Book of Abstracts RETURN Dissemination Workshop

Original
Book of Abstracts RETURN Dissemination Workshop / Costamagna, Elisa; Mazzoglio, Paola. - ELETTRONICO. - (2024), pp. 1-343. (Intervento presentato al convegno RETURN Dissemination Workshop tenutosi a Torino (IT) nel 1-2 February 2024) [10.5281/zenodo.10598007].

Published
DOI:10.5281/zenodo.10598007

Finanziato dall'Unione europea
NextGenerationEU

Ministero dell'Università e della Ricerca

Italiadomani
PIANO NAZIONALE DI RIPRESA E RESILIENZA

Return

Dissemination Workshop

Torino (Italy), 1-2 February 2024

BOOK OF ABSTRACTS

RETURN Dissemination Workshop
Torino (Italy), 1-2 February 2024
DOI: 10.5281/zenodo.10598007

Abstract Book Editors
Elisa Costamagna, Paola Mazzoglio

How to cite an abstract:

Author A., Author B., Author C. (2024). Title of the abstract, *RETURN Dissemination Workshop, Torino (Italy), 1-2 February 2024*. DOI: 10.5281/zenodo.10598007

This work was carried out within the RETURN Extended Partnership and received funding from the European Union Next-GenerationEU (National Recovery and Resilience Plan – NRRP, Mission 4, Component 2, Investment 1.3 – D.D. 1243 2/8/2022, PE0000005)

Table of contents

Multi-Spokes

Multi-scale analysis of flood risk to cultural heritage

Chiara Arrighi[1], Claudia De Lucia[1], Fabio Castelli[1]

(1) Department of Civil and Environmental Engineering, University of Florence, chiara.arrighi@unifi.it

Cultural heritage can be severely affected by floods with consequences going beyond monetary losses such as loss of cultural identity, historical or aesthetic values. The peculiarity of cultural heritage as exposed element makes risk analysis quite complex in terms of hazard, exposure and vulnerability assessment. The scale of analysis used to assess flood risk to cultural heritage reflects different stakeholder's perspectives and needs. In this work we aim at highlighting state-of-art methodologies at different scales to assess flood risk and what type of information is required/developed/detailed to move from one scale to another. The regional/national scale considers cultural heritage often as a point feature (Figueiredo et al., 2019; Arrighi et al., 2023) and usually aims at identifying geographic damage hotspots, i.e., river basin authority perspective. The site/city scale usually considers cultural heritage as a polygon feature with a better description of flood depths and of building characteristics based on constructive typologies (Arrighi et al., 2022) it identifies risk priorities and potential damage, i.e. mayors' perspective. The building scale analysis, i.e., heritage manager perspective, requires moving towards a 3D geometric description of the cultural building by incorporating elevations of features with respect to the terrain to better understand actual inundation depths and their effects. The building scale has been rarely addressed so far in flood risk studies, while seismic analysis started to focus on seismic action modelling on structures many years ago (Lagomarsino and Giovinazzi, 2006). Within the RETURN project a single building analysis of flood hazard has been performed by downscaling a city-scale inundation model to describe the inundation inside the structure. The method has been tested on the proof of concept of the Marino Marini Museum in Florence, where an on-site inspection has revealed the ingress points of floodwaters. A comparison with the historical records of the 1966 flood in the Museum, confirms the findings of the simulation.

References

Arrighi C., Carraresi A., Castelli F. (2022). Resilience of art cities to flood risk: a quantitative model based on depth-idleness correlation. *Journal of Flood Risk Management*, *15*(2), 1-15.

Arrighi C., Ballio F., Simonelli T. (2023) A GIS-based flood damage index for cultural heritage. *International Journal of Disaster Risk Reduction*, 90, 103654.

Figueiredo R., Romao X., Paupério E. (2019). Flood risk assessment of cultural heritage at large spatial scales: Framework and application to mainland Portugal. *Journal of Cultural Heritage*, 43, 163–174.

Lagomarsino S., Giovinazzi S. (2006). Macroseismic and mechanical models for the vulnerability assessment of current buildings. *Bull Earthq Eng*, 4(4), 445-463.

Effects of climate change on the general and on the occupational population: systematic/umbrella reviews with a focus on the urban setting

Francesca Borghi[1], Francesco Decataldo[1], Francesco Saverio Violante[1], Eva Vanna Lorenza Negri[1]

(1) Dept. of Medical and Surgical Sciences, University of Bologna, francesca.borghi12@unibo.it

Climate change has diverse effects on humans' health. To analyze these effects comprehensively, two different literature reviews are currently in preparation, focusing on the evaluation of the effects of climate change on (i) the general population and (ii) the occupationally exposed population.

Climate change and health effects in the general population: a systematic review and meta-analysis

We searched for scientific literature using three different databases (Scopus, Web of Science, and PubMed). A search query, incorporating a list of keywords (Table 1), was set up for each database. A total of 3.015 papers were initially identified, with 427, 390, and 2.198 papers retrieved from Scopus, Web of Science, and PubMed, respectively. After removal of 566 duplicate the total number of identified articles was 2.449. The articles underwent a two-tier screening process involving (i) title evaluation (resulting in the exclusion of 2.341 papers), and (ii) abstract evaluation (resulting in the exclusion of an additional 50 papers). The remaining 58 papers were then selected for full-text retrieval. We selected articles focusing on the evaluation of climate change effects on the general population (Table 1).Inclusion and exclusion criteria were as follows: scientific papers written in English, excluding conference proceedings, review articles, book chapters, case studies, toxicological studies, and animal studies. Phases ii-iii, (i.e., screening of the papers by title and abstract), were conducted independently by different authors to minimize potential operator dependent bias. The reporting of this will adhere to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) criteria guidelines, ensuring a systematic and transparent approach to the review process and reporting.

Preliminary results: Most of the studies identified were carried out in developed countries and investigated short-term effects of climate change. In particular, the effects reported refer to morbidity/mortality outcomes for the following disease groups: (i) cardiovascular diseases; (ii) blood pressure changes; (iii) stroke; (iv) chronic obstructive pulmonary disease; (v) vision problems; (vi) schizophrenia and other psychiatric disorders; (vii) pregnancy complications.

Next steps include the finalization of the systematic review and a focus specific for the urban setting.

Climate change and health effects in the occupationally exposed population: an umbrella review

The search of literature relating to the evaluation of the effects of climate change on the occupational population was also performed using three different databases (Scopus, Web of Science, and PubMed) (Table 1). A total of 2.005 articles were identified, with 874, 496, and 635 papers retrieved from Scopus, Web of Science, and PubMed, respectively. After removal of 555 duplicate entries the total number of screened articles was 1.450. Screening of the title and abstract led to the elimination of 1383 and 22 articles, respectively. We selected systematic reviews investigating effects of climate change on the occupational population. Exclusion/inclusion criteria of the articles were: scientific papers written in English, excluding conference proceedings, book chapters, case studies, toxicological studies, and animal studies. Screening of the articles by title and abstract was conducted independently by two different researchers to minimize potential operator-related errors. We will adhere to the PRISMA and PRIOR criteria guidelines, ensuring a systematic and transparent approach and reporting.

Next steps include (i) finalization of the umbrella review; (ii) review of studies reporting practices for risk prevention in the occupational setting (iii) focus on effects and preventive strategies in the urban setting.

Table 1 - Summary of the review processes.

	Review	
	General population	**Workers**
Review question	What are the effects of climate change (both in hot and cold seasons) on the health of the general population	What are the effects of climate change (both in hot and cold seasons) on the health of the occupational population
Participants	General population	Occupational population
Exposure	General population exposed to heat waves or other events caused by climate change	Occupational population exposed to heat waves or other events caused by climate change
Outcome	Morbidity and mortality from various causes	
Search platforms	PubMED, Scopus, Web of Science	
Search query	Climate change: “climate change” OR “global warming” OR “heat stress” OR “thermal stress” OR “heat strain” OR season* OR heat OR warmth OR temperature OR “apparent temperature” OR “heat index” OR cold OR “low temperature” OR winter OR cold-season OR wintertime AND “mortality” AND “general population”	Hazard exposure: "global warming" OR "climate change" OR "climate variability" OR "air temperature" OR "hot temperature" OR "temperature rising" OR heat OR "extreme weather" OR "extreme heat" OR "heat wave" OR flood* OR landslide* OR storm* OR drought* OR wildfire* OR hurricane*” AND Occupational: "work-related" OR "working environment" OR worker* OR "outdoors worker*" OR "workers' safety" OR "workers' health" OR "workplace exposure" OR "labor safety" OR occupation* OR "occupational exposure" OR "occupational medicine" OR "occupational risk" OR "occupational safety" OR "occupational hazard" OR "occupational health" OR "physical risks" OR "physical hazard" OR "chemical risks" OR "chemical hazard" OR "chemical exposure" OR "biological risks" OR "biological hazard" OR "biological exposure" OR "biohazard" AND Outcomes: cardiovascular OR renal OR respiratory OR kidney OR dehydration OR fatigue OR syncope OR faint* OR heatstroke OR exhaustion OR infection* OR "vector-borne infectious diseases" OR "heat stress" OR "heat strain" OR "heat stroke" OR "heat-related illness" OR mortality OR morbidity OR "acute death" OR injur* OR fatalit* OR safety OR "occupational diseases" OR "occupational health" OR "occupational injury"
Restrictions	We will exclude articles written not in English, literature reviews, conference proceedings, book chapters, case studies, toxicological studies, and animal studies. No publication date restriction	We will exclude articles written not in English, conference proceedings, book chapters, case studies, toxicological studies, and animal studies*. No publication date restriction. *We will focus only on systematic reviews

Preliminary bases on the extreme events analysis of past and future meteocean time series focused on the Calabria Tyrrhenian coast

Carolina Codato[1], Myrta Castellino[1], Gioele Ruffini[1], Mario Calabrese[2], Margherita Carmen Ciccaglione[2], Paolo De Girolamo[1]

(1) Dept. of Civil, Constructional and Environmental Engineering, “Sapienza” University of Rome, carolina.codato@uniroma1.it
(2) Dept. of Civil, Architectural and Environmental Engineering, University of Naples “Federico II”

During the era of global warming, it is important to look at the long-term change in essential physical parameters to define design loads and conduct risk assessments. In the coastal field, climate change will affect wind patterns, sea level, storm surge characteristics and their frequency. These changes will have a significant impact on wind-generated waves and the variation of their synthetic parameters, thus characterizing coastal flooding phenomena in the future, particularly along low-lying coastlines. The impact of extreme wave events on coastlines can result in severe damage to both infrastructure and surrounding areas. The combination of storm surge events and extreme wind waves will enhance the role of coastal flooding in the management of coastal areas and in the definition of long-term adaptation strategies (Pasquali et al., 2023). Therefore, studying and analyzing the risks associated with these phenomena is of utmost importance, with the goal of providing a tool that can be beneficial for the civilian and scientific communities. In this context, within the WP3/DV 3.1.c “Mapping of coastal flooding induced by extreme wind waves”, following analysis of a wide range of reconstructed and historical time series, a mapping of coastal flood areas resulting from extreme events will be provided (as proposed by Fanti et al., 2023).

Climate change can alter the intensity and direction of coastal waves, impacting vulnerable regions. A low-lying area with critical infrastructure along the Italian Mediterranean coast will be investigated. A comparative study between traditional and innovative methodologies that can address future climate scenarios will be developed. The methodology involves utilizing time series data provided by the Copernicus Climate Change Service (C3S) in collaboration with ECMWF. These time series are derived from global or regional scale wave models coupled with atmospheric models to integrate climate forcings. The conventional approach relies on utilizing a reconstructed ocean wave dataset within the ERA5-Reanalysis dataset (Hersbach et al., 2020), offering global coverage from 1940 to the present (referred to as ERA5), along with direct measurements extrapolated from the Italian national wave network (Rete Ondamentrica Nazionale - RON, ISPRA). The innovative approach involves employing another time series dataset that focuses on the coastal wave climate, detailing ocean surface wave parameters computed for a European-wide domain. This dataset enables an understanding of the wave climate's response to climate change across the Northwest European Shelf and Mediterranean Sea.

To assess the impact of climate change on the ocean surface wave field, the SAW wave model, implemented by ECMWF, has been utilized for numerical simulations across three distinct climate scenarios: the current (historical) climate, covering the period from 2001 to 2017, represented by another ERA5-Reanalysis product termed ERA5-RCP (Pörtner et al., 2019). Additionally, the wave time series are projected into future scenarios based on the “Representative Concentration Pathways” (RCP) 4.5 and 8.5, spanning the period from 2041 to 2100. RCPs serve as greenhouse gas emission scenarios used to evaluate potential climate change effects. These scenarios respectively represent the most optimistic (RCP 4.5) and “business as usual” (RCP 8.5) outlooks. The locations of the aforementioned time series are depicted in Figure 1. The black markers refer to the ERA5-RCP and RCP points positioned along the coast at a depth of approximately 20 m. As part of the NRRP RETURN extended partnership project, this methodology will be applied to a specific case study focused on the Tyrrhenian coast of Calabria. Examining Figure 1, the specific points of interest concerning the Calabria region pertain to Cetraro. In the figure, the blue marker denotes the closest point of the ERA5-RCP and RCP time series to the Cetraro wave buoy (red marker). The grey marker indicates the nearest location of the ERA5 reanalysis (from 1940 to present) in proximity to the Cetraro wave buoy. At this stage of the research project, attention is primarily given to the wave parameters. An upgrade of the study will concern a comprehensive data analysis of waves, sea levels and wind fields.

