ECOSYSTEM FOR MOUNTAIN INNOVATIONS

An executive report on all the research activities carried out by the iNEST - spoke 1 project in 2023

Edited by

Fabrizio Mazzetto, Daniele Cortolezzis, Guido Orzes

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List of Authors

Birgit	Alber	UNIBZ	Alessandro	Fornasiero	UNIVR	Lorenzo	Picco	UNIPD
Antonio	Altana	UNIBZ	Ilenia	Fronza	UNIBZ	(*) Anna	Prati	UNIBZ
Camillo	Ayala G.	UNIBZ	Andrea	Gambaro	UNIVE	Matteo	Prina	EURAC
Marco	Baratieri	UNIBZ	Ylenia	Gelmini	UNIPD	Stefan	Rabanus	UNIVR
Ivana	Bassi	UNIUD	Sara E.	Goldoni	UNIVR	Salvatore	Raniolo	UNIPD
Federico	Battini	UNIBZ	Stefano	Grigolato	UNIPD	Faisal	Rasool	UNIBZ
Maria	Battistel	UNIVE	Davide	Imperiali	UNIPD	Francesco	Ravazzolo	UNIBZ
Diego	Begalli	UNIVR	Merve	Karaca	UNIBZ	Paul	Richter	UNIPD
Alberto	Beinat	UNIUD	Michele	Larcher	UNIBZ	Maurizio	Righetti	UNIBZ
Merve	Bektas	UNIBZ	Rigoberto	Arambula	UNIVE	Alberto	Romanzin	UNIUD
Enrico	Bertuzzo	UNIVE	Eleonora	Leonardi	EURAC	Giuseppe	Rotondo	EURAC
Rajeshwari	Bhookya	UNIPD	Emanuele	Lingua	UNIPD	Giulia	Roveri	EURAC
Silvia	Bolognini	UNIUD	Federico	Lovison	UNIUD	(*)Pasqualina	Sacco	UNIBZ
Marco	Borga	UNIPD	Paolo	Lugli	UNIBZ	Riccardo	Scarpa	UNIVR
Roberta	Bottarin	EURAC	Andreas	Mandler	UNIBZ	Michele	Scotton	UNIPD
Stefano	Brighenti	UNIBZ	(*) Carlo	Marin	EURAC	Khalid W.A.	Shomali	UNIVR
Anita	Cabbia	UNIUD	Eleonora	Maset	UNIUD	Emily	Siviero	UNIBZ
(*) Mattia	Callegari	EURAC	Mauro	Masiol	UNIVE	Wolfram	Sparber	EURAC
(*) Giovanni	Carabin	UNIBZ	Fabrizio	Mazzetto	UNIBZ	(*) Marco	Sartor	UNIUD
Raffaele	Cavalli	UNIPD	Giovanna	Mazzi	UNIVE	Anna	Sperotto	UNIVE
Federico	Cazorzi	UNIUD	(*) Andrea	Menapace	UNIBZ	Barbara	Stenni	UNIVE
Francesco	Comiti	UNIBZ	Lorenzo	Menin	UNIBZ	Giulia	Stradiotti	UNIBZ
Mariachiara	Cravero	UNIPD	Steffi	Misconel	EURAC	Giacomo	Strapazzon	EURAC
Chiara	Crippa	EURAC	(*) Guido	Nassimbeni	UNIUD	Enrico	Sturaro	UNIPD
Andrea	Critto	UNIVE	Catia	Nicodemo	UNIVR	(*) Giovanni	Tallarico	UNIVR
(*) Giovanna	Culot	UNIUD	(*)Francesco	Nicolosi	UNIBZ	Marta	Tagliani	UNIVR
(*) Giovanni	Cuozzo	EURAC	Claudia	Notarnicola	EURAC	Mehari	Teshome	UNIBZ
Sara	Cucchiaro	UNIUD	Guido	Orzes	UNIBZ	Enrico	Tomelleri	UNIBZ
Luca	Da Ros	UNIBZ	Aldo	Paolillo	UNIBZ	Alexandra	Troi	EURAC
(*) Matteo	Dainese	UNIVR	Mauro	Pascolini	UNIUD	Secil	Ugur Yavuz	UNIBZ
Tiziana	Danise	UNIVR	Margherita	Pasini	UNIVR	Martina	Vacondio	UNIVR
Jessica	De Agostini	UNIVR	Wilmer	Pasut	UNIVE	Francesco	Visentin	UNIUD
Vanessa	Deotto	UNIUD	Barbara	Pellegrini	UNIVR	Claudio	Zaccone	UNIVR
Jacob	Diamond	UNIVE	Giacomo	Pellegrini	UNIPD	Marc	Zebisch	EURAC
Silvia	Ferrari	UNIVR	Giovanni	Pernigotto	UNIBZ	Alyona	Zubaryeva	EURAC
Mario	Floris	UNIPD	Rossano	Piazza	UNIVE			

(*) people not involved in the iNEST – project

Ecosystem for Mountain Innovations

Table of context

1B.07 - Promoting one-health strategies focusing on understanding and mitigation of geo-hydrological risks and its forecasting

1B.08 - Assessing the Impact of Climate Change on Landslides in an Alpine Environment

1B.09 - Bridges safety in small river basins

1B.10 - Mitigation of geo-hydrological risks: Multi-temporal analysis to support the management of torrent control structures

1B.11 - Promoting one-health strategies focusing on the adoption of safety and ergonomics solutions, on active lifestyle finalized to well-being and health in mountain environmental conditions

1B.12 - Emergency healthcare and healthcare access in mountainous and rural areas

Research Topic 2 – Resilience of Mountain Production Systems and Supply Chains

Introduction to RT2

02.01 - Mountain grasslands: a possible role in reducing enteric methane emissions

02.02 - Integrating economic and natural sustainability in the management of grassland-based ecosystems

02.03 - Agroecology indicators (tool) to favour agro-ecological transition of mountain farms

02.04 - Evaluation of the resilience of extensive mountain grasslands: soil ecosystem services and plant functional diversity in a climate change scenario

02.05 - A stability model to determine rollover performances of farm machinery

02.06 - Setting stability maps for safe operations of farm and forestry machines in rough and steep terrains

02.07 - Technological solutions for alternative cropping systems in mountain extensive agriculture

02.08 - Applied DTW map in forest logging system

02.09 - Innovative methods for forestry planning and management

02.10 - Development of wearable solutions for working and recreational activity in the winter industry domain

02.11 - Development of sensing solutions for environmental monitoring in the winter industry domain

02.12 – Influence of active air supply during avalanche burial on ventilation and oxygenation

02.13 – Methods and tools for sustainability, circular economy and multi-dimensional assessment

02.14 - Feral Wool – Designing with a Vibrant Matter in Times of Uncertainty

02.15 - Fostering local development on mountain contexts through health tourism and cultural ecosystem services

02.16 - Creation of an interactive map with tourism information of the Verona's mountains

02.17 - Analysing the resilience and competitiveness of manufacturing companies located in mountain regions

Research Topic 3A – Decentralisation of Mountain Structures and Infrastructures – Energy Strategies

Introduction to RT3A

3A.01 - System modeling of energy supply and distribution in Alpine contexts

3A.02 - Use of renewable energy sources, sustainable hydropower plants design

3A.03 - Bioenergy as a source of complementary dispatchable renewable power in mountain areas

3A.04 - Definition of archetypes' properties for the characterization of the Alpine building stock

3A.05 - Energy performance and renovation of existing building stock in mountain areas

3A.06 - Economic and social aspects of energy policy in the Alpine region

Research Topic 3B – Decentralisation of Mountain Structures and Infrastructures – Logistic Strategies

Introduction to RT3B

3B.01 - Strategies for the decarbonization of the logistic sector in mountainous areas

3B.02 - Ideas for wheel-based micromobility that connects mountain areas with the logistic structures of the valley

3B.03 - Exploring mountain transport and logistics systems through literature review and patent analysis

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PREFACE

The Italian National Resilience and Recovery Plan (PNRR) dedicates special emphasis to research and innovation activities and has financed a set of innovation ecosystems projects.

The Interconnected Nord-Est Innovation Ecosystem iNEST project, funded by the European Union Next-Generation EU, brings together the nine universities of north-east Italy and a considerable number of public and private research institutes and clusters located in Friuli Venezia Giulia, Veneto and Trentino Alto Adige. The goal of the project is to extend the benefits of digital technologies to the key specialization areas of the northeast territory, boosting digital technologies in the setting of industrial-manufacturing sector, agriculture, sea, mountains, construction, tourism, culture, health and food.

Each of the above themes constitutes a Spoke of the iNEST project. The Free University of Bozen-Bolzano leads the Spoke 1 - Ecosystem for Mountain Innovations.

The whole iNEST project is divided into four phases (Milestones), totalling forty months. In the first four months, the preliminary activities of organising the working groups, defining the projects to be pursued, and collecting and analysing the literature takes place. This is followed by a twelve-month phase in which the project's topics are examined in depth and the theoretical foundations are laid for the subsequent developments that will take the form of proposing new solutions, new ventures and new strategies in the topics indicated in the project. Finally, in the fourth phase, dissemination actions are planned.

The second phase has now been completed. This document therefore contains a compilation of the reports of all the research activities carried out within the Ecosystem for Mountain Innovations project in 2023 (Milestone 2).

INTRODUCTION TO THE ECOSYSTEM GOALS AND ACTIVITIES

The state of the mountain areas of north-east Italy has been problematic for years, and the importance of this project is reinforced by the fact that certain problems have reached a critical point that can only be resolved through significant innovation activities. Moreover, the background, context and characteristics of the areas in north-east mountain region are very different and it is therefore not so easy to find a unique general solution that can be applied for the whole area.

The aim of the Spoke 1 of the iNEST project is therefore to promote the development of new products, processes and lifestyles capable of consolidating and maintaining the local traditions that guarantee the survival and demographic viability of mountain contexts from all points of view (economic, environmental and social). This is achieved through actions that:

(a) enhance the strengths of mountain resources (extensive agro-forestry-livestock activities, flourishing tourism in unique environmental ecosystems, biodiversity, multiculturalism and local traditions);

(b) mitigate risks that are particularly relevant in these contexts (fragmentation and security of production systems, difficult logistics, hydrological risks, reduced quality of life).

To better achieve such important goals, the research lines has been divided into three main research topics: RT1 – Safety and quality of life in mountain environments: Mountain Social Life (RT1A) and Mountain Habitat (RT1B); RT2 - Resilience of Mountain production systems and supply chains; RT3 - Decentralisation of Mountain Structures and Infrastructures: Energy strategies (RT3A) and Logistic Strategies (RT3B).

As the iNEST project, the Ecosystem for Mountain Innovation project has been articulated in four main milestones, since September 2022, and now we completed the first two: the preliminary phase (milestone M1) and the phase in which the efforts have been spent in deepening the strategic issues identified (milestone M2); furthermore, we also started to work on (new) solutions to the problems that had been decided to tackle, leading to the first publications certifying the quality of the work done.

In addition, an important building block in the construction of the ecosystem is the relationships we are creating with companies through the cascading fund calls as well as stakeholder engagement and events.

Next year will be the year of completing the research work, involvement in industrial research and experimental development activities of companies that have received funding through the Cascade Fund calls , and planning the exploitation and dissemination activities in order to identify the best solutions that can become best practices for each area of the North-East Alpine territory when they are implemented.

The problems of the mountains are specific and different from the rest of the north-eastern territory but interesting solutions could also be drawn from the work of other iNEST spokes. We therefore want to introduce different ways of engagement of the other spokes to gather their experiences and apply them together to the mountain region.

ECOSYSTEM RESEARCH TOPICS OBJECTIVES OVERVIEW

As mentioned in the previous section, the aim of the Spoke 1 is to promote the development of new products, processes and lifestyles capable of consolidating and maintaining the local traditions that guarantee the survival and demographic viability of mountain contexts from all points of view (economic, environmental and social). The activities have been organized into five research topics (RTs):

RT1A – Safety and quality of life in mountain Environments – Mountain Social Life

This topic deals with all issues concerning the social and cultural aspects of life in the mountains. At the end of the project, we aim to provide new strategies, technological solutions and policies to tackle the problem of abandonment of mountain areas and desertification of mountain villages by proposing concrete actions to promote the use of digital technologies able to increase the quality of life in "smart" mountain villages.

RT1B – Safety and quality of life in mountain Environments – Mountain Habitat

This topic deals with all issues concerning the habitat and how climate changes may affect the life and the environment in mountain. At the end of the project we aim to provide new strategies, technological solutions, and policies to tackle the problems of the decreasing quality of air and water, the availability of resources affected by the climate change and the mitigation of risk associated with the climate change as well as promoting new lifestyle for health and well-being in mountain areas.

RT2 – Resilience of Mountain production systems and supply chains

This topic aims to define new innovation strategies in order to increase the resilience of mountain production systems and supply chains. This is mainly achieved by working on the following issues: a) extensive farm and forestry system; b) winter and mountain industry; c) mountain crafts, construction, and manufacturing processes and technologies; d) offshoring and reshoring in mountain areas.

RT3A – Decentralisation of Mountain Structures and Infrastructures – Energy Strategies

This topic aims to identify and implement solutions for improving sustainable energy strategies in mountain areas, in terms of both energy supply and energy saving solutions through energy system modelling techniques.

RT3B – Decentralisation of Mountain Structures and Infrastructures – Logistic Strategies

This topic deals with all issues useful to Identify, study and develop proper strategies for low-carbon mountain transport and logistics systems.

These research activities are currently carried out by 47 professors and researchers belonging to the Free University of Bozen/Bolzano (14) and affiliated entities of the Universities of Padua (7), Udine (7), Ca' Foscari - Venice (7), and Verona (9) and of the EURAC - European Academy of Bozen/Bolzano (7). In addition other 47 researchers have been currently recruited to cooperate with the professors and researchers above mentioned, 17 belonging to the Free University of Bozen/Bolzano, 7 to the University of Padua, 5 to the University of Udine, 5 to the University of Ca' Foscari, 8 to the University of Verona, and 5 to EURAC.

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RESEARCH TOPIC 1 A

Safety and quality of life in mountain Environments – Mountain Social Life

INTRODUCTION TO THE RESEARCH TOPIC 1A
MOUNTAIN SOCIAL LIFE

As mentioned above, the ultimate aim of this project is to participate in combating the abandonment of the mountains, by acting on a wide range of factors that can contribute to increasing the attractiveness of life in the mountains, by acting both on the specific cultural aspects of these areas and on the increase of services specifically prepared for the populations living in the mountains and which help to reduce the discomforts of living in the 'highlands'.

In particular, the research activities carried out under this research topic are divided into five projects:

The first project, “Psycho-social aspects in the implementation and multidimensional evaluation of innovative solutions to support well-being and quality of life in the mountain environment” has as its purpose the identification of models relating psychological variables, as well as the psycho-social and contextual aspects, with the proper assimilation of smart technologies solutions in the mountain areas.

The second one, “Digital and training strategies to support smart villages in mountain environment” aims to pursue six convergent objectives fostering intergenerational exchange so that younger people can support less digitized people in learning; offering courses to inspire new generations of digital innovators, Implementing models relating individual psychological aspects (e.g., motivations, beliefs, values), socio-cultural context, and assimilation of innovative solutions in relation to smart villages, using a participatory approach; running community-led exercises to imagine the dimensions of the smart villages and to co-create innovative solutions in collaboration with stakeholders; opening online/hybrid learning opportunities for adults to increase participation from remote parts of mountain areas, and obtaining higher qualified staff in education by organizing training courses for teachers

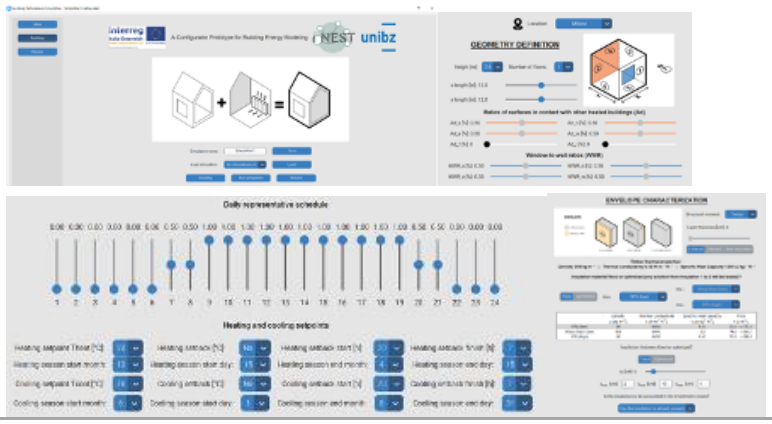
The third one, “Enhance the cultural heritage and landscape of the mountain inhabitants through participatory processes and building an Eco-museum’s network”, the main objectives of the research are the mapping and study of ecomuseum legislation, the development of common guidelines, and the design of a network of mountain ecomuseums, in order to attract new visitors offering new contributions in the geographical, anthropological and cultural fields.

The fourth one, “Promotion of multilingualism for mountain ecosystems”, aims to the development and implementation of processes and services to raise awareness of multilingualism in all generations; the enhancement of language skills in the context of atypical language development, specifically dyslexia; and the enhancement of multilingualism in the context of the mountain tourism industry.

The last one, “The adequacy of the public and private legal tools for identifying innovative strategies aimed at supporting the development of smart villages”, aims to identify the most suitable public and private legal tools envisaged by the relevant reference regulations for enhancing the great potential of mountain areas and verify if these private and public legal tools are adequate to contribute to developing innovative strategies to support smart villages in mountain areas.

In the following sheets, the progress of the five projects and the goals for the coming months until the project is completed are given.

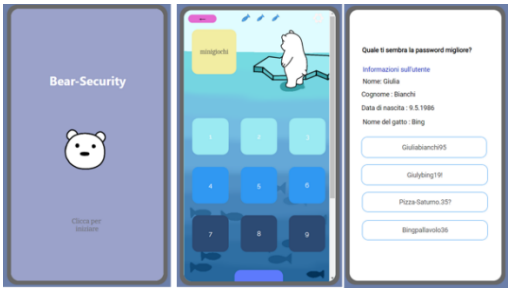
References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) **Psycho-social aspects in the implementation and multidimensional evaluation of innovative solutions to support well-being and quality of life in the mountain environment**	Spoke 1 **RT1A. 01**	Safety and quality of life in mountain Environments – *Mountain Social Life*
Overall Objectives	**01.** Identification of models relating psychological variables, as well as the psycho-social and contextual aspects, with the proper assimilation of smart technologies solutions in the mountain areas. **02.** Develop a multidimensional evaluation system to assess ecosystem services, integrating simultaneously a variety of evaluation criteria of different nature, thus enabling the inclusion of psycho-social perspectives. **03.** Promotion of the innovation strategies, taking into account the psycho-health-socioeducational components (including telemedicine), thanks also to the use of public communication campaigns and participatory techniques that set in motion psychoeducational processes to support the interaction between the implementation of innovative proposals and their assimilation. **04.** Evaluation of the proposed innovative interventions, including aspects such as the difficulties of implementation, the level of acceptability and adoption of the proposed interventions, level of satisfaction. **05.** Analysis of the main obstacles perceived by the population living in the mountain areas which can slow the diffusion or prevent the adoption of smart technologies in residential buildings; simulation study of the potential improvements achievable thanks to the adoption of smart solutions applied to the building HVAC systems; communication of these potential benefits to the population to overcome current obstacles and increase the trust in smart technologies		
Internal Actors	Pasini Margherita - UNIVR, Vacondio Martina -UNIVR, Pernigotto Giovanni -UNIBZ, Battini Federico-UNIBZ, Strapazzon Giacomo-EURAC, Roveri Giulia-EURAC		
Methodology	We adopt a multidisciplinary methodology, integrating literature reviews (using the Unified Theory of Acceptance and Use of Technology), empirical studies on the longitudinal dynamics of technology acceptance, stakeholder engagement, and technical tool development.		
Activities performed and results achieved	**01.** We found a strong interest in telemedicine among the population in mountain areas due to its potential to reach patients remotely. Furthermore, new technologies capable of simulating high-stress scenarios are valuable for training healthcare personnel (e.g., Search and Rescue teams and Helicopter Emergency Medical Services). We studied the psycho-social factors influencing the acceptance and usage of telemedicine using a theoretical approach based on the Unified Theory of Acceptance and Use of Technology (UTAUT). Key factors include perceived usefulness, perceived quality, trust in new technologies, social influence, technological anxiety, resistance to change, system use expectancy, and demographic factors (e.g., gender, age, educational level, and personal or familial illness experiences). Our literature highlighted the need for a longitudinal approach to understand the dynamics of technology acceptance and usage, particularly in telemedicine. Research by Parretti et al. (2022) highlights the work required to implement telemedicine activities effectively in the Italian context. Efforts are underway to identify potential participants for empirical research to collect qualitative and quantitative data on psycho-social aspects related to assimilating innovative proposals, particularly telemedicine. The identified sample includes community members, local organizations, and policymakers.		

	O2. The efforts in this direction were reallocated by a researcher to another RT. **O4.** We started a systematic review to understand the difficulties of implementation, level of acceptability and adoption, and overall satisfaction with the proposed interventions. **O5.** In collaboration with the Municipality of Bolzano, we explored an innovative aspect of organizational well-being: the physical work environment. We started a longitudinal study, focusing on perceived workload, job autonomy, work-life balance, technostress, work engagement, and burnout syndrome. The survey is refined and validated, with data collection scheduled in two waves in 2024. The collaboration involves multiple meetings with the Human Resources (HR) team, union representatives, and a specific municipal office. Moreover, we developed an open-source configurator in Python for simulating smart solutions in residential buildings. The tool employs EnergyPlus for dynamic thermal simulations, allowing users to consider various parameters and variables, including building dimensions, climatic conditions, envelope characteristics, and insulation options. The configurator assesses the potential improvements achieved through smart solutions in building HVAC systems. The tool is validated using representative buildings from the Italian stock. The ongoing literature review, field research initiatives, and tool development underscore the commitment to understanding, implementing, and evaluating innovative interventions. The multidimensional nature of the project positions it as a comprehensive initiative with the potential to bring meaningful improvements to the quality of life in mountainous regions. 
Most relevant Publication ***# of Publications***	Vacondio M., Menardo E., Brondino M., Ciò che s'usa non fa scusa! Uso cross-culturale di questionari, una riflessione sul gap tra pratiche in uso e adeguate tecniche psicometriche di validazione. XXIX Congresso AIP Sezione Sperimentale (Lucca, Italy, 2023) Battini F., Pernigotto G., and Gasparella A. "*Sviluppo di un configuratore semplificato per promuovere l'utilizzo della simulazione dinamica nel processo di progettazione e riqualificazione dell'esistente*", 39th AiCARR National Congress (2023), Naples, Italy, 8th September 2023 # of Publications: 2
External Actors and Stakeholders	The municipality of Bozen (HR team, assesor, offics of statistics for the city), Assoc. Prof. Margerita Brondino-UNIVR, Dr. Valentina Mariani –UNIVR.
Next steps	1) Collection and analysis of data generated by the tool to assess the organizational well-being of the employees of the municipality of Bolzano; 2) Further development of the tool; 3) Collaborations with companies, particularly specializing in smart technologies (e.g., telemedicine) and research groups with different expertise.

References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) **Digital and training strategies to support smart villages in mountain environment**	Spoke 1 **RT1A. 02**	Safety and quality of life in mountain Environments – *Mountain Social Life*

Overall Objectives	Based on the findings of the initial part of the project, we pursue the following innovation strategies: - **IS1.** Fostering intergenerational exchange so that younger people can support less digitized people in learning. - **IS2.** Offering courses to inspire new generations of digital innovators. - **IS3.** Implementing models relating individual psychological aspects (e.g., motivations, beliefs, values), socio-cultural context, and assimilation of innovative solutions in relation to smart villages, using a participatory approach. - **IS4.** Running community-led exercises to imagine the dimensions of the smart villages and to co-create innovative solutions in collaboration with stakeholders. - **IS5.** Opening online/hybrid learning opportunities for adults to increase participation from remote parts of mountain areas. - **IS6.** Obtaining higher qualified staff in education by organizing training courses for teachers.
Internal Actors	Ilenia Fronza– UNIBZ; Giovanni Pernigotto– UNIBZ; Federico Battini– UNIBZ; Riccardo Albertin– UNIBZ; Margherita Pasini– UNIVR; Martina Vacondio– UNIVR
Methodology	We combine a mix of research methods. We performed classroom-based empirical research (qualitative and quantitative methods of Computing Education research). We designed specific assessment frameworks to evaluate the proposed strategies quantitatively and added a psycho-social approach to investigate the relationship between objective and perceived subjective learning.
Activities performed and results achieved	**IS1.** We designed and assessed an instructional strategy for a hybrid coding camp to let younger people develop videogames to raise awareness about cybersecurity. Moreover, we designed a strategy based on Learning by Teaching to support intergenerational exchange: high school students prepare and coordinate robotics activities dedicated to kids. We are creating a tool to assess the association between perceived and objective learning, investigating the psycho-social factors influencing learning through gamification and technology.

A videogame created by high school students to increase awareness about strong passwords.



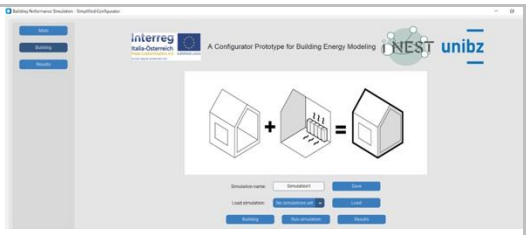
IS2. We organized a series of lectures (at the Free University of Bozen-Bolzano and the NOI TechPar) on the physical quantities typically monitored by smart sensors and how to analyze collected data properly.

We used the Building Energy Modeling Configurator developed by the Research Group in Building Physics (see RT1A SECTOR 1) as a teaching tool in the framework of Blended Intensive Programme "Sustainable cities and communities" (UCLL

Offered courses: number of participants (high school students)

Course	N. participants
Series of lectures (smart sensors)	80
Blended Intensive Programme "Sustainable cities and communities"	20
Coding camp (GameDev 2023)	85
Total	185

Building Energy Modeling Configurator start page

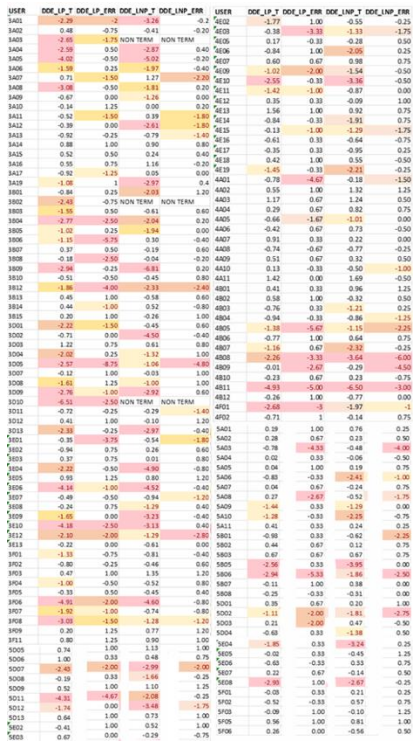
Activities & results (continues)	University of Applied Science, Hasselt, Belgium, 13-17 March 2023[1]), as one of the initiatives of the consortium Euclides (http://www.euclidesnet.eu/). We organized a coding camp (GameDev) based on the results of IS1. The hybrid setting facilitated participation from remote parts of the region. The Ministry of Education and Merit visited the coding camp and praised its quality.	
	IS3. Literature highlights the need to improve smart services and outcomes to fit children's needs. Therefore, we developed an interactive experience as a participatory method to engage children (6-10 years old) in designing solutions for smart villages, i.e., while learning computer science concepts, children express their preferences and needs regarding smart homes. We ran the activity with around 100 participants.	Children taking part to the interactive activity (around 100 participants). 
	IS4. The literature highlights the necessity of evaluating learning processes that happen through new technologies by means of objective outcomes and by investigating the psychological and social determinants of subjective and objective learning. We have decided to apply this knowledge to IS1 to have an interdisciplinary approach to the study of learning through innovative technologies.	
Most relevant Publications *# of Publications*	1. "Sviluppo di un configuratore semplificato per promuovere l'utilizzo della simulazione dinamica nel processo di progettazione e riqualificazione dell'esistente", F. Battini, G. Pernigotto, A. Gasparella, 39° Convegno Nazionale AiCARR, Napoli, 8 Settembre 2023 2. "Learning Robotics by Teaching", I. Fronza, G. Iaccarino, L. Corral. To be submitted (Nov. 2023) to the International Conference on Computer Supported Education (CSEDU 2023) 3. "Coding Camps and Serious Games to teach cybersecurity: the GameDev experience", I. Fronza, G. Iaccarino, L. Corral, V. Rossano, C. Lorusso, A. Curci. To be submitted (Nov. 2023) to Computers and Education # of Publications: 3	
External Actors and Stakeholders	Research collaborations with other institutions: Università degli Studi di Bari (Italy), Tec de Monterrey (Messico). Local schools, local education authorities.	
Next steps	Further validation of the proposed innovative strategies in an iterative fashion. Working on IS5 (challenge: definition of topics, support of online/hybrid participation) and IS6 (intentionally left to the second part of the project, when the innovation strategies proposed by the project will be mature enough)	
Notes	//	

[1] https://www.ucll.be/en/programmes/short-programmes/international-weeks/sustainable-cities-and-communities

References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) **Networking mountains through Ecomuseums**	Spoke 1 **RT1A. 03**	Safety and quality of life in mountain Environments – *Mountain Social Life*
Overall Objectives	The main objectives of the research are the mapping and study of ecomuseum legislation, the development of common guidelines, and the design of a network of mountain ecomuseums.		
Internal Actors	Mauro Pascolini – UNIUD; Francesco Visentin – UNIUD; Federico Lovison – UNIUD		
Methodology	To draw up the guidelines to promote a network of mountain ecomuseums in the Triveneto region, we first researched the legal and geographical literature on the subject (primary and secondary sources). We then systematically examined the legislation on ecomuseums in Friuli Venezia Giulia, Veneto and Trentino Alto Adige, using the **comparative methodology** to highlight the similarities and differences between the various regional realities. We then carried out the **mapping** of mountain ecomuseums, preparing a model form for data collection, in anticipation of the work to be done on site. Finally, we experimented the application of "**Legal Geography**" to our case study, as theoretical framework, in order to identify the problems of legal geography connected to ecomuseums, to understand the extent to which they can be promoters of concrete or legal interventions on the territory.		
Activities performed and results achieved	As far as finding sources about ecomuseums is concerned, there is a **notable presence of contributions in the geographical, anthropological and cultural fields**, with a **clear minority of legal publications** on the subject, generally limited to the citation of these institutions within studies devoted to intangible cultural heritage law. Concerning the retrieval and analysis of the **legislation on ecomuseums** in **Friuli Venezia Giulia**, **Veneto** and **Trentino Alto Adige**, the conspicuous absence of specific regulations in the Autonomous Province of Bolzano is noted. In this context, there is a very limited number of ecomuseums. The laws of Veneto and Trentino are similar both in terms of their general basic approach and the organisation of regional subjects and bodies involved in ecomuseums. The Friuli Venezia Giulia law, on the other hand, is more in line with the principles of administrative law and, like the Trentino, provides for the allocation of public resources to support ecomuseums. Compared to the more general Italian context, where ecomuseums are regulated by regional laws that are fairly similar to each other, there is however a lack of uniformity of standards and reference characteristics. Despite the significant presence of the Network of Italian Ecomuseums, **a national law on ecomuseums is still missing**, as was done for the traditional museums of the State, subject to specific reform between 2014 and 2015, with the consequent launch of the national museum system. Thanks to the **mapping** of ecomuseum structures, it is possible to understand whether ecomuseums have a traditional administrative structure and what kind of management bodies they have. From a general analysis, it appears that ecomuseums are generally managed by associations, consortia and municipalities, where private individuals and public bodies collaborate in the realisation of conservation and enhancement activities. We would like to compare the single ecomuseums' experience (for this reason mapping is necessary) in order to understand the specific impact of Regional laws in their formation but above all how do distinctively legal practices (in this case the Regional legislation) shape or contribute to transformations of geographical phenomena related to the specific objectives that Ecomuseums try to promote? In this way we would like to consider the different ecomuseums' laws outside of the spatial and temporal social, political, and economic conditions of its production.		

Activities & results (continues)	All research works have always used **Legal Geography** as a reference point, useful for the investigation of specific cases and as a tool to study the construction of ecomuseum institutions. The working group has actively participated in the organisation of the seminar series **"Conversazioni sull'ambiente e sul paesaggio"** (UNIUD, PSD, DISG, 2022-2025 WP1. L'identità europea. Cultura e cittadinanza. Identità europea e paesaggio) which is being held in Udine (scientific leader Alessia-Ottavia Cozzi). Mauro Pascolini and Federico Lovison spoke during the seminar on Friday 24 November 2023 entitled **"Gli ecomusei. Una conversazione tra giuristi e geografi"**. Mauro Pascolini recently coordinated the establishment of the university project **"Scuola della Montagna"**, presented on saturday 28 October, in Barcis, at the headquarters of the Magnifica Comunità di Montagna Dolomiti Friulane. This opportunity is intended for people, particularly young people, who have a high school diploma and wish to enrich their skills through an innovative educational experience. During the current and next academic year, in fact, several intensive residential courses will be held in Barcis with lessons, workshops and excursions on specific mountain-related topics: from gastronomy to sport, from agriculture to the wood industry. Mauro Pascolini also coordinated the conference **"La Montagna che educa - Educare alla Montagna"** (saturday 11 November 2023 at the Teatro Miotto in Spilimbergo), dedicated in particular to young people and the younger generation. Federico Lovison participated in the opening ceremony of the **"Giornate con l'Ecomuseo"**, organised on 28.09.2023 in Polcenigo by the Ecomuseo delle Dolomiti Friulane 'Lis Aganis'.
Most relevant Publication *# of Publications*	1. Conti Puorger, A. Guadagnoli, I. Petrella, F. Visentin, *Ritracciare la "Terra cruda": ipotesi eco-turistiche dalle aree interne vastesi*, "Bollettino della Società Geografica Italiana", 2023 (Abstract evaluation). 2. F. Lovison, *Il prestito delle opere d'arte dei Musei nazionali in Italia e Francia*, "DPCE online", 2024 (Abstract evaluation) 3. F. Lovison, *Ecomuseums: encounters between geography, culture and law*, PhD workshop of the first annual conference of Critical Legal Geography, Turin, February 21st-23rd 2024 (Abstract conference). # of Publications: 3
External Actors and Stakeholders	In our work, we have mainly relied on the direct collaboration of the Ecomuseo delle Dolomiti Friulane "Lis Aganis" APS. We had the scientific contribution of Marta Pascolini, who works in the field of ecomuseums at ERPAC (Ente Regionale per il Patrimonio Culturale del Friuli Venezia Giulia) and the scientific contribution of Professor Matteo Nicolini of the University of Verona, who recently published the volume *Legal Geography. Comparative Law and the Production of Space*.
Next steps	The next objectives of our work will concern: the collection of the results of the mapping of mountain ecomuseums in the Triveneto region; the subsequent comparison of ecomuseums and their organisation within the Region to which they belong; the comparison of the organisation of ecomuseums between different Regions; the direct survey by means of interviews with ecomuseum leaders; active participation in conferences and seminars on the subject.
Notes	//

References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) **Promotion of multilingualism for mountain ecosystems**	Spoke 1 **RT1A. 04**	Safety and quality of life in mountain Environments – *Mountain Social Life*
Overall Objectives	The research objectives are: - **01:** the development and implementation of processes and services to raise awareness of multilingualism in all generations; - **02:** the enhancement of language skills in the context of atypical language development, specifically dyslexia; - **03:** the enhancement of multilingualism in the context of the mountain tourism industry.		
Internal Actors	Alber Birgit – UNIBZ, Rabanus Stefan – UNIVR, Ferrari Silvia – UNIVR, Tagliani Marta – UNIVR, Tallarico Giovanni – UNIVR, Siviero Emily – UNIBZ		
Methodology	**01.** We focused on citizen science projects for schools and adult groups such as the chroniclers. The projects combine field methods of linguistic data collection for the various German dialects and Ladin varieties in the territory with methods of measuring the impact of activities via qualitative questionnaires. **02.** For the ReadLet activity, we combined standardized word and non-word reading tasks (from *Batteria per la Valutazione della Dislessia e della Disortografia Evolutiva-2 DDE-2)* with the ReadLet technology, a web-based application where data are collected through audio recordings of the child reading aloud on the tablet and through finger-tracking while reading. For the morphological battery and the materials for the morphological intervention, we adapted materials and tasks widely used in the English literature for the assessment and the intervention at a morphological level to the derivation morphology of Italian. **03.** We relied mainly on the following text to carry out the interviews: L. Revelli, A. Tabouret-Keller, G. Varro (eds) *Langues faibles. Lingue deboli,* L'Harmattan, 2017, which was geared towards obtaining qualitative data, which revealed a great interest in metalinguistic reflection among the informants (mainly staff of mountain accommodation businesses in the provinces of Belluno and Pordenone).		
Activities performed and results achieved	**01.** We carried out a pilot for the citizen science project VinKiamo Südtirol in four high school classes. The students found older speakers of a dialect or Ladin varieties of the region and helped them to fill out the online questionnaire on the crowdsourcing platform VinKo. We collected quality assurance measures through feedback questionnaires. The results in terms of data collection were significant: the corpus of linguistic data was enriched in terms of informants and data points, and the average age increased significantly. We organized the project VinKiamo Südtirol on a larger scale for the first time in the autumn of 2023. Approximately 170 pupils from five different schools around South Tyrol visited the faculty of education in Brixen to participate in the "Tag der historischen Mehrsprachigkeit", which was the start of the first full-scale round of the project. Measures of quality assurance accompanied the various steps of the project. As for VinKiamo Veneto, in November 2023, we conducted school-teacher training on using the collected data in class with the appropriate methods. A second citizen science activity started in November at the yearly meeting of Bolzano's chroniclers. The aim was to appeal to the chroniclers to participate in the transliteration of historic dialect questionnaires collected in the 1940s in South Tyrol (called "Wenkerbögen"). We gathered contact information of interested people to create a network.		

