.si/ta-ra-2017/).

In 2019, a new eLTER Transnational and Remote Access mobility was offered by the Karst Research Institute ZRC SAZU, which hosted two Romanian researchers, Dr. Ioana Nae and Dr. Augustin Nae from the "Emil Racovita" Speleological Institute Bucharest. The 12-day research visit focused on two eLTER sites (the Postojna-Planina Cave System and Škocjan Caves), offering opportunity for extensive field trips and fieldworks related to the rich subterranean biodiversity and its karst habitat in the Slovenian Classical Karst. The mobility offered also the opportunity to establish many contacts with Slovenian karstologists, spelobiologists and other experts in the field of karstological research (https://lter.zrc-sazu.si/ta-ra-2019/).

2.2. CURRENT PROJECTS AND FUTURE PLANS

After completing the Design phase in 2019, the eLTER project entered the Preparation (2020-2027) and Imple-

mentation (Construction) phase in 2022 as an EU level Research Infrastructure (RI). eLTER RI is "a distributed RI to facilitate high impact research and catalyse new insights about the compounded impacts of climate change, biodiversity loss, soil degradation, pollution, and unsustainable resource use on a range of European socio-ecological systems" (NRRI, 2030).

This eLTER phase is currently underway, managed by the eLTER Interim Council (eLTER IC), in which Slovenia is also involved, with the aim of establishing eLTER ERIC in 2025.

By joining eLTER, Slovenia commits to providing data in the field of speleobiology, karst and other terrestrial, freshwater and marine ecosystems. This strengthens its important role in this field and opens the door for participation in new international research on biodiversity and ecosystems (NRRI, 2030). Since 2020, the ZRC SAZU as the headquarters of LTER Slovenia became a partner in two European Horizon 2020 projects:

- **eLTER Preparatory Phase Project** (eLTER PPP; https://elter-ri.eu/elter-ppp) is a project for the eLTER Research Infrastructure under the INFRADEV-02-2019-2020 programme and represents a coordinating and supporting action for the detailed specification and high-level decision-making on the legal, financial and technical maturity aspects required for the implementation of eLTER RI. In this case, eLTER PPP is working closely with eLTER PLUS to ensure the highest relevance of eLTER RI services for connected research communities and other eLTER RI user groups. The project comprises 7 work packages, in which the ZRC SAZU participates as a partner. It is one of the 27 institutions from the 25 countries involved in the project.
- **eLTER Advanced Community Project** (eLTER PLUS; https://elter-ri.eu/elter-plus) is an "Advanced Research Infrastructure Communities" project that is part of the INFRAIA-01-2018-2019 programme and is based on three main pillars - networking (1-networking, 2- joint research activities and 3-transnational, remote and virtual access). Selected areas and platforms of terrestrial, freshwater and coastal ecosystems are involved in the integrated study of ecosystems, climate change impacts and threats to ecosystem services on a pan-European scale. The project identifies and assesses innovative monitoring methods and analytics, develops detailed specifications of eLTER RI according to community needs (standardized monitoring, remote and virtual access), and builds an online community, training and services. eLTER PLUS involves