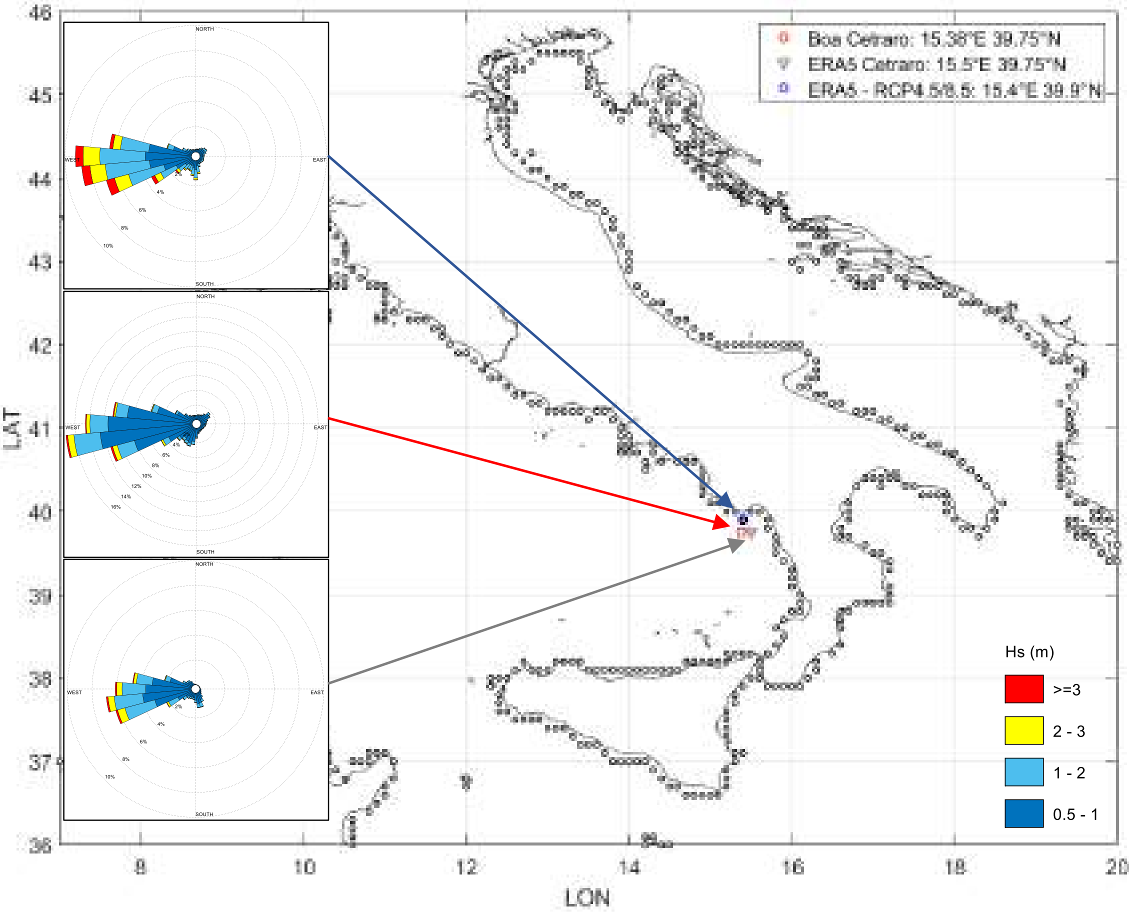


Figure 1 – Geographical location of the ERA5 RCP and RCP reanalysis time series (black marker), Cetraro wave buoy (red marker), and ERA5 Cetraro point (grey marker). In the wave roses, each concentrical circle has a 2% increment of frequency.

As a preliminary result, climate analysis is represented in the left of Figure 1. Starting from the top, the wave rose of the RCP 4.5, wave buoy, and ERA5 scenarios are reported. As it can be seen as a general result, the wave intensity in the RCP4.5 future scenarios is greater if compared to the result given by the buoy and the ERA5. Moreover, a reasonable clockwise rotation of the medium wave direction is observed for the RCP dataset.

References

Pasquali D., Bruschi A., et al. (2023). Wave forcing assessment at regional scale in a climate change scenario: the Sardinia case study. *Journal of Marine Science and Engineering*, 11(9), 1786.

Fanti V., Ferreira O., et al. (2023). Improved estimates of extreme wave conditions in coastal areas from calibrated global reanalyses. *Communications Earth & Environment*, 4(1), 151.

Hersbach H., Bell B., et al. (2020). The ERA5 global reanalysis. *Quarterly Journal of the Royal Meteorological Society*, 146(730), 1999-2049.

Pörtner H.O., Roberts D.C., et al. (2019). The ocean and cryosphere in a changing climate. In: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*, 1155.

An integrated approach for the assessment of ground instabilities-induced damage on critical structures

Rosa Colacicco[1], Alessio Ferrari[2], Isabella Lapietra[1], Giulia La Porta[3], Isabella Serena Liso[1], Giorgio Manno[2], Gian Marco Marmoni[4], Chiara Martinello[5], Michele Matteoni [6], Roberta Narcisi[2], Enrico Paolucci[7], Stefano Pampanin [6], Livio Pedone [6], Fabio Rollo[6], Marco Rosone[2], Domenico Calcaterra[8], Salvatore Martino[4]

(1) Dept. of Earth and GeoEnvironmental Sciences, University of Bari 'Aldo Moro'
(2) Dept. of Engineering, University of Palermo
(3) Dept. of Structural, Geotechnical and Building Engineering, Politecnico di Torino
(4) Dept. of Earth Science, Sapienza University of Rome
(5) Dept. of Earth and Marine Sciences, University of Palermo
(6) Dept. of Structural and Geotechnical Engineering, Sapienza University of Rome, fabio.rollo@uniroma1.it
(7) Dept. of Physics and Astronomy, University of Bologna
(8) Dept. of Earth Sciences Environment and Resources, University of Naples Federico II

Ground instabilities can be responsible for a progressive damaging which acts on civil infrastructures, habitat, and, in extreme cases, human life, due to simultaneous population growth, urban expansion, and climate change. Specifically, the occurrence of combined geohazards (e.g., heavy rainfall and earthquake occurring simultaneously) in a changing climate scenario, highlighting the need for the evaluation of adaptive technologies and the development of innovative approaches for the assessment of ground instabilities and their effects on built and natural heritage. In Italy, landslides, rapid sinkholes, liquefaction and subsidence occur in different natural and anthropogenic environments and may have detrimental impacts on infrastructures and in terms of social and economic losses. As such, occurrence of ground instabilities represents a serious issue to investigate, especially as concerns their predisposing, preparatory and triggering factors.

The research concept presented here aims at developing an integrated multi-hazard approach for quantifying the cumulative effects related to ground instability over time, as a consequence of ongoing deformational processes (i.e. related to soil- or rock mass- creep) as well as of sequence of event occurrence, as in case of rainfalls, earthquakes or subsidence settlements and evaluate the possible damages on existing structures and infrastructure.

As it regards rainfalls occurrence, the sequences of rainfalls play a dual role in the landslides triggering since they can be regarded firstly as preparatory factor and ultimately as triggering actions whose efficiency is subordinate to thresholds related to the previous cumulative rainfalls. Both preparatory and triggering actions depend on changes in pore water pressures distribution and/or soil saturation. Extended field investigations, geotechnical characterisation and the adoption of advanced numerical analyses will allow to highlight the dependence of the time evolution of the horizontal displacement of a rainfall-induced landslide on the pore water pressure variation. Moreover, the implementation of monitoring programmes to measure rainfall, pore water pressures, and deep and superficial displacements will be crucial to back-analyse relevant and well documented case histories, as for the deep ground instabilities (e.g., the Cerda Landslide in Rosone et al., 2018) occurred along the basin of Imera river in northern Sicily, where the reactivations of the Scillato landslide broke down two pillars of the "Imera" viaduct causing the interruption of the A19 motorway (Martinello et al., 2022).

On the other hand, the use of more sophisticated constitutive model for soils and rocks will shed new light on the mechanics of landslides by embracing the role of soil inelasticity throughout the stages of initial triggering of movement from an initially stable condition and eventual propagation. This can also benefit of a series of continuum mechanics numerical analyses aimed at underlining the consequences on propagation of assuming an all-at-once release or a multiple-time release from the many triggering areas spread on the slope, as for the two catastrophic debris-flows occurred in Sarno, Campania region, and Giampilieri, north-eastern Sicily (La Porta et al., 2023). In this perspective, special care will be devoted to the rheology selection and the calibration of the model parameters.

Moreover, long periods of drought make several portions of the territory susceptible to wildfires with detrimental effects on landslide activation and the rheological behaviour of the post-fire debris flow as compared to similar mechanisms happened in the unburned surrounding basins, while anomalous temperature variations play a relevant role in mountainous regions where significant anthropic presence and the dense infrastructure network further worsen the hazard. If one also considers that Italy is characterised by severe seismicity, an even more complex picture emerges that requires a multi-hazard approach of analysis. High and low-magnitude earthquakes have been revealed capable of increasing the number of landslide reactivations in the post-seismic stages, by reducing their pluviometric triggering threshold. For instance, the Molise case study in southern Italy (Martino et al., 2022) revealed that seismic shaking could enhance of about 120% the landslide reactivations during the rainy season following the earthquake, and boost the activity of earthflows, under similar and ordinary pluviometric regime. Such legacy could significantly reduce the safety of strategic infrastructures and existing buildings. For these reasons, the proposed methodology will employ both simplified mechanics-based methods and refined numerical modelling for the vulnerability assessment of existing constructions to earthquakes and landslides. For each considered natural hazard, building-level fragility relationships will be derived in line with the state-of-the-art methodologies for large-scale risk assessment. The synergic collaboration between the Spoke's components will provide essential information/data on the hazard elements, such as expected intensity for both earthquakes and flow-type landslides (e.g., flow density and depth, impact flow velocity). Moreover, the effects of cumulative damage in the case of concatenate events (e.g., earthquake-triggered landslide) will be investigated, building on the recent developments for damage-state-dependent fragility estimation (e.g., Pedone et al. 2023). Such an approach could represent an important step toward an effective evaluation of the resilience of the built environment to seismic and landslide risks.

References

La Porta G., Leonardi A., Pirulli M., Cafaro F., Castelli F. (2023). Time-resolved triggering and runout analysis of rainfall-induced shallow landslides. *Acta Geotechnica*, 1-17.

Martinello C., Cappadonia C., Conoscenti C., Rotigliano E. (2022). Landform classification: a high-performing mapping unit partitioning tool for landslide susceptibility assessment — A test in the Imera river basin (Northern Sicily, Italy). *Landslides*, 19, 539–553.

Martino S., Fiorucci M., Marmoni G.M., Casaburi L., Antonielli B., Mazzanti P. (2022). Increase in landslide activity after a low-magnitude earthquake as inferred from DInSAR interferometry. *Scientific reports*, 12(1), 2686.

Pedone L., Gentile R., Galasso C., Pampanin S. (2023). Energy-based procedures for seismic fragility analysis of mainshock-damaged buildings. *Frontiers in Built Environment*, 9, 1–20.

Rosone M., Ziccarelli M., Ferrari A., Farulla C.A. (2018). On the reactivation of a large landslide induced by rainfall in highly fissured clays. *Engineering Geology*, 235, 20-38.

Future shifts in sub-daily precipitation extremes: a comprehensive analysis with a Convection-Permitting Models Ensemble

Eleonora Dallan[1], Francesco Marra[2,3], Giorgia Fosser[4], Marco Marani[5], Marco Borga[1]

(1) Department of Land Environment Agriculture and Forestry, University of Padova, eleonora.dallan@unipd.it
(2) Department of Geosciences, University of Padova
(3) Institute of Atmospheric Sciences and Climate (CNR-ISAC), National Research Council of Italy
(4) University School for Advanced Studies - IUSS Pavia
(5) Department of Civil, Environmental and Architectural Engineering, University of Padova

Foreseeing the future evolution of intense precipitation events is crucial to enhance risk management in a warming climate. This is particularly important in regions featuring mountainous landscapes and urban areas susceptible to natural disasters arising from extreme weather conditions. The use of convection-permitting climate models (CPMs) operating at kilometer scales have proven to be a significant advancement in the representation of short duration extreme precipitation. These models realistically depict convective precipitation mechanisms and complex orography, offering an enhanced description of extreme precipitation in comparison to coarser resolution regional climate models. However, their computational demands impose limitations on simulations, restricting them to short time spans (10-20 years), and constraining the availability of ensemble members. These limitations hinder the comprehensive assessment of changes in extreme events and the associated uncertainty.

These challenges can be overcome by innovative non-asymptotic extreme value approaches such as the Metastatistical Extreme Value Distribution (MEVD; Marani and Ignaccolo, 2015) and the Simplified Metastatistical Extreme Value distribution (SMEV; Marra et al., 2020). Indeed, these approaches have demonstrated efficacy in estimating rare return levels with reduced stochastic uncertainty, even with short datasets, and offer valuable insights on the underlying processes. Specifically, the study applies SMEV to estimate projected changes in future extreme sub-daily precipitation. The study focuses on the North Italy area, encompassing both lowlands and the Italian Alps. An ensemble of 9 CPMs from the CORDEX-FPS CONV project, remapped on a common grid with a spatial resolution of 3 kilometers, is analyzed. The investigation spans three time periods: historical (1996-2005), near future (2041-2050), and far future (2090-2099) under the RCP8.5 emission scenario. Return levels are estimated for precipitation durations ranging from 1 to 24 hours, and for exceedance probability up to a 1% yearly (100-year return time). The future change in return levels with respect to the historical period is assessed at each grid point, with a permutation test conducted to evaluate the statistical significance of the changes.

A general increase in extreme precipitation is found across the domain and all durations. Spatial patterns of significant changes vary with durations, time periods, and locations. For instance, Figure 1 shows the far future mean change in 20-yr return levels for 5 durations. A pronounced increase occurs in some of the mountainous areas, such as the Eastern Alps at the short durations, and the northern Apennines across all durations. Conversely, the western Alps and surrounding region exhibit moderate and not-significant change and eventually not concordant direction of change across the ensemble members. Leveraging SMEV's capability to separate precipitation intensity distribution from event occurrence, the study also examines projected changes in distribution parameters. This allow us to interpret the shift in return levels in term of changes in the underlying processes, attempting to distinguish thermodynamics controls (linked to temperature and water vapor content) and atmospheric dynamics controls. Focusing on the significant changes in extreme precipitation, thermodynamics appears to drive them at short durations, while small-scale local dynamics have an impact across all durations. Differences in the parameters' change emerge between the Eastern Alps and Northern Apennines, with the latter showing a more pronounced intensification of intense versus moderate precipitation events.

This comprehensive analysis not only highlights the overall increase in extreme precipitation in the study area but also delineates regional variations and the role of specific meteorological factors in driving these changes. Such fine understanding is crucial for improving decision-making planning of risk mitigation of the potential impact of changing precipitation patterns and for enhancing our resilience to climate-change related challenges.