	02. We completed the design of the new materials for assessing (meta)morphological skills before and after the morphological intervention. The morphological battery is a new experimental tool created specifically within this research project to assess morphological awareness in Italian-speaking children. We also designed and structured the morphological intervention planned for the coming months in four fifth-grade classes (~50 children). We created the didactic materials by adapting teaching activities widely used in the English literature of morphological intervention in primary school to the derivational morphology of Italian. The morphological intervention will last 10 hours (5 meetings) per class. Two classes will participate in the intervention, and two will be the control group. In October 2023, we carried out the ReadLet activity with 162 children attending grades 3, 4, and 5. Data showed a highly concerning situation in the Altopiano d'Asiago area, with many children not reading at their grade level. We forwarded parents a questionnaire on the language use of bilingual (and monolingual) children from the Altopiano di Asiago. We delivered the first part of a training course for secondary school teachers about aspects of Italian derivational morphology and related best teaching practices. *Z-scores for word (DDE_LP) and non word (DDE_LNP) speed (T) and accuracy (ERR). Scores with a yellow to red background are below normative values for the grade reading level.* 
	03. We analysed a selective bibliography on multilingualism, which provided a theoretical reference in view of the subsequent documentation work: "the potential for multicultural groups to be more productive is seen as linked to the fact that collectively, teams approach problems from different perspectives" (G. Hogan-Brun, 2017). Moreover, communication conveyed in Global English can often result in only illusory transparency (G. Tréguer-Felten, 2018). Interviews and inspections made it possible to ascertain the vitality of proverbs, although often evoked verbatim in Italian, according to the phenomenon of code-switching. For the Cimbrian villages of Cansiglio, we found interest in the re-establishment of local language courses and the survival of Cimbrian words still in use. The site's main pages have been created and, therefore, accompanied by idiomatic expressions and literary texts.
Most relevant Publication *# of Publications*	1. Siviero E., Alber B., Kokkelmans J.H. [draft ready]. Dialektforschung und Schule: Das Projekt VinKiamo Südtirol. 2. Bertollo, S. and Rabanus, S. (2023): VinKiamo: ein Citizen-Science-Projekt für Schulen zur Förderung von (sprach)übergreifenden Kompetenzen. ALSIC (Special issue Digital Citizenship) # of Publications: 2
Next steps	**01.** We will organize the project VinKiamo Südtirol and the activity for the chroniclers in spring 2024. In VinKiamo Veneto, we will teach the data analysis and interpretation methods introduced in the school-teacher training in selected schools (first classes in December 2023). **02.** We foresee three main future steps: 1) analysis of the data gathered from the ReadLet activity, 2) delivery of the morphological intervention (with pre- and post-intervention assessment tests), and 3) (primary) teacher training course and conclusion of the training for secondary school teachers. **03.** We will continue by completing a glossary, creating a logo, and the bibliography. The site will ask the public to report new lexemes in the languages of the itinerary. These may be studied according to the detection and analysis criteria adopted for Ladin by V. Dell'Aquila et al. (2018): the lack of orthographic adaptation, the novelty of technological innovation, and the collective metacognition of lexical innovation.

References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) **The adequacy of the public and private legal tools for identifying innovative strategies aimed at supporting the development of smart villages**	Spoke 1 **RT1A. 05**	Safety and quality of life in mountain Environments – *Mountain Social Life*
Overall Objectives	We aim to identify the most suitable public and private legal tools envisaged by the relevant reference regulations for enhancing the great potential of mountain areas and verify if these private and public legal tools are adequate to contribute to developing innovative strategies to support smart villages in mountain areas. New regulatory measures have recently been adopted at European and national levels to support production activities typical of mountain areas. We aim to investigate these measures to verify how widespread the knowledge and use of these tools are. Moreover, we will examine if the regulation reserved for these legal tools is adequate to enhance the importance that these legal tools could have in supporting the development of smart villages in mountain areas.		
Internal Actors	Silvia Bolognini - UNIUD		
Methodology	We use the methodology of legal studies, i.e., the study of the relevant doctrine and possible case law, to accompany the identification of the multilevel normative sources of reference. Moreover, we discuss the topics with other experts in the field through participation in study meetings, seminars, and national and international conferences, as well as the organization of various study meetings and conferences.		
Activities performed and results achieved	We investigated the evolution of the concept of sustainable forest management because, on the one hand, the forestry sector is strategically crucial for mountainous areas. On the other, it can be a successful example of pursuing sustainable development in its three dimensions. We found that in the most recent national, European, and international policy documents, sustainable forest management is qualified as active insofar as the conservation and enhancement of the forest heritage must consider the direct involvement of the anthropic factor. The contents of the latest generation policy documents and legally binding acts, as well as the results of sector studies on the current state of forest ecosystems conducted at various levels (i.e., international, national, and European) and in different geographical areas, allowed us to reconstruct how the interaction between the anthropic factor and forest ecosystems have developed over time and to reflect on the role that the anthropic factor has played and can play in the pursuit of sustainable forest management. Despite an increased emphasis on the importance of the contribution of forest ecosystems in achieving sustainable development, it emerges that, recently, the anthropogenic impact on them has been anything but respectful of their sustainability. As mentioned recently in the "State of Europe's forests 2020" (Ministerial Conference on the Protection of Forests in Europe - FOREST EUROPE), in the past, various components of sustainable forest management were balanced, and the level of interaction between the human factor and the forest ecosystems allowed for the harmonious development of both. The subsequent increasing pressures exerted on forests caused a real change. The negative impact of the anthropic factor led to the concept of "sustainable forest management". When it was realized that anthropic activities were beginning to jeopardize the preservation of forest ecosystems, it was deemed suitable to draw attention to the need to adopt measures aimed at safeguarding the capacity of forests to perform several functions at the same time, opting for models of exploitation and interaction between the anthropic factor and forest ecosystems that would not compromise their productivity and regeneration capacity. The "Non-legally binding declaration for a global consensus on the management, conservation and sustainable development of all types of forests" (UN, 1992) affirms the need to adopt «appropriate measures to protect forests from the harmful effects of pollution, including atmospheric pollution, fires, parasites and diseases, in order to fully maintain their multiple benefits». It moves in a remedial perspective, indicating the awareness of		

	the negative impact of human activities on forest ecosystems. As affirmed in various latest generation policy documents, sustainable forest management, like sustainable development, is a dynamic concept that adapts to the contingent situation. However, the characterizing dynamism of sustainable forest management does not so much concern its essence but rather its concretization; the core of sustainable forest management lies, in fact, in the finalization of forest governance to the preservation of their biodiversity, their productivity, their regeneration capacity, and their vitality, to keep intact their capacity to fulfill, now and in the future, relevant ecological, economic and social functions without causing damage to other ecosystems. Therefore, sustainable forest management is based on a principle destined to remain unchanged. However, identifying the actions to translate this principle into reality must be conducted by evaluating the contingent situation and its problems. In synthesis, if how the (ideal) interaction between the anthropic factor and forest ecosystems is conceived remains unchanged over time, the (concrete) modalities with which this interaction needs to be realized vary according to the cases and times, based on the specific problems which one is called upon to face. Two central problems afflict forests: 1) deforestation (quantitative), i.e., the destruction of the tree vegetation in a forest area, and 2) degradation (qualitative), i.e., the poor conditions of an ever-increasing number of forests. These problems made clear that the interaction dynamics between the anthropic factor and forest ecosystems must change. Sustainable forest management is a dynamic and evolving concept that needs to be translated into actions calibrated on the contingent situation while maintaining its matrix intact. The complexity of today's reality, characterized by the progressive deterioration of the conditions of woods and forests, has meant that the admonition to tiptoe into forest ecosystems, originally underlying the concept of sustainable forest management, has given way to a heartfelt invitation to the anthropic factor to take charge of the care and conservation of the forest heritage. In the past, forests were seen as something to be protected, first and foremost, from the anthropic factor and sustainable forest management was founded on the idea that the preservation of biodiversity, productivity, regeneration capacity vitality and the propensity of forest ecosystems to perform several functions at the same time, which are essential on an environmental, economic and social level, could only be guaranteed by imposing limits on anthropic activities, intending to favor, first of all, more respect for the different interests at stake. Nowadays, the anthropic factor is no longer seen (only) as a potential disturbance element but (also) as a necessary actor to whom the problematic task of guaranteeing the survival of forest ecosystems and, in the most severe cases, the recovery of their sustainability must be entrusted. However, one of the biggest remaining problems is the lack of interest of private forest owners in using the public and private legal instruments provided by national legislation to implement sustainable forest management. We drafted a publication (in Italian, which we will later translate into English) highlighting the changes in sustainable forest management over the years. Moreover, a specific conference was held at the University of Udine, targeting students and PhD students, on "Forest Landscapes, Anthropic Factor and Sustainability".
Most relevant Publication *# of Publications*	S. Bolognini, The evolution of the concept of sustainable forest management under the test of public and private legal instruments for implementing it. # of Publications: 1
External Actors and Stakeholders	Mostly academics in this first phase. In the future, we plan to organize informative meetings targeting local production entities.
Next steps	1) in-depth analysis of the discipline reserved for forest agreements and the optional quality term "mountain product" – reg. EU no. 1151/2012 –, to verify the role that these legal tools can play for the achievement of sustainable development goals in the mountain areas; 2) translation of the publication (which is ready in Italian) into English and its possible placement in an open access journal and the participation in a conference to be held in Bologna on 5 December 2023 on the theme: 1923 – 2023. The Redevelopment of the Italian Territory on the Centenary of the "Serpieri" Forestry Law; 3) active participation in conferences and seminars on the subject and organization of a study meeting
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iNEST
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PIANO NAZIONALE DI RIPRESA E RESILIENZA

RESEARCH TOPIC 1 B

Safety and quality of life in mountain Environments – Mountain Habitat

Finanziato dall'Unione europea NextGenerationEU
Ministero dell'Università e della Ricerca
Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA

INTRODUCTION TO RESEARCH TOPIC 1B

MOUNTAIN HABITAT

The RT1B of Spoke 1 involves the development of solutions for improving the resilience in mountain areas, implementing actions for monitoring and assessing the effects of climate change on different aspects of environment and human activities. These aspects include: local environment, air and water quality, hydrological cycle, availability of resources, indoor and outdoor conditions perceived by the population, and human activities. The solutions will aim at preserving biodiversity and ecosystem functions and reducing anthropic contaminations of ecosystems as well as promoting one-health strategies focusing on both understanding and mitigation of geo-hydrological risks, and the adoption of safety and ergonomics solutions for mountain environments.

Previous research conducted by the involved institutions and the wider scientific community constitute the core background and state of the art of the research undertaken as part of iNEST activities.

The research activities are grouped in 7 sectors that deal with 12 projects.

As far sector 1 - air quality - is concerned, the drift phenomenon was conducted in the wind chamber located at the NOI TechPark in Bozen. Analysis of the collected samples (more than two-hundreds) were performed at the Analytical Chemistry laboratory located in Ca' Foscari University of Venice.

In the second sector, field and laboratory monitoring activities focused on habitats and biodiversity of alpine watercourses, impacts of different land uses on the soil-plant system and ecosystem functions. Laboratory data were also collected on the hydraulics of gravel beds, such as in rivers downstream of hydroelectric power stations (dams).

As activity on the hydrological cycle monitoring, in situ and remote sensing on alpine glacial and periglacial areas reveals that permafrost degradation, coinciding with faster rock glaciers creep rates. Complementary to this activity also the activity of water isotopic composition in different rivers has been performed.

In the fourth sector, with the aim to characterize the thermal stress in the built environment, a collaboration with the Municipality of Bolzano-Bozen has been established, with the goal to assess, through monitoring and simulation, the impact of thermal stress on the personal and organizational wellbeing.

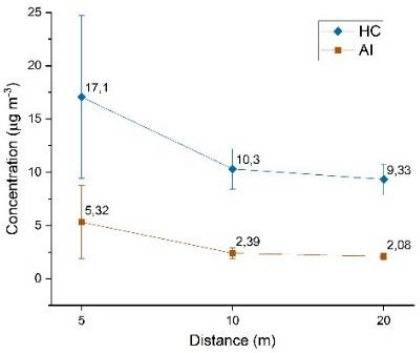
In the fifth sector, a review has been developed, on the current best practice for analysing the hydrologic response, the sediment balance, the flow propagation and the dynamic impact force against bridges in the case of mountain basins. With the aim to improve effectiveness of watershed management projects, High Resolution Topographic survey methodologies have been implemented for river morphological changes assessment.

In the sixth sector, the partners UniVR and EURAc collaborated on the adoption of safety and ergonomics solutions, on active lifestyle finalized to well-being and health in mountain environmental conditions.

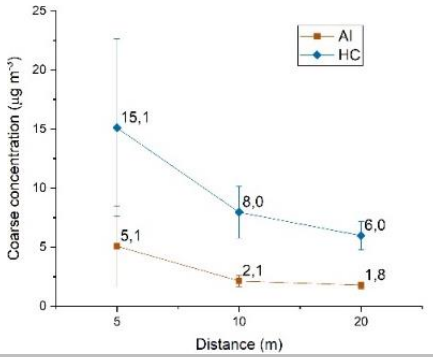
In the last sector, a retrospective analysis of critical incidents reported at the Operation Center (112) of Trento spanning from 2017 to 2023. The aim is to establish an effective risk management strategy to minimize and mitigate incidents related to emergency healthcare in mountain areas.

References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) **Assessing Mountain Air Quality: Plant Protection Product Drift, Community Pollutants & Aerosol Source Identification**	Spoke 1 **RT1B. 01**	Safety and quality of life in mountain Environments – *Mountain Habitat*
Overall Objectives	The aim of this sector is centred on the monitoring and evaluation of mountain air quality, specifically related to presence of Contaminants of Emerging Concern, pesticides transport (drift) phenomenon, and the presence of communitarian pollutants (CO, NO_x, SO_x, O_3...), in collaboration with Regional Agencies for Environmental Prevention and Protection (ARPA and APPA).		
Internal Actors	Andrea Gambaro - UNIVE, Mauro Masiol - UNIVE, Rossano Piazza - UNIVE, Barbara Stenni – UNIVE, Maria Battistel - UNIVE, Giovanna Mazzi - UNIVE Collaboration with Free University of Bozen-Bolzano (Fabrizio Mazzetto, Lorenzo Becce)		
Methodology	Experiment on the drift phenomenon was conducted in the wind chamber located at the NOI TechPark in Bozen. Analysis of the collected samples (more than two-hundreds) were performed at the Analytical Chemistry laboratory located in Ca' Foscari University of Venice. Filters from the Belluno ARPAV monitoring station were collected and analysed at theAnalytical Chemistry laboratory located in Ca' Foscari University of Venice Air quality data were collected from ARPA Veneto, ARPA Friuli-Venezia-Giulia, ARPA Lombardia e APPA Bolzano aiming to map pollution over the North-.		
Activities performed and results achieved	*Drift phenomenon study* The project aims to investigate the different size distribution of spray droplets depending on i) the specific nozzle employed to spray the solution, ii) the distance from the sprayer and iii) the sampling campaign, a preanalytical procedure was developed to extract the fluorescein from the sampler filters and a chromatographic and spectrometric methodology was fully validated. A full-scale orchard sprayer was employed to spray a solution of water and fluorescein (chemical marker) at the NOI TechPark (unibz) wind channel to simulate the real-case scenario of the open-field PPP distribution. Conventional hollow-cone (HC) and an anti-drift (AI) nozzles were compared. Results from the PDIA evaluation were fully discussed by Dr. Becce at the 2023 IEEE International Workshop on Metrology for Agriculture and Forestry (MetroAgriFor), and showed a notable reduction of fine particles by the AI, in accordance with the functioning of the nozzles. A multistage cascade impactor (MOUDI) was placed at 5, 10 and 20 m from the emission point to sample different size fractions of the spray. Results showed i) a notable reduction in the disbursed marker concentration when using AI nozzles; ii) a similar trend for the coarse fraction, for both the nozzles; iii) a strong reduction in the emitted fine droplets when AI nozzles were mounted.		

Total concentration

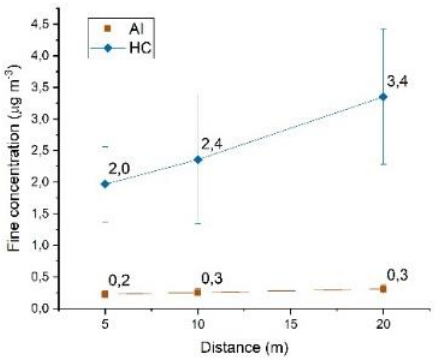


Coarse concentration



surrounding conditions (absence/presence of wind, surfactants and obstacles such as plants). The general experimental set-up included a prior evaluation of the nozzles spray output using a Particle/Droplet Image Analysis (PDIA). Next, the spray of a solution containing a chemical marker (fluorescein) that simulates the plant protection product (PPP), the aerosol sampling with a twelve-stages impactor sampler and the quantitative analyses of the marker present on the sampler filters via High Performance Liquid Chromatography coupled with Tandem Mass Spectrometry (HPLC-MS/MS). Prior to this sampling campaign, a preanalytical procedure was developed to extract the fluorescein from the sampler filters and a chromatographic and spectrometric methodology was fully validated.

Fine concentration



A full-scale orchard sprayer was employed to spray a solution of water and fluorescein (chemical marker) at the NOI TechPark (unibz) wind channel to simulate the real-case scenario of the open-field PPP distribution. Conventional hollow-cone (HC) and an anti-drift (AI) nozzles were compared. Results from the PDIA evaluation were fully discussed by Dr. Becce at the 2023 IEEE International Workshop on Metrology for Agriculture and Forestry (MetroAgriFor), and showed a notable reduction of fine particles by the AI, in accordance with the functioning of the nozzles. A multistage cascade impactor (MOUDI) was placed at 5, 10 and 20 m from the emission point to sample different size fractions of the spray. Results showed i) a notable reduction in the disbursed marker concentration when using AI nozzles; ii) a similar trend for the coarse fraction, for both the nozzles; iii) a strong reduction in the emitted fine droplets when AI nozzles were mounted.

Aerosol contaminants

Filters collected from the Belluno stations were all extracted and analysed. Data elaboration is currently being performed and interpretation will be available soon.

Most relevant Publication	A research article on the drift phenomenon study was submitted to Journal of Aerosol Science. Part of the work was presented at the 2023 IEEE INTERNATIONAL WORKSHOP ON Metrology for Agriculture and Forestry (MetroAgriFor) by Dr. Becce.
# of Publications	1 publication under review
External Actors and Stakeholders	Collaboration with Agenzia Regionale per la Prevenzione e Protezione Ambientale del Veneto (ARPAV), Agenzia Regionale per la Prevenzione e Protezione Ambientale del Fiuli-Venezia-Giulia (ARPA-FVG) and Agenzia Provinciale per la Protezione dell'Ambiente (APPA).
Next steps	Proceed with the drift phenomenon study by changing specific parameters and working conditions (i.e., working pressure, obstacles in the wind chamber) Implement the Air quality mapping by retrieving air quality data from the ARPA/APPA located in the North of Italy.

References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) **Assessing the effect of damming and hydropower plants on riverine ecosystems**	Spoke 1 **RT1B. 02**	Safety and quality of life in mountain Environments – *Mountain Habitat*

Overall Objectives	Contribute to the understanding of the effect of damming and hydropower plants on the downstream riverine ecosystem
Internal Actors	Maurizio Righetti – UNIBZ; Michele Larcher – UNIBZ; Giulia Stradiotti – UNIBZ
Methodology	With the aim of contributing to the understanding of the effect of damming **(a)** and running hydropower plants **(b)** on the downstream riverine ecosystem, we analysed laboratory data to derive a velocity profile suitable to describe the flow in gravel beds, as the ones downstream of dams, to update existing flow resistance formulae and numerical schemes, and we carried out a systematic review on the effects of hydropeaking on the downstream river.
Activities performed and results achieved	**(a)** The description of the flow over gravel-bed rivers is of great interest, as it is related to phenomena of ecological relevance. The modelling of sediment transport, hyporeic zone dynamics, or silting, needs a flow resistance closure that considers the specific features of a gravel-bed, characterized by definition by a higher roughness compared to smooth beds, and by a permeable substrate, which requires the coupling of the velocity above and below the rough crest. With this aim, we analysed laboratory data obtained in the facilities of the LTFD (Thermo and Fluid Dynamic Laboratories) of the University of Bozen-Bolzano to derive and experimental velocity profile suitable for rough beds, and the related flow resistance closure. In the experimental data, we observed 4 regions: a region characterized by a seepage flow, a region characterized by an inflection point in the velocity profile, a logarithmic region, and an outer region. Thus, we adopted a 2 models profile to describe the experimental data: one that goes from the bottom to the inflection depth (darcy + tangent hyperbolic model), and one that goes from the inflection depth to the free surface (logarithmic + wake law model). **(b)** We carried out a systematic review to provide a comprehensive synthesis of the existing scientific literature

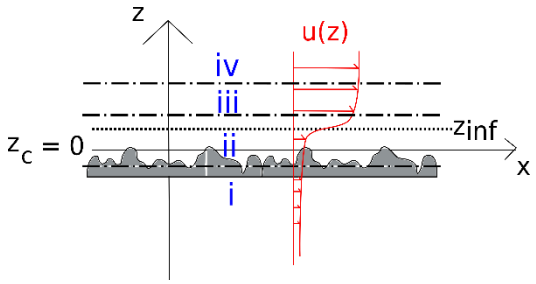
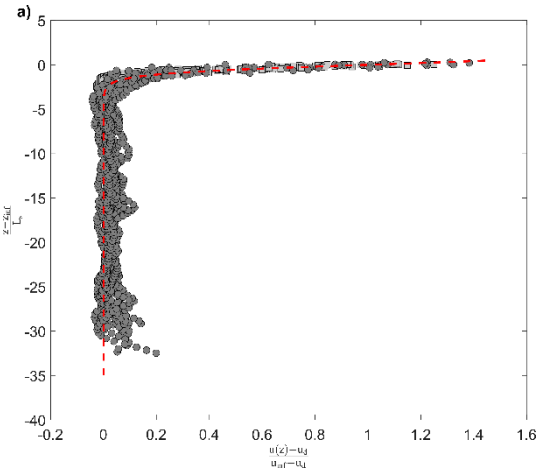


Figure 1 Schematic of the flow and of its sub-regions.



Activities & results (continues)	on hydropeaking impacts, highlighting the range of observed effects on aquatic ecosystems, morphology and human safety, and identifying key knowledge gaps. The review incorporates studies published up until January 2023 and follows a systematic review method, Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), which is a multi-stage systematic procedure for the identification and selection of research documents. A total of 140 relevant studies were selected for further analysis and data extraction, identifying several prominent impacts of hydropeaking on aquatic environments. The primary effects include alterations in flow patterns, modification of water temperature regimes, changes in sediment dynamics and fluctuations in dissolved gas levels. These alterations have been found to affect various aspects of aquatic ecosystems, including fish growth, behavior, reproductive success, habitat, and migration patterns, and benthic macroinvertebrate communities. Furthermore, hydropeaking can also lead to habitat fragmentation, erosion, and loss of riparian vegetation, thereby impacting terrestrial ecosystems that depend on the aquatic environment. Despite the body of literature reviewed, several knowledge gaps were identified, underscoring the need for further research. There is limited understanding of the long-term ecological consequences of hydropeaking and its cumulative effects on aquatic ecosystems. Additionally, there is lack of consensus regarding the quantification of ecosystem services, economic impact, soil moisture content, and weighted usable area due to flow fluctuation and global evolution.

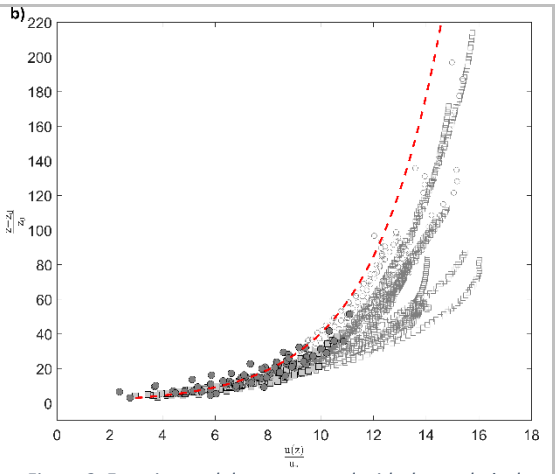


Figure 2 Experimental data compared with the analytical models proposed to describe the velocity profile a) in the Darcy and mixing regions, and b) in the logarithmic region. In b), the faded data are the ones above the logarithmic layer.

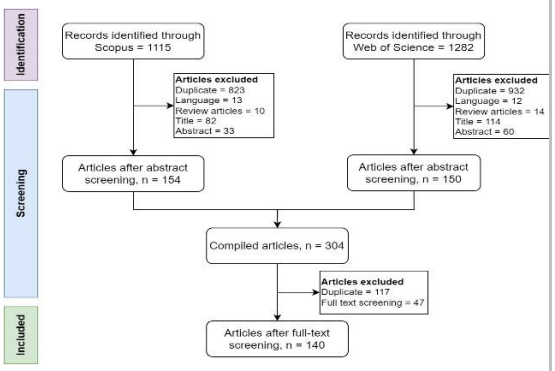


Figure 3 Diagram illustrating the steps followed in the article screening process based on PRISMA method.

Most relevant Publication	Stradiotti, G., Pisaturo, G.R., Noack, M., Righetti, M. (2023). Velocity Profile in Gravel-Bed Rivers Based on Refractive Index Matching Laboratory Experiments, Submitted to Advances in Water Resources. [under review] Nusrat, B., Stradiotti, G., Righetti, M., Pisaturo, G.R. (2023). Impacts of hydropeaking in the downstream catchment: a systematic review. Submitted to Science of the Total Environment. [under review]
External Actors and Stakeholders	//
Next steps	As next steps, we will compare our velocity model with the data available in the literature, and we will derive the relative flow resistance equation. Such closure will be tested trough numerical schemes, to compare the results with the ones obtained through the traditional smooth bed approach.
Notes	//

References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) **Assessing the Impact of Climate Change in Alpine Environments**	Spoke 1 **RT1B. 03**	Safety and quality of life in mountain Environments – *Mountain Habitat*
Overall Objectives	Long term monitoring of water sources, chemical and ecological quality of high mountain areas: Climate change effects on habitats and biodiversity of alpine water courses Relative importance of rainwater, snowmelt, glacier and permafrost ice melt to stream runoff Evaluation of the impact of different land uses on the soil-plant system and ecosystem functions		
Internal Actors	Francesco Comiti - UNIBZ, Andrea Critto - UNIVE, Anna Sperotto - UNIVE, Claudio Zaccone - UNIVR, Stefano Brighenti - UNIBZ, Roberta Bottarin - EURAC		
Methodology	▪ Field activities: samples from snowmelt, rainfall, glacier melt, glacier ice, rock glacier ice, ice melt waters, and stream water, macroinvertebrate communities, soil cores, plant samples; ▪ study of the impacts of land-use intensification on mountain biodiversity and soil associated functions using different habitat types to simulate land-use intensification; ▪ simulation of the conjoined impact of climate change and anthropogenic activities on the quality of water resources and related freshwater ecosystem services in the Adige River basin, by means of a Machine Learning (ML) model trained and validated with historical monitoring data.		
Activities performed and results achieved	<u>Biodiversity monitoring</u> ▪ In 2023, a total of 24 sites were sampled in the Vinschgau. At each site, the macrobenthic fauna was sampled and various abiotic parameters were analysed. Moreover 3 site where samples monthly from April to October in the Mazia Valley belonging to an LTER site. ▪ Almost 60,000 individuals were counted and classified. The dominant taxa belong to the Ephemeroptera, Trichoptera, Plecoptera and dipteran groups. Analyzed parameters see table below. ▪ Biological data and abiotic data have been analysed, results presented at conferences and a publication is in preparation. <u>Hydrochemical monitoring</u> Field activities involved the collection of water samples to be analyzed in the laboratory, and the installation and maintenance of gauges at key sampling locations. These involved: ▪ snow sampling and snow water equivalent estimations at five locations in the Schnals and Martell catchments, January 2023; 19 field campaigns for the installation and maintenance of gauges, discharge measurements, samples collection; ▪ Characterization of the chemical and isotopic conditions of snowmelt, rainfall, glacier melt, glacier ice, and rock glacier ice and ice melt waters; isotopic and chemical characterization of 25 stream; ▪ Analyses of DOC and various indexes of fluorescence, to estimate the relation between dissolved trace element concentrations and organic carbon, on 12 stream locations in the Schnals and Martell catchments, during June, August and September field visits; ▪ Estimation of dissolved and bioavailable Nickel concentrations in rivers of the Venosta valley, 12 sampling locations along the Schnals river network and confluence with the Etsch river. Four field visits during March, June, August and September 2023. <u>Soil-plant system monitoring</u>		

Activities & results (continues)

- 5 meadows and 6 pastures located in Trentino Alto Adige were anaysed: Topsoil (0-15 cm) cores were collected from each site. Soil samples were then air dried, ground and sieved to <2 mm for further analyses (see table and detailed description);
- To test organic matter mineralization ratio as a function of climate change, some enzymatic assays have been carried out including phosphomonoesterase and urease, involved in the phosphorus and nitrogen cycle respectively, as well as fluorescein diacetate hydrolase, used as total biomass activity proxy;
- Plant samples were collected (considering the 10 most abundant species; 70% of total cover) and analysed, functional traits were determined, plant physiology and leaf structure were investigated.

Conjoined impact of climate change and anthropogenic activities

- The review of the state of the art of methodologies for the quantitative assessment of Water-Energy-Food-Ecosystems interactions under climate change was finalized and results has been presented in a publication which has been submitted to the Science of the Total Environment Journal;
- A DPSIR framework to model water quality implications of the interaction between water-energy-food and ecosystems sectors has been elaborated (case study of the Adige River). The framework has been developed collecting knowledge from peer-review papers, as well as report of provincial environmental agencies, and permit to depict how most relevant productive sectors in the area interacts with climate change and land use change/intensification, increasing chemical and ecological risk;
- Moreover, different types of sectoral data including historical water quality monitored data, historical land use change, climatic and hydrological data from the period 2000-2020 has been collected and pre-processed to be used in the next step of the analysis for the training of the ML-model.

Partner	Activity	Field visits	Analysed parameters	Number of collected samples
UniBz	Hydrochemical monitoring	19	Water chemistry, stable water isotopes, discharge, water temperature, DOC and Fluorescence indexes	1020
Eurac	Biodiversity monitoring	24+21	Macroinvertebrate communities, water temperature, pH, susp. Solids, nutrients	60.000 indiv. 180 abiotic samples
UniVr	Ecological impacts of land use intensification	8	Texture, density, pH, EC, CHNS, organic carbon concentrations and stocks, major and trace elements, mineralogy, available P, fluorescence indices, enzimatic activities, plant morphology indices	11x3 (soils) >150 plants

Most relevant Publication

Brighenti, S., Engel, M., Dinale, R., Tirler, W., Voto, G., & Comiti, F. (2023). Isotopic and chemical signatures of high mountain rivers in catchments with contrasting glacier and rock glacier cover. Journal of Hydrology, 623. https://doi.org/10.1016/j.jhydrol.2023.129779

# of Publications

2

External Actors and Stakeholders

APPA Bolzano, Museo delle Scienze di Trento (MUSE), Eco Research Srl, Edmund Mach Foundation (FEM), Austrian Academy of Sciences (OEAW), University of Graz, Basque Centre for Climate Change (BC3), Centro EuroMediterraneo sui Cambiamenti Climatici (CMCC)

Next steps

Ongoing monitoring activities (hydrochemical, biological, soil-plat); validation of a Machine Learning (ML)-based model; statistical elaborations, scientific publications and participation at conferences;

Notes

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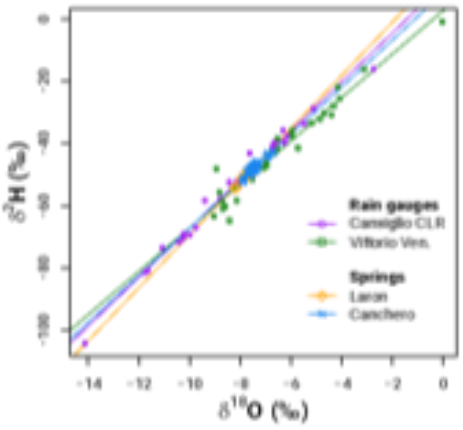
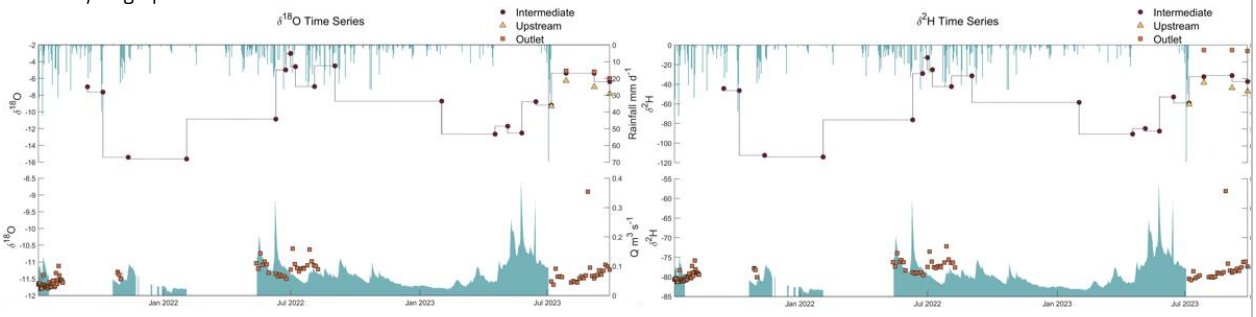
References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) **Implementing Actions for Monitoring and Assessing the Effects of External Drivers on: Hydrological Cycle and Availability of Resources, Risk Prevision**	Spoke 1 **RT1B. 04**	Safety and quality of life in mountain Environments – *Mountain Habitat*

Overall Objectives	i. Assess the effects of **climate change and human activities on the riverine ecosystem health** (e.g., alterations of the thermal and hydrological regimes of mountain streams). Design of best management practices. ii. Analysis of **water stable isotopic composition** of precipitation and streamflow discharge Analysis of water stable isotopic composition of precipitation and streamflow discharge to investigate the hydrologic cycle, to estimate water sources, water residence time, their control on streamwater quality and dissolved carbon export from catchments, and to identify recharging catchment basins. iii. Development of **modelling tools to estimate network scale stream metabolism** (gross primary production and ecosystem respiration) from time series of dissolved oxygen, temperature, light and water level. Method tested in an alpine catchment.
Internal Actors	Berbara Stenni - UNIVE, Enrico Bertuzzo – UNIVE, Mauro Masiol - UNIVE, M. Battistel - UNIVE, Jacob Diamond - UNIVE
Methodology	- Acquisition of past records on hydrology, water quality and stable isotopes in selected mountain areas. - High-frequency continuous measurements of dissolved oxygen, water temperature, photosynthetically active radiation, water level and pH in 4 stations in the Biois catchment. Data analysis to **reconstruct metabolic regime**. - Analysis of the oxygen and hydrogen **isotopic composition of precipitation** (snow and rainfall) and streams of a mountain catchment area.
Activities & results	We focused on two different study areas and freshwater systems: 1. Cansiglio-Cavallo, a vast karst area situated between the provinces of Belluno, Treviso, and Pordenone, and 2. Rio Valfredda, a small pristine tributary of the Piave basin (elevation range 3000 to 1600 m a.s.l.). In the Cansiglio-Cavallo area two mountain springs have been monitored since 2019, with the collaboration of ARPAV. These springs are a good proxy of the many mountain springs that would need to be monitored and protected, since their waters are introduced into the local distribution system and support the local communities. The data collected involved a monthly sampling of the hydrological and the chemical-physical parameters, as well as the isotopic signature of the springs and the local rainwater. All these data are analyzed and interpreted together, leading to the development of strategies based on hydrogeochemical methods for the conservation and management of mountain springs. In Valfredda, Ca' Foscari investigates river ecosystem health, collaborating with Padova University in using isotopes (among other techniques) for understanding the impact of mountain