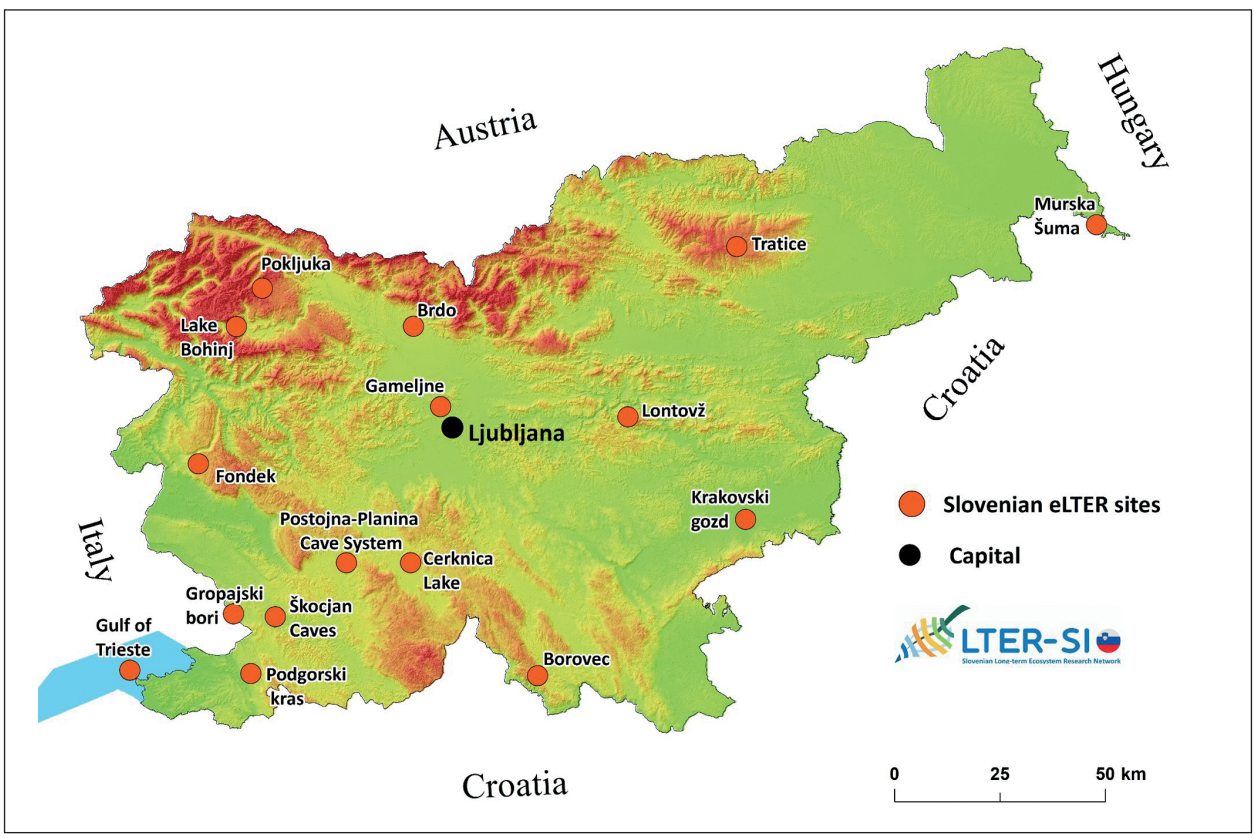

Figure 2: The geographical distribution of the Slovenian eLTER sites.

Table 1: List of the Slovenian eLTER sites, the managing institution and their respective ecosystem types

eLTER site	Managing institution	Ecosystem type	DEIMS code/link
Postojna-Planina Cave System	Karst Research Institute ZRC SAZU	Terrestrial and Freshwater	https://deims.org/b5bcf1f8-b905-4190-bb82-12d0d73904d0
Škocjan Caves	Karst Research Institute ZRC SAZU	Terrestrial	https://deims.org/4d5e8006-f211-467e-b942-8626576a0e0f
Cerknica Lake	University of Ljubljana	Freshwater	https://deims.org/9026e5f2-af78-4610-8e8a-bd73466da65c
Lake Bohinj	University of Ljubljana	Freshwater	https://deims.org/ae055ce5-159c-4d73-8c47-a0708c895197
Gulf of Trieste - Slovenia	National Institute of Biology	Marine	https://deims.org/f2ce5ae3-8873-4a8b-abad-d56d5d6da164
Borovec	Slovenian Forestry Institute	Forest	https://deims.org/d5544ca4-8400-4553-b7f8-9728c358f03a
Podgorski kras	Slovenian Forestry Institute	Forest	https://deims.org/a4822c8a-2cc3-4c44-8456-03e6b0216a0f
Brdo	Slovenian Forestry Institute	Forest	https://deims.org/7e3d1406-6c22-43eb-bf85-e704e3c5a70b
Fondek	Slovenian Forestry Institute	Forest	https://deims.org/96adc9f8-190b-4a7c-be68-e51747d872a0
Krakovski gozd	Slovenian Forestry Institute	Forest	https://deims.org/deaa845b-dbd9-42a4-a9a5-d9db2a86d4c2
Gameljne	Slovenian Forestry Institute	Forest	https://deims.org/6934836e-57af-40f6-bfff-299c12a532a0
Tratice	Slovenian Forestry Institute	Forest	https://deims.org/bbe12f63-af77-4b1a-88dd-a0b156323084
Gropajski bori	Slovenian Forestry Institute	Forest	https://deims.org/a9a6346a-cfdd-4642-944c-7a5f55d5e447
Lontovž	Slovenian Forestry Institute	Forest	https://deims.org/e87be18b-9360-459f-81cb-ec4a53cab57a
Pokljuka	Slovenian Forestry Institute	Forest	https://deims.org/0d3e7231-2414-429f-80bb-71f1e1fc3d17
Murska Šuma	Slovenian Forestry Institute	Forest	https://deims.org/8c280ddb-c31c-45d8-a4eb-77dac64848b3

23 countries and 33 institutions, including ZRC SAZU as a partner that participates in five work packages. Both projects will be completed in 2026 with the aim of achieving eLTER ERIC status. The Slovenian LTER network truly benefits from participating in the eLTER RI community by opening doors to new scientific opportunities and driving the development and better integration of its network of research sites and the national research infrastructure community.

In 20 years of LTER Slovenia, a considerable number of research articles have been published acknowledging the support of the eLTER projects covering karst-dependent ecosystems (e.g., Ravbar & Pipan, 2022; Siegel et al., 2023), karst ecological indicators and hydrodynamics (Ravbar et al., 2021; Mayaud et al., 2023; Vilhar et al., 2022), climate change, surface-subsurface interactions and subterranean biodiversity of the Postojna-Planina Cave System (e.g., Pipan et al., 2018; Aljančič et al., 2023; Culver et al., 2023; Kozel & Pipan, 2020; Kozel et al., 2023; Mammola et al., 2020; Pipan et al., 2020; Kos et al, 2023), long-term microbiological monitoring (Mulec et al., 2023), the UNESCO World Heritage Site of the Škocjan Caves (Prelovšek et al., 2021). Much research has been conducted to develop the eLTER data center at the Karst Research Institute ZRC SAZU (Năpăruş-Aljančič et al., 2019; Năpăruş-Aljančič et al., 2021; Blatnik et al., 2020), while a video presenting the Slovenian LTER node and its karstological research was produced here (Pipan et al., 2022).

With this article we celebrate 20 years of successful partnership of Slovenian researchers and their institutions who have joined forces to form the LTER Slovenia consortium and their active contribution to eLTER RI. With their research results and collaboration, they have built a stronger community and scientific network in the European Research Area. We are grateful for these two decades of LTER Slovenia and look forward to new research challenges.

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