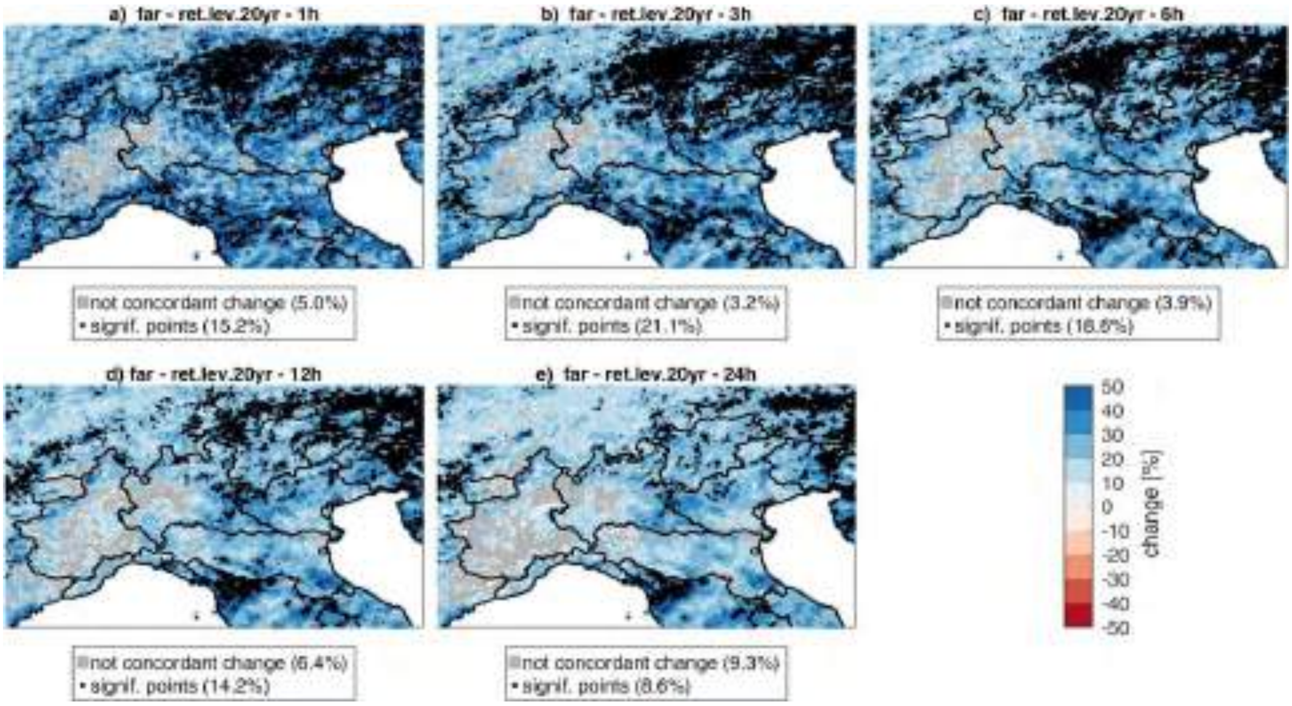


Figure 1 – Ensemble mean change, far future, for 20-yr return level and 5 durations: 1-3-6-12-24h (panels a to e). Below each panel: Percentage of points with not concordant change (that is points where less than 65% of models in the ensemble have concordant direction of change) and percentage of points with significant and concordant change (for at least 50% of models in the ensemble).

References

Marani M., Ignaccolo M. (2015). A metastatistical approach to rainfall extremes. *Advances in Water Resources*, 79, 121–126.

Marra F., Borga M., Morin E. (2020). A unified framework for extreme sub-daily precipitation frequency analyses based on ordinary events. *Geophysical Research Letters,* 47(18).

Towards the identification of climate change impact indicators on ground instabilities: the role of rainfall regime as preparatory and triggering factor for landslides

Marta Della Seta[1], Daniela Piacentini[1], Benedetta Antonielli[1], Matteo Berti[2], Pierluigi Confuorto[3], Marco Marani[4], Alberto Montanari[5], Giacomo Pepe[6], Marianna Pirone[7], Claudio Puglisi[8], Edoardo Rotigliano[9], David Zuliani[10]

(1) Dept. of Earth Sciences, Sapienza University of Rome, marta.dellaseta@uniroma1.it
(2) Dept. of Biological, Geological and Environmental Sciences, University of Bologna
(3) Dept. of Earth Sciences, University of Florence
(4) Dept of Civil, Environmental and Architectural Engineering, University of Padua
(5) Dept. of Civil, Chemical, Environmental, and Materials Engineering, University of Bologna
(6) Dept. of Earth, Environment and Life Sciences, University of Genoa
(7) Dept. of Civil, Building and Environmental Engineering, University of Naples Federico II
(8) ENEA - Laboratory Technologies for the Dynamics of Structures and the Prevention of seismic and hydrogeological risk
(9) Dept. of Earth and Marine Sciences - University of Palermo
(10) Center for Seismological Research, National Institute of Oceanography and Applied Geophysics – OGS

The PE3 RETURN DS spoke "Science underpinning climate services for risk mitigation and adaptation" promoted, with the other spokes' ambassadors, the initiative "Adopt an Indicator". It was aimed at engaging the participants of the other spokes in a critical review of the climate change impact indicators on national and regional communities, as originally defined in the Report on Climate Change Indicators published by the Italian National System for the Environmental Protection.

The VS2 spoke "Ground instabilities", after having inventoried and deeply studied some significant case studies, or Learning Examples (LEs), put the bases for building a Rationale for predisposing (WP2), preparatory (WP3) and triggering (WP4) factors for slope instability, to be used as inputs for the Proof of Concept (PoC).

The first-year deliverables produced by WP2, WP3 and WP4 clearly outline that the rainfall regime has a significant impact on landslide occurrence in a variety of regional environments: from the Alpine mountainous environment, where variations in the frequency distribution of mass movement magnitude and distance is influenced by the precipitation seasonality and intensity (e.g. Zuliani et al., 2022); through the relatively humid hilly environment of Northern and Central Italy, where models have been developed to predict landslides triggered by rainfall (Berti et al., 2012), also highlighting the concomitant role of land abandonment (Brandolini et al., 2018); to the semi-arid hilly environment of Southern Italy, where a correlation analysis has been performed among shallow landslide events (historical and recent) and rainfall forcing as well as soil moisture and soil suction variations (Cama et al., 2015; Napoli et al., 2015; Forte et al., 2019). Therefore, in the frame of a changing climate, the variability of landslide magnitude, frequency, and runout in response to changing rainfall regimes is a good candidate as climate change impact indicator.

Rainfall regime encompasses parameters such as average rainfall at different time scales, as well as the typical intensity and duration of rainstorms, which serve as significant factors for landslides. In regions that experience prolonged rainstorms, the general increase in groundwater levels greatly increases the landslide susceptibility. However, contrasts are expected between areas that experience either low-intensity rainfall over extended periods or areas with short-lived but intense rainstorms. Yet, it is noteworthy that the connection between rainfall patterns and slope stability is complex. This complexity arises from how different types of rainfall parameters interact with the unique geological, geotechnical and hydrological characteristics of each slope, making the relationship between rainfall and slope stability an intricate aspect of landslide susceptibility.

For the above reasons, further interactions between VS2 and DS spokes are needed, to define the different spatial and temporal scales required in climatic model outputs from DS to drive landslide triggering models and provide realistic future scenarios of landslide hazard to inform mitigation strategies.

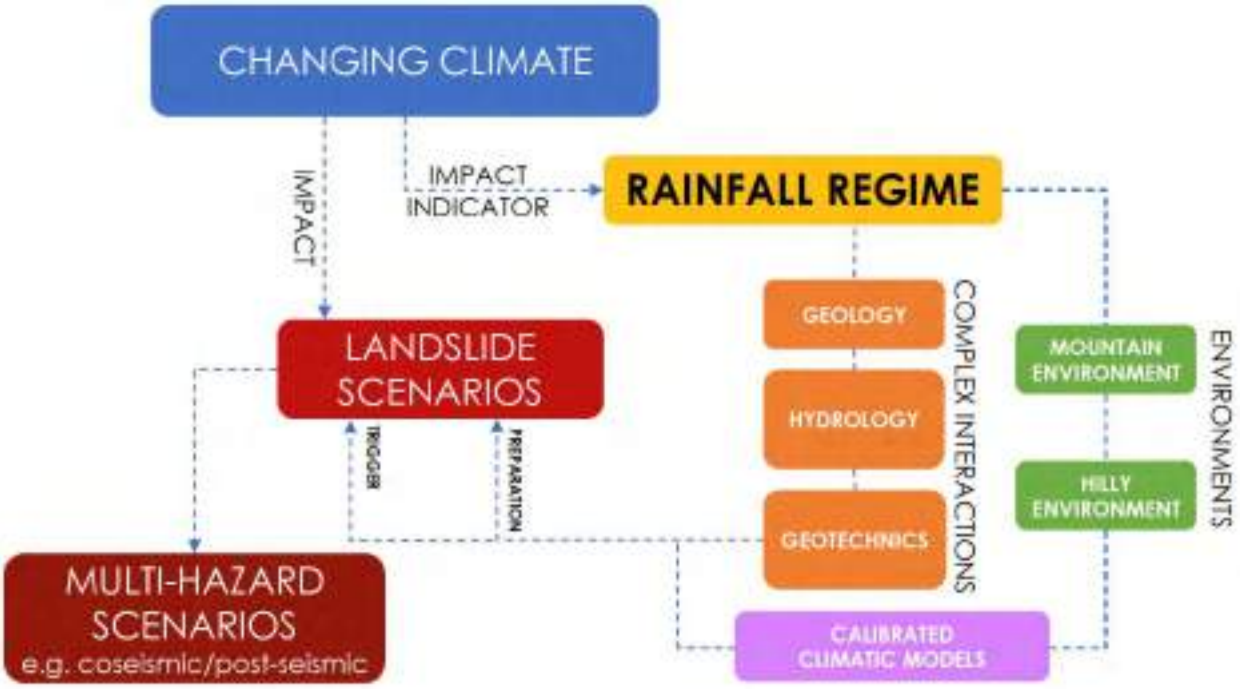


Figure 1 – Conceptual sketch on the role of rainfall regime in landslide scenarios.

References

Berti M., Martina M.L.V., Franceschini S., Pignone S., Simoni A., Pizziolo M. (2012). Probabilistic rainfall thresholds for landslide occurrence using a Bayesian approach. *Journal of Geophysical Research: Earth Surface*, 117(F4).

Brandolini P., Cevasco A., Capolongo D., Pepe G., Lovergine F., Del Monte M. (2018). Response of terraced slopes to a very intense rainfall event and relationships with land abandonment: a case study from Cinque Terre (Italy). *Land Degradation and Development*, 29(3), 630-642.

Cama M., Lombardo L., Conoscenti C., Agnesi V., Rotigliano E. (2015). Predicting storm-triggered debris flow events: Application to the 2009 Ionian Peloritan disaster (Sicily, Italy). *Natural Hazards and Earth System Sciences*, 15, 1785-1806.

Forte G., Pirone M., Santo A., Nicotera M.V., Urciuoli G. (2019). Triggering and predisposing factors for flow-like landslides in pyroclastic soils: the case study of the Lattari Mts. (southern Italy). *Engineering Geology*, 257.

Napoli R., Crovato C., Falconi L., Gioè C. (2015). Soil water content and triggering of debris flows in the Messina area (Italy): preliminary remarks. *Engineering Geology for Society and Territory* – Volume 2, Landslide Processes. Springer International Publishing Switzerland, 2113-2117.

Zuliani D., Tunini L., Di Traglia F., Chersich M., Curone D. (2022). Cost-effective, single-frequency GPS network as a tool for landslide monitoring. *Sensors*, 22, 3526.

Challenges for structure assessment in a multi-risk multi-scalar framework

Mariano Di Domenico[1], Donatella de Silva[2], Maria Teresa De Risi[3], Carlo Del Gaudio[4], Marta Del Zoppo[5], Marco Gaetani d'Aragona[6], Andrea Miano[7], Gabriella Tocchi[8], Marco Di Ludovico[9], Maria Polese[10], Emidio Nigro[11], Andrea Prota[12], Gerardo M. Verderame[13]

(1) Department of Structures for Engineering and Architecture, University of Naples Federico II, mariano.didomenico@unina.it

Researchers dealing with structural assessment by virtue of their history and geographical location, has a profound interest in the assessment of structural vulnerability to various natural phenomena. Primarily, these include seismic activity, volcanic events, and, more recently, floods and fires. Individual research groups have focused their scientific output on these subjects, ranging from hazard characterization to vulnerability assessment, and extending to the evaluation of mitigation techniques and risk reduction.

The RETURN project and the community it has created have catalyzed the research efforts towards a more effective integration of these themes. This involves transitioning from an approach centered on individual natural phenomena affecting single buildings or groups of buildings to a more comprehensive and holistic attention devoted to assessing the broader impact of multiple natural events on the entire community.

In the current year, structural engineers' community aims to contribute to the project's activities by transferring their expertise across various spokes of the project. These include seismic vulnerability analysis of structures subjected to landslide-induced damage or different fire scenarios, vulnerability models capable of accurately interpreting the effects of multiple consecutive earthquakes of varying intensities on existing structures, seismic risk analysis in volcanic areas, and the assessment of the magnitude, in terms of volumes of debris produced by the collapse of both structural and non-structural elements. In this case, the focus extends to the impact that these debris can have on rescue and evacuation operations, particularly in the presence of intense meteorological phenomena. This is done also by examining their effects on the natural environment, particularly in terms of water and field pollution.

Social vulnerability to natural disasters in the EEA and UK: a systematic review with insights for risk reduction and emergency planning

Isabella Lapietra[1], Rosa Colacicco[1], Domenico Capolongo[1], Marco La Salandra[1], Anna Rinaldi[2], Pierfrancesco Dellino[2]

(1) Department of Earth and Geoenvironmental Sciences, University of Bari, Isabella.lapietra@uniba.it
(2) Department of Economy and Finance, University of Bari

The interaction between natural hazards and the socio-economic environment implies multidisciplinary assessments that aim to integrate the physical and the socio-economic features of the affected territories. The quantification and mapping of social vulnerability, coupled with hazard assessment, could be a useful approach to support risk management strategies.