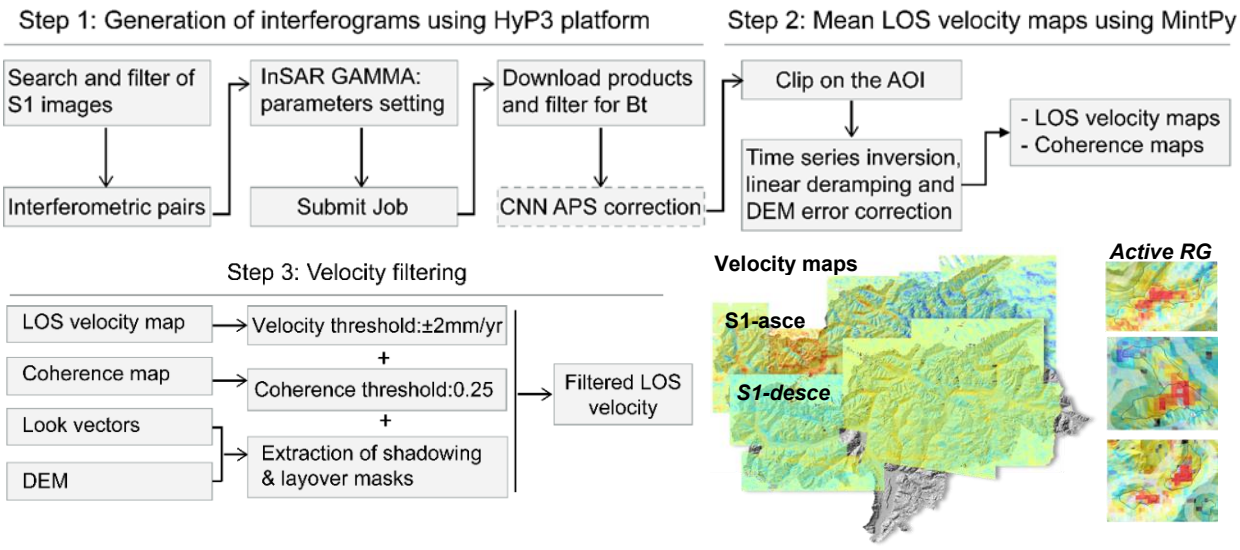
Isotopic composition of the precipitation and the selected mountain springs located in the Cansiglio karst area

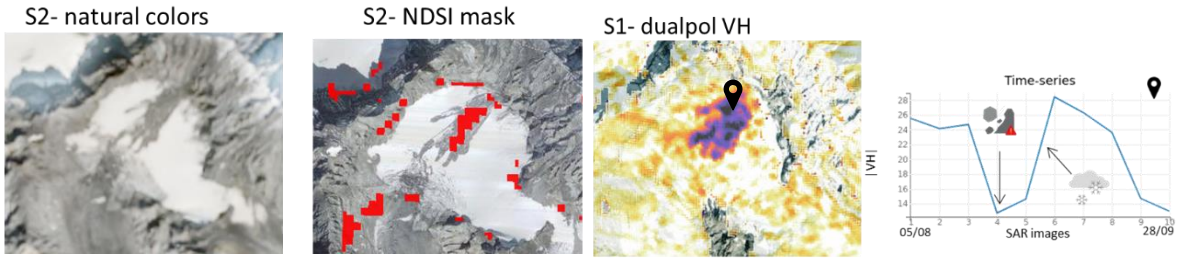


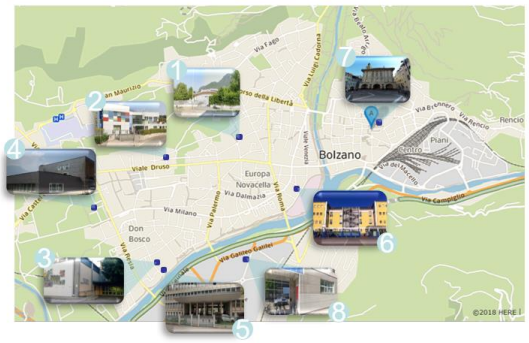
Valfredda sampling campaign (November. 2023)

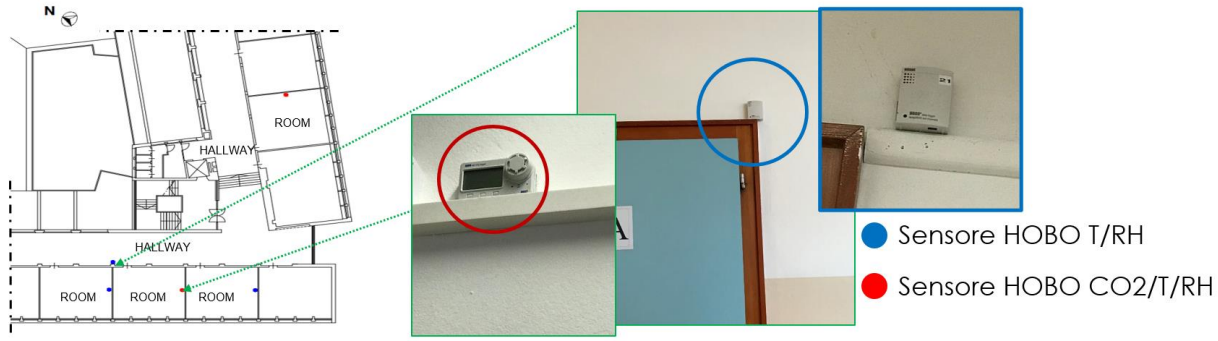
	temporary streams on catchment-scale biogeochemical processes and stream water quality. Several analyses of rain and stream water samples have been conducted and a new campaign started in 2023 that includes the sampling of springs and freshwater sources, rain/snow and river every two weeks.   On the left: Rain gauge installed in Valfredda; on the right: the Picarro instrument used for the water isotopes analyses at Ca'Foscari.   $\delta^{18}O$ and $\delta^{2}H$ signature of the Valfredda stream samples and precipitation collected between 2022 and 2023, displayed together with the stream hydrograph and the rainfall. 
Most relevant Publication	Segatto, P. L., Battin, T. J., & Bertuzzo, E. (2023). A Network-Scale Modeling Framework for Stream Metabolism, Ecosystem Efficiency, and Their Response to Climate Change. Water Resources Research, 59(3), e2022WR034062.
External Actors and Stakeholders	ARPAV, University of Padova
Next steps	As next steps we envision to use other data such as turbidity and microbiological analyses to investigate the best tools for the management of mountain water springs. Simultaneous collection of dissolved gas concentration (carbon dioxide and oxygen) will be collected to estimate stream metabolism, CO2 lateral input and emission to the atmosphere

References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) **High-Mountain Natural Hazards in South Tyrol in the context of Climate Change**	Spoke 1 **RT1B. 05**	Safety and quality of life in mountain Environments – *Mountain Habitat*

Overall Objectives	Establishing relations between the different types of key natural hazards in high alpine terrain and their multi-layered environmental factors through a systematic exploration of remote sensing data. Improvement of standardized methodologies to monitor glacier activity (permafrost degradation) and supraglacial dynamics (debris accumulation and transport).
Internal Actors	Chiara Crippa[1]; Giovanni Cuozzo[1]; Mattia Callegari[1]; Carlo Marin[1]; Marc Zebisch[2]; Claudia Notarnicola[1]; Francesco Comiti[4] *[1]Institute for Earth Observation- EURAC ; [2] Center for Climate Change and Transformation- EURAC; [4] University of Padova*
Methodology	Our methodology focuses on optimizing satellite optical imagery and SAR interferometry for studying the Alpine cryosphere. Leveraging established algorithms and novel developments in platforms like Google Earth Engine and Jupyter notebooks, we create replicable pipelines for integrating multisensor and multisource products. We then utilize data-driven models to interpret and describe the final results.
Activities performed and results achieved	Our activities focused on periglacial and glacial environments which show the clearest signs of degradation of the Alpine cryosphere, with relevant consequences on slope stability. **Periglacial environment** Sentinel 1A/B C-band images from ascending orbit 117 and descending orbit 168 were utilized for velocity quantification of rock glaciers. Interferograms were processed using the Alaska Satellite Facility's Hybrid Pluggable Processing Pipeline (ASF HyP3) and the MintPy package in Python (Yunjun et al. 2019), which was used to perform time-series inversion, yielding mean Line-of-Sight displacement rate maps. The so structured workflow (Fig.1) provided us with spatial distributed velocity maps over the entire South Tyrol region. It is replicable and can be applied to other regions.  *Fig.1: Analytical workflow implemented to process mean velocity maps over the entire South Tyrol*

	We conducted a comprehensive analysis of various geomorphological factors, such as slope, aspect, insolation, curvature, as well as environmental variables like precipitation, land surface temperature, and snow cover duration. These factors were derived from a combination of digital elevation models (DEMs), satellite imagery, and ground-based interpolations. By identifying descriptive parameters influencing rock glacier evolution and activity, we aimed to categorize each landform as active, inactive, or transitional, utilizing multiclass generalized additive mixing models (GAMs) and referencing the rock glacier activity classes defined by RGIK (2023). We were able to classify 96.5% of the 1779 mapped landforms; approximately 3.5% (63 rock glaciers) could not be classified due to missing input variables. Our analysis not only successfully categorized these landforms but also provided insights into the descriptive parameters that primarily control the distinction between the three classes. For example, we found that active landforms exhibit distinct characteristics such as a high Vector Ruggedness Measure (VRM), greater convexity within the rock glacier compared to its exterior, high coherence variance within the rock glacier boundaries, and a notable disparity with lower coherence levels inside and higher coherence levels outside the rock glacier area.
Activities performed and results achieved	**Glacial environment** Our current research line lies in extracting descriptive indices and spectral signatures for the effective differentiation of debris accumulation on glaciers. This approach allows us to map the multi-temporal evolution of debris and outline the changes in the size and distribution of debris patches over the ice. From the integration of multisource and multispectral satellite images we retrieved descriptive indexes and thresholds to outline the occurrence of debris covers on glaciers (Fig.2). Relying on optical data we exploited NDSI index (normalized difference snow index) on multitemporal images to detect surface changes and identify the presence of fresh debris cover. Using Sentinel1 GRD images we considered the VH band to identify changes in backscattering properties of the surface to distinguish ice polarimetric signature from the debris one (|VHice|> |VHdebris|). All these analyses are implemented in GEE.  *Fig.2: identification of debris accumulation on glaciers*
Most relevant Publication	**Abstract and poster contribution:** C. Crippa, S.Steger, G.Cuozzo, C. Notarnicola (2023): Regional screening of rock glaciers activity integrating InSAR and remote sensing data. ESA 12th advanced training course on land remote sensing hydrology and hazards, Wroclaw-Poland
External Actors and Stakeholders	Automous Province of Bolzano - South Tyrol, Office for Geology and Building Materials; Dr. Francesca Bearzot - *University of Calgary;* Dr. Stefan Steger - *Geosphere, Wien*
Next steps	Periglacial Environment: Selection of critical case studies to be analyzed through detailed combined remote sensing and in situ techniques. Glacial Environment: i) establishing a standardized code to integrate multisensory and multisource satellite data for classifying supraglacial debris accumulation and determining its genetic characteristics; ii) quantify stress release from glacial retreat on surrounding valley flanks to identify potential unstable sectors.

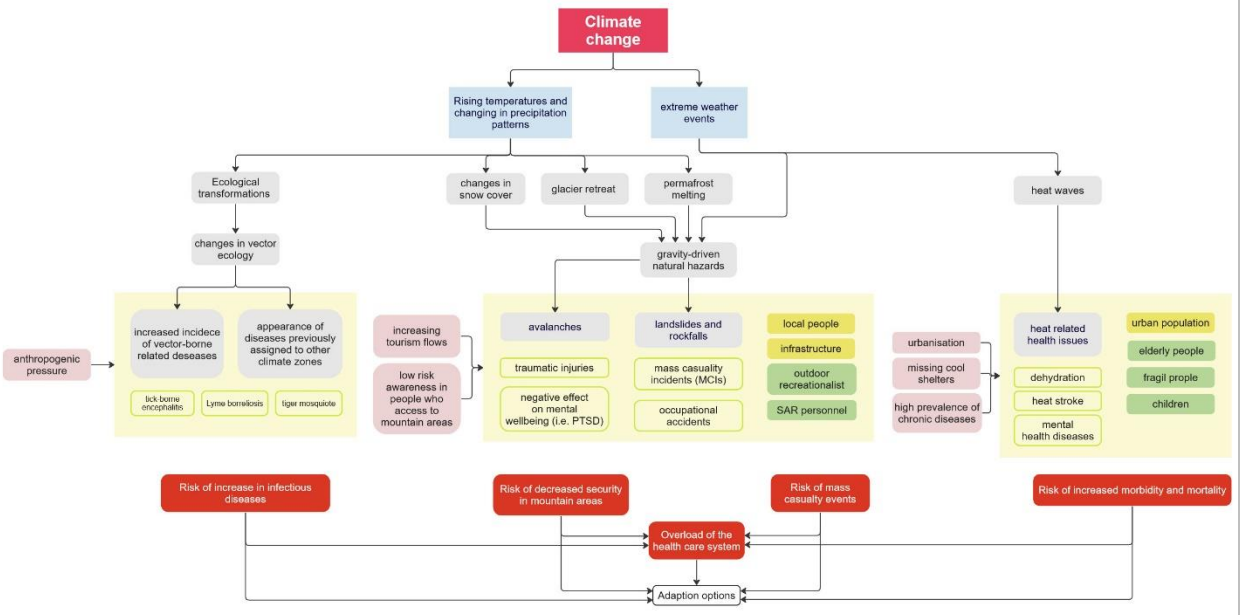
References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) **Impact of thermal stress on occupants' personal and organizational wellbeing and thermal comfort in the built environment**	Spoke 1 **RT1B. 06**	Safety and quality of life in mountain Environments – *Mountain Habitat*
Overall Objectives	Assessment through monitoring and simulation of the impact in thermal stress on occupants' personal and organizational wellbeing and comfort in the built environment in the mountain regions, considering also the effects on people's task performance and the effectiveness of mitigation strategies.		
Internal Actors	Giovanni Pernigotto– UNIBZ; Federico Battini – UNIBZ; Margherita Pasini-UNIVR; Martina Vacondio-UNIVR		
Methodology	Establishment of a collaboration with the Municipality of Bolzano-Bozen with the goal to assess, through monitoring and simulation, the impact of thermal stress on the personal and organizational wellbeing, and comfort of occupants in the built environment in mountainous regions, considering also the impact on people's task performance and the effectiveness of mitigation strategies. The collaboration led to the identification of a group of public buildings to be used as case studies. In each building the internal conditions were monitored by sensors, and psychological variables were assessed by means of longitudinal questionnaires. Participants have been assessed every other week for four months at the present moment. An assessment of organizational well-being will be added to the psychological assessment beginning in January 2024.		
Activities performed and results achieved	8 public buildings were selected for the monitoring activity according to their use (schools and public office buildings), construction or renovation period, quality of the building system. For each building, representative rooms were selected and a set of sensors was installed to monitor the indoor environmental conditions in the selected rooms with a 10-minute interval (HOBO carbon dioxide, temperature, RH data logger sensor and HOBO temperature, RH data logger sensor). For 2 of the 8 chosen public buildings (1 kindergarten and 1 primary school) the energy model was developed, calibrated and validated, taking into account the surrounding urban context. A shoebox simplification algorithm developed by Federico Battini in his doctoral thesis was applied to one of the two buildings to see if it could be used to speed-up the simulation process to evaluate different control strategies to reduce the energy consumption of a public building. The results of this work were presented at the 78th ATI National Congress in Carpi (MO) on September 14-15. Moreover, a questionnaire was developed to measure the thermal comfort of the occupants of the public offices of the	 	

Activities & results (continues)	Municipality of Bolzano-Bozen. To this questionnaire psychological variables such as perceived well-being and job-related performance and an assessment of employees' emotional states were added. The questionnaire has been developed on the basis of the available scientific literature to record the thermal perception and psychological well-being of the occupants in the different seasons of the year. The employees of the Municipality were asked to fill in the questionnaire every two weeks for one year, starting at the end of July. To this questionnaire a longitudinal assessment (prepared during this year of work) of the organizational well-being of the municipality employees will be added beginning in January 2024. We will assess the municipality's employees on their organizational well-being seasonally four times (in winter 2024, spring 2024, summer 2024 and autumn 2024). Activities about the evaluation of physical exercise in the built environment with respect to the outdoors have been performed in the framework of RT1B Sector 6 and therefore are presented in detail in that section.	
		
Most relevant Publication *# of Publications*	El Hokayem A., Battini F., Pernigotto G., and Gasparella A. "*Assessment of the Capabilities of a Simplification Algorithm for Building Energy Modelling for the Evaluation of Control Strategies: a Case Study in Bolzano, Italy*", 78th ATI National Congress (2023), Carpi, Italy, 14th-15th September 2023 1 conference proceeding paper	
External Actors and Stakeholders	Assoc. Prof. Margherita Brondino-UNIVR; Dr. Valentina Mariani-UNIVR; Municipality of Bozen-Bolzano	
Next steps	The next steps will involve the collection of the monitored data and questionnaires in order to evaluate the comfort of the occupants and evaluate possible strategies to improve it and mitigate the effect of climate change.	
Notes	//	

References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) **Promoting one-health strategies focusing on understanding and mitigation of geo-hydrological risks and its forecasting**	Spoke 1 **RT1B. 07**	Safety and quality of life in mountain Environments – *Mountain Habitat*
Overall Objectives	Understanding and mitigation of geo-hydrological risks, focusing on the impact of climate change on health in alpine environments.		
Internal Actors	Strapazzon Giacomo – Eurac Research, Roveri Giulia - Eurac Research		
Methodology	We have been working on the implementation of international mountain registries in order to enables a systematic collection of data on strategies for the initial medical care of patients in the field and their further treatment in hospital. Those registries are accessible through the website www.mountain-registries.org. We have also been working inside a multidisciplinary group aiming to establish an "Adaptation South Tyrol factsheet" to climate changes and natural disasters. Together with them we have been working on the analysis of the impact of Climate Change on Human Health in Alpine Environments.		
Activities performed and results achieved	Many issues surrounding rescue and emergencies in alpine and remote terrain still need to be worked out. Due to the impact of climate change, the number of environmental and natural disasters, such as landslide and avalanches, will lead to a growing number of emergency events in mountain areas. The development of international registries is therefore essential and indispensable to generate robust data, as well as to generate possible new strategies for management of multicasualties. We have been working on the implementation of those registries in order to enables a systematic collection of data on strategies for the initial medical care of patients in the field and their further treatment in hospital. Those registries are accessible through the website www.mountain-registries.org. Giulia Roveri had the opportunity to present this project at the HEMS annual conference who took place in Bergamo with the aim of recruiting new center in order to augment the record of trauma and avalanche cases happening in the alpine area. During 2023, we have also been working inside a multidisciplinary group aiming to establish an "Adaptation South Tyrol factsheet" to climate changes and natural disasters, getting contact with the neighbour areas of Trentino and Veneto (https://www.eurac.edu/en/institutes-centers/institute-of-mountain-emergency-medicine/news-events/ii-convegno-nazionale-di-medicina-di-montagna). This has happen through multidisciplinary and individual expertise of members of the alliance, including multiple Eurac Research partners (meaning experts from the participating research institutions). We are working on a factsheets serve, listing relevant climate change impacts and drivers of the risks for each sub-system (sub-systems in the case of human health could be: Heat- and cold-related illnesses and mortalities, vector-borne diseases, health effects of aerogenic substances, health effects of reduced water quality and food safety, health infrastructure) for the present and the future periods.		

Thanks to this multidisciplinary collaboration, in autumn 2023, we had finalized and submitted a paper dealing with the impact of Climate Change on Human Health in Alpine Environments.

Moreover, together with the Hospital of Trento and the Hospital of Pieve di Cadore we have been focusing on the Marmolada Glacier Accident, as a case study for multi-casualty events in mountain areas driven by the impact of climate change.



Most relevant Publications

National conference

Roveri G. *Mountain Registries:* IX edizione convegno HEMS "Elisoccorso sanitario tra prospettive e realtà" (Novembre, 2023)

International conference

Strapazzon G.. *Marmolada Glacier Accident.* International Commission of Alpine Rescue (ICAR) Congress 2023 (Dobbiaco – October, 2023).

Paper submitted

Roveri G, Strapazzon G **-** *Climate Change and Human Health in Alpine Environments: an Interdisciplinary Impact Chain Approach. Understanding today's risks to address tomorrow's challenges*

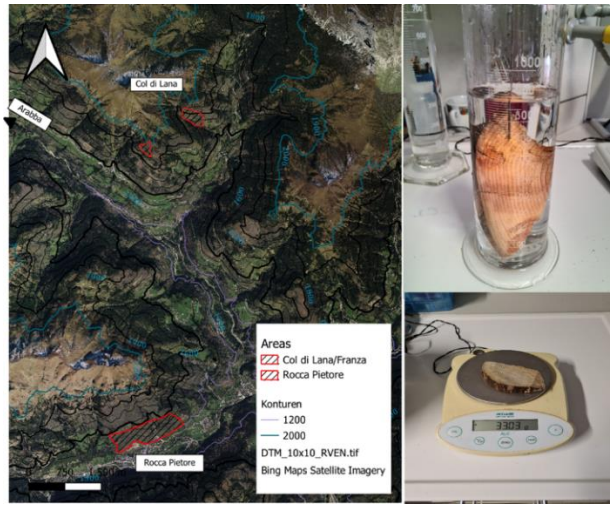
External Actors and Stakeholders

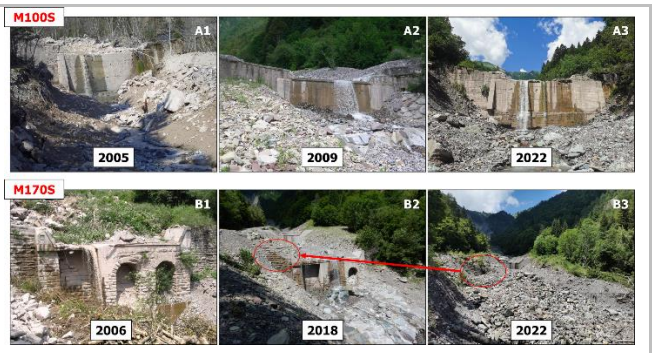
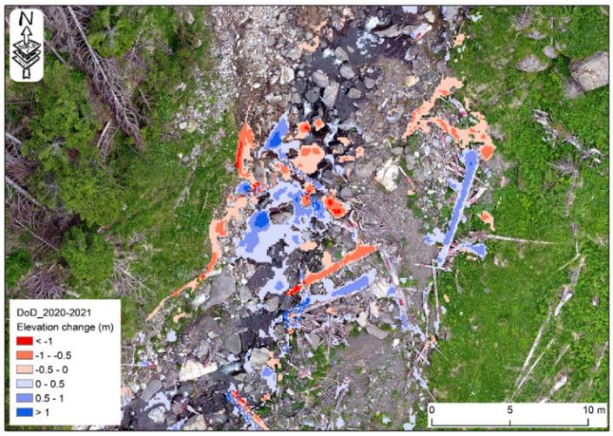
Provincia autonoma di Bolzano. Azienda Sanitaria dell'Alto Adige. Center for Climate Change and Trasformation

Next steps

We are recruiting new centers for the international mountain registries. We are now helping them in the submission of the Ethical committee documents.
In February 2024 we will release the Adaptation South Tyrol factsheet.
Beginning 2024 we want to submit the Marmolada Glacier Accident paper.

Notes

References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) **Assessing the Impact of Climate Change in Alpine Environments**	Spoke 1 **RT1B. 08**	Safety and quality of life in mountain Environments – *Mountain Habitat*
Overall Objectives	Our composite research unit aims to comprehensively investigate rainfall-runoff relationships, analysing temporal trends and rainfall erosivity changes. We seek to establish empirical links between landslides and changing climate scenarios and explore nature-based solutions in alpine protective forests. We also aim at developing frameworks for risk prevention and innovative approaches for monitoring rivers dynamic.		
Internal Actors	Marco Borga– UNIPD, Emanuele Lingua– UNIPD, Lorenzo Picco– UNIPD, Mario Floris – UNIPD, Giacomo Pellegrini – UNIPD, Ylenia Gelmini – UNIPD, Paul Richter – UNIPD, Rajeshwari Bhookya – UNIPD.		
Methodology	Adapting to climate change impacts in the Alps requires comprehensive strategies for mountain basins. Interdisciplinary analyses, spanning various spatial scales, examined temporal trends in causative variables influencing rainfall-runoff relationships over a decade. This involved 383 runoff-generating events, with isolation based on precipitation and discharge thresholds. Landslides in the Cordevole and Alpago area were studied through a compiled inventory, and the role of biological legacies in mitigating rock-fall events was explored using LiDAR and field/lab activities. Collaborating with the University of Udine, remote and field surveys assessed the efficiency of channel control structures in managing sediment fluxes. UAV-LiDAR surveys provided insights into the dynamics, load, and budget of large wood in the Piave and Tagliamento rivers, Tegnas Torrent, Vegliato, and Malgonera streams.		
Activities performed and results achieved *Activities & results (continues)*	At broader scale, rainfall-runoff relationships and rainfall erosivity analyses were carried out. The former show that the observed increase rainfall intensity does not appear to have translated to observed increases in flood peak. Only for events exceeding a threshold of extremeness, a further increase in causative precipitation will yield increased flood magnitudes. The latter, demonstrated that convection-permitting simulations (CPS) provide high-resolution precipitation data and a better representation of extreme rain events, but they are mostly limited to relatively small spatial extents and short time periods. At basin scale, the compilation of a multi-temporal landslide inventory was performed considering orthophotos from 1989 to 2021. To do so, visual detection and manual delimitation of the landslides was carried out. After a literature review on the role of biological legacies, at hillslopes scale, a sampling protocol has been implemented and starting in summer 2023. Field work in windthrown areas of the Storm Vaia (2018) was carried out, using a grid of transect lines. Next to the site data, 160 deadwood-samples were collected in the field. Subsequently, the samples were analysed in the university laboratory to measure	 Fig.1: sampling area and lab experiments carried out during summer 2023.	

	water content and density, in order to correlate the decay rate with the structural parameters (Fig. 1). At channel network scale, Channel Control Works were monitored and a protocol for data collection, computation, and evaluation of the functionality of existing structures has been developed (in collaboration with prof. Federico Cazorzi - UNIUD-unit) (Fig.2). Moreover, large wood recruitment and riparian dynamics were analysed taking advantage of UAVs and field survey. Information on the dynamics, load, and budget of large wood (LW) in various riverine environments was collected following primary disturbances (e.g., floods) and secondary events (e.g., hillslope instabilities or bark beetle attacks) (Fig.3).  Fig. 2: Examples of torrent control structures (i.e., check dam M100S and M170S) surveyed and entered into the updated database  Fig. 3: DoD analysis highlighting changes in LW spatial distribution and morphology
Most relevant Publication *# of Publications*	Cucchiaro, S., Martini, L., Maset, E., Pellegrini, G., Poli, M. E., Beinat, A., Cazorzi, F., Picco, L., 2024. Multi-temporal analysis to support the management of torrent control structures, CATENA, Volume 235, 2024, 107599. doi: 10.1016/j.catena.2023.107599. Other 4 pubblications
External Actors and Stakeholders	In the next months, the collaboration with the UNIUD research team, led by Prof. Federico Cazorzi, will continue. Moreover, the project activities will benefit from the cooperation with national and international research teams. Finally, both practitioners and local authorities involved in watershed and forest management will take advantage of the project's results.
Next steps	• Further analyses on precipitation and rainfall erosivity modelling will be carried out at large scale to improve preliminary results; • Finalizing the multi-temporal landslide inventory, collecting and organizing of the most relevant landslide conditioning factors, such as variations in precipitation patterns, changes in land use, alterations in vegetation cover, seismic activity, and other temporal influences; • Data analyses to correlate the decay rate with the structural parameters (LiDAR, Physical Tests) will be done. • Application of innovative approaches to generate a holistic view and prevent excess sediment fluxes from source areas through the channel network. This will involve the use of multisensors and computational tools such as seismic instruments and IC models, to form an alert system. • Further innovative approaches for automatically detecting in-channel large wood (LW) will be implemented. Additionally, interdisciplinary approaches will be undertaken to better understand the mechanisms of LW recruitment from hillslopes, working together with Professor Lingua's team.

References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) **Bridges safety in small river basins**	Spoke 1 **RT1B. 09**	Safety and quality of life in mountain Environments – *Mountain Habitat*
Overall Objectives	Contribute to the understanding of bridge collapses due to hydraulic causes in mountain environments		
Internal Actors	Maurizio Righetti – UNIBZ; Michele Larcher – UNIBZ; Francesco Comiti – UNIBZ; Andrea Menapace – UNIBZ; Anna Prati – UNIBZ		
Methodology	Establishment of a working group with the objective of formulating best practice proposals and guidelines for bridge hydraulic compatibility assessments, as a basis for both bridge safety and flood risk analysis. In addition, the analysis of debris flows triggered by intense precipitation has been investigated, assessing the changes in the probability of occurrence of these extreme hydrogeological events given as forcing precipitation of climate scenarios provided by the convective permitting climate model. The probability of exceeding the precipitation triggering threshold has been evaluated on extreme precipitation events from actual time to different future decades, e.g. 2030, 2050, and 2070.		
Activities performed and results achieved	In 2022, a working group on the "Hydraulic Compatibility of Bridges" was set up within the Italian Group of Hydraulics (GII - Gruppo Italiano di Idraulica), with the aim of formulating proposals for good practices and guidelines for assessing the bridge hydraulic compatibility, as a basis for both bridge safety and flood risk analysis. This initiative arose from the observation that regulations provide vague guidance on hydraulic design and test criteria for river crossing bridges, although a significant number of bridge collapses are due to hydraulic causes. The working subgroup on "small basins" aims to provide analysis tools for small river basins: they have peculiar features, requiring the adoption of appropriate criteria for the analysis of forcing scenarios and safety measures to be implemented for the hydraulic compatibility of river-crossing bridges. Particular attention is devoted to climatic changes that, although gradual, can induce strongly non-linear responses. The recent activities were devoted to a review of the current best practice for analysing the hydrologic response, the sediment balance, the flow propagation and the dynamic	 *Fig. 1. Obstructed bridge after a debris flow event on the Rio di Croda Rossa (Anterselva, BZ). Courtesy of Agenzia per la Protezione Civile della Provincia Autonoma di Bolzano.*	

Activities & results (continues)	impact force against bridges in the case of mountain basins, pointing out limitations and possible future developments required in order to develop guidelines for bridge safety and flood hazard assessment. Regarding the extreme precipitation analysis, the study focuses on analyzing extreme precipitation events that trigger debris flows, involving data collection, preprocessing, and analysis of precipitation events specific to debris flow triggering. High-resolution climate simulations from convection-permitting models (CPMs) are utilized over historical and future decades. To address biases in CPM simulations without bias-correction procedures, a methodology is proposed to map debris-flow thresholds into simulated climates by evaluating return levels of threshold precipitation rates at different durations. The Simplified Metastatistical Extreme Value (SMEV) methodology is used for precipitation statistical analysis. The framework is tested in the Moscardo catchment in the eastern Italian Alps, assessing changes in frequency, depth, and seasonality of debris-flow triggering precipitation events, with promising preliminary results supporting its efficacy in evaluating debris flow hazards in a changing climate.	 *Fig. 2. Obstructed bridge after a debris flow event on the Rio di Croda Rossa (Anterselva, BZ). Courtesy of Agenzia per la Protezione Civile della Provincia Autonoma di Bolzano.*
Most relevant Publication	"How is climate change affecting hydro-meteorological triggering for debris flows? An assessment based on convection-permitting models and a bias-neutral procedure" EGU abstract, 2024	
External Actors and Stakeholders	Universities and research institutes	
Next steps	Analysis of case studies in cooperation with the Agency for Civil Protection of the Autonomous Province of Bozen-Bolzano, with the collaboration of other universities and research institutes. Finalization of the extreme event methodology for the analysis of a case study.	
Notes		

References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) **Mitigation of geo-hydrological risks: Multi-temporal analysis to support the management of torrent control structures**	Spoke 1 **RT1B. 10**	Safety and quality of life in mountain Environments – *Mountain Habitat*
Overall Objectives	The overall goal is the development of a reference framework aimed at optimizing the effectiveness of risk prevention actions and structures in mountain basins. The practical outcome will be an operational protocol for high-resolution remote sensing surveys and data handling methods to optimize watershed management design.		
Internal Actors	Federico Cazorzi - UNIUD, Alberto Beinat - UNIUD, Sara Cucchiaro - UNIUD, Eleonora Maset - UNIUD Activities are carried out in synergy with Lorenzo Picco and Giacomo Pellegrini (UNIPD).		
Methodology	The increased frequency and magnitude of extreme storms in mountain watersheds is one of the effects of the current climate change, thus increasing the hazard due to flood and debris flow and, consequently, the risk for human structures, infrastructures and for the people. New strategies for risk reduction are needed, improving the effectiveness of the interventions in watershed management projects. To achieve these goals, the following topics are addressed: (i) Improving high-resolution topographic (HRT) surveys to monitor torrents and sediment-related phenomena; (ii) Quantifying and study sediment dynamics to offer effective suggestions on the best watershed management design chance; (iii) Defining a protocol of operational techniques for topographic remote sensing surveys that allows quantifying the problems at different scales.		
Activities performed and results achieved	1. Thanks to repeated HRT surveys, it is possible to derive multi-temporal Digital Terrain Models (DTMs) and DTMs of Difference (DoDs) to quantify the morphological changes and continuously study the catchment morphodynamics. The first activity was therefore aimed at defining a methodological approach based on the integration of the sediment morphology dynamics data over large time spans, obtained by DoDs, with an updated cadastre of torrent control structures (https://zenodo.org/records/10015015) enriched by a simple, quick, and user-friendly Maintenance Priority index (MPi). The proposed workflow proved to be useful in the test basins (Fig. 1), providing sediment dynamics evidence to stakeholders (Fig. 2-3). Moreover, it serves as a proxy to assess the long-term effectiveness of the management interventions.		

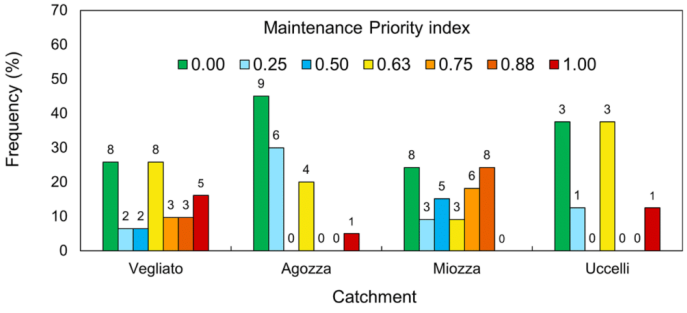


Fig. 2. Relative frequency and number of the structures with a specific value of the Maintenance Priority index (MPi), for each study catchment.

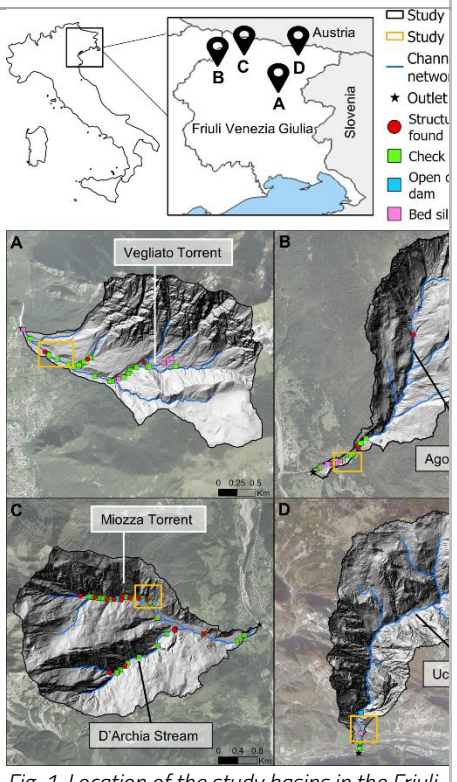
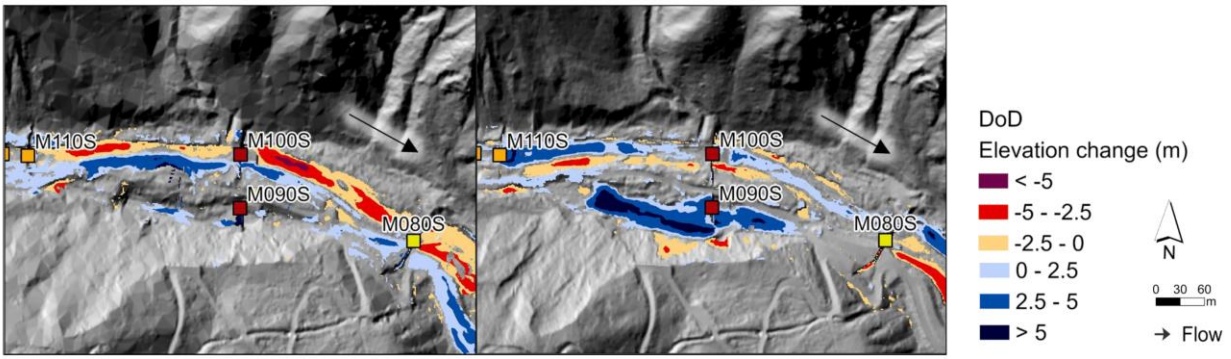
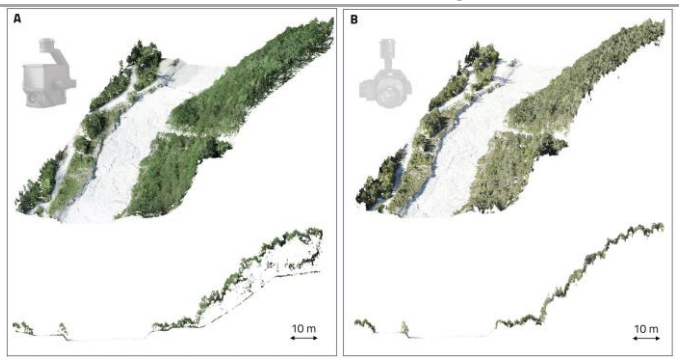


Fig. 1. Location of the study basins in the Friuli Venezia Giulia Region. The Vegliato Torrent (A), the Agozza Torrent (B), the Miozza Torrent (C), the Uccelli Torrent (D). The check dams and bed sills analysed in the work are shown in the maps alongside the structures that were not found in the 2022 survey.

Activities & results (continues)	 *Fig. 3. Multi-temporal DoDs to analyse sediment morphology dynamics. DoD 2004-2009 (left) and DoD 2009-2019 (right) for a reach of the Miozza Torrent.* 2. An ongoing data collection activity is currently carried out for the Vegliato and Moscardo torrents, to obtain high-resolution orthophotos and DTMs (based on UAV Structure from Motion photogrammetry and laser scanning data) at reach scale. The results will be merged and analysed in a GIS environment to enhance the understanding of the phenomena affecting the aforementioned basins and support the prediction of their temporal evolution. 3. Multi-temporal surveys of the Piave and Tagliamento rivers have been performed in collaboration with the UNIPD research group, to consider the active channels and their interaction with riparian vegetation. 4. How high-resolution topographic techniques are used in mountain watersheds is often subjective and best practices need to be established, especially for novel technologies such as UAV laser scanning (ULS). In a preliminary study, we investigated the ability of ULS to effectively penetrate vegetation and provide high detailed DTMs (Fig. 4). Results showed that ULS guarantees greater canopy penetrability than photogrammetry, but several limits still exist in the presence of low vegetation. More tests are required to assess the accuracy and level of detail provided by such systems.  *Fig. 4. ULS point cloud (A) and photogrammetric point cloud (B) of a reach of the Vegliato Torrent. ULS was able to reconstruct both the upper part of the tree crowns and the bare ground, whereas no ground points were measured under the canopy by photogrammetry.*
Most relevant Publication *# of Publications*	Cucchiaro, S., Martini, L., Maset, E., Pellegrini, G., Poli, M. E., Beinat, A., Cazorzi, F., & Picco, L. (2024). Multi-temporal analysis to support the management of torrent control structures. *Catena*, 235, 107599. 1 journal article published, 1 journal article submitted [under review], 1 conference proceedings [accepted for publication], 1 oral presentation, 3 poster presentations.
External Actors and Stakeholders	In the forthcoming months, the activities will benefit from the cooperation with the Hydrogeomorphology Research Group (CNR IRPI Padova). The operational protocol that will be provided as a practical deliverable could be used in the future not only by researchers, but also by practitioners and local authorities involved in watershed management projects.
Next steps	On the basis of the acquired data, analyses will be conducted to evaluate the effect of recent hydro-erosive process on the Moscardo and Vegliato torrent basins, to provide insights into the effectiveness of channel structures in mitigating the impacts of climate change-related risks. Furthermore, an in-depth evaluation on the accuracy and precision provided by UAV laser scanners will be carried out, and best practices will be proposed to guide the choice of sensor and flight settings. Alternative solutions to raster DoD will also be investigated for estimating erosion and deposition volumes.

References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) **Promoting one-health strategies focusing on the adoption of safety and ergonomics solutions, on active lifestyle finalized to well-being and health in mountain environmental conditions**	Spoke 1 **RT1B. 11**	Safety and quality of life in mountain Environments – *Mountain Habitat*
Overall Objectives	• Devising tailored strategies for physical activity/exercise prescription in mountain environments (from high-level athletes to the general population) • Promoting health and well-being in mountain areas		
Internal Actors	Barbara Pellegrini - UNIVR, Margherita Pasini - UNIVR, Giacomo Strapazzon - EURAC, Alessandro Fornasiero - UNIVR, Martina Vacondio – UNIVR, Giulia Roveri - EURAC		
Methodology	Through the adoption of a multidisciplinary approach, we intend to conduct: • The investigation of the physiological and health-related effects of various (physical) activities conducted in mountain environments • The assessment of impact of the environmental stimuli of mountain areas (nature, climatic conditions, altitude) on the physiological and affective responses of individuals • The implementation of smart and wearable technologies in the context of mountain activities to individually target specific physical and health-related goals		
Activities performed and results achieved	**ACTIVITY 1 - Independent and combined effects of cold and hypoxia on physiological and perceptual responses to exercise.** The aim was to evaluate the effects of hypoxia (3500m) and cold (-20°C) on the physiological and perceptual responses to exercise in healthy individuals. 14 subjects performed a maximal exercise under 4 different environmental conditions. **RESULTS:** Maximal and submaximal (lactate threshold) exercise workload are reduced by both a hypoxic (18-21%) and a cold (2-3%) **with an additive effect of the two stressors combined** (21-24%). The results can help guide **optimal exercise intensity prescription** and training load monitoring in people engaged in **physical activities in mountain environments**. **STATUS:** Published **ACTIVITY 2 - The effects of a passive exposure to natural and urban scenes on the physiological and psychological responses under normoxic and hypoxic conditions.** The aim was to explore the **psychological and physiological effects of nature exposure** in hypoxia. Participants were randomly exposed to **images of natural or urban environments** for 10 minutes, either in a normoxic or a hypoxic **(simulated altitude)** environment. **STATUS:** Ethical approval for the project was obtained and data collocation begun. **RESULTS:** Preliminary results (N=11) confirm the influence of hypoxia on emotional states, with **higher positive and deactivating emotions reported after the exposure to natural images** (vs. urban). **ACTIVITY 3 - Physical activity in natural, urban and indoor environments.** This project aims at investigating the **impact of natural environments** on both **objective** (i.e., salivary cortisol, heart rate variability, blood pressure) and **subjective** (i.e. psychological) responses. Participants completed a 60-min brisk walking at 6 km/h in three different environments (**natural, urban and indoor environment**). **RESULTS:** Preliminary results on 15 male subjects presented during an international congress indicated that one hour of **light-to-moderate intensity exercise conducted in a natural green environment elicited positive physiological and psychological stress-related responses**. The study also highlighted the higher restorative power of a green natural environment compared to other built environments. **STATUS:** measurements will be completed in spring 2024.		

	ACTIVITY 4 - The effects of exposure to restorative environments in muscle fatigue recovery. The proposed study employs a between-group design comparing the effects of "**Exposure to perceived restorative natural environment" versus "Exposure to a non-restorative built environment**" **on Muscle Fatigue, Metabolic Fatigue, and Autonomic Fatigue**. Participants will undergo an induction of anaerobic fatigue, by pedalling at their maximal effort for 30 s on a cycle ergometer (Wingate Test), and then be exposed to a 3-minute video clip depicting either a **natural or urban environment. STATUS:** The **collaborative team** (with the Department of Biological and Health Psychology at Autónoma University of Madrid and the NEXS – Department of Nutrition, Exercise and Sport at the University of Copenhagen) has conducted initial meetings to establish consensus on the methodology and procedures. **Data collection will be conducted in spring 2024** across three countries. **ACTIVITY 5 -Development of innovative sensors for monitoring vital parameters in emergency medicine, MedSENS - Roveri, Strapazzon.** In pre-hospital care in mountainous areas, core temperature is a fundamental parameter driving in-field treatment and triage decisions in different conditions. However, physiological monitoring in pre-hospital settings requires instruments to be portable, easy to use, and minimally invasive. These features need to be conjugated with measurement accuracy under different environmental conditions, which may be particularly challenging in hostile environments. We are working on the implementation of different devices for implementing monitoring in the mountain areas, including a prototype resulted as the output of funding from the FESR Program 2014–2020 of the Autonomous Province of Bolzano – Alto Adige, under Grant Agreement [513/2019]/Project number [FESR 1114] **STATUS:** We are now internally revising the main paper and plan to submit it in the next few weeks.
Most relevant Publications	**Published paper:** Callovini, A., Fornasiero, A., Savoldelli, A., Decet, M., Skafidas, S., Pellegrini, B.,Bortolan, L., Schena, F. (2023). Independent, additive and interactive effects of acute normobaric hypoxia and cold on submaximal and maximal endurance exercise. European Journal of Applied Physiology, 1-16. **International conference :** ● Roveri G. Innovative sensors for vital signs measurement in emergency medicine – Medsense. 28. Internationale Bergrettungsärztetagung (Innsbruck - November, 2023) ● Fornasiero A., Mancini L., Laezza L., Vacondio M., Brondino M., De Dominicis S., Pasini M., Schena F., Pellegrini B.. Acute physiological and psychological responses to exercise in indoor and outdoor environments in built and natural surroundings; 9th International Congress Mountain, Sport, & Health (Rovereto, Italy, 2023) ● M. Vacondio, L. Laezza, A. Fornasiero, B. Pellegrini, M. Brondino, S. De Dominicis, F. Schena, M. Pasini. Natural images and hypoxia: a study on the effects of exposure to natural images in simulated high-altitude conditions. 9th International Congress Mountain, Sport, & Health (Rovereto, Italy, 2023) **National Congresses** L. Laezza, M. Vacondio, A. Fornasiero, B. Pellegrini, M. Brondino, S. De Dominicis, F. Schena, M. Pasini. Immagini naturali e ipossia: uno studio sugli effetti dell'esposizione a immagini naturali in condizioni d'alta quota simulata. XXIX Congresso AIP Sezione Sperimentale (Lucca, Italy, 2023) **Paper under submission:** Masè M, Amicarelli A, Roveri G, Strapazzon G - MedSENS: an innovative in-ear multisensordevice.
External Actors *Next steps*	Stefano Dedomincis (University of Copenaghen), Luca Laezza (UNIVR), Victor Rubio (Autónoma University of Madrid), Margherita Brondino (UNIVR) Alexa Callovini (UNIVR) The next steps for activity 2 and 3 will be focusing on finishing the data collection, analysing the data, writing and submitting journal articles. The goal for activity 4 will be to finalize the methodology, beginning the data collection and analyzing the data in three countries. For activity 5, the next steps involve implementing wearable devices to monitor exercise and safety in mountainous areas, with a focus on winter conditions. We aim to address individual health goals, including those with different pathologies like cardiovascular disease. Collaboration with tech companies specializing in wearable devices will facilitate parameter monitoring during mountain activities. The devices and activities could be shared with sectors 4, 5, and 7. For all the activity, the plan is to disseminate the findings to conferences and scientific publications.

References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) **Emergency healthcare and healthcare access in mountainous and rural areas**	Spoke 1 **RT1B. 12**	Safety and quality of life in mountain Environments – *Mountain Habitat*
Overall Objectives	Addressing specificities of emergency healthcare in the mountain areas, focusing on the training of health care personnel involved in the search and rescue mission in mountain areas and on professionals' soft skills.		
Internal Actors	Pasini Margherita - UNIVR, Vacondio Martina - UNIVR Strapazzon Giacomo – Eurac Research, Roveri Giulia - Eurac Research		
Methodology	Employing a multidisciplinary methodology, our work endeavors to empirically examine the influence exerted by soft skills upon out-of-hospital emergency health care professionals. Additionally, we endeavor to construct a robust tool for the systematic assessment of these soft skills, thereby discerning optimal avenues for the training and refinement of these professionals in the context of these pivotal competencies. Our approach integrates conventional medical research methodologies with insights from the domain of psychology, alongside the utilization of psychometric tools.		
Activities performed and results achieved	**UNIVR and EURAC collabroation:** The collaboration between the University of Verona's Human Sciences Department and the Institute of Mountain Emergency Medicine at Eurac Research focuses on addressing the challenges of mountain rescue operations, especially enhancing the importance of the training activities of emergency health care professionals and emphasizing the importance of scientific evidence and the improvement of soft skills such as teamwork and communication. **HEMS congress 2023:** Giulia Roveri, researcher at the Insitute of Mountain Emergency Medicine of Eurac Research, and Martina Vacondio, researcher at the Department of Human Science of the University of Verona, had the opportunity to present this project at the IX edition of the HEMS congress who took place in Bergamo, Italy on the 17th November 2023. ## Research Projects: **Retrospective analysis of critical incidents reported at the Operation Center:** To initiate our project, Giulia Roveri and Martina Vacondio conducted a retrospective analysis of critical incidents reported at the Operation Center (112) of Trento spanning from 2017 to 2023. This anonymized report is spearheaded by the emergency medical services personnel. The primary objective of this retrospective analysis is to scrutinize the epidemiology and root causes of these accidents. The aim is to establish an effective risk management strategy to minimize and mitigate such incidents. **Training in Simulated Austere Einvironment and ICAR Congress 2023:** In order to start assessing the training of the health care personnel involved in the out-of-hospital emergency-rescue Giulia Roveri and Giacomo Strapazzon organized a simulation training event for the medical commission of the International Commission of Alpine Rescue (ICAR), which took place on 16th and 17th October at the terraXcube in NOI Tech Park, Bolzano. During this event they run a research study with the purpose of evaluate the effectiveness of three advanced medical procedures under both normal and cold temperature conditions (-20°C). This study will contribute valuable insights into the effectiveness of advanced medical procedures		

	performed in extreme environmental conditions. The results may enhance the training of emergency medical personnel and improve patient outcomes in challenging settings. Exploring Soft Skills Impact: The collaborative effort involves a multidisciplinary research project examining the impact of soft skills on stress experienced by medical professionals during out-of-hospital emergency rescue operations. The study specifically investigates the use of organized versus disorganized medical bags in simulated rescue scenarios in adverse mountainous conditions. The research includes emotional baseline assessments, self-evaluations after simulations, and measurements of individual differences, such as personality traits. Preliminary data has been collected, and ongoing efforts involve further data collection, analysis, and publication of findings. Development of Soft Skills Assessment Tool: Another initiative aims to address the need for a comprehensive tool to assess soft skills in out-of-hospital emergency-rescue professionals. The goal is to shift the assessment paradigm from solely focusing on hard skills to a holistic consideration of soft skills during the hiring process. The project involves an extensive review of existing literature, observations of a helicopter rescue team, and collaboration with medical doctors and psychologists to develop an assessment tool capable of discerning variations in soft skills among different stakeholders in emergency care scenarios. Future steps include interviews with professionals and the refinement of the assessment tool.
Most relevant Publications	**National conference** Vacondio M., Roveri G., Cipollotti G., *Soft skills: progetto di ricerca congiunto fra EURAC, HEMS Association e Dolomiti Emergency*. IX edizione convegno HEMS "Elisoccorso sanitario tra prospettive e realtà" (Novembre, 2023) **International conference** Roveri G., Strapazzon G., *TerraXcube simulation training.* International Commission of Alpine Rescue (ICAR) Congress 2023 (Dobbiaco – October, 2023). Roveri G., *Occupational Accidents Among Search and Rescue Providers During Mountain Rescue Operations and Training.* 28. Internationale Bergrettungsärztetagung (Innsbruck - November, 2023)
External Actors and Stakeholders	HEMS, Dolomity Emergency, Unità Operativa Trentino Emergenza
Next steps	We aspire to finalize the ongoing data collection initiative and articulate our findings for dissemination within the scientific community. Concurrently, we engage in collaborative efforts with healthcare professionals to formulate an assessment tool tailored for the evaluation of soft skills.
Notes	//

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RESEARCH TOPIC 2

Resilience of Mountain Production Systems and Supply Chains

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INTRODUCTION TO RESEARCH TOPIC 2

RESILIENCE OF MOUNTAIN PRODUCTION SYSTEMS AND SUPPLY CHAINS

In recent decades, mountains have seen job opportunities in the manufacturing sector thinning out, pushed downstream by higher logistics costs compared to companies located in easily accessible areas. In addition, climate change also foreshadowed significant impacts on what until now has been the leading activity in the Alpine context: mass skiing and, more generally, mountain tourism.

These facts have had an important impact on the mountain economy and highlights the need to find solutions aimed at increasing the territory's competitiveness, both in the traditional agro-forestry areas, in the search for innovative products in the tourism sector, in the development of new mountain craft products, and in the search for new elements of attraction for mountain tourists. Nevertheless, methods and tools for sustainability, circular economy and multidimensional assessments must be investigates in order to achieve the previous goals.

More specifically, in this research topic, new innovation strategies to increase the resilience of the mountain production systems and related supply chains are investigating. In order to better frame the research and innovation activities, the research has been articulated as seven parallel lines of activities (sectors): (01) Extensive grassland based farming systems in mountain areas; (02) Technological solutions for alternative cropping systems in mountain extensive agriculture; (03) Innovative methods for forestry planning and management; (04) Sensors and digital solutions in the Winter Industry domain; (05) Methods and tools for sustainability, circular economy and multi-dimensional assessment; (06) Mountain Crafts and future developments of new materials and scenarios; (07) Enhancing the attractiveness of mountain territories.

The research activities have been mainly focused on: (a) the collection of spatial and technical information of geographical themes from national and regional agencies; (b) the set-up and starting of the monitoring of two highland pastures with different management (based on GPS tracking, Heart Rate Monitoring, behaviour observation on grazing livestock, soil and biomass analysis, and remote sensing); (c) the sampling and analysis of soils at different altitudes; (d) the identification of plants and definition of the experimental setting for studying the effect of pasture plants and hays on ruminal methane emissions; (e) the analysis of ISTAT data to get a better understanding of the types of agriculture predominant in specific landscapes; (f) the elaboration of a test procedure to determine rollover stability of machinery used in agriculture; (g) the identification of key variables for categorizing suitable areas for wood supply (with an initial focus on forest areas in the province of Trento); (h) the preliminary conceptualization of an infrastructure for testing forest LiDAR applications; (i) the starting the design of a sensing platform connected to a web server for monitoring various environmental parameter; (l) the development of a minimum viable product (MVP) prototype of the Circularity and Maturity Firm-Level Assessment tool (CM-FLAT); (m) the analysis of the platform Open-es to study how digital platforms can support integrative approaches to supply chain sustainability assessment and improvement; (n) the development of literature review, field visits and expert interviews to develop scenarios on wool crafting and re-use; (o) the analysis of resilience and competitiveness of manufacturing companies located in mountain regions; and (p) the definition and creation of an organizational model able to build a local network of stakeholders supporting the practice of health tourism.

References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) **Mountain grasslands: a possible role in reducing enteric methane emissions**	Spoke 1 **RT2. 01**	Resilience of Mountain production systems and supply chains
Overall Objectives	The project activity aims to provide farmers and territorial management bodies with scientific elements useful for enhancing mountain forages, optimizing meadow management, and improving the environmental sustainability of the mountain livestock sector.		
Internal Actors	Alberto Romanzin – UNIUD; Anita Cabbia - UNIUD.		
Methodology	The effect of alpine pasture plants (i) and mountain hays (ii) on ruminal methane emissions and the nutritive value of forages was carried out. In order to evaluate the effect of several pasture plants on rumen fermentation **(i)**, we use an innovative batch in vitro fermentation system for continuous measurement of methane production (Braidot et al., 2023. J. Anim. Physiol. Anim. Nutr., 107(3):747-753). Based on the results of previous studies carried out on the alpine pastures of the Friuli Venezia Giulia Region and the information available in the bibliography, 12 forage species were selected (*Achillea millefolium, Carum carvi, Festuca rubra, Hypericum maculatum, Lotus corniculatus, Plantago atrata, Poa alpine, Potentilla erecta, Prunella grandiflora, Ranunculus acris, Trifolium repens,* and *Veronica chamaedrys*). The criterion that guided the choice was the contribution that these can potentially provide to the diet of grazing dairy cattle (availability, coverage index, palatability, etc.). The forage species were sampled at the beginning of the grazing season, before the animals entered the pasture. The sample of each species was divided into two sub-samples. The first was dried in an oven and milled through a 1-mm screen for chemical composition analysis. The other sub-sample was chopped manually (simulating the chewing of cows) and used fresh as a substrate for in vitro fermentation.  **Figure 1**. A sample site in Primiero (Parco Naturale Paneveggio Pale di San Martino - Trento Province). In the first part of the project, the discussion with the stakeholders involved (mountain breeders and the Park Authority) highlighted the need to study in more depth the effect of the mowing time **(ii)** on the quality of the hays, also taking into account the constraints imposed for the protection of meadow biodiversity. In particular, the fibrous composition, the protein content, and the rumen fermentations of the hays were considered.		

	The trial took place at two sites in the Province of Trento within the Paneveggio and Pale di San Martino Natural Park. Electric fences have been installed at the two sites so that there is no interference between the growth of meadow plants and wild herbivores (deer, roe deer, wild boars, and hares) present in the area (Figure 1). At each site, five portions (with three replicates) and five sampling times (every two weeks from the end of May to the beginning of August) were considered for a total of 150 grass samples. The samples were hayed under controlled conditions (placed on metal wire frames and exposed to the sun for three days with periodic turning).
Activities performed and results achieved	Trial on alpine pasture plants (i). Figure 2 shows the production of methane (2a) and the percentage of methane on total gas production (2b) obtained in the 24 h of *in vitro* fermentation with continuous measurement. Some species can be distinguished by their lower fermentation capacity, which has generated lower methane production (<120 mL) (*Hypericum maculatum, Potentilla erecta, Poa alpine,* and *Festuca rubra*). On the contrary, others have proven to be much more degradable (*Carum carvi, Achillea millefolium,* and *Lotus corniculatus*), reaching higher values (>165 mL). In terms of percentage of methane in total gas, *Hypericum maculatum, Carum carvi, Ranunculus acris, and Veronica chamaedrys* show values <25% of methane, probably due to the presence of bioactive compounds.

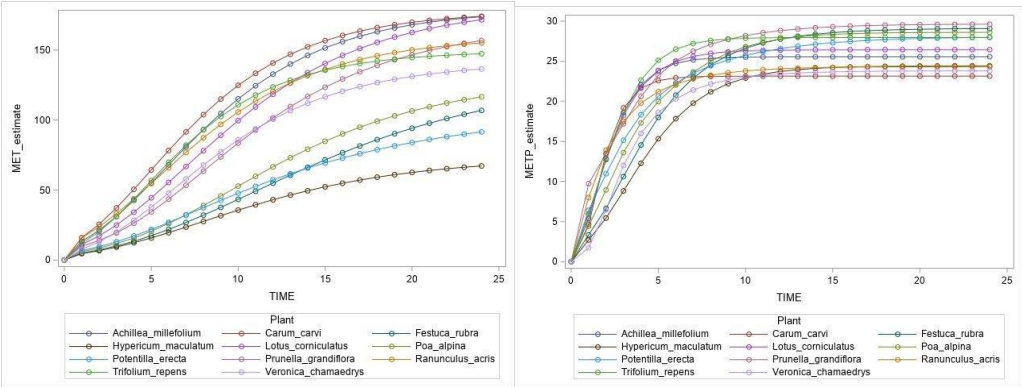
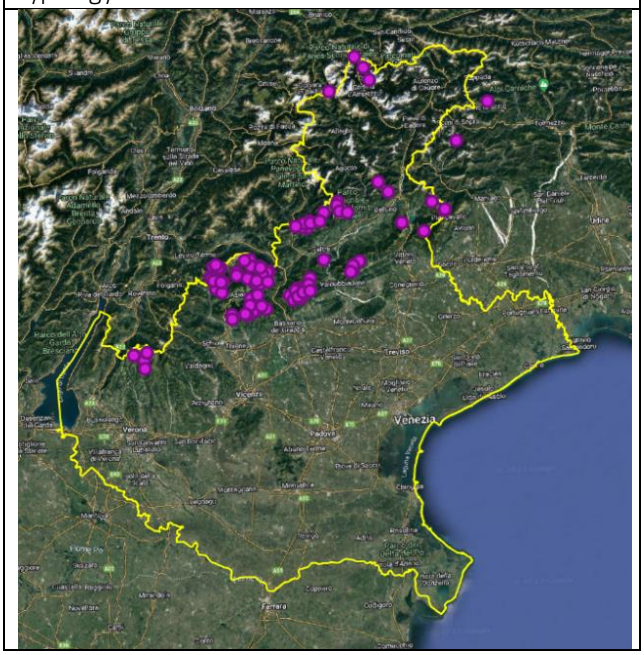


Figure 2. Production of methane (2a) and methane % (2b) obtained during *in vitro* fermentation.

Trial on mountain hays (ii). Laboratory analyses on experimental hay samples are being completed. The following Table shows, just as an example of the chemical analyses carried out, the chemical compositions and nutritional value of the fresh grass samples taken from the two sites under study at the beginning of the trial.

	Dry matter (%)	Ash (%DM)	Neutral detergent fibre (%DM)	Acid detergent fibre (%DM)	Acid detergent lignin (%DM)	Crude protein (%DM)	Ether extract (%DM)	Nutritive value (UFL)
Site 1_a	17.65	6.64	48.37	27.00	5.79	15.04	3.37	1.05
Site 1_b	16.35	6.52	43.62	25.20	7.12	15.35	3.38	1.10
Site 2_a	18.52	5.40	53.19	28.87	5.53	13.42	2.91	1.00
Site 2_b	18.30	6.05	50.46	28.19	5.72	12.80	2.99	1.01

External Actors And Stakeholders	Mountain farmers and Park Authority (Paneveggio and Pale di San Martino Natural Park).
Next steps	In the next few weeks, the first scientific article "Composition, methane production, and *in vitro* fermentation characteristics of alpine forage plant species" will be submitted for the publication, and the chemical and *in vitro* fermentation analyses of the mountain hays will be completed. Subsequently, we will proceed with the development and preparation of the field trials to be carried out in the next growing season. Other meetings will also be scheduled with stakeholders to update them on the progress of the studies and present the main results.

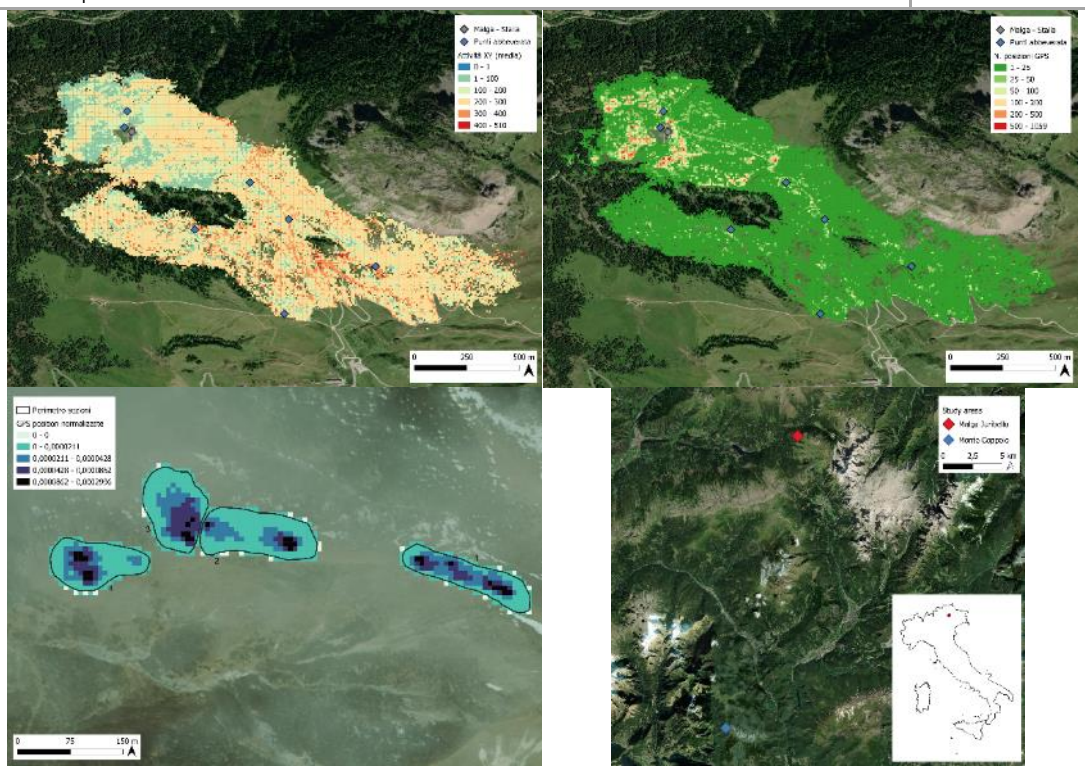
References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) **Integrating economic and natural sustainability in the management of grassland-based ecosystems**	Spoke 1 **RT2. 02**	Resilience of Mountain production systems and supply chains
Overall Objectives	Creating an expert system for the planning of the management of alpine grazed grasslands. Developing a georeferenced information system for the sustainable utilization of the mountains by different user categories.		
Internal Actors	Michele Scotton – UNIPD; Mariachiara Cravero - UNIPD		
Methodology	The creation of the expert system is based on already available technical knowledge or thematic cartographic products concerning the environmental, vegetation, forage production of (semi-)natural grazed surfaces and the pasture and animal management. The geographical area of reference is the Venetian region. The collected technical and cartographic knowledge is combined and processed in order to produce the main documents and maps necessary for the sustainable management of individual alpine grazed summer farms (e.g., maps of the pasture type, production amount and quality, animal charge, grazing techniques etc.) The expert system creation is performed within the geographical information system QGIS as it is freely available and easily usable for most people involved in the environmental and agricultural planning.		
(Activities performed and results achieved	In the reporting period the activity was focussed on the collection of vegetation studies performed on alpine grazed grasslands useful for the creation of an agro-ecological pasture typology and on the collection of cartographic material concerning environmental aspects important for planning the grazed grassland management. An agro-ecological pasture typology is the base reference for an effective planning of the Alpine summer farms. The vegetation and agronomic studies performed in the Venetian region were retrieved, computerized and preliminarily analysed to create the identification key of the pasture types. Seventeen studies performed in the past 40 years (from 1983 onwards) were considered. The 107 surveying areas covered by these studies (see the nearby map) include all Veneto provinces with mountain areas (Verona, Vicenza, Treviso and Belluno and a sector of the Udine province close to the Veneto border. The vegetation tables in the seventeen studies were joined into a single large table after checking the species identity and standardizing their names according to the recently published Checklists of the Italian vascular flora and the Flora of Veneto. The vegetation table obtained contains a total of 949 species and	Distribution of the 107 areas surveyed for pasture vegetation in the 17 studies considered for the pasture typology. 	

Activities & results (continues)	1081 surveys which are distributed over an altitude range of 1000-2250 m a.s.l. Preliminary analyses show that the surveys can be referred to seven main categories of pasture types: nitrophilous vegetation; manured pastures; alpine and subalpine grasslands on carbonate soils; semi-arid pastures of the mountain belts on carbonate soils; calcareous small sedge fens; matgrass swards on acid soils; shrubby vegetation in the mountain and subalpine belts. Many surveys describe pasture types which are intermediate forms between the main categories or vegetation less important for occupied surfaces but important for their ecological value. As in the mountains, the substantial change of the land topography at very low scale can greatly influence geology, soil, microclimate, vegetation, production and animal behaviour, the georeferenced cartographic information available for the environmental traits of interest for the expert system was retrieved with the highest possible detail. The cartographic materials collected concerned the environmental variables shown in the nearby table. A specific search was also done for aerial and satellite imagery which can be useful in the context of the expert system. The multispectral ESA Sentinel2 (pixel 10x10m) and PlanetScope (pixel 3x3m) imagery were retrieved for sampling areas and considered suitable for some analysis in the expert system. Orthophotos and cadastral maps from different sources (Veneto region, AGEA, Revenue Agency) were also found useful for some tasks. A first set of derived maps was obtained. The most accurate map of the Digital elevation model was used to calculate slope and aspect raster maps. The Geological map of Italy was used to produce a map of the rock paedogenetic value describing the potential of each lithological substratum to produce a fertile soil.
Publications	No publications have been prepared until now.
External Actors and Stakeholders	Public administrations in the field of environmental management (agricultural and forestry regional, province, mountain unions and municipality offices), public or private owners and managers of the alpine summer farms, planners in charge of management documents at territorial or individual farm level.
Next steps	In the next steps: + the pasture typology (pasture type identification key and cards) will be produced; + the methods to produce maps of the physiognomic pasture types and potential maps of pasture types from the analysis of aerial/satellite imagery will be tested; + the technical information regarding farm infrastructures, animal management and grazing techniques will be summarised; + some alpine grazed farms will be chosen as concrete scenarios for the development of the expert system. In the final step, the expert system will be created which will be organised according to a two-level scheme: input information (environmental maps specific for each summer farm and suitable techniques of pasture and animal management) and output management plans (suitable herbivores and animal, correct stocking rate, grazing areas, techniques and times, pasture management and restoration).
Notes	//

Digitalised georeferenced maps retrieved for the construction of the expert system.

Category	Variable	Owner	Type
Topography	Regional technical map	VENETO REGION	Vect./rast.
Topography	Digital elevation model	VENETO REGION	Raster
Geology	Litology	VENETO REGION	Vector
Geology	Geology and litology	ISPRA	Vector
Soil	Soil type	ARPA VENETO	Vector
Soil	Soil permeability	ARPA VENETO	Vector
Climate	High-resolution temperature and monthly precipitation	CNR-ISAC	Raster
Climate	A high-resolution 1961–1990 monthly temperature climatology	Hiebl et al., 2009	Raster
Climate	Clima Koeppen-Geiger	Rubel et al., 2017	Raster
Climate	Min, mean and max daily temperature, monthly values 1994-2022	ARPA VENETO	Raster
Climate	Total yearly and monthly prec. 1994-2022	ARPA VENETO	Raster
Climate	Growth season lenght index	ARPA VENETO	Raster
Vegetation	Map of the forest types	VENETO REGION	Vector
Vegetation	Map of the Nature	ISPRA	Vector

References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) **Agroecology indicators (tool) to favour agro-ecological transition of mountain farms**	Spoke 1 **RT2. 03**	Resilience of Mountain production systems and supply chains
Overall Objective	The research aims to develop indicators to implement agroecological management practices of livestock farms in mountain areas.		
Internal Actors	Enrico Sturaro – UNIPD, Salvatore Raniolo – UNIPD		
Methodology	We used the GPS tracking to monitor the use of two mountain pastures during the summer 2023. The GPS data were used to extract intensity use map through the application of GIS system (QGIS and PostgreSQL with PostGIS) after the pre-processing of geodatabase to remove outlier. The geodatabase was integrated with environmental variables (habitat type, slope, altitude, temperature) to assess the habitat use and selection of animals monitored. At the same time, in the considered pastures, multiple soil samples were collected to assess the microbial communities through sequencing (biodiversity and functional biodiversity) and real-time PCR (functional potential) after the DNA extraction and purification through standard kit. From the same site where the soil samples were collected, we monitored the green-house gasses (GHG)' fluxes to assess possible effect of animal intensity use, vegetation type and microbial community structure on the GHG emissions. The multiple methodologies used open new holistic prospectives in the pasture management with possible implications on the improvement of its sustainability and the use of marginal areas.		
Activities performed and results achieved	The research activities in the period January-October 2023 have been mainly focused on 3 steps: (1) monitoring of a dairy cow herd with GPS collars at the pasture of Malga Juribello (Province of Trento – Passo Rolle) and a flock of sheep (Lamon breed) with GSM GPS collars at the pasture of Monte Coppolo (Province of Belluno – Lamon) during summer 2023. The dairy cows were also equipped with Polar HR system to monitor the heart-rate frequency per one day of week (8 sampling times from 8 to 24 hours). The data were stored in two different geodatabases merging the GPS positions and activity data. The two geodatabases were also integrated with environmental data (local atmosphere Temperature with a resolution of 15minutes, presence-absence of rain, slope, elevation) and they were preprocessed to classify outliers; (2) collection of soil samples from the two alpine pastures (160 samples: 88 samples from the pasture of Malga Juribello and 72 samples from the pasture of Monte Coppolo). For all sampled areas, we characterized the vegetation through vegetation sampling, and we monitored the green-house gasses fluxes from soil (N_2O, CH_4) for each replicate before the soil sampling using the GASMET T5000 combined with a dome and a frame. We collected about 1440 infrared spectra and green-house gasses concentrations. In the pasture of Monte Coppolo, we also collected faecal samples during grazing period to extract selection index of sheep combining the GPS data collected using the 3 GSM GPS collars and vegetation sampling. (3) collection of NDVI data with a resolution of 10m from Sentinel-2 for all sampled areas from May to mid-October. The NDVI database has been filtered to remove clouds and we start to combine the GPS data with the NDVI data.	 *Application of GPS GSM collar on Lamon sheep*  *Dairy cattle with GPS collars and HR system*	

	In terms of results, we concluded a preliminary analysis of fix-error of Polar HR system highlighting a significant effect of fix-schedule and sky-view type on the GPS error. In general, the GPS error was under 5m confirming the manufacturer indications. In terms of pasture use, the preliminary analysis highlighted a heterogeneous use of all considered pasture with area used more intensively than others. The pasture of Malga Juribello had an extensive use with hotspot of intensive use close to the barn, where animals spent more time to rest as the activity data showed (blue areas in left map of first row). The sectors of pasture of Monte Coppolo had hotspot of intensity use. In Monte Coppolo, we found a positive correlation between the NDVI of autumn (30 September) and intensity use of pasture.  *GASMET T5000 during the monitoring of GHG fluxes*
Activities results achieved (continued)	 Maps of pasture use: first row summer pasture of Malga Juribello in function of activity index and GPS positions; second row summer pasture of Monte Coppolo in function of sector and normalized GPS position
Most relevant Publication *# of Publications*	Raniolo S., Maretto L., Ramanzin M., Stevanato P., Concheri G., Squartini A., Sturaro E. (2023). Microbial genes highlight different trends in short term for N cycling in historical alpine pastures. Submitted to Crop and Pasture Science. 1 Journal article + 1 conference paper
External Actors and Stakeholders	Breeders Federation of the Autonomous Province of Trento; Parco Naturale Paneveggio Pale di San Martino; Municipality of Lamon; ISS (Agriculture High School) 'ANTONIO DELLA LUCIA', Feltre (BL).
Next steps	By next February, the samples of soil collected last summer will be analyzed through sequencing and real time PCR after DNA extraction and purification. Moreover, the NDVI data will be interpolated with different approaches (GAM and linear model) to assess the possible impact of grazing activity on vegetation. About the hearth rate data, they will be analyzed in function of climate condition (temperature and humidity), habitat use and animal behaviors to assess possible animal welfare index at pasture. In summer 2024, the experimental design will be repeated to take into account the potential variability. Meetings with local stakeholders will be organized to formulate and share guidelines to implement agroecological management practices of livestock farms in mountain areas.