With this aim, we carried on a systematic review on the role of social vulnerability in the natural hazard literature in the European Economic Area (EEA) and United Kingdom (UK) over the last twenty years. The various definitions, measurements and mapping of social vulnerability were studied, providing an instrument for conducting hazard assessment and demonstrating the relevance of multidisciplinary approach in disasters research.

The PRISMA methodology and frequency analysis were used to extract and analyze the literature.

According to our selection criteria, 95 papers were included in the final analysis. Results (Figure 1) revealed that: i) 53 % of papers focuses on social vulnerability related to flood hazard, ii) 61 % of case studies include hazard assessment, while the rest only investigate the socio-economic component of vulnerability, iii) Portugal and Italy are the most investigated countries, iv) 51,6 % of papers carry out an integrated approach. The review underlines a pronounced perception of the scientific community to the more recurrent events (floods) rather than to the number of deaths (heat waves). The gap of studies that analyze social vulnerability to volcanic eruption is a relevant example as only 3 significant volcanic activities and 0 deaths were registered in the last twenty years. Moreover, this study underlines the high need of multidisciplinary approach (Earth, Social, Economic, Engineering Sciences) in the context of disaster management and risk reduction strategies.

The review represents a methodological manual for all those who works on data integration in risk analysis or emergency planning. For this reason, a scheme of data integration between hazard, vulnerability and exposure is proposed (Table 1).

Starting from the main results, the review provides a broader look at future research developments in the field of climate change and emergency planning pointing out the need to improve integration methods and the development of territorial socio-economic indicators.

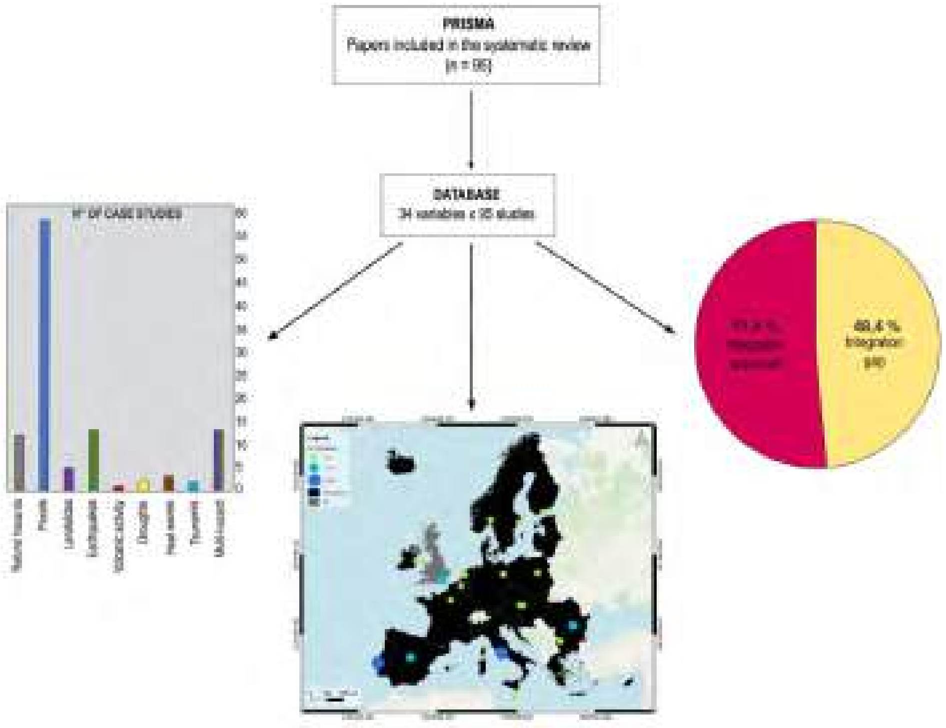


Figure 1 – Main results deriving from the systematic review.

Table 1 – Multidisciplinary proposal for risk analysis in the EEA and UK.

HAZARD			EXPOSURE	VULNERABILITY	
	Category	Data	Data	Category	Data
Single hazard	***Flood***	Flood exposure map Flood extent Flood hazard index Flood hazard map Hydraulic model Hydrographic unit map Susceptibility map Pluvial flood components	Land use Population density	***Social***	Age Income Employment Education level Disability
	Earthquake	Earthquake scenario Map of earthquakes Seismic hazard map		***Built***	Construction age Construction material Maintanance
	Volcanic activity	Geophysical risk map	Density of buildings (household stay and grocery stores)		
	Landslide	Landslide hazard map Landslide susceptibility map		***Economic***	Productvity sector Food production Income dependency from private sector
	Heat waves	Heat composite index Mean annual temperature map Minimum mortality temperature threshold			
	Drought	Composite drought index De Martonne index	Density of infrastractures (transport network, hospitals and medical centers, schools, institutional and enforsment centers)	***Environmental***	Flora characteristics Fauna characteristics Environmental quality Land cover
	Tsunami	Tsunami numerical model			
Multi-hazard	***Coastal hazard (erosion and flooding)***	Coastal hazard map Coastal sensitivity index Susceptibility index for each hazard type			
	Earthquake and industrial	Seismic and industrial risk zone	Density of natural and heritage sites	***Institutional***	Socio-cultural pillar Socio-political pillar legislative and regulatory pillar fiscal-economic pillar
	Flood and landslide	Flood and quick clay hazard map			
	Heat waves, flood and earthquake	Seismic and flood hazard map			
	Earthquake, flood and landslide	Multihazard index			
	Earthquake, flood, landslide, tsunami and coastal erosion	Susceptibility map			

Combined assessment of fluvial-marine sediment transport to determine the impact of coastal risks

Valeria Lo Presti[1], Andrea Brenna[2], Monica Corti[3], Carlo Tacconi Stefanelli[4], Laura Longoni[3]

(1) Dept. of Earth and Marine Sciences, University of Palermo, valeria.lopresti@unipa.it
(2) Dept. of Geosciences, University of Padova
(3) Dept. of Civil and Environmental Engineering – DICA, Politecnico di Milano
(4) Dept. of Earth Sciences, University of Florence

The study of morphological changes of a river channel, linked to erosion-deposition processes, taking place in the riverbed, is a topic of current interest in relation not only to the morphometric variations of the fluvial features (e.g., active channel width, area of sediment bars) and the sedimentary balance of the whole relative hydrographic basin but also in relation to the role of the sediment load transferred downstream up to the near shore area (Figure 1).

Figure 1. Fluvial sediments transferred to the coast. Alcantara river (Sicily).

These sediments constitute the solid transport that is pushed towards the coast and poured into the sea, representing a crucial sedimentary contribution to the beaches volumetric balance. The quantitative estimate of the volume of this fluvial load is currently achievable through robust approaches such as the morphological method grounded in the continuity principle applied to river sediments. To define the transport rates at selected locations (e.g., the river mouth) over a given time period, the method requires to measure the erosion and sedimentation volumes, which can be calculated using repeated Digital Elevation Models (DEM)and deriving a DEM of Difference (DoD) (Vericat et al., 2017; Capito et al., 2023). The coastal sedimentary balance is function of both the sediment load provided by rivers and the quantity of sediment transported by the longshore currents that move parallel to the coastline. For this reason, it is crucial to assess the impact of coastal erosion considering both the sediment input from the hydrographic basins and the longshore transport.

Up to now there are no techniques capable of providing continuous and spatially distributed measurement of this sediment transfer, a fact of considerable interest if we think of the anthropic structures present along the shores, and the coast erosional problems.

This study aims to evaluate, at the regional scale, the possibility of borrowing some techniques that are often used in fluvial contexts (e.g., geomorphological approach), to estimate the quantity of sediment that nourishes the coast. This information is essential as a preliminary step for further studies on the sediment transport process, considering, for instance, different climatic scenarios. A measured volume of sediments deposited over a specific time interval can be used to calibrate a physically-based sediment erosion and transport model, such as SMART-SED described by Gatti et al., 2023. Following calibration, the model can be employed to predict future scenarios by considering climate projections.

An important aspect will be to assess the transferability of such methodologies taking into consideration the technical limitations (e.g., greater difficulty in acquiring bathymetric data in the submerged environment) and the morphodynamic differences of the two contexts (e.g., partial lack of lateral confinement of flows in the marine environment).

Once it is established that meaningful estimates can be obtained, using the two solid transport estimates volumes (river and marine) it could be possible to obtain the budget of sediments that could benefit the near shore. This estimation certainly has a margin of error linked to all the uncertainties processes both in the river and coastal contexts, but it reveals an evaluation of sedimentary tendency of a coastal area: retreat, advancement or stationary.

Today the studies of coastal balances certainly not considered the presence of submarine morphologies that favor the sediments deposition (e.g., submerged bars and terraces) or the sediments removal (e.g., submarine canyons that arise very close to the coast) from near shore environment, significantly influencing the trend of longshore currents. In Italy there are many regions in which submarine canyons are very close to the coasts; these structures can act as collectors of sediments which are swallowed up towards greater depths (Lo Presti et al., 2022).

Therefore, the quantitative study of sediment volume available on a near shore environment, linked to the presence of submarine morphologies favorable or not to the removal or stasis of sediments and to the intrinsic characteristic of the beach (e.g., long exposed beach, gulf, pocket beach), it constitutes a means of defining the sediment load that moves along a near shore area and which could influence and define possible scenarios of anthropic damage, as ports and fluvial bridges siltation but above coastal erosion risks.

References

Capito L.M., Pandrin E., Bertoldi W., Surian N., Bizzi, S. (2023). Path length and sediment transport estimation from DEMs of Difference: a signal processing approach, *EGUsphere* [preprint].

Gatti F., Bonaventura L., Menafoglio A., Papini M., Longoni L. (2023). A fully coupled superficial runoff and soil erosion basin scale model with efficient time stepping, *Computers & Geosciences,* 177, 105362.

Lo Presti V., Antonioli F., Casalbore D., Chiocci F.L., Lanza S., Sulli A., Randazzo G. (2022). Geohazard assessment of the north-eastern Sicily continental margin (SW Mediterranean): coastal erosion, sea-level rise and retrogressive canyon head dynamics. *Marine Geophysical Research,* 43(1), 1-18.

Verticat D., Wheaton J.M., Brasington J. (2017). Revisiting the morphological approach: opportunities and challenges with repeat high-resolution topography. Gravel-Bed Rivers: Processes and Disasters, First Edition. Edited by Daizo Tsutsumi and Jonathan B. Laronne. John Wiley & Sons Ltd

Sediment transport in different environments: problems and challenges

Laura Longoni[1], Alessio Radice[1]

(1) Dipartimento di Ingegneria Civile e Ambientale, Politecnico di Milano, laura.longoni@polimi.it

River sediment transport has been extensively studied over several decades because of its important implications for a number of environmental processes (and, in turn, the consequent societal challenges) including, for example, channel morphology, river–structure interactions, flood risk, water quality, reservoir siltation, agriculture, urban planning and habitat creation (e.g., Brown et al., 1995; de Miranda and Mauad, 2014; Dotterweich, 2008; Montgomery et al., 2000; Pimentel, 2006; Radice et al., 2016;). The need to suitably account for sediment transport while developing land-use policies has been recognized (Sear et al., 1995; Hartmann & Driessen, 2013). Moreover, in a changing world the intensification of rainfall, melting of glaciers, variations in hydrological regimes, increase in temperatures and changes in vegetation patterns will undoubtedly have a major impact on slope erosion and sediment supply into rivers, further increasing the demand for smart strategies for spatial planning.

In the RETURN Project a technical team, composed of various members from different spokes (VS1, VS2 and TS2), is thoroughly examining some crucial issues: dam siltation, coastal risk and floods with major impact of sediment transport.

These three topics are described in the following companion abstracts:

1. evaluation of dam siltation in different Italian geological context through sediment transport model;
2. sediment transport modelling in the design of flood-event scenario;
3. combined assessment of fluvial-marine sediment transport to determine the impact of coastal risks.

References

Brown E.T., Stallard R.F., Larsen M.C., Raisbeck G.M., Yiou F. (1995). Denudation rates determined from the accumulation of in situ-produced ^{10}Be in the Luquillo experimental forest, Puerto Rico. *Earth and Planetary Science Letters,* 129, 193–202.

de Miranda R.B., Mauad F.F. (2014). Influence of sedimentation on hydroelectric power generation: case study of a Brazilian reservoir. *Journal of Energy Engineering,* 141, 1-7.

Dotterweich M. (2008). The history of soil erosion and fluvial deposits in small catchments of central Europe: deciphering the long-term interaction between humans and the environment – a review. *Geomorphology,* 101, 192–208.

Montgomery D.R., Schmidt K.M., Greenberg H.M., Dietrich W.E. (2000). Forest clearing and regional landsliding. *Geology,* 28, 311–314.

Pimentel D. (2006). Soil erosion: a food and environmental threat. *Environment, Development and Sustainability,* 8, 119–137.

Radice A., Longoni L., Papini M., Brambilla D., Ivanov V.I. (2016). Generation of a design flood-event scenario for a mountain river with intense sediment transport. *Water,* 8, 597–613.

The problem of model validation in natural hazard forecasting

Warner Marzocchi[1], Thomas H. Jordan[2], Jacopo Selva[1]

(1) Dept. of Earth, Environmental, and Resources Sciences, University of Naples Federico II, warner.marzocchi@unina.it
(2) Dept. of Earth Sciences, University of Southern California

Science is rooted in the concept that a model can be tested against independent observations and rejected when necessary. However, the problem of model testing becomes formidable when we consider natural "open" systems. Owing to their scale, complexity, and openness to interactions within a larger environment, most natural systems cannot be replicated in the laboratory, and direct observations of their inner workings are always inadequate. These difficulties raise serious questions about the meaning and feasibility of "model validation" and have led to the pessimistic view that the outcome of natural processes in general cannot be accurately predicted by mathematical models and that they can never be validated (Oreskes et al., 1994).

In this talk we discuss some efforts in different fields on natural hazards (with example coming from seismology, volcanology, and climate changes) to address the validation problem, and the link with the current procedures of calibration and scoring of the models. The discussion emphasizes the importance of clarifying the probabilistic framework adopted for natural hazard forecasting, which is aimed at quantifying the ubiquitous uncertainties of different kind that pervade the modeling of the processes.

De facto, most practitioners recognize that distinguishing between different types of uncertainties can be useful in the interpretation of hazard estimates, but the confusion surrounding the topic is evident in the wide variety of schemes proposed for classifying uncertainties: shallow and deep, intra- and inter-model, external and internal, value and structural uncertainty, likelihood and confidence on the validity of a finding, model parameters and initial/boundary conditions. It has been unclear whether these classifications are profound categories that must be reflected in the probabilistic framework or merely convenient, model-based divisions (e.g., NRC, 1997; Rougier and Beven, 2013). Undoubtedly, the lack of clear and unambiguous definition of these different uncertainties has provided a fertile ground for criticism (e.g. Aven and Renn, 2015; Stark, 2022).

Generally, speaking, these uncertainties can be differentiated into three fundamental types: (1) the natural variability of the systems, usually represented as stochastic processes with parameterized distributions (aleatory variability); (2) the uncertainty in our knowledge of how systems operate and evolve, often represented as subjective probabilities based on expert opinion (epistemic uncertainty); and (3) the possibility that our forecasts are wrong owing to behaviors of processes about which we are completely ignorant and, hence, cannot quantify in terms of probabilities (ontological error). Here we first describe a probabilistic framework for hazard analysis (Marzocchi and Jordan, 2014), which unifies the treatment and provides a coherent definition of all three types of uncertainty. This framework is rooted in the definition of an *experimental concept* that characterizes hazard events in terms of exchangeable data sequences with well-defined frequencies. Within this framework, a forecasting model is said to be complete only if it (a) fully characterizes the epistemic uncertainties in the model's representation of aleatory variability and (b) can be unconditionally tested (in principle) against observations to identify ontological errors, which is the key to model validation. Then, we illustrate the application of this unified probabilistic framework to characterize the complete forecast in some real applications in seismology, volcanology and climate chance.

References

Aven T., Renn O. (2015). An evaluation of the treatment of risk and uncertainties in the IPCC reports on climate change. *Risk Analysis*, 35(4).

Marzocchi W., Jordan T.H. (2014). Testing for ontological errors in probabilistic forecasting models of natural systems. *Proc. Natl. Acad. Sci.*, 111(33), 11973-11978.

NRC (1997). National Research Council Panel on Seismic Hazard Evaluation: Review of Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and Use of Experts, National Academy of Sciences, Washington, DC, 84 pp., ISBN 0-309-56207-4.

Oreskes N., Shrader-Frechette K., Belitz K. (1994) Verification, validation, and confirmation of numerical models in the Earth sciences. *Science*, 263(5147), 641–646.

Rougier J. C., Beven K. J. (2013). Model and data limitations: the sources and implications of epistemic uncertainty, in: Risk and uncertainty assessment for natural hazards, edited by: Rougier, J., Sparks, S., and Hill, L., Cambridge University Press, Cambridge, 40–63, 2013.

Stark P.B. (2022). Pay no attention to the model behind the curtain. *Pure Appl. Geophys.,* 179, 4121–4145.

Sea level changes over the past 30 years along the Emilia-Romagna coast and related impacts

Matteo Meli[1], *Claudia Romagnoli*[1]

(1) Dept. BiGeA, University of Bologna, matteo.meli7@unibo.it

Coastal zones, dynamic interfaces between terrestrial and marine environments, are influenced by both natural and anthropogenic factors that vary over time. Currently, rising sea levels and climatic alterations pose significant risks, particularly to highly populated coastal lowlands. The concerns of rising sea levels include various coastal consequences such as episodic and enduring inundations, beach erosion, damage to coastal structures, saline encroachment, and the depletion of land and ecosystem functions. Nowadays, human activities predominantly shape coastal lowlands, overshadowing natural processes due to extensive land modification, and affecting hydrological processes in related river basins. This clearly happens in the Emilia-Romagna coast, which has undergone severe anthropization since the 1950s, and where subsidence due to underground fluid exploitation, and reduced sediment supply due to river regulation, have increased coastal vulnerability to flooding and erosion.

Variations in sea level arise from a complex interplay among the Earth's system components, encompassing the ocean, solid Earth, atmosphere, and cryosphere, interacting across a broad spectrum of spatial and temporal scales. Generally, the main contributors to contemporary global mean sea-level changes are shifts in seawater density, affected by temperature and salinity fluctuations, and the water mass exchange between oceans and continents. Regionally, sea level can be markedly influenced by phenomena like ocean circulation and mass redistribution among ice, land reservoirs, and oceans. Yet, at a local scale, these variations may be overmarked by vertical land movements due to natural and anthropogenic factors (such as alluvial sediment compaction, local tectonic shifts, land reclamation, and fluids withdrawal).

Currently, sea-level change measurement primarily depends on two tools: satellite altimetry and tide gauges. Satellite altimetry (SA) records sea level data against a geocentric reference, offering broad spatial coverage. Conversely, tide gauges (TG) track sea level relative to a local ground benchmark, known as relative sea level. This measurement is directly affected by the local vertical land movements mentioned earlier and provides location-specific spatial data. While data from SA unaffected by land movement distortions, their accuracy decreases near coastlines, complicating precise coastal evaluations. Moreover, altimetry missions commenced in the early 1990s, constraining their application for extended sea-level studies, unlike some tide gauges which have been operational since the 1800s. Considering these spatial and temporal differences, a combined approach becomes crucial, especially for in-depth local assessments. This subject is explored in Spoke VS1 and DS8 of the RETURN project, by conducting a thorough analysis of relative sea level changes and their subsequent impact on the Emilia-Romagna coast (Figure 1).

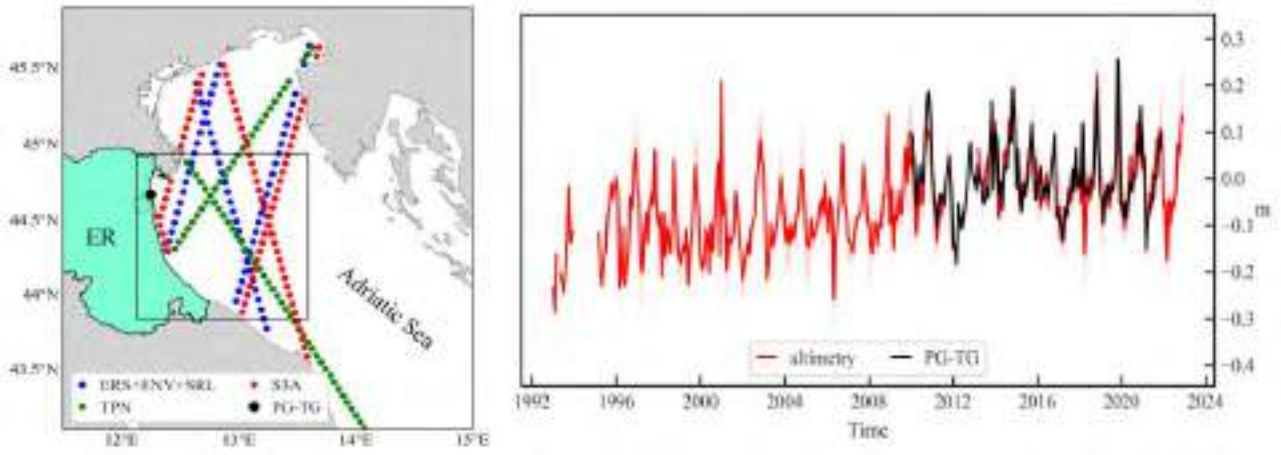


Figure 1 – (left panel) Reprocessed sea surface height data suitable for coastal applications (X-TRACK-L2P) from various satellite missions (tracks in red, blue, and green), while the tide gauge located at Porto Garibaldi (PG-TG) is indicated by a black dot; all SA data points within the black square are taken into account for reconstructing the geocentric sea level. (right panel) The displayed time series in red represents the sea level changes along the ER coast over the past 30 years (seasonal variations retained), while the black line are TG data.

The geocentric sea level variable on the scale of Emilia-Romagna (Meli et al. 2021) can be reconstructed through the use of dedicated altimetric products for coastal applications, such as X-TRACK (Figure 1; Birol et al., 2017), along with data from tide gauges. For comparison and integration purposes, data from SA were adjusted for the Glacial Isostatic Adjustment contribution, while the Porto Garibaldi TG data (PG-TG; Figure 1), active from 2009, were corrected for both the Inverse Barometer effect and the local vertical ground movement, as indicated by a co-located GPS station.

Over the common time span, SA and TG data show very high correlation, although their comparison suffers from the short overlapping period. A rate of SLR of about 2.8 ± 0.5 mm/year is obtained for the period 1993-2019 from SA on the 30-year time laps (Meli et al., 2021). A particular focus should also be dedicated to the non-linearity of the geocentric sea level variation, which is differentially induced by the various components, described above, acting on a broader scale (Meli et al., 2023) and ultimately reflected at the coast. In the same project, InSAR data along the coast will be considered to reconstruct the relative variability of sea level (including vertical ground movements, still present on most of the ER coast).

Finally, the impact of Relative Sea level changes on coastal evolution will be investigated at the decadal scale, based on the regular regional topo-bathymetric monitoring made by Arpae ER and on the shoreline evolution. The latter is enabled by new shoreline detection products from satellite imagery (e.g., CoastSat; Vos et al., 2019) that will ultimately provide a new set of indicators useful for coastal hazard assessments.

References

Birol F., Fuller N., Lyard F., Cancet M., Niño F., Delebecque C., et al. (2017). Coastal applications from Nadir altimetry: example of the X-TRACK regional products. *Advances in Space Research*, 59, 936-953.

Meli M., Olivieri M., Romagnoli C. (2021). Sea-level change along the Emilia-Romagna coast from tide gauge and satellite altimetry. *Remote Sensing*, 13, 97.

Meli M., Camargo C.M.L., Olivieri M., Slangen A.B.A., Romagnoli C. (2023). Sea-level trend variability in the Mediterranean during the 1993–2019 period. *Frontiers in Marine Science*, 10:1150488.

Vos K., Splinter, K.D., Harley, M.D., Simmons J.A., Turner I.L. (2019). CoastSat: a Google Earth Engine-enabled Python toolkit to extract shorelines from publicy available satellite imagery. *Environmental Modelling and Software,* 122, 104528.

Biogeochemical indicators for marine ecosystems

Stefano Piani[1], *Marco Reale*[1], *Gianpiero Cossarini*[1], *Cosimo Solidoro*[1], *Stefano Salon*[1], *Paolo Lazzari* [1]

(1) Oceanography Section, National Institute of Oceanography and Applied Geophysics – OGS, spiani@ogs.it

Biogeochemical indicators allow to monitor the state and to assess trends in key marine ecosystem processes such as primary production, nutrient cycles, carbon budget and acidification, de-oxygenation and eutrophication. The EU Copernicus Marine Service (CMS) has developed ocean monitoring indicators (OMIs), defined as trends and variability indexes of key marine variables computed for the global ocean and European seas (https://marine.copernicus.eu/access-data/ocean-monitoring-indicators). At the global scale, OMIs for the ocean biogeochemistry presently account for pH, chlorophyll-a, CO2, nitrate, and oxygen minimum zones, whereas in most regional seas, only the surface chlorophyll-a OMI extracted from reprocessed satellite ocean color data is available.

Within the Return Spoke DS Work Package (WP) 2 we aim at delivering data and compute indicators for the Marine Ecosystem and Coastal zones impact sectors. The selected indicators are temperature, salinity, dissolved oxygen, Dissolved Inorganic Carbon, pH, and trophic index (TRIX, an eutrophication index proposed by Vollenweider et al. 1998). Biogeochemical models provide the data to compute the selected indicators. Moreover, the area selected for the Proof-of-Concept task is the Northern Adriatic.

Biogeochemical models integrate ocean dynamics with biological and chemical processes to understand and predict the complex biotic and abiotic interactions within the marine ecosystems. The suite of investigated/selected models features NEMO (https://www.nemo-ocean.eu/) and MITgcm (https://mitgcm.org/) ocean general circulation models (OGCMs) to determine the physical parameters such as water temperature, salinity and circulation fields. They are then (offline and online) coupled with the BFM biogeochemical model (www.bfm-community.eu/). The resulting coupled systems are able to simulate the complex relationships among living organisms, nutrient cycling, and physical processes (e.g. light attenuation with depth, vertical mixing etc.), assessing the relative importance of the factors influencing the distribution of nutrients, oxygen levels, primary production, acidification trends, and the locations of ecological hotspots.

In particular, the indicators within Spoke 8 WP2 “State of the art and knowledge base to define impact-oriented hazard indicators” are derived from the CMS reanalysis (Teruzzi et al., 2021), a high-resolution implementation of the MITgcm-BFM for the northern Adriatic Sea (Cossarini et al., 2017) and two Mediterranean-scale climate simulations (Solidoro et al., 2022; Reale et al., 2022). CMS reanalysis covers the period 1999-2023 with an horizontal resolution of 1/24o (approximately 4.5 km) for the whole Mediterranean basin and 100 vertical levels. The CMS reanalysis features ERA5 as atmospheric forcing, the assimilation of satellite chlorophyll-a and sea surface height (SLA), temperature and salinity vertical profiles, and climatological run-off and nutrient discharges for 39 major Mediterranean rivers (including Po, Rhone, Ebro and Nile). The North Adriatic Sea model is based on MITgcm-BFM coupled system (Cossarini et al., 2017) with an horizontal resolution of 1/128o (approximately 700 m) and 27 vertical levels and features meteorological forcing from the Regional Climate Modelling system RegCM4 and from the COSMO-I2 model (IdroMeteoClima Service from ARPAE) and run-off and nutrient discharges from real data for major rivers (e.g. Po).

Additionally, two climate simulations covering the period 2005-2100 provide the data for the activities within WP3 (“Generation of specific hazard indicators based on state-of-the-art and high- resolution climatic scenarios to support hazard assessment at multiple scales”). The first climate simulation has a horizontal resolution of 1/8o (approximately 12 km) and considers the A2 scenario. The second set of simulations has a resolution of 1/16o (approximately 6 km) and considers the Representative Concentration pathways (RCP) 4.5 and 8.5 emission scenarios.

The evaluation of uncertainties in the estimation of the indicators is a challenging task. Different approaches are available to tackle it, such as the distance of the simulated variables versus available observations (e.g., GODAE skill performance metrics) or ensemble prediction systems based on different modeling systems or model parameters, (e.g., examples from the EU SEAMLESS project). The perturbation parameter space can be identified with an explorative sensitivity analysis finalized to rank the key parameters important for a given indicator. Then a 3D ensemble simulation can be constructed, and intrinsic model uncertainty can be then estimated. We performed such a study for the year 2019 as preliminary work for WP5 ("Uncertainty assessment for climate and weather scenarios").