References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) **Evaluation of the resilience of extensive mountain grasslands: soil ecosystem services and plant functional diversity in a climate change scenario**	Spoke 1 **RT2. 04**	Resilience of Mountain production systems and supply chains

Overall Objectives

The main aim of this research is to assess the impacts of climate change on mountain biodiversity and soil associated functions (e.g., carbon sequestration, enzymatic activity) using an elevational gradient allowing to simulate climate warming.

Internal Actors

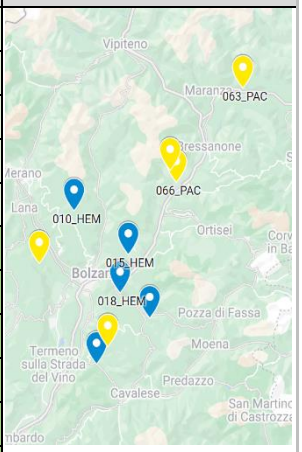
Claudio Zaccone – UNIVR; Matteo Dainese – UNIVR; Tiziana Danise - UNIVR; Sara Elena Goldoni – UNIVR.

Methodology

To deepen the knowledge about extensive ecosystems impact on the plant-soil system in mountain areas, 11 extensive grassland systems (5 meadows and 6 pastures) were identified in the Trentino Alto Adige, North of Italy, and included in this study.

Site description and location along an altitude gradient

Code	Land use	Elevation (m a.s.l.)	Site	Slope (%)	y	x	Map
018_HEM	Meadow	732	Eggental/Valdega	31	46,462233	11,420063	
020_HEM	Meadow	928	Truden/Trodena	25	46,338601	11,357089	
015_HEM	Meadow	1173	Klobenstein/Collalbo	21	46,528022	11,442162	
003_HEM	Meadow	1326	Eggental/Valdega	25	46,419562	11,501205	
010_HEM	Meadow	1531	Flaas	23	46,603585	11,298000	
063_PAC	Pasture	769	Vintl/Vandoies	29	46,815303	11,748955	
063_PAC	Pasture	769	Vintl_2/Vandoies_2	29	46,815303	11,748955	
066_PAC	Pasture	925	Verdings	34	46,653465	11,571354	
072_PAM	Pasture	1068	Gaid	10	46,513710	11,203170	
071_PAM	Pasture	1328	Latzfons	25	46,674850	11,555955	
078_PAM	Pasture	1548	Aldein/Aldino	15	46,370142	11,387693	



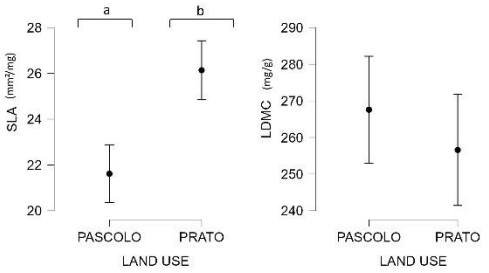
Topsoil cores (0-15 cm) were collected from each site for physical (e.g., texture, density), chemical (e.g., pH, EC, organic carbon and total nitrogen – by CHNS -, major and trace elements – by XRF -, available P – by UV-Vis -, mineralogy – by XRD) and enzymatic activity (e.g., FDAH, urease, phosphomonoesterase) analyses.
Plant samples were also collected (considering the 10 most abundant species; 70% of total cover). The functional traits of the most abundant plant species were measured; in particular, for these species, different functional traits, which together describe plant physiology and leaf structure, were determined (e.g., specific leaf area – SLA; leaf dry matter content - LDMC). The MultispeQ instrument was used to measure leaf chlorophyll content, leaf thickness, leaf temperature, ambient temperature, ambient relative humidity, and ambient photosynthetically active radiation.

Activities performed and results achieved	 Soil and plant sampling

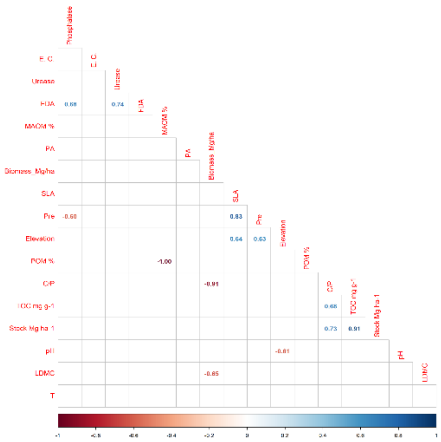
The pH value recorded in the studied sites ranged between 6.2 to 7.4, while the electrical conductivity (EC) between 54 and 224 µs/cm, without showing a clear trend. Both organic C (2.0-7.5%) and total N (0.17-0.65%) contents, as well as enzymatic activities, showed higher average values in pastures compared to meadows. In both land uses, C and N concentrations in particulate organic matter (POM) and mineral associated organic matter (MAOM) increased as a function of altitude, while N and C contents in POM showed significantly differences with land use. Urease showed statistically different values between the two land uses, and it is a promising predictor of C and N related to POM. Available P seemed to play an important role in the functioning of photosystems as a function of altitude and, potentially, with climate change.

SLA was significantly higher in meadow than in pastures, while LDMC did not show significant differences. SLA showed a strong relationship with altitude underlining the impact of the thermal gradient on the plant community. Biomass values showed no significant differences between meadows and pastures, although it decreased in both meadows and pastures as a function of altitude. A general linear model showed a strong significative correlation between the biomass and urease activity for both land uses. The MultispeQ instrument provided useful parameters related to the Photosystem I (PSI); in detail, PSI Over Reduced Center values showed a decreasing trend as a function of altitude in meadows and an inverse trend in pastures. The values of PSI Oxidized Centers, PSI Active Centers and PSI Open Centers showed an increasing trend as a function of altitude in meadows and an inverse trend in pastures.

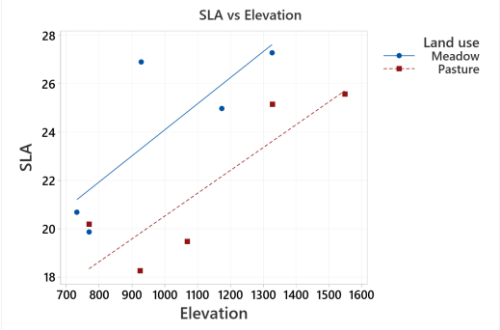
Specific leaf area (SLA) and leaf dry matter content (LDMC) as a function of land use



Spearman correlation matrix ($p < 0,05$)



Example of General Linear Model



# of Publications	1 journal article and 2 conference proceedings are almost ready and will be submitted soon.
External Actors and Stakeholders	Farmers, universities and research centres.
Next steps	Analysis of residual soil, fraction and plant samples and statistical elaboration of obtained results. Preparation of 1-2 scientific papers to be submitted on WoS-JCR journals. Participation at one international conference.
Notes	//

References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) ***A stability model to determine rollover performances of farm machinery***	Spoke 1 **RT2. 05**	Resilience of Mountain production systems and supply chains

Overall Objectives	Developing of a tractor rollover stability simulator able to predict the behaviour of the agricultural and forestry vehicle through the generation of a series of stability maps. Different context of operational risk conditions for mountain environments, as well as tractor configurations, can be easily analysed through this methodology.
Internal Actors	Fabrizio Mazzetto – UNIBZ; Giovanni Carabin – UNIBZ; Merve Karaca – UNIBZ; Andreas Mandler - UNIBZ; Francesco Fabio Nicolosi - UNIBZ
Methodology	The rollover stability simulator has been developed in the MATLAB environment as a series of modules as represented in Figure 1. The computation is based on the known of: (1) the tractor type (e.g., wheeled, articulated, tracked, etc.), (2) its driving type (e.g., Ackermann, skid, crab, etc.), (3) its physical dimensions (e.g., wheelbase, rear and front track, etc.) and in particular (4) the position of the Centre of Gravity. As illustrated in Figure 1, the model initiates with foundational assumptions and subsequently progresses to the determination of the Centre of Gravity (CoG) through the platform. Accounting for tire properties and steering modes, stability angles are ascertained. The outputs of this methodology are a series of stability map that represent the stability limit.
Activities performed and results achieved	Utilizing the capabilities of the stability test-rig (Figure 2) is integral to determining the centre of gravity (CoG). Meticulous measurement of contact forces at diverse tractor orientations is made possible by the enhanced positioning features of the new testing platform. The calculation of the CoG position is a result of resolving a mechanical equilibrium problem. To fortify both measurement precision and the comprehensive accuracy of the assessment, the analysis is extended to several orientations of the machine. The advancement of the stability simulator marks a crucial stride in comprehending tractor stability. The existing iteration relies on specific assumptions: encompassing rigid wheels, straight steering, and a 4-wheel tractor featuring a front pivoting axle. The simulator adeptly recognizes between Phase I and Phase II instability, where Phase II characterizes a scenario with a locked front pivoting axis, inducing behaviour reminiscent of a rigid frame. Mechanical equilibrium solutions are employed in the model to ascertain the four-wheel contact forces across diverse orientation and slope angles. The critical stability threshold manifests as the angle where at least one of the wheel contact forces reaches zero. The creation of the stability map entails an iterative approach, systematically scrutinizing the machine's behaviour point by point to gain a comprehensive understanding. As depicted in Figures 3 and 4, the stability map serves as a comprehensive tool indicating the critical thresholds of machines based on various factors. These include a) the incline of the terrain

Figure 1. The modules of the rollover stability simulator

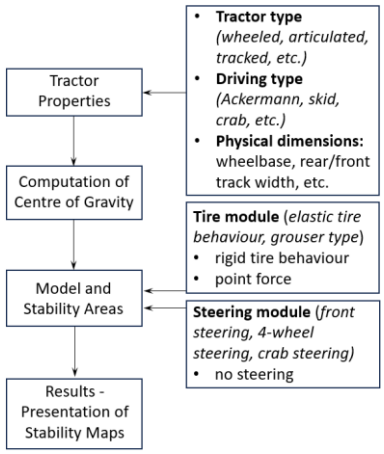


Figure 2. The rollover testing platform

Figure 3. Stability map for a narrow trackwidth orchard (New Holland TN-75V)

Activities & results (continues)	over which the machine is operating., b) the orientation of the tractor's longitudinal axis concerning the lines of maximum slope (direction of travel), and c) the specific vehicle configuration, such as tire pressure and the presence of implements. The map employs a color-coded system to identify distinct stability zones: green signifies a stable machine, yellow represents a danger zone (i.e., at least one contact force is less than 25% of the normal load on that tire), orange marks an extreme danger zone as instability is imminent (i.e., at least one contact force is less than 10% of the normal load on that tire), and red indicates a state of rollover. Figure 3 and 4 provides a visual representation of the stability of a typical orchard tractor (New Holland TN-75V) and a specialized mountain tractor (Reform Metrac H75). This comparison offers insights into the unique stability characteristics of different tractors under varying conditions, contributing valuable information for practical applications and safety considerations. Lateral roll-over angle reaches up to 27° for orchard tractor with a symmetric CoG position while it reaches 51° for mountain tractor model with an asymmetric and lower CoG position along with a wide track width. However, for the mountain tractor, an asymmetrical CoG position leads to different limit angles for opposite sides. This asymmetry defines stability areas with lateral tilting angles of 38° and 51°, depending on the side of the machine where the CoG is situated. As depicted in the aforementioned figures, the positioning of CoG assumes a pivotal role in determining stability modes.
Most relevant Publication	G. Carabin, L. Becce, A. Mandler, F. Mazzetto. Integrated determination of tractor centre of gravity and lateral rollover angle. Proceedings of the 49th International Symposium "Actual tasks on Agricultural Engineering" (ATAE 2023), Februray 28 - March 2, 2023, Opatija, Croatia. Pages 23–32. https://atae.agr.hr/49th_ATAE_ proceedings.pdf.
External Actors and Stakeholders	Consorzio Agrario di Bolzano
Next steps	In the upcoming phase of our research, the aim is to delve into crucial factors impacting tractor rollover stability. This includes an examination of how tire contact patch geometry influences the likelihood of rollovers, providing practical insights. Additionally, it will be assessed that the effects of varying tire pressure on rollover stability to offer guidance on optimal settings. In order to understand how changes in the angular position of the tire affect the contact patch configuration, thereby influencing overall stability, specialized coding will be implemented to address the steered wheel condition, a crucial element for certification. Lastly, the variations in wheel rolling radius will be explored, especially under steered wheel conditions to contribute to the overall stability landscape. These succinct steps form a strategic approach to advancing our understanding of tractor rollover stability, covering key aspects like tire geometry, pressure, angular positioning, steering dynamics, and wheel rolling radius.
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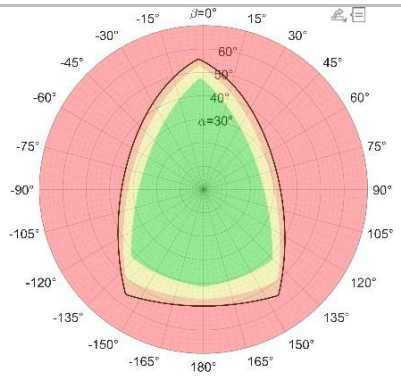
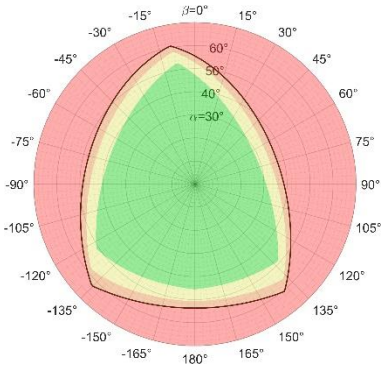
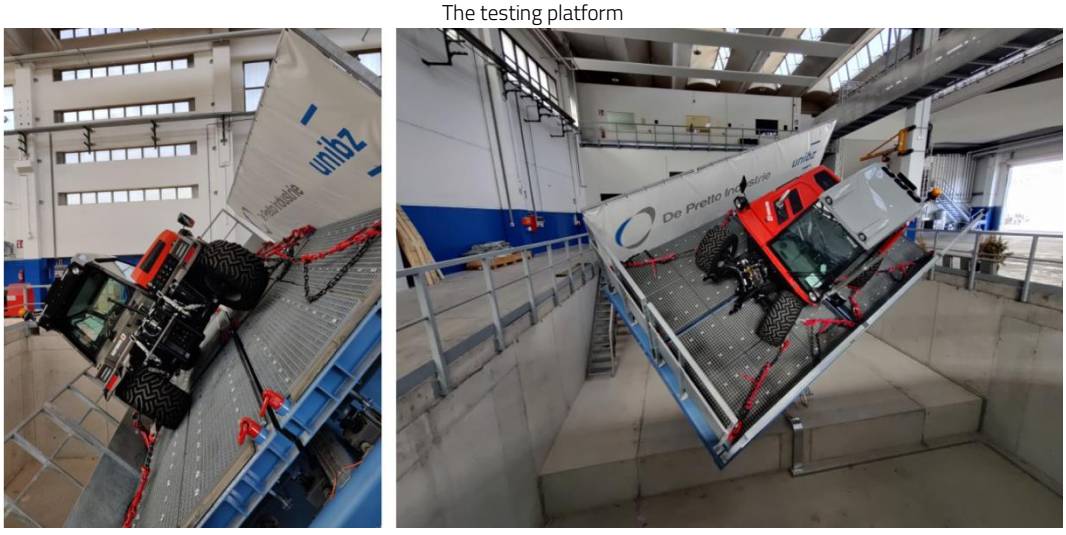
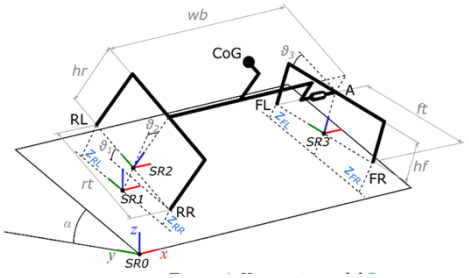
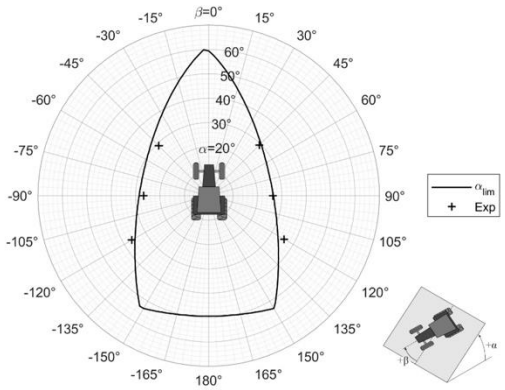
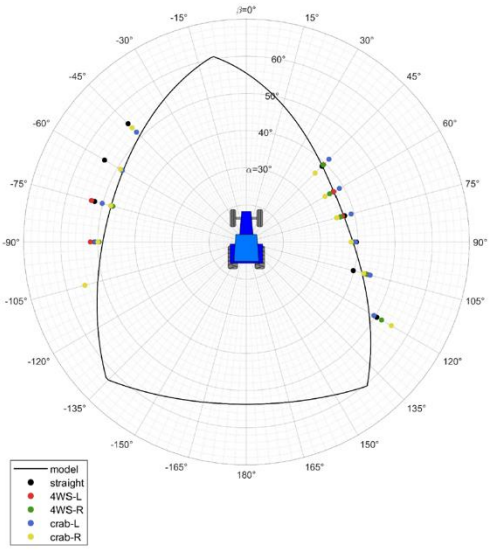


Figure 4. Stability map for a specialized mountain tractor (Reform Metrac H75)



References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) **Setting stability maps for safe operations of farm and forestry machines in rough and steep terrains**	Spoke 1 **RT2. 06**	Resilience of Mountain production systems and supply chains
Overall Objectives	Defining and building stability maps to allow reliable and safe driving of agricultural and forestry vehicles in the various operational risk conditions for mountain environments, or in general for contexts characterised by a high degree of soil irregularity and slope.		
Internal Actors	Fabrizio Mazzetto – UNIBZ; Giovanni Carabin – UNIBZ; Merve Karaca – UNIBZ; Andreas Mandler - UNIBZ; Francesco Fabio Nicolosi - UNIBZ		
Methodology	Stability maps indicate the tipping points of machines as a function of: a) the **slope** of the terrain on which the machine is operating; b) the direction of the longitudinal axis of the machine in relation to the lines of maximum slope (**direction of travel**). The maps provide a twofold set of information on the rollover conditions determined by means of: 1) a **simulation model,** which takes into account the real structural characteristics of the machine; 2) real measurements, conducted by surveying the rollover condition using a special **tilting and rotating platform**. The use of the platform also makes it possible to determine the real position of the machine's centre of gravity. The proposed approach opens up **new perspectives in the certification** of agricultural machinery, providing fundamental information for machine operation in critical conditions.		
Activities performed and results achieved	The testing platform  **Four different tractor types** were tested (*4DW conventional and ' frutteto ' type; mountain tractor; transporter*). The relevant stability maps show the results of the rollover limits obtained with the simulation model (considering the vehicle under normal driving conditions, i.e. without steering), together with all stability conditions associated with particular vehicle conformations (during steering).		Theoretical assumptions of the stability predicting model 

Activities & results (continues)	The first test cycles served above all to refine the survey methodology and to define the formats of the relative reports. The results obtained confirmed the expected performance for the different types of tractors. In short: **a)** lateral roll-over angles vary from 27° for "frutteto" versions to over 50° for typical mountain tractor versions (with a wide track and very low centre of gravity); **b)** however, for the latter, "attention situations" may also arise due to an asymmetrical position of the centre of gravity with respect to the longitudinal axis of the vehicle (shifted even more than 80 cm); this leads to the definition of relative areas of stability that are also asymmetrical, with lateral tilting angles of 38° and 51° depending on whether one considers the side of the machine on which the centre of gravity falls or not; **c)** in machines with a highly asymmetrical centre of gravity, the steering modes of the wheels also have an effect on stability, especially in versions that allow 2- or 4-wheel steering rather than crab steering. This is in accordance with the theoretical predictions of the model, which is able to predict two levels of instability, namely: (1) **phase I instability**, in which the front pivoting axle is free to rotate, resulting in a triangular stability base (i.e., vertices at the contact points of the rear wheels and the pivot joint); (2) **phase II instability**, in which the front axle is no longer free to rotate (e.g., it has reached the mechanical end stop) and thus the behaviour is analogous to that of a rigid chassis with a four-sided stability base. In particular, once the angle of rotation of the front pivoting axle has been determined, if this is greater than the limiting angle of the axle joint, only phase II instability may occur.	Typical stability map (**symmetric CoG**) – NHT4  Typical stability map (**asymmetric CoG**) - Metrac 
Most relevant Publication *# of Publications*	Mazzetto F., "*Experimental validation of the influence of obstacles on tractor rollover stability*" [Proceedings SHWA – Ragusa 2023] 2 journal articles (draft ready), 3 conference proceedings	
External Actors and Stakeholders	Farm/forestry machinery manufacturer, machinery resellers, extension services, production associations, certifications authorities and services, universities and research centres. Examples: Consorzio Agrario di Bolzano, BZ; Metrac Gmbh; Enama Servizi srl, Roma.	
Next steps	In the next test cycles, specific operational aspects of the machines' operating conditions will be assessed in detail, in particular: 1) type of tyre and relative conformations; 2) presence of a coupled implement; 3) effects of unevenness of the terrain with respect to the individual wheel rest points; 4) performance of the tracked versions.	
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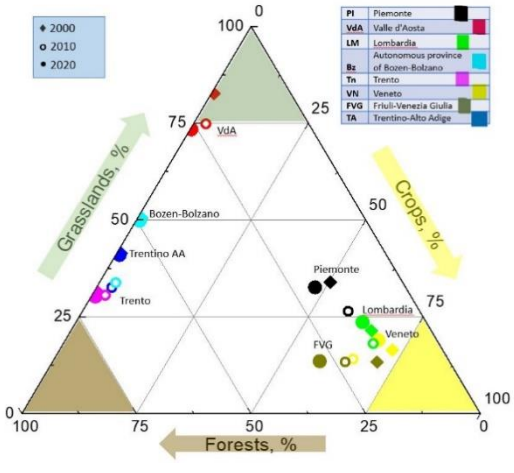
References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) ***Technological solutions for alternative cropping systems in mountain extensive agriculture***	Spoke 1 **RT2. 07**	Resilience of Mountain production systems and supply chains

Overall Objectives	The tasks of this research topic are trifold: a) Analysis of the potentials for niche markets in mountain agriculture. Niche Production and alternative value chains in South Tyrol b) Dynamics and problems of the mechanization of production processes in mountain agriculture c) Development of technology packages for agricultural niche production in mountain areas
Internal Actors	Fabrizio Mazzetto – UNIBZ; Giovanni Carabin – UNIBZ; Merve Karaca – UNIBZ; Andreas Mandler - UNIBZ; Francesco Fabio Nicolosi - UNIBZ
Methodology	Analysis, desk study, expert consultations, literature research, field visits, academic conferences, technical exhibitions, public and expert conferences, exchange with professional associations.
Activities performed and results achieved	In the past eleven months research, practical outreach to farmers and industries, and educational endeavours were conducted. Most of these activities were carried out in parallel and are interconnected. a) Potentials for niche markets in mountain agriculture b) Problems of the mechanization of production processes on steep mountain slopes c) Technology packages for agricultural niche production in mountain areas The first research task (a) started with the collection and analysis of statistical data from (ISTAT) on agricultural production related to the general agricultural area in different Italian regions and provinces (SAT). This provided a picture of predominant agricultural activities in the selected regions and provinces. Fig.1 displays for the years 2000, 2010 and 2020 the temporal expansion of forests, cereals and grasslands. Relating these parameters allows for a view on the characteristics and trajectory of agricultural activities in the last 3 decades. The diagram reveals two distinct groups of production areas. Group 1 with high levels of crop cultivation, but rather little share of forests and grassland. Group 2 shows an inverted picture, displaying high levels of forests and grassland.  While areas of intensive agriculture put high pressure on natural resources, areas of extensive production, as mountain and hilly areas, provide room for flexible, innovative forms of production. This allows for experiments of production for niche markets. Conceptually, niche production or niche markets cannot be predominant in one region, but complement existing production systems (Ezcaray et al., 2023). Niche production is particularly favorable when it enables not only primary production processes but kicks-off also local post-production and subsequent value chains (Duglio et al., 2022; Roep & Wiskerke, 2004).

Activities & results (continues)	An innovative economic niche in South Tyrol is the cultivation of cereals with subsequent establishment of alternative value chains such as cereal-flour-bread or cereal-malt-beer (Sacco, Cornella, et al., 2023; Sacco, Don, et al., 2023). Nevertheless, central to the re-introduction of cereals on mountain farms is (b) the problem of the mechanization of production processes on steep mountain slopes. In order to see beyond cereal production and potentially identify new niche markets, we developed a questionnaire on the specific interests and mechanization needs of smallholder farmers. This questionnaire is available online and shared among farmers and partners in South Tyrol, as well as in other countries. The results will be used for the next steps of research and development efforts, in particular to identify suitable technology packages for agricultural niche production in mountain areas (c). Which smart farming technologies are suitable for innovations in mountain agriculture? New technologies make use of digital services, automation and robotics, have the potential to be used to mechanize tasks in mountain agriculture, e.g. precision positioning, robotics, or farm management information systems. Two international fairs for agricultural machinery were visited to get informed about latest development in the industry.
Most relevant Publication *s*	- Mandler, A., Carabin, G., Becce, L., & Mazzetto, F. (2024). Niche production in mountain farming: Re-introducing cereal production in alpine areas through state-of-the-art mechanization. *Biosystemsengineering, (forthcoming) - Carabin, G., Becce, L., Mandler, A., & Mazzetto, F. (2024). Mechanization of mountain farming: Experimental results of cereal production in steep terrain. *Biosystemsengineering, (forthcoming) - Bernhardt, H., Treiber, M., Paulus, C., Gronauer, A., Mazzetto, F., Mandler, A., & Herlin, A. H. (2022). Development of a Life Long Learning concept for smart farming. 1. https://doi.org/10.13031/aim.202200130 - Carabin, G., Becce, L., Mandler, A., & Mazzetto, F. (2023a). Primary Production Prediction from Aerial Spectrographic Survey. Proceedings of METROAGRIFOR 2022. - Carabin, G., Becce, L., Mandler, A., & Mazzetto, F. (2023b). Rotating testing-rig for the integrated determination of tractor center of gravity and lateral rollover angle. ATAE, 10. - Mandler, A., Carabin, G., Becce, L., Liberatori, S., Bernhardt, H., Treiber, M., Paulus, C., Gronauer, A., Herlin, A. H., & Mazzetto, F. (2023). LLL strategies for new educational approaches in smart agriculture from an agricultural engineering perspective in Italy. In AIIA 2022: Biosystems Engineering Towards the Green Deal. Improving the Resilience of Agriculture, Forestry and Food Systems in the Post-Covid Era (Lecture Notes in Civil Engineering (LNCE), Vol. 337, pp. 697–704). Springer. https://doi.org/10.1007/978-3-031-30329-6
External Actors and Stakeholders	Visit at Agro Alpin | Fachmesse für Land und Forsttechnik, Bolzano-Bozen and Agritechnica, Hannover, SEFI2023, Dublin. Internationales Forum Mechatronik, Bruneck Industry contacts to Geier srl., Consorzium agrario, Caffini srl.
Next steps	Further research will address multifunctional technological solutions that allow for alternative production schemes in mountain agriculture systems.
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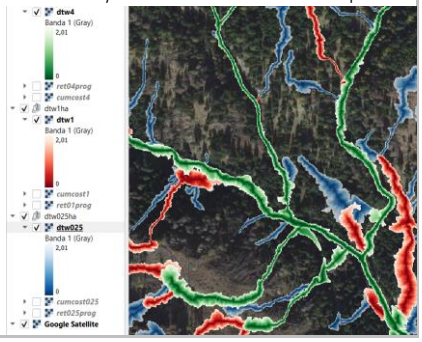
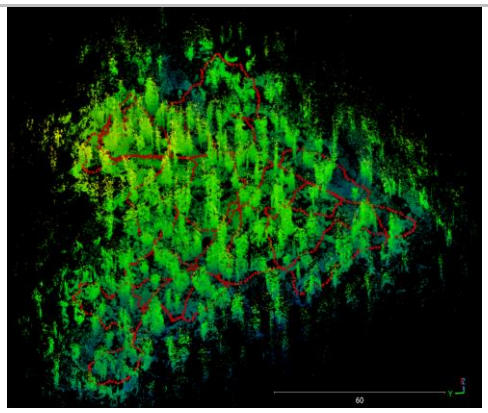
References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) ***Applied DTW map in forest logging system***	Spoke 1 **RT2. 08**	Resilience of Mountain production systems and supply chains

Overall Objectives	The use of DTW maps signifies a commitment to integrating technological advancements for informed decision-making, with the overarching goal of fostering sustainable practices in forestry by optimising extraction routes and minimising the ecological footprint associated with soil compaction.
Internal Actors	Raffaele Cavalli – UNIPD; Stefano Grigolato – UNIPD; Davide Imperiali – UNIPD
Methodology	The utilization of DTW maps involves a dynamic modelling process facilitated by GIS analysis. These maps works as a predictive tool, enabling an understanding of subsurface water accumulation, particularly in close proximity to the hydrographic network. GIS analysis offers a spatial perspective, creating a comprehensive depiction of potential scenarios of water accumulation. The integration of indices into this process brings about adaptability. By accounting for varying soil moisture conditions, these indices play a crucial role in pinpointing areas increasingly prone to soil compaction. This predictive aspect holds significance in forestry planning, allowing proactive decision-making in identifying and safeguarding vulnerable zones. The primary objective is to prevent the passage of extraction machinery over areas susceptible to waterlogging.
Activities performed and results achieved	Logging area – Forest of Paneveggio  Collaboration with the Forestry Agency of Trento (Aprofod) hasn't just facilitated but significantly enhanced the forest site monitoring process through the utilization of advanced technologies: harvesters and forwarders. Considering the site as a dynamic ecosystem, it underwent a thorough analysis spanning critical phases, including pre-felling assessments, concurrent evaluations during active operations, and post-felling preparation and extraction appraisals. Overlay of three different DTW map. 

Activities & results (continues)	In a meticulous effort to comprehend the intricate analysis of the site, special attention was focused on characterize the soil along machinery paths. This detailed examination enabled the identification of specific areas with heightened vulnerability to compaction, offering insights into the ecological impact of forestry activities. To improve the precision of these analyses, integrating cutting-edge technology was essential. Dep to water map (DTW) maps were meticulously crafted, creating a detailed cartographic representation of the micro-hydrographic network within the specified area. This sophisticated map served as both a visual guide and a dynamic tool, illustrating the gradual movement of subsurface water over time. Furthermore, the generated DTW maps were intricately linked to soil moisture levels, aiming to serve as a real-time indicator influenced by precipitation events. This dynamic connection between soil moisture and topographical features bolstered the predictive capabilities of the monitoring system. Strategically, three distinct DTW maps were carefully tailored and applied during different construction phases. This tactical approach depended on prevailing soil conditions, whether characterized by aridity, moisture, or water saturation. The result was a comprehensive suite of maps providing operators with continuous and detailed insights into evolving soil conditions. The use of these crafted maps proved to be a proactive measure in identifying areas prone to subsurface water accumulation. Consequently, the integration of these technological tools not only deepened the understanding of ecological impact but also played a crucial role in mitigating potential damage from soil compaction. Essentially, this collaborative and technologically driven approach sets an example for sustainable forestry practices, where precision and environmental consciousness converge for optimal outcomes.	Application of DTW map on the forwarder pat. 
Most relevant Publication *# of Publications*	Imperiali, D., Grigolato, S. (to be submitted on January 2024). Applied DTW map in forest logging system: a case study in the Alpine forest of Paneveggio. Annals of Forest Research Journal article – (draft ready)	
External Actors and Stakeholders	Aprofod – Agenzia forestale delle foreste demaniali, Provincia autonoma di Trento	
Next steps	In the upcoming phase, we will establish correlations between the soil analysis and the paths traversed by the harvester and forwarder, aiming to quantify the machine's impact on the soil. Additionally, we intend to explore the potential applications of the DTW map as a predictive tool, evaluating its viability as a supportive system for the local community.	

References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) ***Innovative methods for forestry planning and management***	Spoke 1 **RT2. 09**	Resilience of Mountain production systems and supply chains
Overall Objectives	Establishing a network of experimental forest sites for testing LiDAR aerial end ground technologies and processing algorithms		
Internal Actors	Enrico Tomelleri, Luca Da Ros, (unibz)		
Methodology	The LiDAR technology is quickly developing and there is need for standardized approaches for evaluating, deploying, and combining multiple observation approaches. In the most recent years several algorithms for segmentation and obtaining forest traits has become available. We were creating an experimental sites network to provide test areas for testing such technologies and algorithms. Typically, a test area is 1ha and the all the trees were inventoried. In doing this we collected structural data with different LiDAR instruments and from various platforms. We implemented standard processing pipelines using multiple classification and segmentation algorithms. Lastly, we started comparing the acquired point clouds.		
Activities performed and results achieved	In cooperation with the South Tyrolean Forest Service and the Agency for Province-Owned Forests, our endeavoured to identify suitable test areas within the Latemar Forest has progressed significantly. Three potential test areas have been meticulously selected. These areas will serve as testbed for our experiments in forestry technology and management. Specifically, one of the chosen areas has already become the focal point of our investigations, serving as the stage for comparing ground-based and aerial LiDAR technologies, along with the testing of various processing algorithms. In a synchronized effort, a comprehensive campaign was executed, employing a terrestrial laser scanner (the Focus 3D by Faro Technologies Ltd.) (Fig. 1) and a SLAM device (the Frontier by Oxford) (Fig. 2). These instruments, equipped with cutting-edge technology, have allowed us to create 3D models of the experimental sites. Additionally, we had at our disposal a benchmark dataset obtained from UAV-based LiDAR (utilizing the Mini-VUX1 by Rigl	 *Figure 3: the used terrestrial laser scanner (Focus 3D, FARO Technologies)*  *Figure 4: the used SLAM device (Frontier, Oxford)*	

Activities & results (continues)	GmBH), collected during a flight campaign back in 2020. Our primary aim with these activities was to benchmark the performance of these three distinct instruments within a forest environment characterized by complex vertical structures and steep topography, as illustrated in Figure 3. Through rigorous analysis and comparison, we strived to gain insights into their respective strengths and limitations, thus informing future technological developments and forest management strategies. Expanding our vision beyond the experimentation, we were also laying the groundwork for the establishment of martelloscopes within the selected areas. These specialized observation sites serve multifaceted purposes, acting as educational tools, demonstration sites, and hubs for further research endeavours. Our collaboration with the European Forest Institute was established to integrate our activities into the "iplus" network. This partnership holds potential, offering opportunities for standardizing site establishment protocols, leveraging sophisticated site management software, and tapping into an extensive network for testing and refining algorithms and technologies across diverse forest ecosystems. Ultimately, through the synergy of expertise, technology, and collaboration, we aim to unlock new frontiers in forestry research and pave the way for using new technologies for a climate-smart forest management.	 *Figure 5: acquisition path and point cloud from the Frontier survey.*
Most relevant Publication	Vaglio Laurin, G., Cotrina-Sanchez, A., Belelli-Marchesini, L., Tomelleri, E., Battipaglia, G., Cocozza, C., Niccoli, F., Kabala, P., Gianelle, D., Vescovo, L., Da Ros, L., Valentini, R. Integrating spectral below-canopy and satellite data for an improved forest phenology monitoring system. Ecological Indicators, Volume 158, 2024, 11132.	
External Actors and Stakeholders	South Tyrolean Forest Service and the Agency for Province-Owned Forests	
Next steps	In the next steps, the collected datasets will be co-registered and further selected sites will be inventoried (tree numbered and traits measured) and martelloscopes will be established.	
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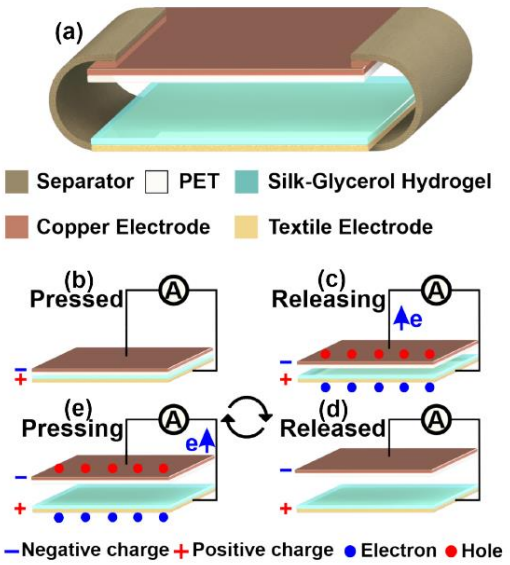
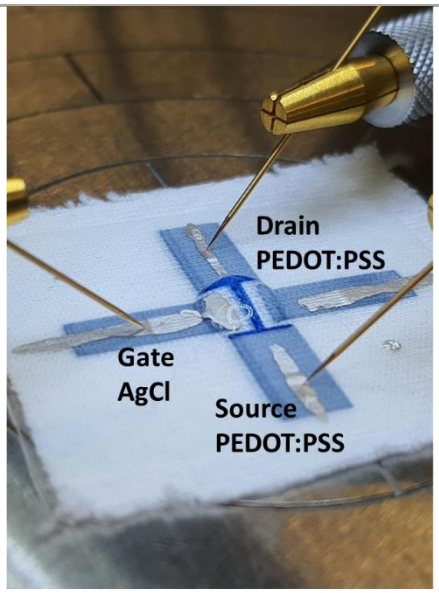
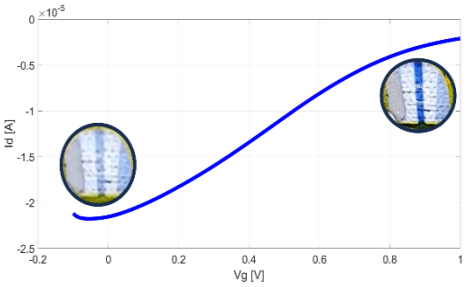
References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) **Development of wearable solutions for working and recreational activity in the winter industry domain**	Spoke 1 **RT2. 10**	Resilience of Mountain production systems and supply chains
Overall Objectives	Develop innovative solutions in wearable applications to monitor physiological indicators during work and recreational activities in the winter industry domain.		
Internal Actors	Antonio Altana – UNIBZ Paolo Lugli – UNIBZ		
Methodology	Synthesis of hydrogels in different compositions, exploiting the triboelectric nano-generated power. Screen-printed on textile of electrochemical transistors for ion sensing and electrodes for bioimpedance measurement. Electromechanical characterization of the realized samples gives information regarding the stability and the sensitivity of the device to biomechanical stimuli. In the case of triboelectric generators, give information about the total amount of energy produced and in the case of electrodes the sensitivity to movement. Electrical characterization is necessary to extract the calibration curve for the specific analyte of interest.		
Activities performed and results achieved	 Fig. 2. (a) Structural representation and working mechanism of silk-glycerol hydrogel-based triboelectric nanogenerator showing the current generation status when pressed (b), during releasing (c), when released (d), and during pressing conditions (e).	 Device under test during electrical characterization.	

Activities & results (continues)	A novel flexible composite material based on the silk-glycerol hydrogel. Silk and glycerol were selected for their excellent triboelectric and antifreezing properties, respectively. Additionally, silk is also a natural bio-derived material. The proposed hydrogel yielded good mechanical (minimum stretchability of around 130% and Young's Modulus of about 0.08 MPa) and triboelectric properties (maximum current output of 12.5 nA), independent of the **temperature up to -20 oC**. Moreover, the developed triboelectric nanogenerator (TENG) showed a linear relation between the current and the applied compressive force up to 35 N, demonstrating the possibility to be used for **wearable TENGs and biomechanical sensors for extremely cold conditions.** Electrodes for bioimpedance measurements and organic electrochemical transistor have been realized on textile, for future integration in **smart garments**. The fabrication process involved the patterning of the components by screen printing on thermoplastic polyurethane (TPU) substrate, and subsequently transferring via heat press onto textile. The realized electrodes for bioimpedance measurement can be employed for **unobtrusive measurement of phyisiological parameter** such as heart rate, breath rate and vascular activity. A miniaturized planar organic electrochemical transistor (OECT) for ion sensing on a textile for wearable applications is under development. The device utilizes poly(3,4-ethylenedioxythiophene):poly(styrenesulfonate) (PEDOT:PSS) as the active material and silver/silver chloride (Ag/AgCl) as the planar gate electrode. The OECT reacts to ion presence and The miniaturization of the dimensions of the device is necessary to exploit the screen-printed platform for impedance measurement between gate and channel, facilitating the identification of various ions in a solution (e.g., Na+ and K+).
Most relevant Publication *# of Publications*	Novel silk hydrogel-based material for wearable energy harvesting and sensing mountaineers' activities R Riaz, MAC Angeli, A Mejia-Aguilar, R Monsorno, B Dudem, SRP Silva, P Lugli, L Petti 2023 IEEE International Workshop on Metrology for Industry 4.0 ..., 2023▪ieeexplore.ieee.org 1 journal article (draft in preparation) and 2 conference proceedings (1 published and 1 in preparation)
External Actors and Stakeholders	Center for Sensing Solutions EURAC Research Advanced Technology Institute University of Surrey Oslo University Hospital
Next steps	About the hydrogels, the next steps include the investigation of a new composition as electrode for biomechanical monitoring. Regarding the printed devices on textile, the next steps imply the characterization by means of electrical impedance spectroscopy, in terms of physiological parameter monitoring and ion concentration characterization.



Transfer characteristic of the device, where the change in color of the PEDOT:PSS is noticeable due to the ion permeation.

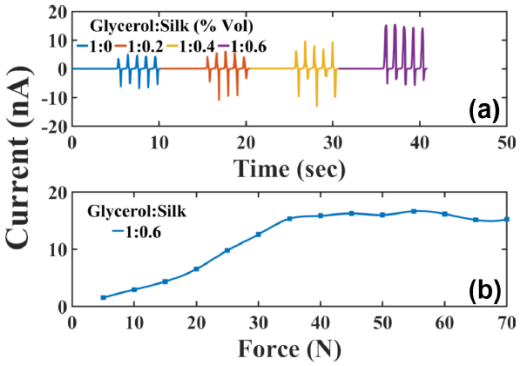
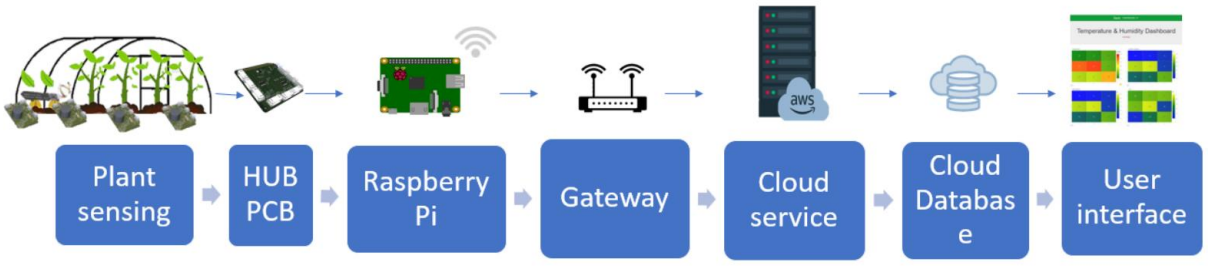
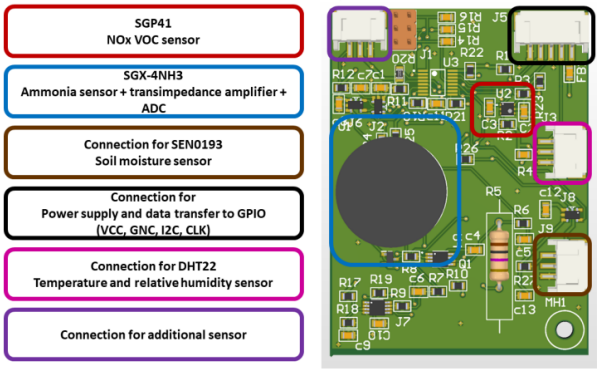
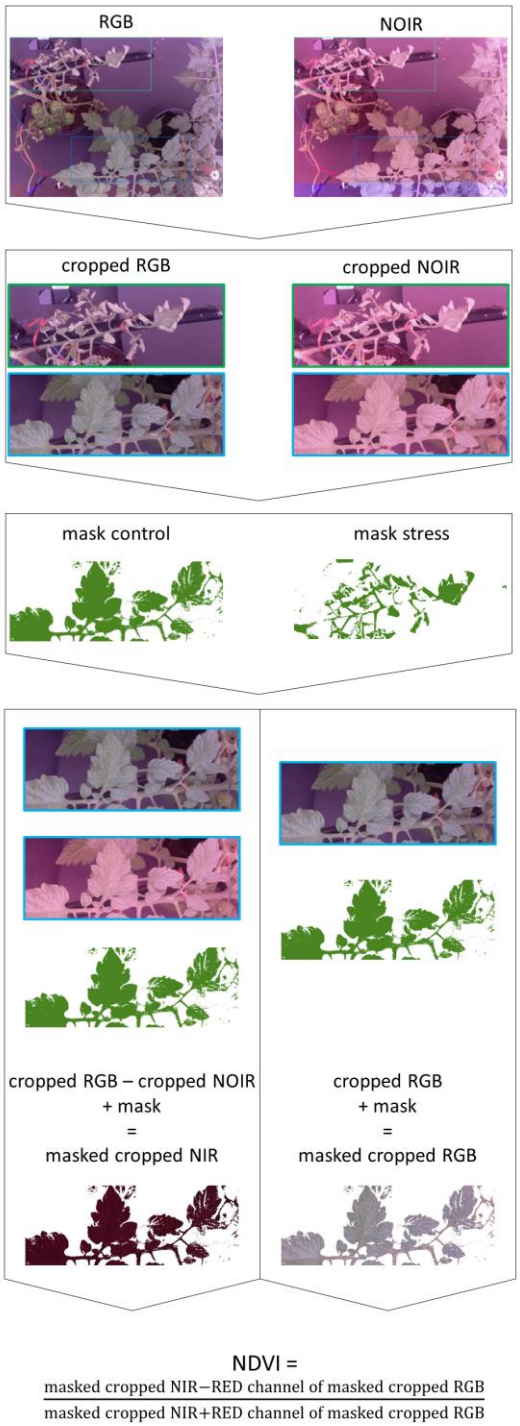
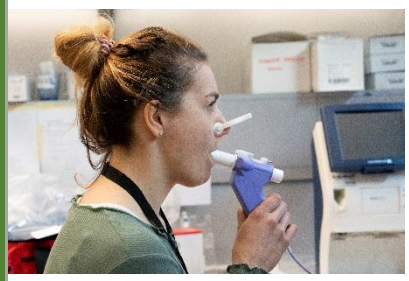


Fig. 4. Current output characterization of silk-glycerol hydrogel-based triboelectric nanogenerator. (a) Demonstrating the current output of samples with 1:0, 1:0.2, 1:0.4 and 1:0.6 by vol% of glycerol-silk concentration at 35 N and 1 Hz of compressive forces. (b) The current output response of 1:0.6 by vol% glycerol-silk sample for on the sweep of 5-70 N of compressive forces at 1 Hz frequency.

References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) ***Development of sensing solutions for environmental monitoring in the winter industry domain***	Spoke 1 **RT2. 11**	Resilience of Mountain production systems and supply chains
Overall Objectives	Design and develop a sensing platform to monitor environmental parameters, to be employed as decision support system and acquire measurement overtime to create a dataset for further processing and analysis.		
Internal Actors	Antonio Altana – UNIBZ Paolo Lugli – UNIBZ		
Methodology	The designed platform is composed by commercial sensor to collect environmental data (i.e., temperature, soil moisture, relative air humidity), calculate the NDVI, and measure the gas emissions (ammonia, VOC and nitrogenous oxide (NOx)). The sensors are integrated in a custom PCB connected to a Raspberry Pi4 device that pre-processes the data and formats it to JSON package format. Gas detection is managed using an SGP41 sensor from Sensirion for NOx and VOC, which is a digital gas sensor that uses the I2C protocol and has a built-in gas index algorithm to calculate the total VOC. The soil moisture is measured using a SEN0193 sensor from Dfrobot, which is an analogue capacitive soil sensor. The platform converts the analogue signal of the soil moisture sensor using an MCP3021, which is a 10-Bit analogue digital converter with the I2C protocol builtin. For the temperature and relative air humidity, the platform uses a DTH22 from Dfrobot, which is a thermistor sensor for sensing the temperature with an accuracy of 0.2 per cent for temperature and 5 per cent for humidity. The NDVI can be calculated by the normalization of the sum of the red channel and the NIR channel: NDV I = (NIR – Red)/(NIR + Red). The channels:near-infrared and red, are obtained by a commercial NO Infrared filter(NOIR) camera IR-CUT removable filter. The cloud architecture has the responsibility to process, store and send the data when requested. For that, we created an architecture for the database that is stored in Amazon web service (AWS) using the relational database service (RDS).		
Activities performed and results achieved	A web application has been developed so that a user with low experience or knowledge can easily understand the system's purpose, the current environment status and the trends for plant status. The dashboard triggers an API to query the data in the cloud database from the last 24 hours of the plant selected. If the operator/farmer of the web application selects "overview", another API will be triggered to query the current situation for all plants, which will be displayed in the dashboard.  Fig. 2. Overview of the developed platform: nutshell of the architecture and of the data flow, with sensors placed in a small PCB that is connected to a PBC hub throughout cables and then connected to the Raspberry PI sending data to the cloud throughout a gateway .		

Activities & results (continues)	 Fig. 4. Schematic of the PCB, indicating the components and the connections. The platform was developed employing lowcost sensors, while data storage was managed via database. The designed platform is also capable to use its temperature and humidity sensor to auto-compensate the gas sensors. In the platform developed, all the components were designed to operate from an outlet, while power and communication are performed through cables except for the communication to the gateway. This was done to avoid battery replacement and reduce maintenance. Indeed, the platform can be operated with minimal maintenance for long periods. As a case study to validate the measurement acquisition and data processing the platform was employed during several days to collect data about temperature and humidity, in a gas chamber to measure Ammonia concentration and to evaluate the stress condition of two tomato plants using NDVI and soil moisture. The advantages of the platform were introduced in the presented use case of water stress monitoring in tomato plants, paving the way to the employment of the platform in a more complex application, and providing a user-friendly and low-cost decision support system to be employed in the greenhouse. The results obtained demonstrate that the NDVI and water stress can be strongly correlated as several previous studies have demonstrated.  $NDVI = \frac{\text{masked cropped NIR} - \text{RED channel of masked cropped RGB}}{\text{masked cropped NIR} + \text{RED channel of masked cropped RGB}}$
Most relevant Publication *# of Publications*	Enhancing precision agriculture through cyber-physical systems: a functional monitoring platform as decision support tool. E Suraci Picchiotti, S Krik, P Ibba, P Tosato, A Altana, M Valt, A Gaiardo, L Petti 2023 IEEE INTERNATIONAL WORKSHOP ON Metrology for Agriculture and Forestry..., 2023▪ieeexplore.ieee.org 1 journal article (draft in preparation) 2 conference proceedings (1 accepted for publication and 1 in preparation)
External Actors and Stakeholders	MNF-Micro Nano Facility Unit, Sensors and Devices Center, Bruno Kessler Foundation Tessa Agritech
Next steps	The next steps involve the testing of multiple sensors to evaluate the best performance in terms of monitoring condition of environmental parameters and the employment of the prototypes for gas emission characterization in real case scenario

References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) **Influence of active air supply during avalanche burial on ventilation and oxygenation**	Spoke 1 **RT2. 12**	Resilience of Mountain production systems and supply chains
Overall Objectives	Survival of fully buried avalanche victims depends in major part on a triad of hypoxia, hypercapnia, and hypothermia and therefore decreases rapidly after complete burial. Besides optimizing companion rescue, which still today and even by trained people often takes more than 15 minutes to the extraction of an avalanche victim, prolonging the ability to breath after critical avalanche burial increases survival probability by giving rescuers more time to find and unbury avalanche victims. Based on previous research, the Norwegian company Safeback SE (Bergen, Norway) developed a new non-medical device using an innovative functional principle. The device, called "Safeback SBX" (Safeback SE, Bergen, Norway), has the aim to prevent asphyxia by delivering fresh air to the air pocket. Company claims to achieve a prolongation of survival up to over 60 minutes, giving companion rescuers as well as professional rescue teams more time to get access to the victim. Technical tests conducted by the developing company already provided some promising results regarding the general functioning. We run an in-field study to investigate the effectiveness of this new developed auto rescue device for avalanche burial victims.		
Internal Actors	Roveri Giulia, MD - Eurac Research Strapazzon Giacomo, MD, PhD – Eurac Research		
Methodology	We run a randomized, controlled and single-blinded in-field trial in the Dolomites (Italy). 30 participants were included. The subjects were randomly assigned to either the intervention or the control group by a statistician. The day before each test, a snow pile mimicking an avalanche deposit using a snow groomer was prepared. Inclusion Criteria were healthy ASA I subjects. Exclusion Criteria were ASA class II or higher, chronic high degree cardiovascular or pulmonary disease, claustrophobia, psychiatric or neurological disease, long-term medication, pregnant woman, no informed consent. Specifically, we investigated the effectiveness of the device and the influence on physiologic parameters (i.e. End-tidal CO2 (EtCO2), Minute ventilation (VE), Cerebral Regional Oxygen Saturation (rSO2), NASA-task load index (NASA-TLX) questionnaire, Reactive oxygen species – ROS) in humans buried in snow debris under realistic conditions. More informations are accessible through the website below:https://www.safeback.no/news/press-releases/eurac-research-conducts-independent-medical-trial-of-safeback-sbx		
Activities performed and results achieved	In-field study In January and February 2023, the preparation for the study involved a recruitment phase, resulting in the selection of 30 participants from 120 applications. Preliminary medical tests were also conducted		

	during this period to assess the health status and suitability of the subjects. These rigorous procedures ensured a well-prepared and reliable participant pool for the study. In the beginning of March 2023 we run the in-field study at Passo Rolle (Dolomites- Italy). The study was conducted by a multidisciplinary team comprising emergency physician's expert in the field of Mountain Emergency Medicine (i.e. Giulia Roveri and Giacomo Strapazzon from the Institute of Mountain Emergency Medicine of Eurac Research), snow expert from di WSL Institute for Snow and Avalanche Research SLF (Switzerland), biologists and statisticians. Additionally, the team consisted of expert professionals from various European countries including Italy, Austria, Switzerland, and Norway.    From April 2023 to November 2023, statistical analyses of the data were conducted.   
Most relevant Publication	International conference Roveri, G., Strapazzon, G., et al., Influence of active air supply during avalanche burial on ventilation and oxygenation. *28. Internationale Bergrettungsärztetagung (Innsbruck - November, 2023)*
External Actors and Stakeholders	• WSL Institute for Snow and Avalanche Research SLF (Switzerland) • Guardia di Finanza, Passo Rolle. • Safeback SE, Bergen, Norway
Next steps	We are now internally revising the main paper and plan to submit it in the next few weeks. We are already start working on the secondary aims data and we plan we will submit 3 more papers in 2024.
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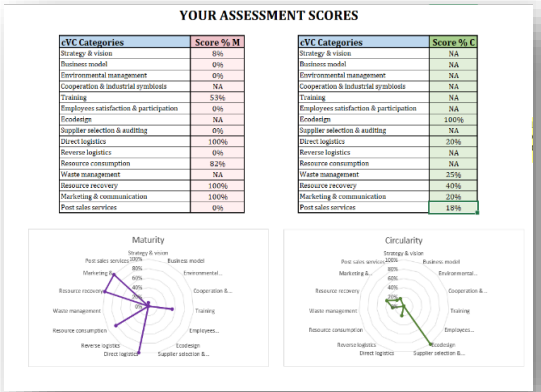
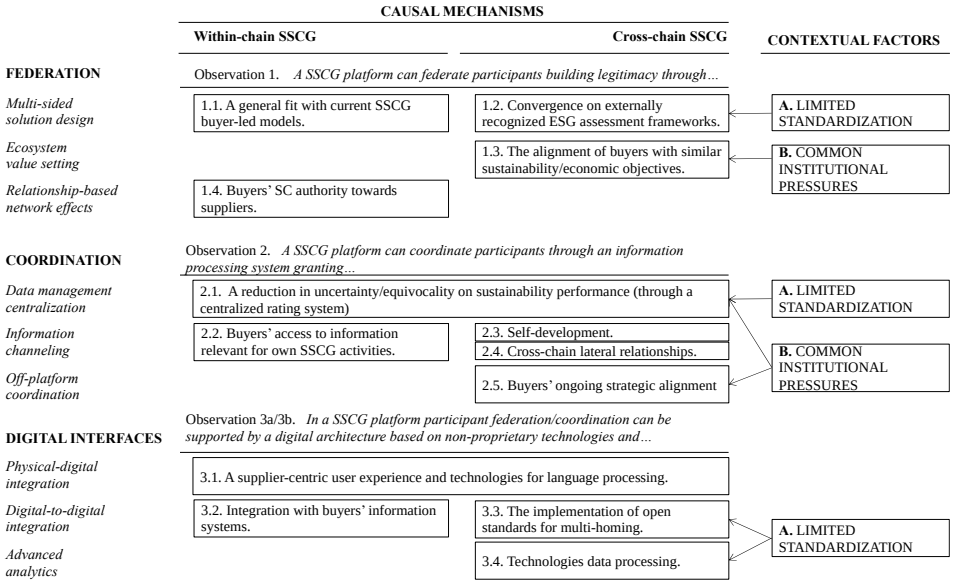
References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) ***Methods and tools for sustainability, circular economy and multi-dimensional assessment***	Spoke 1 **RT2. 13**	Resilience of Mountain production systems and supply chains
Overall Objectives	The research seeks to <u>define and validate methods for circular economy (CE), sustainability and multi-dimensional assessment</u> of mountain production systems and related supply chains. More in detail, the following research and innovation needs have been identified: (1) analysis of the needs of companies located in mountain areas or more in general of companies in the winter and mountain industry for circular economy and/or multi-criteria assessment tools; (2) development of one or more circular economy assessment tools specific for these companies; (3) conceptual evaluation and design of a new Laboratory targeted for companies and production systems in mountain areas.		
Internal Actors	Guido Orzes – UNIBZ; Fabrizio Mazzetto – UNIBZ , Faisal Rasool – UNIBZ, Mehari Teshome – UNIBZ Pasqualina Sacco (*) – UNIBZ, Guido Nassimbeni (*) – UNIUD, Marco Sartor (*) – UNIUD, Giovanna Culot (*) – UNIUD		
Methodology	A variety of methodological approaches have been employed to achieve the abovementioned objectives. First of all, we employed **virtual prototyping methodologies** (creation of a minimum viable product - MVP) to test and assess the Circularity and Maturity Firm-Level Assessment tool (CM-FLAT), conceptually developed in the last years by some members of the iNEST research team. Second, we carried out a **multiple case study** investigation to analyze the different tools available and compare their influence in measuring the CE level of a company. More in detail, we carried out six case studies of companies located in Nort-East Italy. Finally, in order to shed light on how digital platforms can support integrative approaches to supply chain sustainability assessment and improvement, we performed a **single case study.** The selected case was the platform Open-es, which involved around 12,000 companies from 89 countries and 66 industrial sectors and is further expanding.		
Activities performed and results achieved	We created a **minimum viable product (MVP) prototype** of the Circularity and Maturity Firm-Level Assessment tool (CM-FLAT), that was conceptually developed in the last years by some members of the iNEST research team (Sacco et al., 2021). More in detail, we developed an online questionnaire (with Limesurvey) with the questions and an Excel spreadsheet to visualize the radar charts of the results. We then started to test and compare the CM-FLAT assessment tool with three other readiness/circularity tools, namely the Readiness Assessment tool for the Circular Economy of MATCHE (Pigosso & McAloone, 2021), the Circularity measurement toolkit by Garza-Reyes et al. (2019), and the UNI/TS 11820:2022 through six case studies of companies located in Nort-East Italy. Second, we **started to update, revise and customize a multicriteria assessment tool** developed in a previous research project financed with ERDF funds 2014-2020 (Gallo et al.,		

	2019a and 2019b) to adapt it to the needs of the iNEST project.	
	Third, we **analyzed how digital platforms can support integrative approaches to supply chain sustainability assessment and improvement**, by focusing on the platform Open-es (https://www.openes.io/).  Finally, we **defined the research topics of a new Lab** (tentative name: Supply Chain Impact Lab): (a) technologies for purchasing and supply chain management – SCM (such as blockchain, artificial intelligence, and internet of thing applications in SCM; and supply chain platforms); (b) certifications and standards for sustainable operations and supply chains (e.g., SA8000, B-corp, UNGC; (c) integrated supply chain sustainability assessment (e.g., LCA and multi-criteria sustainability assessment). We then also started to build relationships with local stakeholders (companies, public administration) in the view of the establishment of the new lab.	
Most relevant Publication *# of Publications*	Culot G., Orzes G., Marcuzzi I., Sartor M., "Sustainable Supply Chain Governance through digital platforms: evidence and theoretical implications", XXXIV Annual Scientific Meeting - RSA AiIG 2023 "Humanizing technologies for a better society. Purpose-driven innovation to empower people" · Lecco, October 2023. One conference paper (presented) + one journal article (draft in preparation)	
External Actors and Stakeholders	Manufacturing companies located in mountain/alpine areas	
Next steps	Refine the multicriteria assessment tool developed in a previous research project, adapt it to the needs of the iNEST project, and make it available online. Finalize the CM-FLAT tool or another tool for the assessment of CE at a different level (e.g., product level). Proceed with the conceptualization and the starting of the new Lab.	
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References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) **Feral Wool – Designing with a Vibrant Matter in Times of Uncertainty**	Spoke 1 **RT2. 14**	Resilience of Mountain production systems and supply chains
Overall Objectives	Exploring mountain craft techniques with a focus on wool craft to develop future scenarios through research-through design methodology.		
Internal Actors	Secil Ugur Yavuz – UNIBZ; Merve Bektas – UNIBZ; Camilo Ayala Garcia – UNIBZ		
Methodology	• The project follows a research-through design methodology that starts with a contextual inquiry for generating various knowledge (tacit, embodied, and situated) and follows with design actions to visualize and make sense of the knowledge in order to give rise to future scenarios. • The contextual inquiry embraces field research that includes visits and excursions to contact with (local) wool manufacturers, wool entrepreneurs, design experts, craftsmen, wool and crafts associations and innovators. These visits also help to understand the processes, practices and controversies around wool, wool cultivation and production in South Tyrol and beyond. • Besides the contextual inquiry, the literature review (LR) serves for exploring and analysing best practices. • Design actions include developing a stakeholder map going beyond human actors (designers, crafters, farmers, shepherds, etc.) towards a more-than-human understanding including sheep, pastures, etc. and visualizing wool production processes based on the collected knowledge.		
Activities performed and results achieved	Field visits and excursions 4 field excursions were organised during 2023. The first excursion was to Spinnradl, a local wool producer, to observe the different wool processes and to better understand the complexities and problematics around wool and wool production. Following this, we had the opportunity to visit the 9th wool festival of South Tyrol - Wollstrasse - at St Leonhard in Passeier. The festival is dedicated to the local sheep and its importance as a versatile animal in the Passeier Valley and involved local wool producers, spinners, artisans, sheep breeders and breeds, permaculturists, and farmers. The festival also showcased the various processes of wool, such as spinning and felting.  ***Figure:*** *Field visit to Spinnradl – processing of raw wool from washing-sorting, carding. spinning to knitting.* Following this, the Biolife Fair 2023 was visited to meet wool-related projects and producers. "Alpinehanf 360°", a systemic project using hemp fibres from the Tyrolean region, was visited and the working team was		

Activities & results (continues)	contacted. Finally, we had the chance to attend a public event on "craftsmanship between tradition and innovation" dedicated to the complex world of handicrafts with a film screening gala "Made in Südtirol". A well-known local designer was invited to give a presentation on the topic, in which he emphasised the importance of creativity and design for Alpine craftsmanship, where knowledge and skills are on the verge of being lost. The literature review (LR) provides a broader understanding of the research context. The LR is grouped into the following categories: a) historical overview of wool; b) wool waste; c) mountain crafts; d) multi-species design; e) alternative materiality and will continue to deepen with the previously identified themes, followed by other topics such as more-than-human design, politics of wool, wool production and transhumance and pastoralism. Furthermore, the case studies analysis is being examined and categorised as "circular wool production, tool making, wool systems, multispecies design and new value through design". A first version of the stakeholder map has been developed and will be transformed into a digital open map in the future.
Most relevant Publication	Publications are scheduled for 2024.
External Actors and Stakeholders	Designers, crafters, wool manufacturers, academicians, scientists, small-farmers, shepherds, associations, mountain craft schools, innovation hubs/agencies, rural entrepreneurs, nature conservation/promotion projects.
Next steps	**Design Research (DR):** Design ethnography, prototyping, workshops, design interventions as a form of inquiry, and artefact analysis will be included. Formal and unformal interviews are planned with stakeholders. Practice-based research will be conducted and visual design tools such as infographics will be designed to map and visualise processes (wool cultivation and production) and controversies between human (designers, crafters, farmers, shepherds, etc.) and more-than-human actors. **Material Experimentation:** Wool will be experimented through textile techniques and design. **Field research:** Further excursions will be made to reach more actors and expand our network. The stakeholder map will be transformed into a digital open map. In close dialogue with anthropologists, field research will be conducted to carry out multispecies ethnography methodology with sheep. **Initial speculative scenario building:** In December, it is planned to participate in the 3-day programme "Like Life", organised by MUSE Trento and hosted by Fiona Raby, one of the leading theorists of the concept of speculative design, to create future scenarios of wool in mountain craft in South Tyrol, which could then be transformed into a workshop format to bring together various stakeholders in South Tyrol. **Workshops:** In 2024, workshops will be organised by inviting experts. **Cross-collaborations:** Meetings and potential workshops are planned to explore possible collaborations with the project "Global Pastures" and "LifeStockProtect". **Publication(s), conference(s):** It is planned to submit publications for DISCERN and Inmaterial 2024 Journals and submit an abstract for a presentation at the STS Amsterdam 2024 Conference.
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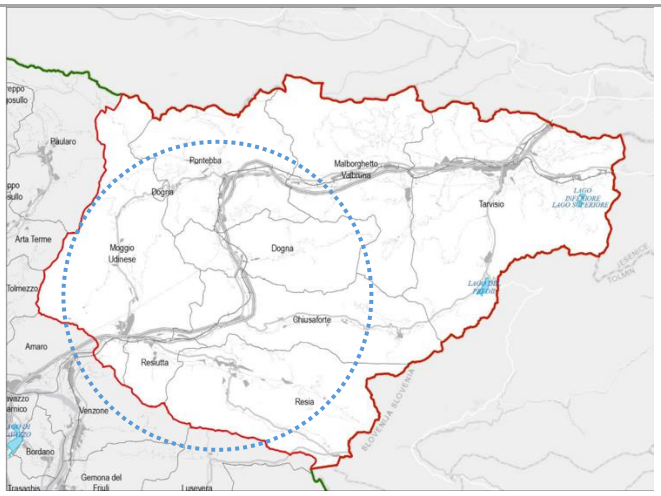
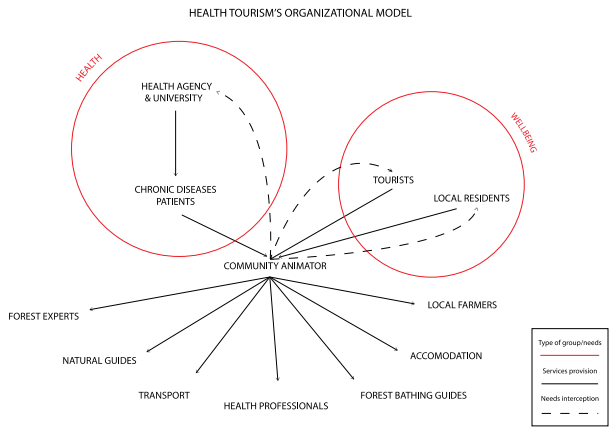
References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) **Fostering local development on mountain contexts through health tourism and cultural ecosystem services**	Spoke 1 **RT2. 15**	Resilience of Mountain production systems and supply chains
Overall Objectives	Studying and defining the possibilities that health tourism and the attendance of forests for touristic and recreational purposes have on supporting local socio-economic development of depopulated mountain areas on the region of Friuli Venezia Giulia		
Internal Actors	Ivana Bassi – UNIUD – Vanessa Deotto - UNIUD		
Methodology	1. Definition of an organizational model able to support a local network of stakeholders related to the health/wellbeing tourism and the use of the forest as a natural resource for touristic and recreational purposes 2. Measurement of people's attitudes on the attendance of mountain context for health/wellbeing purposes 3. Identification of standards and procedures for the certification of pilot forest areas in FVG region		
Activities performed and results achieved	After a preliminary mapping of stakeholders in the FVG mountain contexts, a specific area has been defined in order to increase the effectiveness of the actions carried on. The selected area are the valleys Val Canale and Canal del Ferro (fig 1.) located in the north-east of the region. Then a study field has been conducted in order to collect general opinions regarding the concept of health tourism and, specifically, the practice of forest therapy. The result is a first delineation of a possible organizational model with two macro-subjects. The first macro-subject is health, and it considers medical actors such as the local health agency and related patients with chronic disease interesting on experiencing forest therapy; the second macro-subject is wellbeing, and it include local community and tourists (fig. 2). In order to raising awareness about the topic, the first survey has been intended for the local health agency group of patients with stable chronic dis-ease. The aim of the survey is to collect data on the knowledge related to forest therapy practice, to analyse the aptitudes in carrying out sporting	 Fig. 1 Study area (Picture credits: report Strategia Nazionale per le Aree Inte assetti istituzionali, Canal del Ferro Val Canale, Dossier d'Area Organizzativo, 2019)	

Activities & results (continues)	activities and frequenting the woods and, lastly, the availability at attending sessions of forest therapy on mountain contexts. The second survey has been intended for people living on the Italian alpine regions, it will be widespread in three macro-areas: the Friuli Venezia Giulia region, the Triveneto area and the rest of the alpine regions. Aim of the survey is to measure the aptitude on attending mountain areas and woods for touristic/recreational/sporting purposes and the availability on paying for cultural ecosystem services' benefits, related to the forest therapy. Two ad hoc questionnaires were developed to carry out the two surveys. The activity of collecting information by filling in the questionnaires is ongoing. A first test has been conducted with university students where emerges a spread propensity on paying more willingly for ecosystem services related to management and protection of the forest environment. Work is underway to identify standards and procedures for the certification of pilot forest areas in the FVG region.	 Fig. 2 Health tourism organizational model
Most relevant Publication	Bassi, I., Deotto, V., (2023), *Development opportunities in mountain territories: forest therapy experiences in the region of Friuli Venezia Giulia*, 2nd Croatian Congress on Forest Therapy, Sibenik, Croatia.	
External Actors and Stakeholders	Local community, University of Udine – medical department, local health agency, patients, tourist, students, researchers, local administrations	
Next steps	In the next steps the survey data will be analysed and compared, structured interviews with local stakeholders will be conducted in order to define the structure of the organizational model and the certification of the forest will be presented and carried on in collaboration with different typologies of forest owners.	
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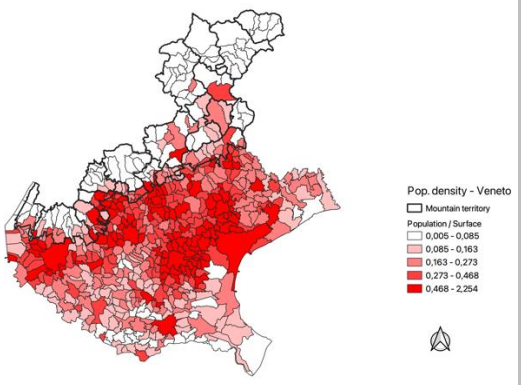
References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) **Creation of interactive map for tourism information of the Verona's mountains**	Spoke 1 **RT2. 16**	Resilience of Mountain production systems and supply chains

Overall Objectives	The main objective is the creation of a map that contains useful information for visitors to a particular mountain area and study the local supply chains. The map/app should allow to view commercial activities, accommodation facilities and places of interest, including modes and times of access.
Internal Actors	Diego Begalli – UNIVR; Riccardo Scarpa – UNIVR; Jessica De Agostini – UNIVR.
Methodology	Creation of a repository of geographical information and their on-site validation. Creation of a catalog of data providers and developer. Definition of several layers of geo-referenced information relevant to tourism activity. Access mapping and seasonal event chronograms. Focus groups and interviews with local tourism operators, stake holders and local government officers. Georeferencing at different scales and with different granularity and density of information. Query testing and response retrieval, developement of current Origin-Destination (O-D) matrices.
Activities performed and results achieved	Following insights from the literature review, at this stage we are developing skills with programming software and Geographic Information System software especially QGIS, R and python programming language. We used datasets provided by the Veneto region portal to create georeferenced maps via QGIS.