Finally, we implemented a tool within the bit.sea package (https://github.com/inogs/bit.sea) to compute the indicators considering multimodal sources and performing statistical aggregations of the data (Figure 1).

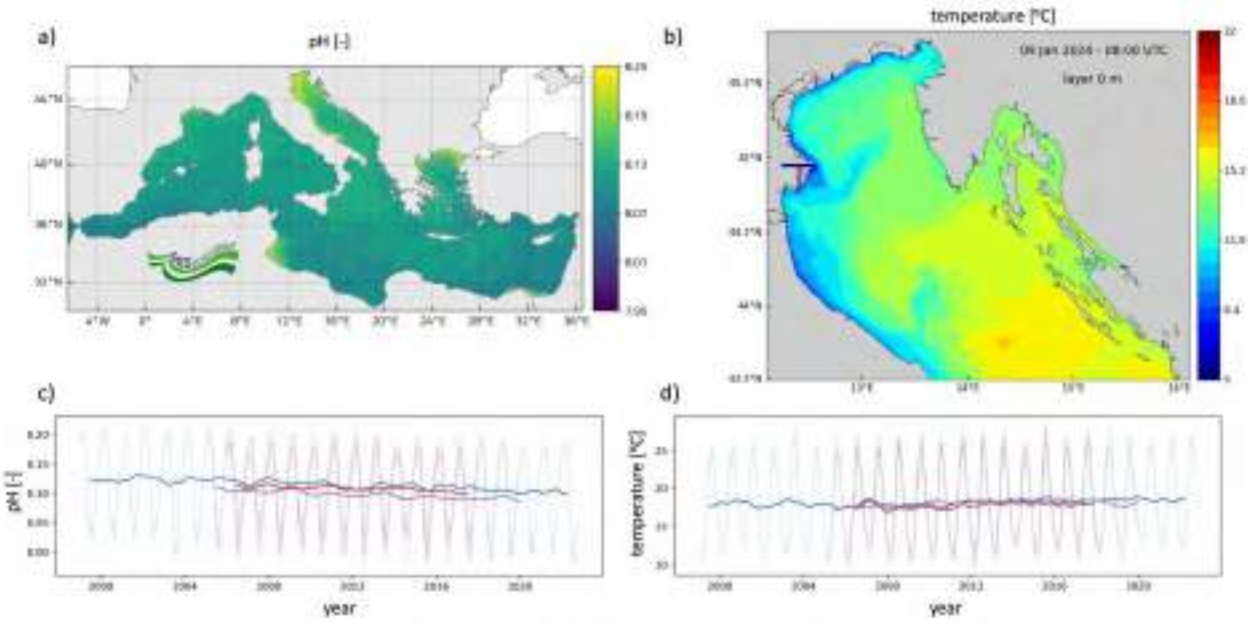


Figure 1 - Examples of daily maps for (a) pH from CMS reanalysis, and (b) surface temperature (degrees Celsius) from MITgcm-BFM high resolution model. Timeseries of pH (c) and temperature (d) averaged over the North Adriatic (Proof-of-Concept area) from models at different resolutions: North Adriatic high resolution MITgcm-BFM (red), CMS reanalysis (blue) and climate simulation (magenta), solid thick lines in panels (c) and (d) are the running means with 1 year time window.

References

Teruzzi A., Di Biagio V., Feudale L., Bolzon G., Lazzari P., Salon S., Coidessa G., Cossarini G. (2021). Mediterranean Sea Biogeochemical Reanalysis (CMEMS MED-Biogeochemistry, MedBFM3 system) (Version 1) [Data set]. Copernicus Monitoring Environment Marine Service (CMEMS).

Salon S., Cossarini G., Bolzon G., Feudale L., Lazzari P., Teruzzi A., et al. (2019). Novel metrics based on Biogeochemical Argo data to improve the model uncertainty evaluation of the CMEMS Mediterranean marine ecosystem forecasts. *Ocean Sci.*, 15, 997-1022.

Cossarini G., Querin S., Solidoro C., Sannino G., Lazzari P., Di Biagio V., et al. (2017). Development of BFMCOUPLER (v1.0), the coupling scheme that links the MITgcm and BFM models for ocean biogeochemistry simulations. *Geosci. Model Dev.,* 10, 1423-1445.

Solidoro C., Cossarini G., Lazzari P., Galli G., Bolzon G., Somot S., et al. (2022). Modeling carbon budgets and acidification in the Mediterranean Sea ecosystem under contemporary and future climate. *Front. Mar. Sci*., 8, 781522.

Reale M., Cossarini G., Lazzari P., Lovato T., Bolzon G., Masina S., et al. (2022). Acidification, deoxygenation, and nutrient and biomass declines in a warming Mediterranean Sea. *Biogeosciences*, 19, 4035–4065.

Vollenweider R.A., Giovanardi F., Montanari G., Rinaldi A. (1998). Characterization of the trophic conditions of the marine coastal waters with special reference to the NW Adriatic Sea: proposal for a trophic scale, turbidity and generalized water quality index. *Environmetrics*, 9, 329-357.

An indirect validation of national and international gridded precipitation products in Northern Italy through rainfall-runoff model application

Gökhan Sarigil[1], Mattia Neri[1], Elena Toth[1]

(1) Department of Civil, Chemical, Environmental, and Materials Engineering, University of Bologna, mattia.neri5@unibo.it

Accurate meteorological forcings are a fundamental component for reliable hydrological modelling. Gridded meteorological products offer spatially distributed information facilitating hydrological model applications. In addition, they are often available at large scale (e.g. regional or continental scale), easing the application on large samples of basins, and generally enhancing the replicability of the experiments. Nevertheless, the accuracy of these products varies, and it must be rigorously assessed to ensure the validity of model simulations.

This study aims to evaluate the accuracy of four gridded meteorological products based on ground observations: one international dataset (E-OBS), one national dataset (SCIA) and two regional products (ARCIS and ERG5-Eraclito), across a large sample of over 150 catchments in three administrative regions of Northern Italy. To assess their reliability, we adopt an indirect evaluation method. This involves assessing the performance of a conceptual hydrological model, which is forced with each of the four gridded meteorological products, over the selected catchments.

The E-OBS dataset, developed by the ECA&D project, offers climatic variables at a 0.1° x 0.1° (~11 x 11 km) resolution from 1950 onwards across Europe. SCIA (Desiato et al., 2007) is an Italian national meteorological dataset at 10 x 10 km spatial resolution, starting from 1961. Finally, ARCIS (Pavan et al., 2019) and ERG5-Eraclito (Antolini et al., 2015) dataset are regional gridded products both at 5 x 5 km spatial resolution starting from 1961, but while the first, including only precipitation data, covers the entire Northern Italy, the latter, including also temperature data, covers Emilia-Romagna region exclusively.

For the study catchments, four distinct meteorological forcings, including the daily time series of areal mean precipitation, temperature, and potential evapotranspiration, were estimated using each of the four gridded products. Daily streamflow data were collected from three different regional agencies managing hydroclimatic data and were manually validated.

The rainfall-runoff model used for the indirect validation is the CemaNeige-GR6J (Coron et al., 2023), a daily lumped and continuously simulating model. We investigate the performances of the model in simulating streamflow, in order to get insights on the reliability of the gridded products across the region and along the years.

Model performances are also analysed against catchment features and data set characteristics to investigate whether certain conditions influence the representativeness of the gridded products and the corresponding streamflow simulations, enhancing our understanding of their applicability and limitations. As an example, Figure 1 shows which of the four meteorological gridded products lead to the best rainfall-runoff model accuracy in the different catchments of Emilia-Romagna.

Figure 1 – Example of the results for Emilia-Romagna region: meteorological gridded products leading to the best model accuracy. Streamgauges are coloured accordingly to the best meteo product: blue for E-OBS, red for ARCIS, green for SCIA and grey for ERG5-Eraclito.

References

Antolini G., Auteri L., Pavan V, Tomei F., Tomozeiu R., Marletto V. (2015). A daily high-resolution gridded climatic data set for Emilia-Romagna, Italy, during 1961-2010. *International Journal of Climatology,* 08/2015.

Cornes R. C., van der Schrier G., van den Besselaar E.J., Jones P.D. (2018). An ensemble version of the E-OBS temperature and precipitation data sets. *Journal of Geophysical Research: Atmospheres*, 123(17), 9391-9409.

Coron L., Delaigue O., Thirel G., Dorchies D., Perrin C., Michel C. (2023). airGR: Suite of GR Hydrological Models for Precipitation-Runoff Modelling. R package version 1.7.4.

Desiato F., Lena F., Toreti A. (2007). SCIA: a system for a better knowledge of the Italian climate. *Bollettino di Geofisica Teorica ed Applicata*, 48(3), 351-358.

Pavan V., Antolini G., Barbiero R., Berni N., Brunier F., Cacciamani C., et al. (2019). High resolution climate precipitation analysis for north-central Italy, 1961–2015. *Climate Dynamics*, 52, 3435-3453.

Spoke VS1: Water

Advances in pluvial flooding modelling for the assessment of risk scenarios

Marzia Acquilino[1], Giorgio Boni[1], Arianna Cauteruccio[1], Ilaria Gnecco[1]

(1) Dept. of Civil, Chemical and Environmental Engineering, University of Genova, arianna.cauteruccio@edu.unige.it

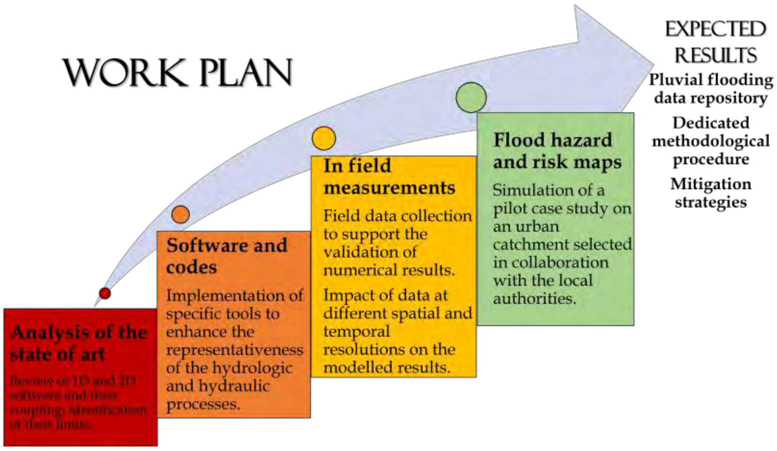
The proposed work is part of the RETURN project, specifically falling under VS1 – Spoke Water, WP 1.2 – Flood risk under environmental and climatic changes. The research will be conducted as part of a Ph.D. project within the Ph.D. program in Civil, Chemical and Environmental Engineering, curriculum of fluid dynamics and environmental engineering, at the University of Genova.

The increasing frequency of pluvial flooding due to climate change and the high urbanization rate, that causes soil impermeabilization and the narrowing of already-existing rivers, has led to a rise in the number of peoples affected by floods. Pluvial flooding caused by inadequate stormwater management systems is receiving increasing attention; therefore, this research aims to improve the modelling of pluvial flooding events.

The approach involves a thorough examination of the coupling of 1D and 2D hydraulic and hydrological models, including a review of existing literature and software limitations, to select the most appropriate modelling approach. Field data will be used to validate the modelled results, and the role of the input data in terms of spatial and temporal resolutions will be assessed. The developed procedure can be applied to densely populated urban catchments.

The adopted data will be collected in an appropriate repository and a dedicated methodological procedure will be summarized. Results will be shown in terms of flood hazard and risk maps. A pilot case study will be chosen in the Genova Metropolitan Area (Italy) among urban catchments recently affected by pluvial flooding events in collaboration with local authorities. Flood scenarios will be simulated and coupled with vulnerable asset maps, categorizing damage scenarios. The study will also explore mitigation strategies to be potentially installed in the urban catchment under investigation.

The work plan of the ongoing research is schematized in Figure 1.


WORK PLAN

Analysis of the state of art

Review of 1D and 2D software and their coupling, identification of their limits.

Software and codes

Implementation of specific tools to enhance the representativeness of the hydrologic and hydraulic processes.

In field measurements

Field data collection to support the validation of numerical results.

Impact of data at different spatial and temporal resolutions on the modelled results.

Flood hazard and risk maps

Simulation of a pilot case study on an urban catchment selected in collaboration with the local authorities.

EXPECTED RESULTS

Pluvial flooding data repository

Dedicated methodological procedure

Mitigation strategies

Figure 1 – Work plan of the ongoing research activities.

Simulation of flood and debris flows in mountainous regions and of their impact on hydraulic structures

Elena Bachini[1], Antonia Larese[1,2] Mario Putti[3]

(1) Department of Mathematics "Tullio Levi-Civita", University of Padua, elena.bachini@unipd.it
(2) Institute for Advanced Study, Technical University of Munich
(3) Department of Agronomy, Food, Natural resources, Animals and Environment, University of Padua

In the last decades we have observed a rapid growth of extreme floods and rock/debris or mud flows especially in mountainous regions. The possibility to reproduce, using numerical simulations, the physics behind such extremes could be crucial to evaluate their impact on structures such as check dams and downstream villages.

Physics-based simulations tools have the potential to achieve an extremely high fidelity and are often reliable ways for describing complex engineering and physical systems. Nevertheless, the possibility to accurately simulate multiphysics phenomena is still an open challenge in computational engineering. On the one hand, a widespread expertise in many different fields (e.g., hydraulic, structural, geotechnical) is required to accurately describe the physical model. At the same time, a deep knowledge of cutting-edge computational approaches is required to handle and integrate together different numerical techniques, ranging from classical finite elements to continuum particle-based methods, is necessary to overcome the intrinsic limitations of any single method.