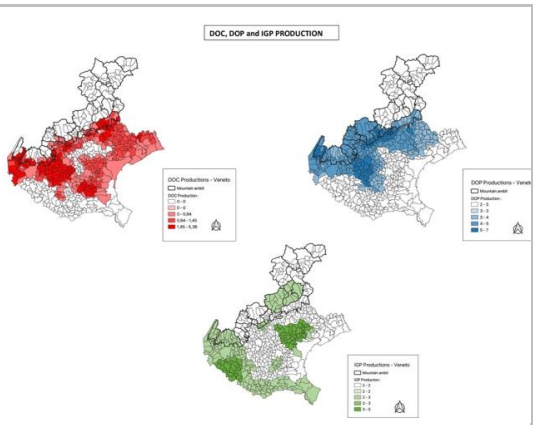
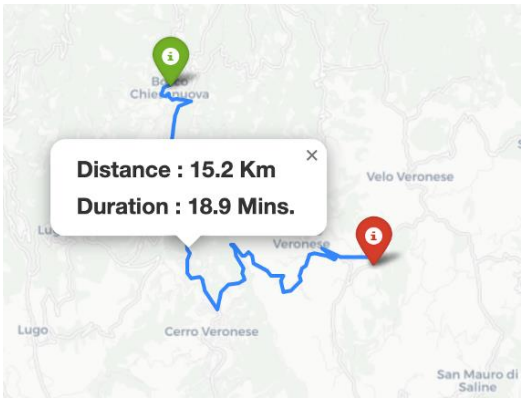
We mapped altimetry, population density, mountain parks, presence of refuges and bivouacs, etc. For example, it is possible to note the difference in population densities across mountain areas (delimited by the thick black boundary lines) and the rest of the Veneto Region (Map 1).

Logistic difficulties and differences in altitudes make mountain regions comparatively less attractive for permanent (year round) settlements, causing severe seasonal slowdowns in productive, commercial and employment activities. Lack of public transport adds to these connectivity problems, with repercussion to the operation of local supply chains and their economic sustainability. We studied these elements to scope the project.

We focussed on geographical distribution of typical food products in these areas, and from the maps of DOC (in red), DOP (in blue) and IGP (in green) products, it is possible to notice the potential of the mountain territory, especially the area of the province of Verona (Map 2).
Although DOC certifications are comparatively fewer if contrasted with those in the rest of Veneto region, the DOP and IGP productions represent a significant economic value.



Map 1. Population density of the Veneto Region. Created with QGIS.

Activities & results (continues)	This can provide a great potential for the mountain area under study. Certified products can generate a strong boost in the development of a given territory, especially in one with great potential for tourism activities. Mechanisms to attract some of the tourism flow to these areas from the large amounts of visits enjoyed by the neighbouring area of the east shore of the Garda lake were investigated. To facilitate the study of the movements of tourists in this area, we implementated an Origin-Destination (O-D) matrix. This enable us to provide information relating to the distance between origins of visitors and their travel destinations in the area of interest, the duration of the trip and the possible travel cost for visitors (Map 3) and the segmentation of the supply chain of tourism activities. This would be an important tool that should make it possible to highlight and enhance an area with lower tourist intensity and tourist services, such as mountain areas. We plan to produce new layers of GIS information that can provide the listings of activities, resources, events, typical food products and tourism offerings at each destination in the mountain area. This will be implemented in the interactive app that we will try to create in collaboration with local municipalities.	 **Map 2**. DOC, DOP and IGP Production in Veneto. Created with QGIS.  **Map 3**. Connection route between two commercial activities in Lessinia. Created with Open Route Service.
Most relevant Publication # of Publications	None	
External Actors and Stakeholders	Lessinia IAT Office of Bosco Chiesanuova, the municipality and the "Pro Loco" association of Ferrara di Monte Baldo, Lessinia Regional Natural Park.	
Next steps	Our goal in the coming months is to acquire the appropriate skills to be able to develop the app (also thanks to collaboration with other departments, such as the Computer Science Dpt which will assist us with the development of the App), collect and manage the data that will be necessary to populate the App information system and analyze the main problems of the study area.	
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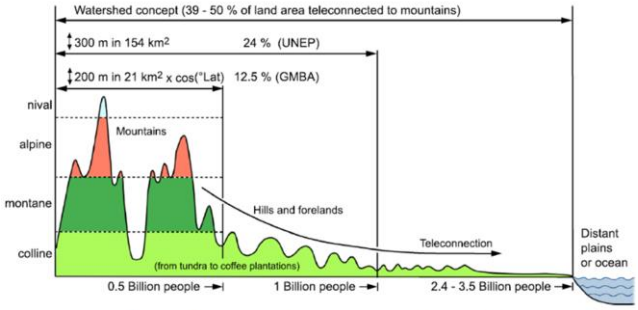
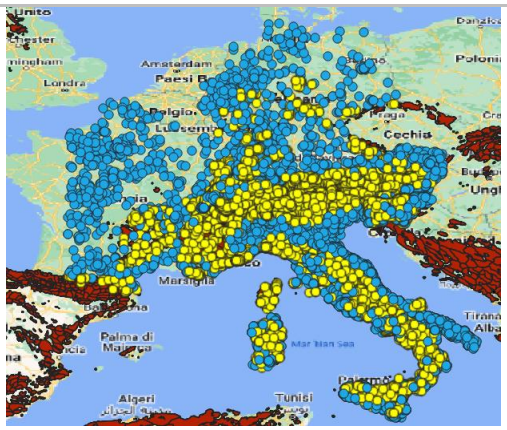
References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) **Analysing the resilience and competitiveness of manufacturing companies located in mountain regions**	Spoke 1 **RT2. 17**	Resilience of Mountain production systems and supply chains

Overall Objectives	The research aims to increase the manufacturing activities in mountain regions by encouraging firms to reshore and opening new facilities in mountain regions. To this end, the research will focus on increasing the resilience and competitiveness of manufacturing companies located in mountain regions in terms of economic, financial, innovation and sustainability performance.
Internal Actors	Guido Orzes – UNIBZ; Faisal Rasool – UNIBZ
Methodology	In the first phase, the European Reshoring Monitor database was consulted to locate cases where manufacturing companies have reshored to Northeast Italy. In the second phase, a list of 690,000 active companies in the manufacturing sector located in alpine countries (Austria, Germany, Italy, France, and Slovenia) was gathered from the ORBIS database. After preparing the dataset, further analysis was carried out on the acquired dataset. To make the dataset manageable, 10% of the companies were randomly selected from the database. To keep the sample relevant, the ratio of country, firm size and sector was maintained in the new data set. To perform the analysis, the countries that have data available for 2022 and later were selected. As a result, 34,371 companies were included in further research. Following the GMBA definition, the firms were classified into mountain and non-mountain companies. From the available data set of 34,371 companies, 6,668 were located in mountain regions, while 27,703 firms were in non-mountain region. Further one-on-one propensity score matching resulted in a data set of 13,336 companies. The matching was performed by restricting the criteria of size, country and sector.
Activities performed and results achieved	 Definitions of mountainous land by UNEP or GMBA (see Körner et al. 2021) In the first phase of the project, 52 cases from the European Reshoring Monitor database were identified that reshored in Northeast Italy between 2007 to 2022. The location of these cases was acquired by manually collecting the GPS coordinates of the case firms. None of the cases identified are located in the Mountain regions.  The GPS coordinates for the selected companies from the ORBIS database were procured using the R studio by installing "tidygeocoder" and "tidyverse" packages. Several alternative approaches were adopted to correctly procure the longitude and

Activities & results (continues)	latitude of the selected companies including manual Google search and Google API for missing data. The obtained GPS coordinates were plotted on the GMBA map of the mountains of the world.. After the processing, a list of Mountain and Non-Mountain companies was developed for further analysis. Indicators related to financial and economic performance, such as sales, profit margin, return on assets, etc, were retrieved from the ORBIS database for the selected companies. One-on-one matching was performed using the propensity score matching method to balance the dataset. The final data set had 6,500 companies located in Mountain regions and 24,500 companies in non-mountain regions. The Propensity score matching was conducted by utilising the factors of location (mountain, non-mountain), firm size, sector and country. Statistical analysis was carried out on the procured data on the years 2022 and 2018. The year 2022 was selected to include the maximum no of companies with the latest data. The tests on 2018 data were conducted as a robustness check and to register the performance before COVID-19. Contrary to the common belief, the preliminary results indicate that the companies in mountain regions perform better than the companies in non-mountain regions in terms of productivity, sales growth and return on assets, among other financial indicators. These results are useful as they show that even though the companies operating in mountain regions face difficulties in logistics and talent procurement perform better in several aspects than their counterparts located in non-mountain regions.