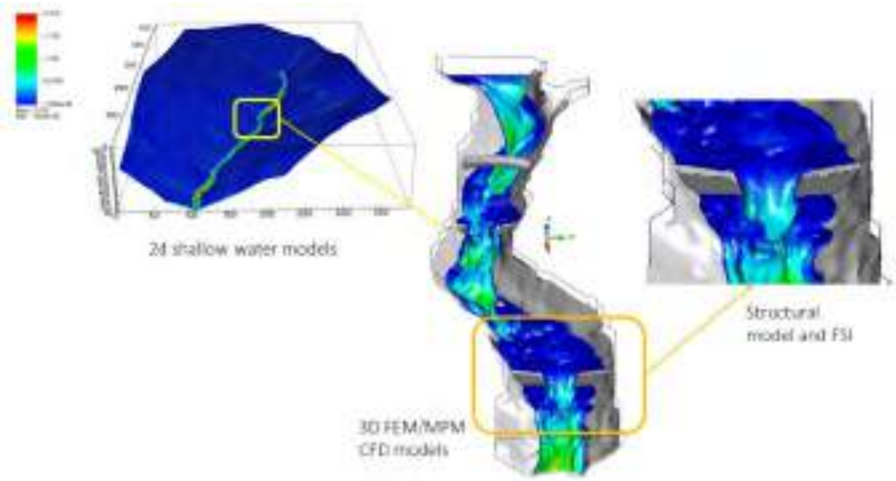


Figure 1. Shallow water models will be used for the flow simulation at the basin scale. These models will be coupled with 3D local models in the surrounding of critical areas or structures. Finally the extreme forcing history will be evaluated on critical structures using, if needed, appropriate FSI approaches.

We plan to tackle the problem using a multi-scale approach to simulate the dynamics of the rock/ debris flow and its interaction and impact on existing structures (Figure 1). We are working on the development of 2-dimensional shallow water (SW) models able to simulate the dynamics of the flow at river basin scale (~km^2) also on steep slopes (Fent et al. 2018, Bachini, Putti 2020) and of 3-dimensional free surface models able to capture the dynamics of the flow at local scale (~10-100m^2), considering the real topography of the studied test case (Larese et al. 2015a, Rossi et al. 2013).

We are investigating the downscaling between the large-scale shallow water modeling and the small-scale 3D models and their interaction. The final goal will be to use these models for evaluating the impact of such extreme forcing scenarios on massive structures such as check dams or flexible retaining nets used as protection systems (Singer et al., 2022, 2023).

References

Bachini E., Putti M. (2020). Geometrically intrinsic modeling of shallow water flows. *ESAIM Math. Model. Num. Anal*., 54(6), 2125–2157.

Larese A., Rossi R., Oñate E. (2015). Finite Element Modeling of free surface flow in variable porosity media. *Archives for Numerical Methods in Engineering*, 22(4), 637-653.

Rossi R., Larese A., Dadvand P., Oñate E. (2013). An efficient edge-based level set finite element method for free surface flow problems. *International journal for numerical methods in fluids*, 71-6, 687-716.

Singer V., Sautter K.B., Larese A., Wüchner R., Bletzinger K.U. (2022). A partitioned material point method and discrete element method coupling scheme. *Advanced Modeling and Simulation in Engineering Sciences*, 9(16).

Singer V., Teschemacher T., Larese A., Wüchner R., Bletzinger K.U. (2023). Lagrange multiplier imposition of non-conforming essential boundary conditions in implicit material point method. In press in *Computational Mechanics.*

Characterization of extreme drought events over Europe

Fabiola Banfi[1], Carmelo Cammalleri[1], Carlo De Michele[1]

(1) Dept. of Civil and Environmental Engineering, Politecnico di Milano, fabiola.banfi@polimi.it

Drought can be considered the most severe and the most complex weather-related natural hazard. With impacts that may extend to large areas and log time spans, and the capability to occur in all climatic zones, drought is the first hazard for the number of people affected. Due to its complex spatio-temporal structure and a complex web of impacts – involving delayed effects and indirect damages, also in distant locations – droughts are in fact quite difficult to characterize.

Due to the transboundary nature of drought events, an effective monitoring of their evolution must properly account for the full spatio-temporal structure. This characterization is a key step for a proper attribution of the related impacts. In addition, understanding common features in major droughts is of utmost importance for both monitoring and forecasting activities.

Here, drought events were characterized in their spatio-temporal evolution following the approach proposed by Cammalleri and Toreti (2023), based on a generalized 3D clustering using the Density-Based Spatial Clustering of Applications with Noise algorithm. This approach was applied at global scale to the 3-month accumulated Standardized Precipitation Index (SPI-3) dataset derived from ERA-5 reanalysis for the period 1981-2020 as described in Cammalleri et al. (2023). Over Europe, 198 events were identified with a duration greater than 1 month and a total cumulative area of at least 350,000 Km^2.

From the European dataset of drought events obtained as described above we extracted only the events that were extreme in terms of maximum extension, and we further analyzed their spatio-temporal properties. We computed Normalized Area - Time Accumulation (NATA) curves (Chen et al., 2023) to follow their expansion/contraction as a function of time. With these curves, we were able to subdivide the drought evolution into three phases, roughly corresponding to the early growing (phase 1), consolidation (phase 2), and exhaustion (phase 3) stages.

The NATA curves are useful to summarize the temporal evolution of droughts, however they do not provide information on the simultaneous spatial evolution. For this reason, we combined this analysis with the analysis of the main direction of expansion of the events, which allows us to fully characterize each drought events using a small number of characteristics.

The final aim of this study was to classify the extreme drought events into similar categories, to understand which variables have common values through all the events and which variables allow a distinction between them. This was achieved through a cluster analysis, which resulted in the identification of two main groups of events with similar spatio-temporal traits.

The different steps of the analysis are summarized in Figure 1.

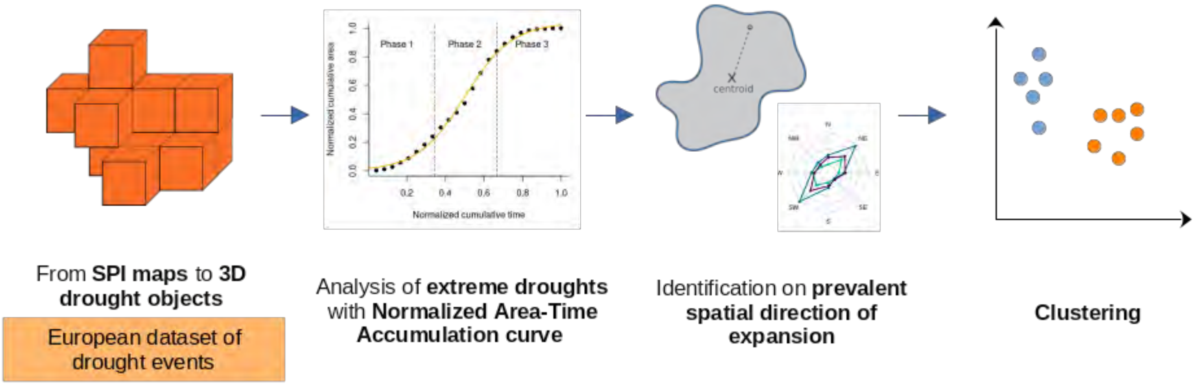


Figure 1: Schematization of the steps carried out in the present analysis.

References

Cammalleri, C., Toreti, A. (2023). A Generalized Density-Based Algorithm for the Spatiotemporal Tracking of Drought Events. *Journal of Hydrometeorology*, 24(3), 537-548.

Cammalleri C., Acosta Navarro J.C., Bavera D., Diaz V., Di Ciollo C., Maetens W., et al. (2023). An event-oriented database of meteorological droughts in Europe based on spatio-temporal clustering. *Scientific Reports*, 13(1), 3145.

Chen R., Liu Y., Zhu Y., Ren L., Qu J., Otkin J.A., et al. (2023). A spatiotemporal deconstruction-based approach for identifying flash drought expansion: normalized area-time accumulation curve. *Journal of Hydrology*, 621, 129509.

The Emilia-Romagna extreme flooding event: monitoring coastal water quality

Riccardo Bentivogli[1], Luigi Elia Petrozzi[1], Martina La Torre[1], Alessandro Piazza[1], Paola Valbonesi[1], Elena Fabbri[1], Nicolas Greggio[1], Laura Pezzolesi[1], Beatrice M.S. Giambastiani[1], Federica Costantini[1], Sonia Silvestri[1]

(1) *Department of Biological, Geological and Environmental Sciences (BiGeA), University of Bologna*, riccardo.bentivogli4@unibo.it

The escalating frequency and magnitude of extreme events in the coming decades are anticipated to rise not solely due to climate-related physical stressors, but also due to persistent socio-economic stressors and urban areas development (Edmonds et al., 2020). Floods can have significant environmental consequences, leading to substantial economic damage and biodiversity reduction. River floods directly impact coastal water quality, affecting the aquatic ecosystem. The discharge of freshwater and nutrients from rivers profoundly affects biological and environmental patterns in coastal areas, triggering phytoplankton blooms (Hoshiba et al., 2021). Here, the consequences of the devastating Emilia-Romagna flood occurred in Spring 2023 are investigated. Around 350 million cubic meters of rainfall caused overflowing rivers and landslides between May 16th and 18th. We aimed to conduct a transdisciplinary analysis of the water matrix including biogeochemical observations to assess and monitor environmental and biological variables immediately following the extreme event. We conducted three field campaigns on May 30th, June 14th and October 10th to collect water samples and evaluate the flood consequences right after the event as well as the recovery process. In-situ data collection encompassed both drainage canals (6 stations) and coastal sea (8 stations) in Ravenna, an area significantly impacted by the floods. Collected environmental parameters included: (i) salinity, (ii) water depth, (iii) temperature, (iv) dissolved oxygen, (v) pH, (vi) chlorophyll-a, (vii) organic and inorganic nutrients, and (viii) emerging pollutants. Sediments and their geochemical compositions were analyzed, and environmental DNA from water samples was extracted for studying microalgal and bacterial communities.

While satellite imagery could play a substantial role in monitoring seawater, most satellite missions designed for monitoring sea water quality focuse on open ocean conditions (case 1 water). Unfortunately, there are currently only a few high spatial/spectral resolution sensors specifically available for monitoring coastal waters (case2 waters). In coastal areas, the abundance of optically active substances like chlorophyll-a (Chl-a), Total Suspended Matter (TSM) and Colored Dissolved Organic Matter (CDOM) introduces additional challenges, leading to complexities during the remote sensing monitoring process. In this work we aimed to couple in-situ observations and satellite images to investigate the capability of rapidly exploiting remote sensing data to monitor Chl-a, TSM, CDOM during extreme events. With this purpose in mind, three different cloud-free L1C Sentinel-2 MSI satellite images collected concurrently with the field campaigns were acquired from the Copernicus Open Access Hub. These images were used to derive the concentration of water constituents, and the results were evaluated by comparison with in-situ matchups. A set of processors (C2-Nets, Brockmann et al., 2016) including the Case 2 Regional Coast Colour (C2RCC), Case 2 Extreme neural nets (C2X-Nets) and Case 2 Extreme Complex neural nets (C2XC-Nets) was used. These processors are implemented in SNAP software *v9.0.0* (*ESA Sentinel Application Platform*). Atmospheric correction parameters as well as water salinity and temperature were set according to in-situ measurements. Chl-a and TSM factors were also obtained from in-situ samples, whereas air pressure and ozone interpolation were obtained from the meteorological agency (https://www.meteo.it/) and the NASA Open Data Portal (https://data.nasa.gov/) respectively. For the validation stage, an area of 3x3 pixels centered around the sampling station was considered with the purpose of enhancing water homogeneity and minimizing the likelihood of selecting anomalous pixels. The water quality parameters maps generated using the C2-Nets are shown in Figure 1.

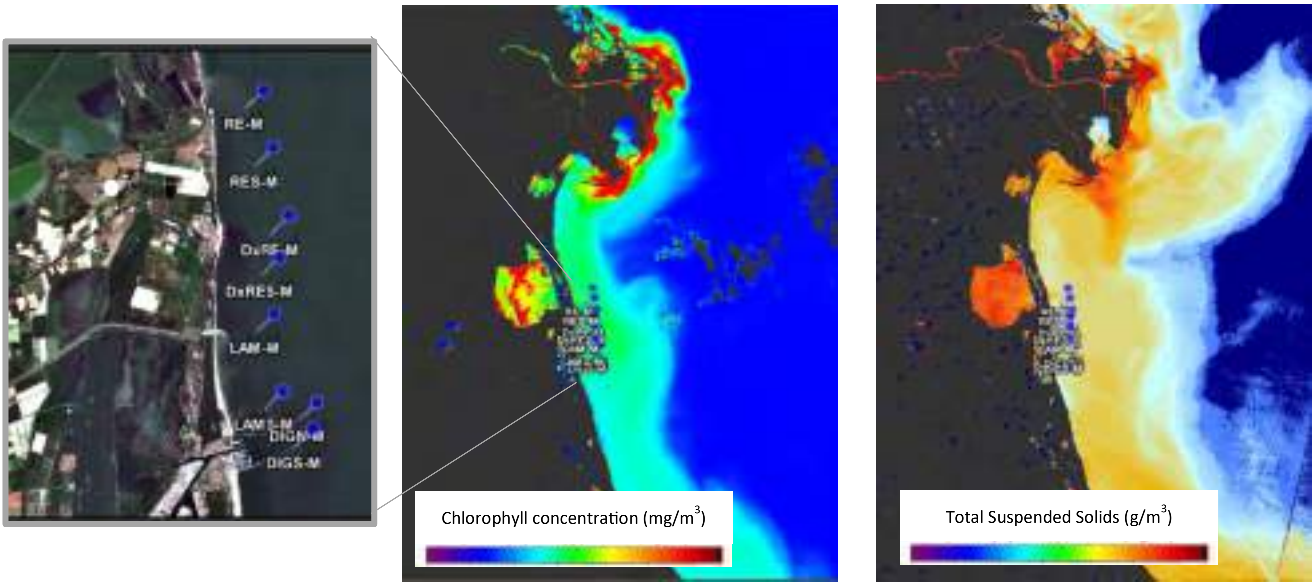


Figure 1. Example of Chl-a (left) and TSM (right) maps obtained with C2X processor on 14th July Sentinel-2 MSI image.

Multiple statistical metrics, including RMSE, NRMSE and R^2, were employed to evaluate the performance of the C2-Nets products. Considering the three different times, the findings showed that C2X and C2XC processors constantly outperformed the C2RCC, exhibiting lower RMSE values for Chl-a (average RMSE = 8.00 mg/m^3) and TSM (average RMSE = 12.00 g/m^3). The correlation between in-situ data and algorithm results was overall good for Chl-a for the October dataset ($R^2 > 0.6$) while poor during for May and June datasets ($R^2 = 0.3$). The R^2 never exceeded 0.4 for TSM for all datasets.