Country	Location1 Mountain	Non-Mount	Total
Austria	340	827	1,167
France	238	2,406	2,644
Germany	133	4,849	4,982
Italy	3,826	16,023	19,849
Slovenia	364	917	1,281
Switzerland	1,767	2,681	4,448
Total	6,668	27,703	34,371

```
Two-sample Wilcoxon rank-sum (Mann-Whitney) test

    Location2 |      Obs       Rank sum    Expected
--------------+---------------------------------
     Mountain |      469      916103.5    877733.5
 Non-Mountain |     3273     6087049.5   6125419.5
--------------+---------------------------------
     Combined |     3742        7003153     7003153

Unadjusted variance    4.788e+08
Adjustment for ties   -37.556744
                      ----------
Adjusted variance      4.788e+08

H0: Salesp~1(Locati~2==Mountain) = Salesp~1(Locati~2==Non-Mountain)
                z =   1.754
Prob > |z| =   0.0795

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Most relevant Publication # of Publications	Rasool F., Orzes G., Podrecca M., Molinaro M. "Summiting Success: The Unexpected Advantages of Mountain Manufacturing [data analysis completed – article draft in preparation] One journal article (draft in preparation)
External Actors and Stakeholders	Manufacturing companies, policymakers, service providers, mountain communities, universities and research centres, regional governments in mountain/alpine areas
Next steps	In the next step, we want to understand how to take advantage of the good performance of the companies in the mountains and translate them into policy actions to motivate firms to reshore and open new manufacturing facilities in mountain regions. At the end, we aim to improve the performance of firms located in mountain regions by identifying their weaknesses and proposing solutions. The study area of the reshored companies will be increased from Northeast Italy to Alpine countries to locate more reshoring cases. Once the companies that have reshored to mountain regions are identified, the study and understanding will also be deepened through direct interviews in the next year.
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iNEST
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RESEARCH TOPIC 3A

Decentralisation of Mountain Structures and Infrastructures – Energy Strategies

INTRODUCTION TO RESEARCH TOPIC 3A
ENERGY STRATEGIES

The RT3A of Spoke 1 involves the analysis and optimization of a set of aspects of particular relevance in the context of the Italian North-Eastern mountain environment, under both an engineering analysis and a modelling and simulation perspective. These aspects include 1) regional energy system modelling, 2) the engineering of hydropower reservoirs and district heating networks, 3) the integration of biomass into the broader renewable energy landscape, 4) the renovation of existing buildings for improved energy efficiency and indoor environmental quality, and 5) economic and social aspects of energy markets and policies.

Previous research conducted by the involved institutions (The Free University of Bozen-Bolzano and Eurac Research) and the wider scientific community as well as policy documents recently released by local authorities constitute the core background and state of the art of the research undertaken as part of iNEST activities.

Up to M2, literature review activities, methodological and experimental setups development as well as initial results have been achieved along with some publications and articles or proceedings submissions for review procedures.

More specifically, in the context of regional energy system modelling, the use of Python programming for power system analysis has been undertaken as a novel modelling methodology, while Marginal Abatement Cost curve analysis has been applied to the South Tyrolean territory yielding a first journal publication. Regarding hydropower engineering, experimental work has been conducted on the interaction between sediments and hydraulic structures through particle imagery velocimetry techniques indicating negligible velocity in the tank cavity and an increasing suspension capacity for increasing discharges, while numerical modelling on the BASEMENT platform was initiated to device operable sediment management techniques. The techno-economic aspects of bioenergy integration into fully renewable energy supply were investigated and applied to the case study of a public building in South Tyrol, yielding an article, currently under review, on the optimal sizing of storage and bioenergy components. An Urban Building Energy Modelling tool enabled optimizing a range of energy efficiency enhancement measures for efficiency, cost and sustainability, while the analysis of building archetypes conducted via intensive data surveying indicated that it is not possible to find clearly defined clusters due to the large number of data points obtained (more than 90000 for each province considered) but clearly identified a set of common construction materials (stone, wood and brick masonry). In addition, initial simulations conducted in Dolphin indicated that the hygrothermal performance of interior insulation depends on many parameters, including the type of existing wall and led to the hypothesis that the lambda of the existing wall plays an important role, while the effect of mu is negligible. A macroeconomic model was developed based on econometric techniques, to enable the separation of the effects of the pandemic and recovery while analysing the relative weight of single energy commodities and their substitutability and the identification of the role of fiscal and monetary institutions in energy shocks. A longer-term natural gas price forecasting model was also developed to serve an integration with other modelling tools developed within the RT in the coming year.

Operational challenges were limited to 1) delays encountered in operations at an external partner's site, that put off a data collection campaign to 2024, and 2) difficulties in the collection of data on buildings archetypes, that were highly dependent on prompt interactions with local authorities. Both obstacles were overcome by postponing and restricting the scope of the activities without affecting the outcomes of the research as of now.

The next steps planned by the RT3A team include several expansions and replications of the modelling and experimental activities developed as well as new interactions between different research topics that may lead to collaborative work and shared outputs in the coming year.

References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) **System modeling of energy supply and distribution in Alpine contexts**	Spoke 1 **RT3A. 01**	Decentralization of mountain structures and infrastructures *Energy strategies*
Overall Objectives	The Overall Objectives focus on developing integrated renewable energy systems for North-East Italy's mountain areas. This involves optimizing energy supply and distribution using advanced modeling techniques that address both technical-economic aspects and climate neutrality goals. An additional objective is monitoring of key indicators of the energy system transformation, including emissions, final energy consumption, and other critical metrics, to ensure an informed and measurable progression towards the project's sustainability and efficiency targets.		
Internal Actors	Steffi Misconel, Matteo Giacomo Prina, Giuseppe Rotondo , Wolfram Sparber - EURAC		
Methodology	To achieve the stated Overall Objectives, the methodology employed centers around the use of the Python for Power System Analysis (PyPSA) linear programming energy system framework. The Oemof framework has also been considered for this purpose but then the final choice has been to use PyPSA due to its larger community and flexibility. This framework is instrumental in optimizing energy supply and distribution, particularly in the complex and varied terrain of North-East Italy's mountain areas. In addition, the Marginal Abatement Cost Curve Analysis approach is crucial for evaluating the cost-effectiveness and potential of different energy transition measures. In this project, the MAC curve analysis focuses on incentives in South Tyrol, assessing their impact on CO_2 abatement costs and potential emission reductions. The methodology also includes monitoring key energy transformation indicators like emissions, final energy consumption, and other crucial metrics.		
Activities performed and results achieved	Energy System Modeling Using PyPSA • Initiation of PyPSA Usage: We have embarked on the use of the Python for Power System Analysis (PyPSA) framework, a significant step towards sophisticated energy system modeling. • Data Collection: Essential data on the transmission grid and generation units have been meticulously collected. This data forms the backbone of our energy system model, providing the necessary details for accurate simulation and analysis. • Model Setup: Currently, we are in the phase of setting up the PyPSA model. This involves integrating the collected data into the framework and configuring the model to accurately reflect the unique energy requirements and resources of the North-East Italian mountain areas. Monitoring Energy Indicators Collection of Historical Indicators: A comprehensive set of historical energy indicators has been compiled. These	Scientific Publication on Energies about the MAC curve evaluation of different local energy transition incentives: We have conducted an in-depth analysis of energy transition incentives, particularly focusing on their cost-effectiveness and potential for CO_2 emission reduction. The results of this analysis have been successfully published in a scientific paper on "Energies," contributing valuable insights to the field and aiding in the development of more efficient energy transition strategies. Upcoming Availability on Eurac Website: The collected indicators, including those from the "Klimaplan Monitoring South Tyrol," will soon be available on the Eurac Research website. This will provide public access to crucial information, enhancing transparency and informing both the public and policymakers about the ongoing	

Activities & results	indicators are crucial for monitoring the progress towards the Klimaplan targets and impact of energy transition initiatives in the region.	changes and challenges related to climate and energy in the region.
Most relevant Publication	Billi S, Prina MG, Castagna M, Sparber W. Assessing the Cost-Effectiveness of Incentives for Energy Transition Using Marginal Abatement Cost Curves. Energies 2023, Vol 16, Page 7412 2023;16:7412. https://doi.org/10.3390/EN16217412.	
External Actors and Stakeholders	Companies such as Alpitronic (charging station producer), EDYNA (distribution system operator), NEOGY, Leitner Energy, and public administration institution such as the Province of Bolzano.	
Next steps	Validation of PyPSA Model • **Model Validation with CO2 Emission Data**: This involves comparing the CO2 emissions projected by the model with those measured by various sources. This comparison is essential to ensure the reliability and accuracy of the model's predictions and its applicability in real-world scenarios. Development of Future Scenarios • **Scenario Development for 2030 and 2040**: We will develop different future scenarios targeting the years 2030 and 2040. These scenarios will be instrumental in understanding the pathways to achieve the targets set by the Klimaplan, a strategic framework for climate action. • **Identifying Cost-Effective Solutions**: A key objective in developing these scenarios is to identify the solutions that not only help meet the Klimaplan targets but also do so at the lowest possible cost. Impact of Electrification in Heating and Transport • **Assessing Electrification Impacts**: Electrification is a major component of the energy transition, and its implications on energy demand, system efficiency, and CO2 emissions need thorough evaluation. • **Testing Smart Charging and Vehicle-to-Grid Measures**: We plan to test and analyze various measures, including smart charging and vehicle-to-grid (V2G) technologies. These technologies are pivotal for enhancing the integration of renewable energy into the grid and reducing overall system costs. • **Improving Renewable Energy Integration**: The adoption of smart charging and V2G technologies is expected to improve the management of fluctuating renewable energy sources, such as solar and wind power. This, in turn, enhances the stability and efficiency of the energy grid. • **Cost and System Efficiency Analysis**: These technologies will also be analyzed for their potential to lower system costs. By optimizing the usage of renewable energy and reducing dependency on traditional energy sources, these measures could lead to significant economic benefits. Implementing a Near-Optimal Solution Approach • **Near-Optimal Solutions in PyPSA**: This approach is designed to identify solutions that, while not absolutely optimal, are very close to the ideal, considering the practical constraints of computational resources and real-world limitations. • **Balancing Ideal and Practical Solutions**: This method allows for a pragmatic balance between the ideal theoretical models and the practicalities of implementation in actual energy systems. It acknowledges that while perfect optimization might be unattainable due to various constraints, near-optimal solutions can still provide significant benefits and improvements. Development of Climate Change Impact Representations • **Impact of climate change on the energy system**: The aim is also to understand the potential impacts of climate change on the energy system, implement them in the PyPSA model and understand what is the additional cost needed to reach the energy targets due to climate change.	
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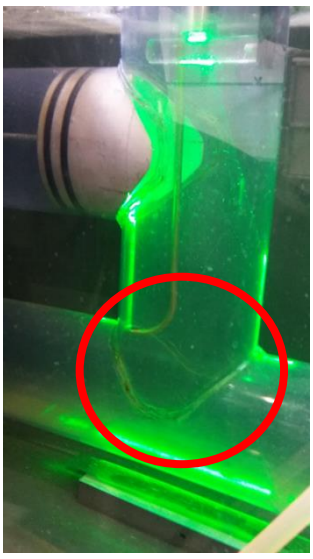
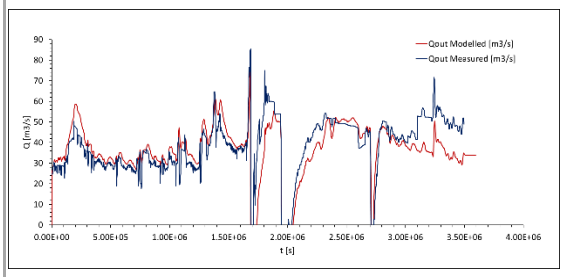
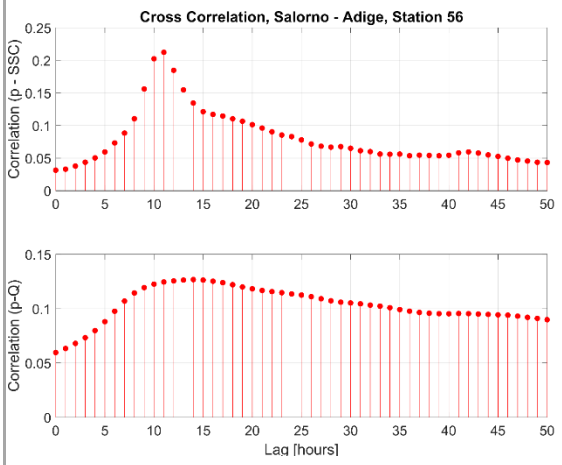
References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) **Use of renewable energy sources, sustainable hydropower plants design**	Spoke 1 **RT3A. 02**	Decentralization of mountain structures and infrastructures *Energy strategies*
Overall Objectives	Targeting the problem of the reservoirs' life duration due to the interaction with sediments		
Internal Actors	Maurizio Righetti – UNIBZ; Michele Larcher – UNIBZ; Giulia Stradiotti – UNIBZ		
Methodology	This research targets the problem of the long-term sustainability of hydropower plants though a combined approach: on one side, we study the interaction between sediments and hydraulic structures through lab experiments **(a)**, and the strategies for the management of sediments in reservoir through numerical modelling **(b)**; on the other, we study the features of the relation between precipitation and suspended sediment concentration in rivers, with the aim of developing a methodology for the turbidity forecast, to help managers reducing the siltation in the reservoirs with informed strategies **(c)**.		
Activities performed and results achieved	**(a)** We performed experiments in the lab to study the flow field in the T junction between the penstock and the surge tank through PIV: due to the sediment inlet, the lower chamber of the surge tank may get silted, interfering with the designed hydraulic function of the system. The hydraulic scheme can be traced back to the case of the well-know cavity flow, but on the vertical plane. The experimental results show that the velocity is negligible in the cavity, whereas the Reynolds intensities exhibit a peak in the cavity inlet, and their value increases for increasing flow rates. Additionally, the shear layer thickness in the junction increases along the flow direction, and the rate of increase was found to be a decreasing function of the flow discharge, in agreement with literature studies on a lateral cavity flow. Defining the suspension capacity of the flow as the ratio between the falling velocity and the Reynolds intensities relative to quadrants Q1 and Q2, the results show that such capacity increases for increasing discharges.	 Figure 6 Experimental apparatus.	

Activities & results (continues)	**(b)** We identified a case study for modelling the application of different managing strategies for limiting the deposition of the sediments in the reservoirs and to remove the accumulated ones. Such case study (Fortezza- Franzensfeste Reservoir, South Tyrol) exhibits the typical features of an alpine reservoir, as it is long and narrow because of the conformation of the valley where it is located, and it is subjected to periodical flushings (every 4-5 years), due to the sediment yield from upstream. To compare different managing strategies, we performed the calibration of the numerical model (adopting the software BASEMENT) by tuning the parameters on a recorded event. **(c)** Alongside defining the best strategies to minimize the siltation in reservoirs, the prediction of the incoming sediment wave can help the hydropower plant manager in planning efficient measures. We carried out a literature review, and to our knowledge, little has been done in the forecasting of turbidity from precipitation data. To this aim, we collected the data from the turbidimeters, the gauging stations, and the pluviometers installed by the Province of Bozen-Bolzano and we carried out an analysis of the relations between the variables.
	 Figure 7 Calibration result on the outflow discharge.
	 Figure 8 Cross correlation between precipitation and turbidity, and precipitation and discharge for one pluviometric station in a South-Tyrol sub-basin.
Most relevant Publication *# of Publications*	Oral presentation in the 40th IAHR World Congress "Flow field in the T junction between the penstock and the surge tank: an experimental study" 2 Abstracts submitted for the 8th IAHR Europe Congress
External Actors and Stakeholders	Companies producing energy through hydropower generation and managing reservoirs, as Alperia SpA.
Next steps	Following the successful calibration of the model, we will compare alternative scenarios for the management of sediments in an Alpine reservoir, and we will start comparing the relative results with those obtained by applying a different numerical model (a). Based on the analysis of the features relating precipitation, discharge, and turbidity, we will start applying machine learning models to understand if they lead to promising results for the forecasting of the suspended sediment inlet in hydropower reservoirs (c).
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References and Research Title	Milestone M2 (Jan 2023 – Dec 2023)	Spoke 1	Decentralization of mountain structures and infrastructures
	Bioenergy as a source of complementary dispatchable renewable power in mountain areas	**RT3A. 03**	*Energy strategies*

Overall Objectives	1) Develop a flexible techno-economic model describing power supply through biomass systems, drawing on real industrial data 2) Apply the model to a relevant case study, in specific by looking at a public building energy demand profile and at the role of bioenergy as a complementary generator alongside photovoltaic and storage 3) Identify the economic implications of the use of biomass as a dispatchable power source and determine the subsidization needs related to its feasible adoption
Internal Actors	Lorenzo Menin – UNIBZ; Marco Baratieri – UNIBZ
Methodology	The work combined consolidated **techno-economic modelling techniques based on a net present value approach** with the **analysis and simple forecast of a public building electricity load profile** to determine the required size of a virtual bioenergy generator connected to the building, and thus to estimate the levelized cost of energy delivered by the generator. Interestingly, the study relied on **real industrial data** retrieved from operating bioenergy plants in a previous plant monitoring campaign conducted by UNIBZ. A **Python program** was developed to generate a demand-PV generation **mismatch curve** and thus size a suitable complementary generator. An **electrochemical storage** plant was first considered as a means of redistributing PV power surpluses over deficit periods. The hypothesis was made that the building is supplied by another variable virtual connected generator (a solar photovoltaic plant), with a fixed peak power size. A **discrete levelized cost optimization** was thus applied to find the **optimal bioenergy generator size** delivering the lowest levelized cost of energy to the building. Finally, fixing the optimal bioenergy generator size, a **sensitivity analysis** of different economic conditions was conducted to identify the most appropriate subsidization strategy capable to reach price parity with electricity generated from other renewable or low-carbon vectors.
Activities performed and results achieved	Electricity load profiles were obtained from historical consumption billed to the main UNIBZ building in Bolzano, Italy, and were projected into the future over a 20-year horizon, by applying demand growth factors in line with other forecast models available in the literature. Similarly, historical PV generation data were retrieved from the EU JRC PV-GIS platform and projected over the remaining time horizon as an average of historical data (Fig. 1). With the available data, a demand-generation mismatch curve could be obtained, indicating a yearly average surplus of 284 MWh/y from the PV generator and a yearly average power deficit of 1972 MWh/y. By considering the magnitude of the available surplus loads, it was found that the use of electrochemical storage would be suboptimal at any selected storage size, due to currently high capital costs and low capacity factors.

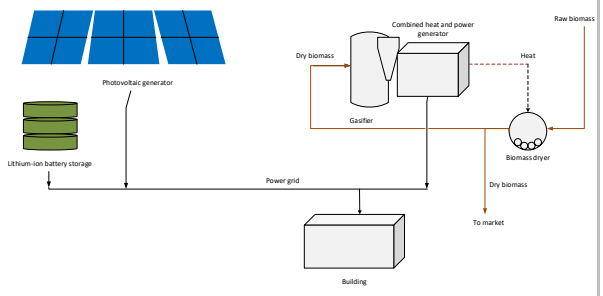


Fig. 1. Conceptual system diagram

Activities & results (continues)	The discrete optimization of the bioenergy generator size indicated that the lowest LCOEs could be found at a bioenergy peak power of 190 kW (LCOE = 217 €/MWh with PV plant size: 1 MWp, grid electricity purchase cost: 300 €/MWh , **Errore. L'origine riferimento non è stata trovata.**), under pessimistic grid electricity cost condition (300 €/MWh), or equal to zero under optimistic grid electricity cost conditions (200 €/MWh). The selling price of the dried biomass by-product delivered by the bioenergy generator was found to be a prominent factor influencing LCOE, with a linear slope of 1.55 t/MWh on the average LCOE sustained by the building (Fig. 2). The sensitivity analysis also showed that at biomass cost of 80 €/t and a dry biomass selling price of 165 €/t, the average LCOE could move below a 200 €/MWh threshold. An appraisal of prospective subsidization mechanisms, including three combinations of tariff-based remunerations, and a capacity market mechanism showed that a single 234 €/MWh subsidy granted on the generated bioenergy or a capacity market with capacity premia up to 1000 €/kW/y would be ineffective support mechanisms for the case study proposed (**Errore. L 'origine riferimento non è stata trovata.**). Instead, a single subsidy on solar energy self-consumption (110 €/MWh) or a double subsidy on bioenergy and solar energy self-consumption would be abundantly sufficient in delivering a competitive economic profile for the adoption of integrated PV-bioenergy virtual power plant systems. The results of the study provide an initial evidence basis and a replicable methodology for the assessment of integrated PV-bioenergy concepts capable of granting renewable energy self-reliance for buildings in regions with accessibility to biomass resources and in line with the EU Green Deal and Italy's Recovery and Resilience Plan.

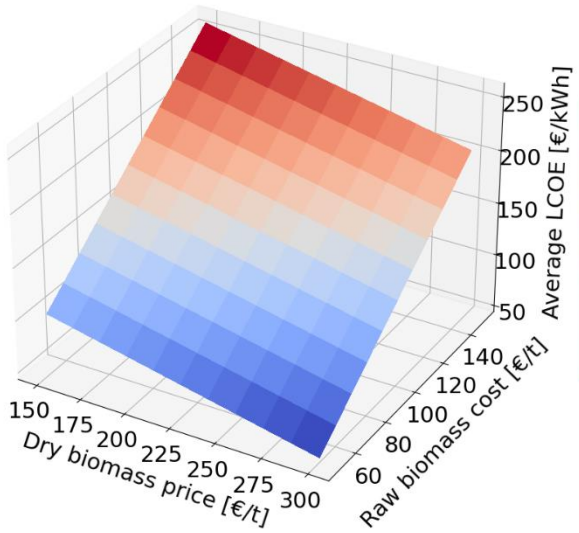


Fig. 2. Variation of the bioenergy component LCOE (left) and weighted average system LCOE (right) against raw biomass cost and dried biomass selling price for a fixed bioenergy selling price (150 €/MWh).

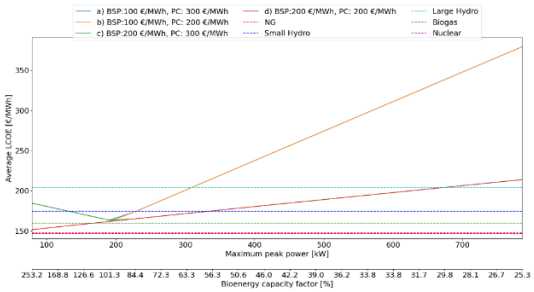


Fig. 3. Variation of the average system LCOE against the variation in bioenergy design power

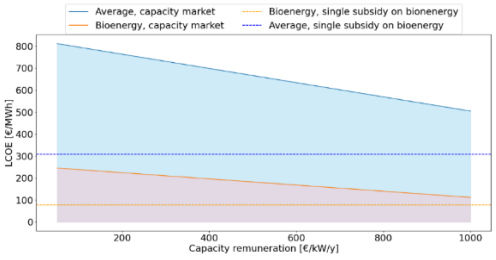
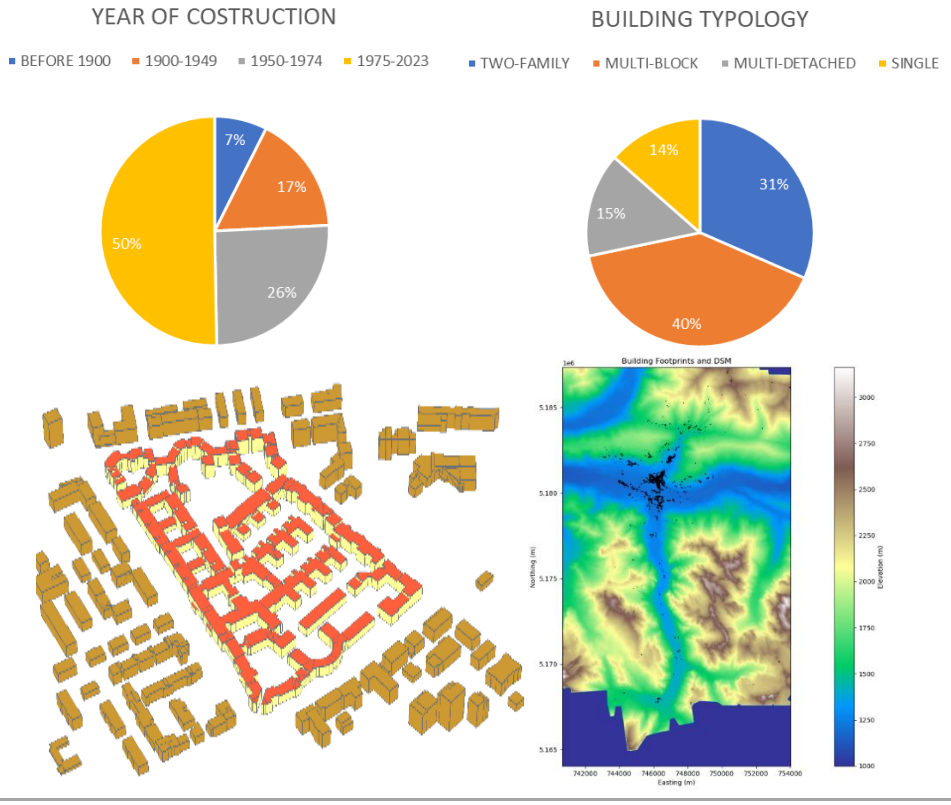
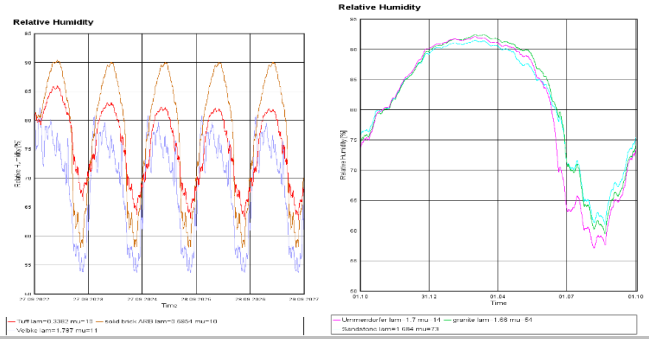


Fig. 4. Effect of the capacity market mechanism on the bioenergy and average system LCOE for capacity premia between 50 and 1000 €/kW/y.

Most relevant Publication	Menin L., Piazzi, S., Antolini, D., Baratieri, M. "*Bioenergy, photovoltaic and battery storage for fully renewable electricity supply to buildings: a techno-economic analysis of cost conditions and subsidization mechanisms for a public building case study in Italian mountain region*" [article submitted to the Sustainable Energy Research journal]
# of Publications	2 journal article (submitted) and 1 conference presentation (submitted for oral presentation)
Next steps	The results and the methodology will be used in two possible directions: 1) make use of a forecast of energy commodities data to simulate the effect of realistic market conditions on the feasibility of the proposed concept (together with Prof. Ravazzolo and Dr. Paolillo), 2) conduct a similar study on the production of decarbonized biofuels for high temperature heat provision making use of realistic market conditions in the assessment of its economics (together with Prof. Ravazzolo and Dr. Paolillo).

References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) **Definition of archetypes' properties for the characterization of the Alpine building stock**	Spoke 1 **RT3A. 04**	Decentralization of mountain structures and infrastructures *Energy strategies*
Overall Objectives	Identification of energy efficiency measures for an extensive application to the existing building stock in mountain environment, selected through multi-objective optimization techniques accounting for several goals (e.g., energy, economic, indoor environmental quality, sustainability goals) and tested at both single-building and district-scale. Evaluation of IEQ in buildings in mountain environment and user-centred energy efficient solutions for mitigation and adaptation.		
Internal Actors	Giovanni Pernigotto– UNIBZ; Federico Battini – UNIBZ; Wilmer Pasut- UNIVE; Rigoberto Arambula - UNIVE		
Methodology	The research focused on two topics: (i) investigate the impact of subsidy strategies in different scenarios on the most suitable energy efficiency measures (EEMs) for a case study district in the city of Bolzano, and (ii) development of a methodology to identify buildings representative of the mountain existing building stock to identify the most suitable EEMs for climate resilience. The most suitable techniques and tools were identified to carry out the research and the necessary data collected. For what concerns the first topic, an Urban Building Energy Modeling tool was used to estimate the energy needs of the district and the results of the different scenarios analyzed and compared. On the other hand, for the second topic, a huge effort was required by the data collection by contacting the authorities of the different provinces involved in this study and then several clustering techniques were tested in order to select representative building of the mountain building stock. In addition, a literature review was performed to find the main characteristics of the building typologies present in the existing building stock of the Alps. Relevant information relevant information on traditional and contemporary building practices in mountain environments were retrieved from different sources: (i) publications on the development of typical architecture morphology and construction practices in mountain environments, (ii) scientific articles on the classification of large building stocks in the Alps, and (iii) directives and standards have been consulted to characterize buildings based on the location.		
Activities performed and results achieved	To model the district, CitySim was used as the modeling tool and an initial model of the district was developed that accurately reflected its current state. This model was validated against available energy consumption data. The district model was then further developed to investigate the impact of energy efficiency measures (EEMs) and subsidy strategies under different climatic (considering climate change), economic (considering inflation) and energy supply scenarios. The research unfolded as follows: The research considered three main objectives that included energy, economic and sustainability performance as a focal point. The results aimed to advocate the economic viability of investments and to identify the EEMs that provide optimal solutions within the Pareto front of each profitable case. This study was published as a journal paper in the MDPI journal Energies in August 2023. To define building archetypes representative of the building stock, a preliminary analysis on data of the Environmental Agency of Trento was conducted. Data include specific information about the geometry, age, location and conditioning systems, which were analyzed and synthetically described the mountain building stock of the area. In addition, contacts have been established with the relevant energy labeling authorities in the Italian provinces of interest, namely Belluno, Bolzano-Bozen, Pordenone, Trento and Udine. This would make it possible to collect the necessary information to create reliable building energy models. Although the process of collecting data from various authorities was time consuming, it was possible to obtain the data sets for the provinces of Trento and Bolzano-Bozen. Similarly, the authorities were contacted to obtain the digital elevation data of the		

	areas in order to collect the geometric characteristics of the buildings, and the necessary data were obtained only for the provinces of Bolzano-Bozen and Trento. The geometric data of the buildings in each province in Zone F were collected using a 9-step procedure. For each building it was possible to retrieve its elevation, area, height, perimeter, orientation of the sides, and sky view factor. Once the geometric data was obtained, it was analyzed to find groups of similar buildings to create building archetypes. Dimensionality reduction techniques were used to perform a preliminary analysis to identify groups of similar buildings. Then, different clustering methods were used to identify clusters of buildings. The analysis performed allowed to understand that it is not possible to find clearly defined clusters due to the large number of data points obtained (more than 90000 for each province) and the similarity of the distribution of the building characteristics. Therefore, other methods such as sampling the distributions will be pursued to define building archetypes. To complete the definition of the building archetypes, the typical construction techniques in the mountain context have been analyzed to define the representative construction materials and technologies, and thus the thermophysical characteristics of the typical building envelopes. The most common materials are stone, wood and brick masonry, present both in the form of wooden frames with stone or brick facing and in the form of solid brick or stone walls. The current research is still under development, although the main results will result in a journal paper by the end of 2024.
	
Most relevant Publication	Battini F., Pernigotto G., Morandi G., Gasparella A., and Kämpf J. H. "*Assessment of Subsidization Strategies for Multi-Objective Optimization of Energy Efficiency Measures for Building Renovation at District Scale*" Energies 16, no. 15 (August 2023), 5780. https://doi.org/10.3390/en16155780 Battini F., Pernigotto G., and Gasparella A. "*Influence of radiation modeling on a simplification shoeboxing algorithm for Urban and Building Energy Modeling*", Proceedings of Building Simulation 2023 (2023), Bruges, Belgium, 4th-6th September 2023
# of Publications	1 journal paper and 2 conference proceeding paper
Next steps	Use alternative techniques to identify buildings representative of the mountain building stock. Implementation of energy efficiency measures on the create representative building models to optimize their operation with respect to several objective considering climate change.

References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) **Energy performance and renovation of existing building stock in mountain areas**	Spoke 1 **RT3A. 05**	Decentralization of mountain structures and infrastructures *Energy strategies*
Overall Objectives	Identification of best practice and robust solutions for the energy retrofit of the historic building stock with special focus on hygrothermal aspects		
Internal Actors	Alexandra Troi – Eurac Research; Eleonora Leonardi – Eurac Research		
Methodology	The research focused on the following topics: (i) investigate and quantify the performance of energy renovation of historic buildings and (ii) investigate with advanced hygrothermal simulations specific needs in historic buildings as well as opportunities deriving from the combination of traditional solutions with innovative materials. For the specific focus on historic buildings, the analysed data is based on the one hand side on the case studies collected with the IEA SHC Task59 Renovating Historic Buildings Towards Zero Energy and documented in the "Historic Buildings Energy Retrofit Atlas" (www.hiberatlas.com) on the other hand side on cases identified in the Interreg project SHELTER as well as data collected in the frame of a running PhD at Eurac Research. As for the hygrothermal aspects, specific needs deriving both from the analysis of real cases and from stakeholders are addressed via simulations with Delphin. This includes parametric analysis and sensibility studies for changing boundary conditions and material characteristics with the aim to investigate the opportunities of combining traditional knowledge and innovative materials as well as to improve the robustness and at the same time ambition of retrofit solutions.		
Activities performed and results achieved	From From Eurac Research side, the focus in this first year was on the one hand side on the material characterization and advanced simulation of two approaches to combine traditional materials with innovative concepts for the retrofit of historic buildings: the hygrothermal characterization of a lime plaster with recycled and/or innovative materials as e.g. aerogel used as interior insulation, and assessing the impact of moisture buffering value of interior finishing layers on indoor environmental quality for a recycled material plaster. In both cases data have been elaborated to be presented at conferences and papers are being elaborated. To give some details, the performance of interior insulation depends on many parameters, among them the type of existing wall plays an important role. The study of an aerogel-based interior insulation plaster tested in our laboratory and subsequently tested by means of simulations had led to the hypothesis that the lambda of the existing wall plays an important role, while the effect of mu is negligible. The aim of the paper is to test this hypothesis for several outdoor and indoor climates and for several insulation thicknesses. 		

	On the other hand side, the quantitative analysis of the best practice energy retrofits and respective conclusions are being submitted to a special issue of the journal Heritage. The comprehensive and further analysis of the data from the SHELTER project activities in Valbrenta (energy self-sufficiency of an alpine hut from the refurbishment of an ex- tobacco farm) led to the presentation at the SDEWES conference and has been submitted to a special issue in the journal Energies. Finally, measured and monitored data on both retrofitted and not retrofitted historic buildings are being brought together – a first selection of results has been presented and discussed at the conference "Denkmal-Dämmung-Wand" at the Bauarchiv (archive of historic building elements of the Bacarian heritage authority) with the stakeholder community and will feed into a more comprehensive journal publication next year. Moreover, as partner in the NEB lab "New European Bauhaus of the Mountains" Eurac Research (i) contributed to a brokerage event in Brussels early this summer, (ii) investigated the collaboration possibilities with BASIS Schlanders as a case study which resulted in a proposal being written for the Horizon Europe Call in February 2024 and (iii) contributed to the preparation of the workshop and congress "NEB meets 39100 BZ+" with a presentation on climate neutrality in historic buildings. These activities are considered key to on the one hand size guarantee a strong interaction with local stakeholders and at the same time benchmark results in an international network.
Most relevant Publication *# of Publications*	Journals Herrera-Avellanosa D., Haas F., Exner D., Hüttler W., Kuchar S., Rose J., Thomsen K.E., Leijonhufvud G., Broström T., Troi A. (submitted to Heritage) *Best practices in energy retrofit of historic buildings: a repository to demonstrate and upscale energy conservation potential* Bottino-Leone D., Exner D., Adami J., Balest J. Troi A., (submitted to Energies), *Study for the energy self-sufficiency of an alpine hut from the refurbishment of an ex- tobacco farm in Valbrenta through the introduction of Building Integrated Photovoltaic (BIPV) technologies* Presentations Troi A. Climate neutrality in historic buildings. New Eureopan Bauhaus of the Mountains meets 39100 BZ+, Bolzano, 19.6.2023 Troi A. Keynote: Moisture safe decarbonization. Understanding and communicating the role of moisture in a safe decarbonisation of the built environment. ICMB23 - 2nd International Conference on Moisture in Buildings 2023, London, 3.-4.7.2023 1 journal papers submitted 4 presentations at conferences 1 keynote at conference 1 presentation at stakeholder event
External Actors and Stakeholders	
Next steps	Selecting case studies for the retrofit of historic buildings. Advanced hygrothermal simulation of key points for mitigation and adaptation measures as well as characterization of traditional materials (pure or combined with innovative materials)

References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) **Economic and social aspects of energy policy in the Alpine region**	Spoke 1 **RT3A. 06**	Decentralization of mountain structures and infrastructures *Energy strategies*

Overall Objectives	Identifying the effects of the recent large shocks on the supply of energy and evaluating the impacts of alternative energy policies.
Internal Actors	Francesco Ravazzolo – UNIBZ; Aldo Paolillo – UNIBZ.
Methodology	Our research has focused on two main economic and econometric methodologies. First, we have made use of a **Dynamic Stochastic General Equilibrium (DSGE)** modelling technique to identify the transmission of large energy shocks. Second, we have employed a time series model with **Time-Varying trend and Stochastic Volatility (TV-SV)** to forecast the price of natural gas in the long run.
Activities performed and results achieved	We developed and estimated a state-of-the-art **macroeconomic model** with a core sector and an energy sector. In the model, we have included three crude energy sources (oil, coal, and gas) to describe the **transformation of crude energy into refined energy.** The model was estimated on updated data series regarding both economic and energy-related variables. Through model simulations, we have studied the **impacts of recent large shocks to the price of energy on the economic system.** Simulations include: (i) disentangling the effects of pandemic shocks (2020) and recovery shocks (2021 and beyond) on the economy; (ii) assessing the relative importance of oil, coal, and gas; (iii) analyzing the role of the substitutability of energy in the transmission of shocks; (iv) addressing the role of fiscal and monetary institutions in mitigating energy shocks. To better analyze the interdependence between the supply of crude energy sources, we have proposed an extension of the model where the

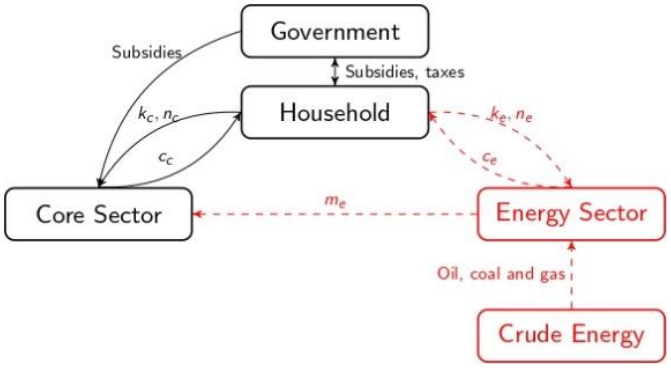


Figure 9: The flowchart of the two-sector DSGE model.

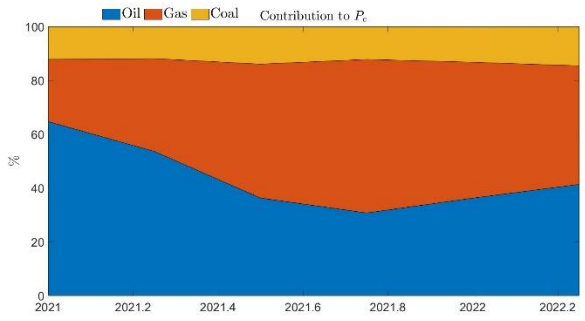


Figure 10: The relative contribution of oil, coal and gas to the movement of the energy price level.

Activities & results (continues)	prices of oil, coal, and gas depend on **a common component and on global economic conditions**. The second strand of our research has focused on forecasting the price of natural gas in the long run (the next ten years). To do so, we have made use of a time-varying trend and stochastic volatility model, that **can deal with the recent large movements in this market.** These forecasts are the basis for an energy price estimation framework suitable for **integration with other techno-economic renewable generation modeling studies**, first and foremost, those related to the evaluation of renewable power plants proposed by other research subtopics.

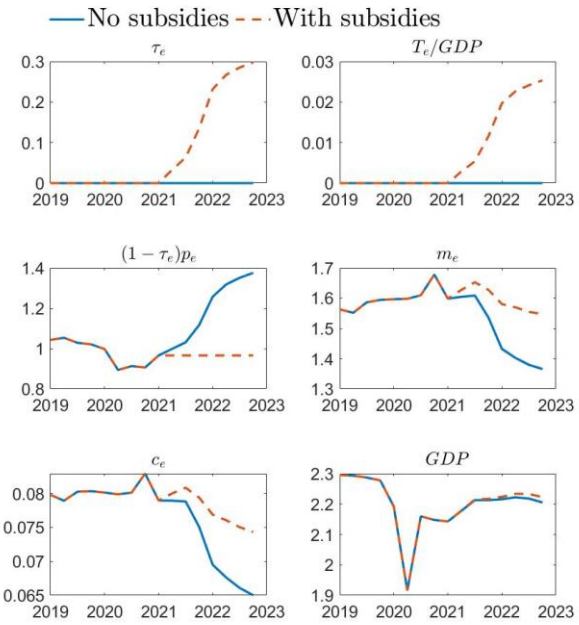


Figure 11: Simulation of a policy intervention to subsidize the price of energy faced by households and firms.

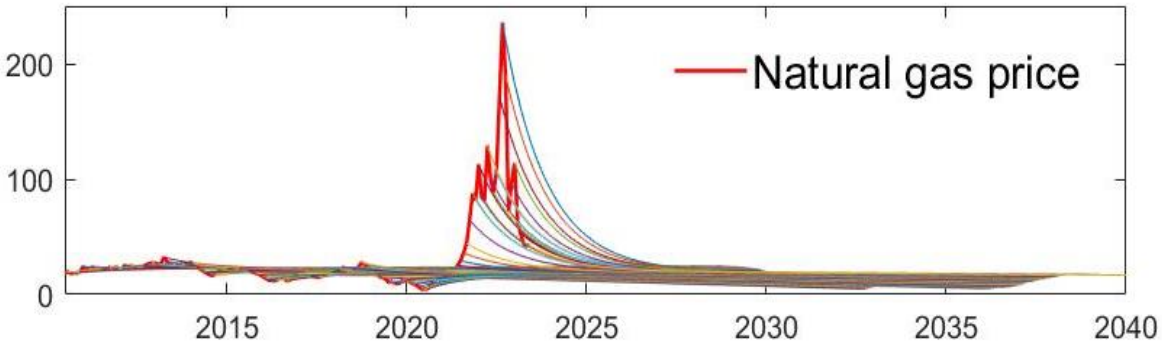


Figure 12: Forecast of the price of natural gas in the long run.

Most relevant Publication # of Publications	Corrado, L., Grassi, S., Paolillo, A., Ravazzolo, F. (2023). *Energy Shock, Pandemics and the Macroeconomy* [article draft ready]. 1 journal article (draft ready)
External Actors and Stakeholders	//
Next steps	Based on the extended macroeconomic model where the prices of oil, coal, and gas depend on a common component and global economic conditions, we aim to estimate the model again to check the robustness of our findings. We expect to disseminate this study as a publicly available working paper as soon as possible. Based on the forecasts for the price of natural gas in the long run, we aim to finalize the connection with the other research subtopics.
Notes	//

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Ministero dell'Università e della Ricerca
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RESEARCH TOPIC 3B

Decentralisation of Mountain Structures and Infrastructures – Logistic Strategies

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INTRODUCTION TO RESEARCH TOPIC 3B

LOGISTIC STRATEGIES

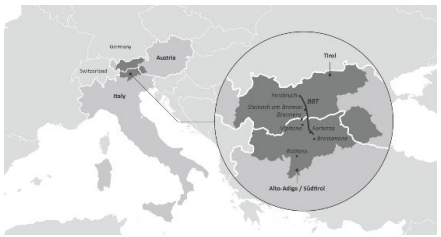
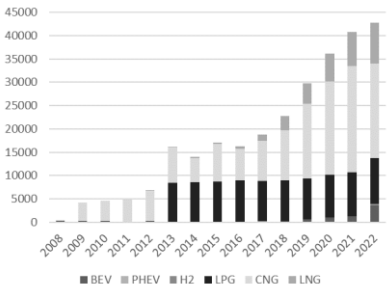
The overall goal of the RT3B is to study how the logistics sector revolution(s) can provide alternative strategic choices to achieve the dual objective of efficiency and decarbonisation in mountain transport, through the greening of propulsion systems of traditional road vehicles, the introduction of new vehicles or the widespread use of route optimisation systems. Indeed, the fact that we are facing an epochal change is evidenced by the striking increase in patents and publications on mountain logistics over the last two years, as shown by the work of the third RT working group.

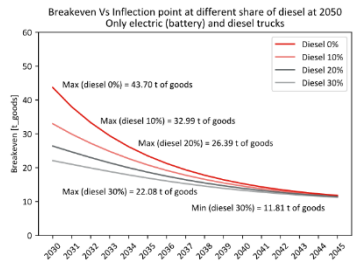
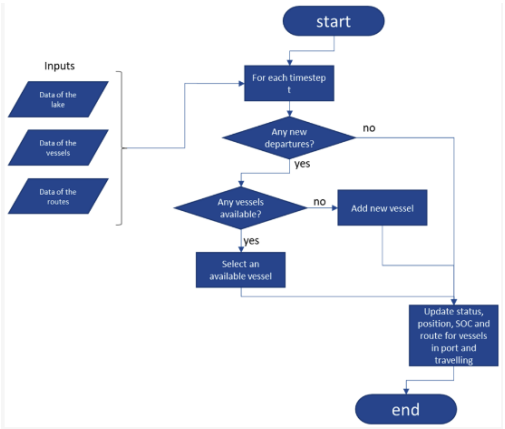
On this theoretical background of great interest, two specific topics unfold. The first focuses on determining the criteria according to which the most appropriate strategies for achieving de-carbonisation in transport in mountainous areas can be declined. The second aims to develop alternative ideas for micro-mobility, based mainly on redetermining the locations of logistics facilities, for wheeled vehicles, so as to optimise the connection between mountain areas and logistics facilities in the valley. In fact, the inadequacy of logistics facilities constitutes a major challenge to production in mountain areas, particularly in relation to greenhouse gas (GHG) emissions, noise and the general impact of traffic on existing facilities. This challenge is even more significant for agricultural production in the mountains. Indeed, in addition to the limitations imposed by the accessibility and usability of logistical infrastructures, it also adds to the perishability of the products transported.

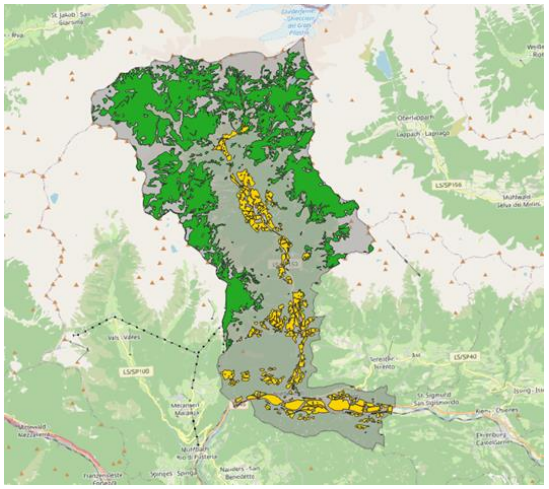
More in detail, in the first working group the focus was on the identification of suitable strategies for the de-carbonisation of the logistics sector in urban and rural mountainous areas, providing a breakeven point for assessing the complete substitution of wheeled transport powered by diesel fuels compared to rail transport, also calculating in the balance the overall CO2 production for the provision of railway lines.

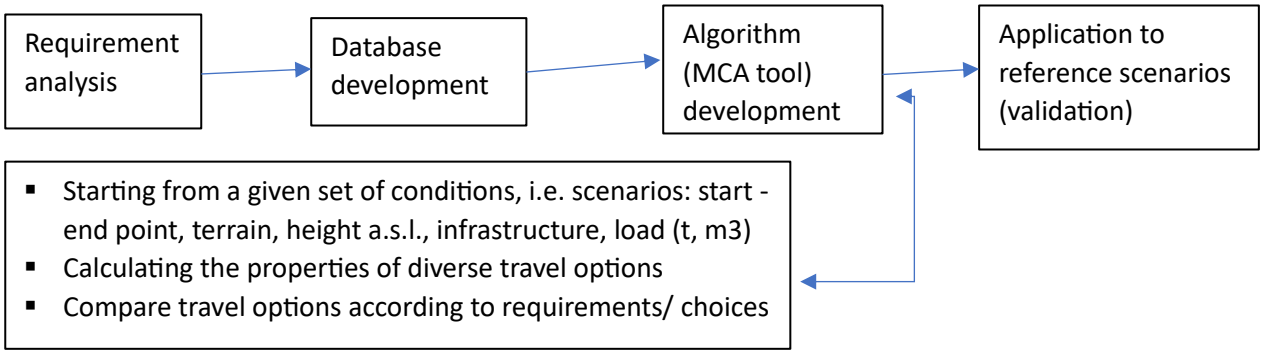
In the second, after GIS modelling of some significant areas in South Tyrol, the maps were processed through QGIS to show the pros and cons of the different transport options. From the first case studies, results are still at a preliminary stage, as conceptual and technical difficulties prevent precise and comparable results from being obtained. The next steps will see the formalisation of different logistical structures and micro-mobility scenarios, e.g. for milk production and cereal cultivation.

In the third group, based on the feedback received so far, the most promising technological solutions, both established and emerging, will be identified and scenario analyses will be started to improve the efficiency and sustainability of transport and logistics systems in mountain areas.

References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) **Strategies for the decarbonization of the logistic sector in mountainous areas**	Spoke 1 **RT3B. 01**	Decentralization of mountain structures and infrastructures *Logistics strategies*
Overall Objectives	Identification of strategies for the decarbonization of the logistics sector in urban and rural mountainous areas		
Internal Actors	Alyona Zubaryeva – EURAC RESEARCH, Wolfram Sparber – EURAC RESEARCH		
Methodology	The research is composed of several methodological approaches: • Literature review on the last-mile, long-haul fleet decarbonization policies and technologies; • Literature review on the existing strategies of public-transport-freight integration for urban-rural connections; • Structured logistics and decision-makers stakeholder assessment and opinion elicitation; • Methodological approach for road freight transport CO2 balance calculation; • Optimization model development for the optimization model to determine the minimum number of electric vehicles required to replace the existing diesel/petrol-based fleet of a given logistics sector.		
Activities performed and results achieved	We have performed a 1) detailed **literature review** on the trends in **long-haul truck electrification** (Fig. 2), indicating that battery electric and hydrogen-fuelled technologies are the two main zero-emission options that are seen to substitute the conventional diesel HDV. Both technological solutions present a high potential for the CO2 emission reduction both in well-to-wheel and tank-to-wheel assessment. It was found that more than half of TTW emissions in HDV sector can be reduced with the deployment of electric and hydrogen vehicles in Japan by 2050. 2) Calculation of **CO2 balance** of large-scale **train** infrastructures considering the impact of the **electrification of heavy-duty road transport** applied to a BBT tunnel case study (Fig 1). The results show that the electrification of freight transport reduces the relative disadvantage of long-distance road transport in terms of greenhouse gas emissions compared to rail (Fig 3). Nonetheless the infrastructure's sustainability goal of compensating the emissions generated during the construction phase could be relatively easily achieved under scenarios that do not assume a rapid penetration of electric trucks in the circulating mix. While in scenarios where electric trucks are adopted more abruptly the quantity of goods that needs to be shifted, combined with the current quantity of goods transported over rail, could become quite significant. However, the lower energy consumption and the contribution to lower traffic		 *Figure 13 BBT tunnel location*  *Figure 14 Total number of alternative fuelled (BEV, PHEV, H2, LPG, CNG, LNG) heavy duty trucks (N2&N3) in EU 5*

Activities & results (continues)	congestion and fatalities of railway transport remain a significant advantage. The former advantage will become increasingly significant in future scenarios featuring a completely decarbonized electricity mix and a zero-emission road transportation system.	 *Figure 15 Breakeven vs inflection point at different share of diesel trucks at 2050*
	3) First optimization model development for the optimization model to determine the minimum number of electric vehicles required to replace the existing diesel/petrol-based fleet of a given logistics sector. The optimization problem in this study can be formulated as a mixed-integer linear program, with the decision variables representing the number of vehicles and their assignments to routes, and constraints enforcing requirements like route coverage and vehicle charge levels. This problem structure represents the ideal mathematical formulation for finding the globally optimal fleet size and assignments (Fig 4).  *Figure 16 Diagram of the model*	
Most relevant Publication	Vaccaro, R, Maino, F., Zubaryeva, A., Sparber, W. 2023. CO2 balance of large-scale train infrastructures: An impact analysis considering the electrification of heavy-duty road transport. Manuscript submitted to IScience. D'Alonzo, V., Zambelli, P., Zilio, S., Zubaryeva, A., Grotto, A., & Sparber, W. (2023). Regional Infrastructure Planning Support Methodology for Public and Private Electrified Transport: A Mountain Case Study. Applied Sciences, 13(12), 7181. https://doi.org/10.3390/app13127181	
External Actors and Stakeholders	BBT management authority, logistic operators, public administration	
Next steps	- Perform a market analysis of light and heavy-duty vehicles for a given sector to be integrated in the model developed - Apply model for the logistics operations in a given sector (i.e. milk transportation in the mountains) - Perform a MCA analysis based on the stakeholder feedback; - Write a related publication; - Perform a detailed GIS-based analysis of the infrastructure needs to support the decarbonization model above based n D´Alonzo, V et al 2023. - Collaborate with the DIGITAL INNOVATION HUB for a sectorial analysis	
Notes	// Additional senior and junior staff need to be hired to support the research activities planned.	

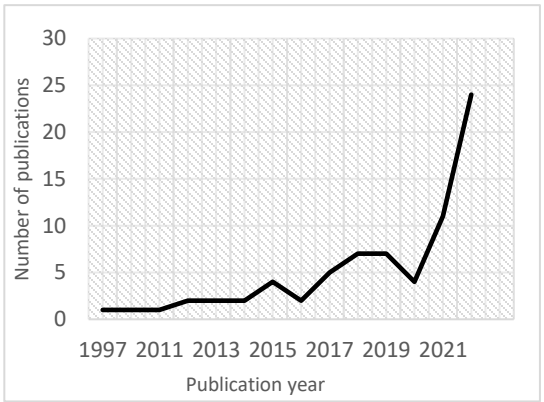
References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) **Ideas for wheel-based micromobility that connects mountain areas with the logistic structures of the valley**	Spoke 1 **RT3B. 02**	Decentralization of mountain structures and infrastructures *Logistics strategies*
Overall Objectives	The research seeks to develop alternative ideas for mainly wheel-based micromobility travel options that connect mountain areas with the logistic structures of the valley. We are building a geo-referenced database that allows to calculate certain parameters with regard to travel option and scenario in mountain areas.		
Internal Actors	Fabrizio Mazzetto – UNIBZ; Giovanni Carabin – UNIBZ; Merve Karaca – UNIBZ; Andreas Mandler - UNIBZ; Francesco Fabio Nicolosi - UNIBZ		
Methodology	Desk research and literature review, QGIS, design thinking, geo-databases		
Activities performed and results achieved	During the eleven months of the project iNest SP1 RT3B we worked on identifying potential and viable options to decentralize logistical structures in mountain areas. Inadequate logistic structures present a severe challenge to agricultural producers in mountain areas, especially with regard to the reduction of greenhouse gas (GHG) emissions, noise and general impact on traffic. Due to geo-morphological conditions, agricultural production in mountain areas has limited logistic accessibility and usability. Big machinery for agriculture or forestry is prohibited from entering and being used in mountain areas. At the same time, travel distances and time are significant, which constrains carriers to take additional measures (cooling) to protect agricultural produce as milk, cheese or meat.	 Fig. 1 Municipality of Vintl with visualization of cropland (yellow) and grassland (green)	
	The present research aims to evaluate alternative ideas for wheel-based micromobility travel options that connect mountain areas with the logistic structures of the valley. We are using a geo-referenced database to support a multicriteria analysis tool which allows us to compare different mobility options for a given scenario. We calculate certain parameters with regard to travel options and given scenario in mountain areas. This concerns the time for transporting materials in determined mountain environments (scenarios)		

Activities & results (continues)	according to evident parameters (kg, volume, t, costs, GHG emissions), using different travel options as conventional gasoline vehicles, cable cars, freight cableways, ground monorail and inox pipelines. ACTIVITIES PERFORMED Based on digital mapping models of some trial regions in South Tyrol, we have started elaborating these maps with QGIS to improve the database that effectively displays the pros and cons of the different travel options with regard to parameters and scenarios. Fig.1 shows eligible areas for the cultivation of grains in the municipality of Vintl-Vandoies. Based on the request made with QGIS, the geo-database of the autonomous province Bozen-Bolzano provides the information of potentially eligible areas. Having established the scenario (location, starting/ending points, land cover, height difference, infrastructure, etc) we aim to apply a second algorithm (Fig.2) to identify best logistical options to access this area in the perspective of certain transport choices (fast, low price, etc). We value to compare these logistical options in a designated area according to economic, social and environmental indicators using multicriteria analysis (MCA). The concrete integration of MCA into the geo-referenced algorithm is still subject to research, as well as the enlargement of the scenarios to social and economic criteria.  Fig.2 Scheme to calculate travel options RESULTS ARCHIEVED The algorithm applied on the QGIS assembled geo-databases for the municipality of Vintl was tested. The results are preliminary as conceptual and technical difficulties prevent precise, comparable results. Next steps will see the formalization of different logistic structures and micromobility scenarios, for instance milk production and cereal cultivation.
Most relevant Publication	Given the conceptual phase of the research, so far no publication has been submitted.
External Actors and Stakeholders	/
Next steps	Integrate multicriteria analysis in the process to further specify along socio-economic criteria the logistic choices proposed by the algorithm.
Notes	The described research is carried out in close relation to the activities RT2.2., to estimate potentials of niche production in mountain areas.

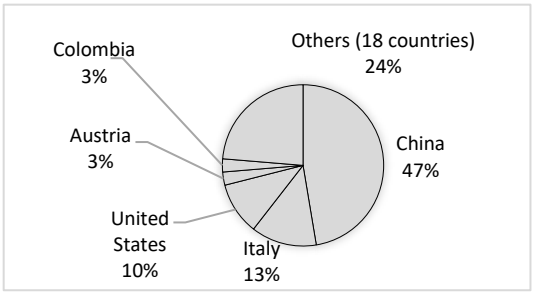
References and Research Title	Milestone M2 (Jan 2023 – Dec 2023) **Exploring mountain transport and logistics systems through literature review and patent analysis**	Spoke 1 **RT3B. 03**	Decentralization of mountain structures and infrastructures *Logistics strategies*

Overall Objectives	Identifying key technologies and solutions for improving efficiency and sustainability of transportation and logistics systems in mountain areas.
Internal Actors	Guido Orzes– UNIBZ; Mehari Teshome – UNIBZ; Faisal Rasool – UNIBZ
Methodology	The research is based on a twofold methodological approach. First, we rely on a **systematic literature review approach** to identify, frame and summarize existing academic contributions on transportation and logistics in mountain areas. Second, we perform a **patent analysis** to identify the main innovation trends on mountain transportation vectors. We identify patents through a keyword search in the Derwent Innovation Index database. We then apply unsupervised machine learning algorithms in Python, specifically Latent Dirichlet Allocation (LDA), to perform topic modelling on patent documents (abstracts). This approach allows for extracting underlying patterns related to mountain transportation vectors within the technological landscape.
Activities performed and results achieved	We identified, coded, analysed, and framed **76 scientific articles** on the topic of logistics in mountain areas. Both descriptive and thematic analyses have been performed. Considering the temporal distribution of papers, we observed a **consistent increase over time**. The fall in publication during 2023 is due to our search being conducted in the early months of the year. In addition, **most of the contributions was focused on China** (47% of papers). **Italy follows** with 13%, while (only) 10% of the papers focus on the United States. The remaining papers are distributed across a variety of other countries. **Four distinct thematic areas** were identified and summarized: **design of logistics infrastructure or vector, optimization of logistics systems, safety in logistics systems,** and **impact of logistics systems.** We then explored **further sub-themes within these categories**. For instance, the design theme covers infrastructure and transport vectors for freight and passenger mobility, including UAV system design, urban ropeway design, and electric vehicle charging infrastructure design. Similarly, optimization of logistics systems mainly

Temporal distribution of reviewed articles

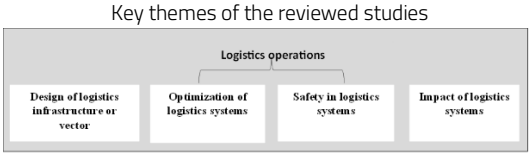


Distribution of publications by country

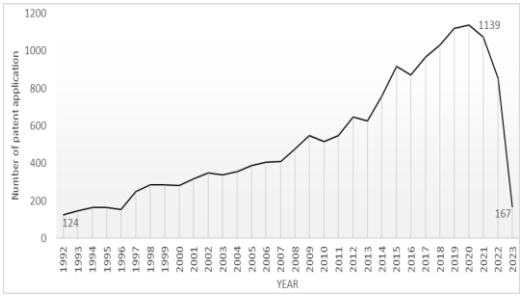


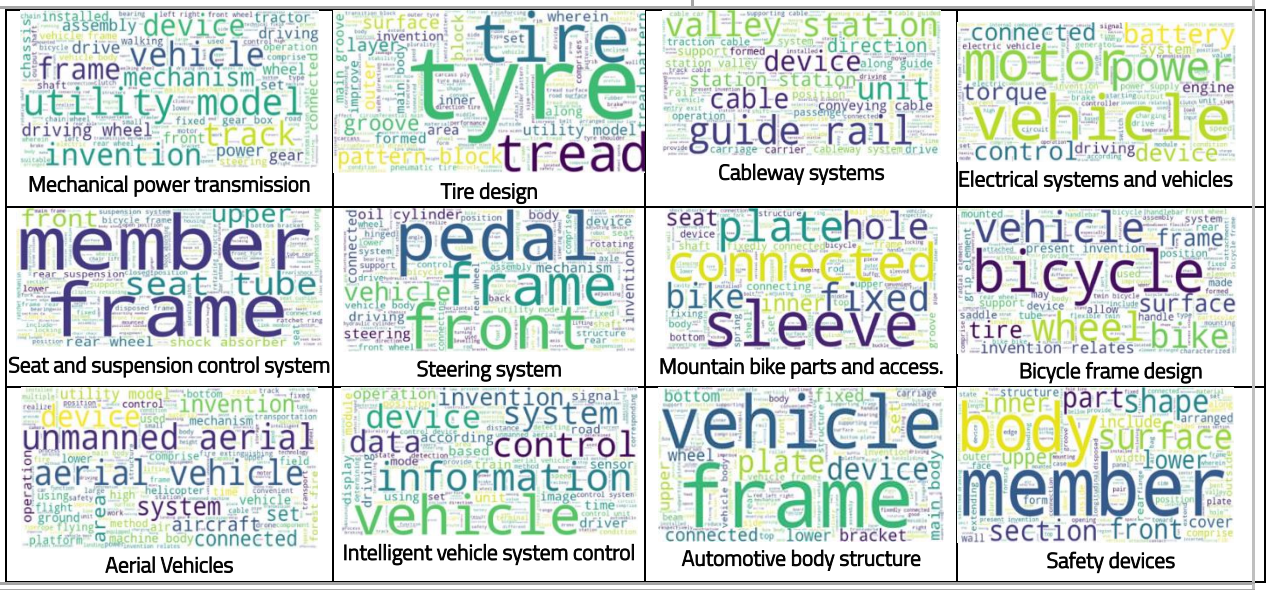
Activities & results (continues)	focuses on logistics operational activities that aim to optimize individual subcategories, which include transport network optimization, traffic flow monitoring and optimization, and last-mile logistics optimization. We then **identified over 7,084 patents** on logistics in mountain areas. We found a **growing trend in patent applications** over time, with China leading in patent applications by country followed by Japan and Korea, respectively. The drop in publication number in 2023 is because patent applications are published 18 months after the earliest priority date. We then **analysed** the patents **through** unsupervised **machine learning** algorithms, identifying **12 key technological areas/clusters**. These clusters were then labelled and defined based on reading abstracts of patents with high document-to-topic probability.

Key themes of the reviewed studies



Annual number of patents (1992 - 2023) on logistics in mountain areas





Most relevant Publication *# of Publications*	Teshome M., Rasool F., Orzes G., "*Mountain logistics: A systematic literature review*" [article draft ready for submission] 2 journal articles (draft ready)
External Actors and Stakeholders	Companies producing components, vehicles and solutions for transportation of goods and people, logistics service providers, local public transport companies, universities and research centres. Examples: Leitner Ropeways, STA - Strutture Trasporto Alto Adige SpA, Gruber Logistic
Next steps	Based on the analyses conducted (literature review and patent analysis) we will define most promising established and emerging technologies and solutions and we will start to carry out scenario analyses to improve efficiency and sustainability of transportation and logistics systems in mountain areas.
Notes	//