We conclude that despite the significant development in utilizing remote sensing for water quality studies, considerable uncertainty persists regarding the performance of atmospheric correction algorithms in diverse optical water types. Discrepancies among processors may arise from differences in training datasets, impacting their effectiveness. Notably, processors exhibited the lowest errors in October, suggesting their effectiveness when the ecosystem recovered from the flood event. However, during May and July, C2RCC algorithms faced challenges, emphasizing the need for systematic adjustments to processor parameters based on local conditions after extreme events.

References

Brockmann C., Doerffer R., Peters M., Kerstin S., Embacher S., Ruescas A. (2016). Evolution of the C2RCC neural network for Sentinel 2 and 3 for the retrieval of ocean colour products in normal and extreme optically complex waters. In *Living Planet Symposium,* 740, 54.

Edmonds D.A., Caldwell R.L., Brondizio, E.S., Siani S.M. (2020). Coastal flooding will disproportionately impact people on river deltas. *Nature communications*, 11(1), 4741.

Hoshiba Y., Hasumi H., Itoh S., Matsumura Y., Nakada S. (2021). Biogeochemical impacts of flooding discharge with high suspended sediment on coastal seas: a modeling study for a microtidal open bay. *Scientific Reports*, 11(1), 21322.

Characterization of karst spring response to rainfall events

Fulvio Boano[1], Ilaria Butera[1], Alberto Viglione[1], Bartolomeo Vigna[1]

(1) Dept. of Environment, Land and Infrastructure Engineering, Politecnico di Torino, fulvio.boano@polito.it

In recent years, the general concern that climate change may affect water resources availability seems to be confirmed by the observed phenomena. Recent drought periods have manifested the vulnerability of this resource. In periods of drought, the lack of water is initially evident in surface water bodies and subsequently in springs and aquifers, which initially can compensate for the water shortage in the surface water network, but they too are a limited resource. Among the others, springs are an important source of water supply in Italy and a decline in their water availability would be problematic. The presence of many sources of drinking water at high altitudes requires timely and accurate analyzes to evaluate the effect of climate change on this resource. The risk of overexploitation of springs during periods of drought is high, with environmental damage that will probably take a long time to eliminate.

In karst catchments, aquifer recharge occurs through a composite mosaic of subsurface flow paths, difficult to model in detail. Precipitation infiltrates in the subsurface and flows along a complex network of fractures – that are characterized by different sizes and degrees of saturation – before eventually reaching the catchment outlet. The discharge of a karst spring is the result of the contributions of these flow paths, that may differ widely in terms of lengths, velocities and travel times. Monitoring the spring discharge can thus provide information about flow within the aquifer. In particular, the spring discharge signal can be interpreted as the lagged response of the aquifer to precipitation inputs over the catchment, with the aquifer being characterized by a distribution of response times that relates input (precipitation) to output (discharge). Identifying these response times is important to forecast water availability but it is not a trivial task as the input-output problem is often mathematically ill-posed, which leads to amplification of the errors and may prevent finding a physically meaningful solution (e.g. Pansa et al., 2023).

In this work we present preliminary results of a method developed on purpose to evaluate the distribution of response times of a karst aquifer that feeds a spring. The method, that is a variant of other methods originally developed to deal with ill-posed problems in geostatistical applications (e.g. Barati Moghaddam et al., 2022) relies on a probabilistic description of precipitation inputs and discharge outputs, and it provides an estimate of the response time distribution and of its uncertainty. The method is here tested through the application to datasets collected in Bossea cave system in Northern Italy (Antonellini et al., 2019). The identification, at single event scale of the precipitation-flow relationship, considered rainfall events separately according to the season because, for instance, the snow effect is present only in spring events.

The results demonstrate that the method successfully identifies different response time distributions that reflect the differences aquifer dynamics in each season. The outcomes are compared with the results obtained with another methodology (Pansa et al., 2023) to highlights its strengths and weaknesses. On the basis of the preliminary results, the developed method seems to be an efficient tool for the indirect investigation of karst systems and to evaluate the possible future impact of climate change on the flow from springs.

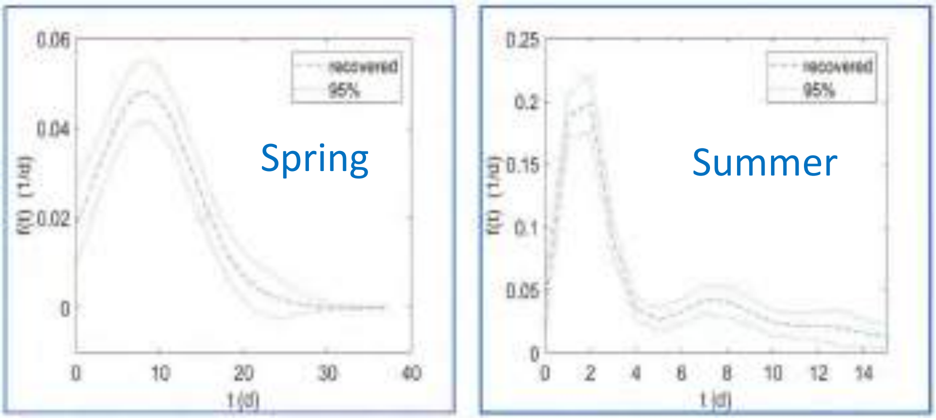


Figure 1 – Example of the obtained response times relating rainfall and spring discharges in case of a spring event and a summer event.

References

Antonellini M., Nannoni A., Vigna B., De Waele J. (2019). Structural control on karst water circulation and speleogenesis in a lithological contact zone: The Bossea cave system (Western Alps, Italy). *Geomorphology*, 345, 106832.

Barati Moghaddam M., Mazaheri M., Mohammad Vali Samani J., Boano F. (2022). An innovative framework for real-time monitoring of pollutant point sources in river networks. *Stochastic Environment Research and Risk Assessment*, 36(7), 1791–1818.

Pansa A., Butera I., Gómez-Hernández J.J., Vigna B. (2023). Predicting discharge from a complex karst system using the ensemble smoother with multiple data assimilation. *Stochastic Environment Research and Risk Assessment.*, 37(1), 185–201.

Stochastic temporal downscaling in Northeast Italy using convection-permitting climate models: from hourly to sub-hourly timescales

Maria Francesca Caruso[1], Eleonora Dallan[2], Giorgia Fosser[3], Marco Borga[2], Marco Marani[1]

(1) Department of Civil, Architectural, and Environmental Engineering, University of Padova, mariafrancesca.caruso@unipd.it
(2) Department of Land Environment Agriculture and Forestry, University of Padova
(3) Department of Civil, Architectural, and Environmental Engineering, University School for Advanced Studies – IUSS Pavia

The statistical properties of rainfall at short durations are pivotal for many hydrological applications. Commonly available rainfall records nor km-scale model, i.e. Convection-Permitting Models (CPMs), do not provide rainfall data at the sub-hourly scales needed for many applications, such as hydrological modelling in small or urban catchments or landslide or debris-flow models. Motivated by the above considerations, in this application a statistical downscaling technique is proposed for inferring the rainfall correlation structure at sub-hourly scale by using hourly statistics from CPM simulations. The proposed approach is based on the theory of stochastic processes, which establishes statistical relationships between coarse-scale predictors and fine-scale predictands. To validate the temporally downscaled results against observations, here we use, as a benchmark, high-resolution rainfall records from a dense network of rain gauges in northeastern Italy considering aggregation timescales ranging from 5 minutes to 24 hours. We then explore how the downscaling method developed here, coupled with the Complete Stochastic Modelling Solution (CoSMoS; Papalexiou, 2018) framework, may be used to generate sub-hourly rainfall sequences that reproduce the observed short- and long-timescale variability. Applied to statistics for each month in a year, to reproduce seasonality, the proposed downscaling method appropriately reproduces the observed correlation structure at desired fine-scale resolution. Consequently, the rainfall generator used here, by exploiting the downscaled information from CPM runs, allows to generate rainfall records at the desired scale that may be used for evaluating risk and risk change scenarios, for example associated with debris flows.

References

Papalexiou S.M. (2018). Unified theory for stochastic modelling of hydroclimatic processes: Preserving marginal distributions, correlation structures, and intermittency. *Advances in Water Resources*, 115, 234-252.

Summer drought predictability in the Mediterranean region in seasonal forecasts

Giada Cerato[1], Katinka Bellomo[1,2], Jost von Hardenberg[1,2]

(1) Department of Environmental, Land and Infrastructure Engineering, Politecnico di Torino giada.cerato@polito.it
(2) Institute of Atmospheric Sciences and Climate, Consiglio Nazionale delle Ricerche

The Mediterranean region has been identified as an important climate change hotspot, over the 21st century both air temperature and its extremes are projected to rise at a rate surpassing that of the global average and a significant decrease of average summer precipitation is projected, particularly for the western Mediterranean. On average, Mediterranean droughts have become more frequent and intense in recent years and are expected to become more widespread in many regions. These prolonged dry spells pose a substantial threat to agriculture and impact several socio-economic sectors. In this context, long-range weather forecasting has emerged as a promising tool for seasonal drought risk assessment. However, the interpretation of the forecasting products is not always straightforward due to their inherent probabilistic nature. Therefore, a rigorous evaluation process is needed to determine the extent to which these forecasts provide a fruitful advantage over much simpler forecasting systems, such as those based on climatology.

In this study, we use the latest version of ECMWF's seasonal prediction system (SEAS5) to understand its skill in predicting summer droughts. The Standardized Precipitation Evapotranspiration Index (SPEI) aggregated over different lead times is employed to mark below-normal dryness conditions in August. We use a comprehensive set of evaluation metrics to gain insight into the accuracy, systematic biases, association, discrimination and sharpness of the forecast system. Our findings reveal that up to 3 months lead time, seasonal forecasts show stronger association and discrimination skills than the climatological forecast, especially in the Southern Mediterranean, although the prediction quality in terms of accuracy and sharpness is limited. On the other hand, extending the forecast range up to 6 months lead time dramatically reduces its predictability skill, with the system mostly underperforming elementary climatological predictions.

This approach is then extended to examine the full ensemble of seasonal forecasting systems provided by the Copernicus Climate Change Service (C3S) to test their skill in predicting droughts. Our findings can help an informed use of seasonal forecasts of droughts and the development of related climate services.

Numerical model of the response of urban drainage networks in heterogeneous precipitations scenario

Elisa Costamagna[1], Francesco Loddo[2], Fulvio Boano[1], Luca Ridolfi[1]

(1) Dept. of Environment, Land and Infrastructure Engineering, Politecnico di Torino, elisa.costamagna@polito.it
(2) Department of Structural, Geotechnical and Building Engineering, Politecnico di Torino

The role of urban drainage network in urban areas is essential to guarantee a safe control of precipitation events. In recent years, according to ISPRA analysis of the climate indicators in Italy, the recorded rainfall events are less frequent but more extreme. Since the drainage networks are usually formed by small subnetworks, hence resulting in small-sized basins with fast times of response, the prediction of pluvial flood hydrographs in urban basins is hindered by considerable uncertainty due to the spatial and temporal variability of rainfall intensity, which is difficult to characterize with the sparse observations from the limited amount of rain gauges that are typically available. To better understand and quantify this uncertainty, the drainage network of Turin is considered a case study to be modelled.

The city of Turin has more than 800.000 residents and is located in Northwestern Italy on a relatively flat area bordering a hill on the East. The area is mostly urbanized, and it receives an average precipitation of around 800 mm per year. The drainage network was developed starting at the end of the 19th century as a separate network that receives only stormwater from a catchment area of around 100 km2, for a total network length of around 1200 km. At present, the network experiences some criticalities due to infrastructure ageing and urban development, and occasional flooding episodes are observed at some points.

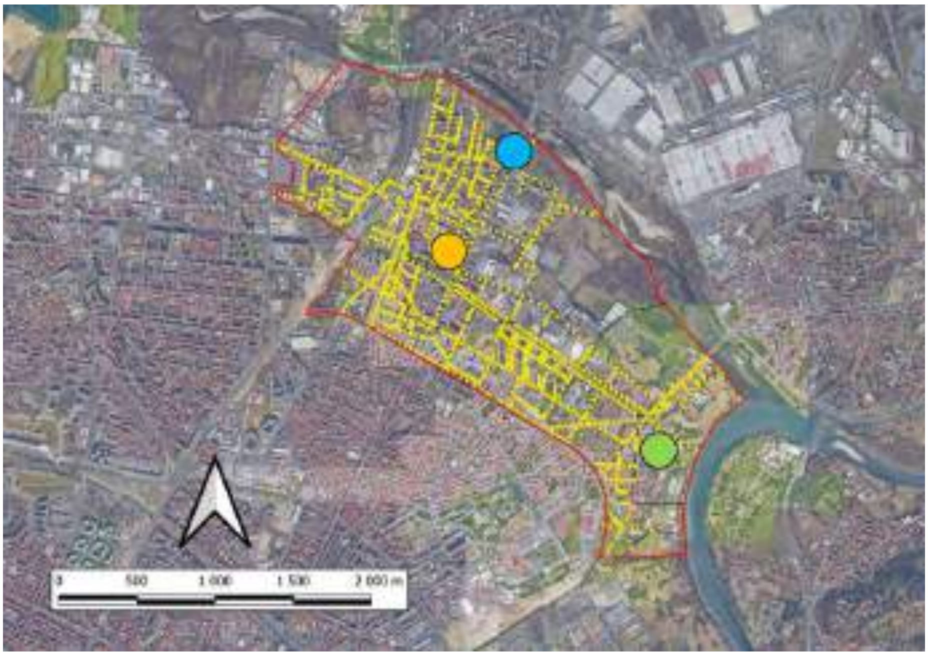


Figure 1 – location of the rain gauges (yellow and green dots) and one flow meter (blue dot).

The sensitivity of flood hydrographs at the basin outlet to spatial and temporal patterns of rainfall intensity is analysed using a SWMM hydraulic model of different parts of the drainage networks. Spatial and temporal variability of rainfall intensity over the area is quantified using the observations of a set of 21 rain gauges.

Then, the analysis of the sensitivity of the flood hydrograph in a monitored subnetwork is performed based on two rain gauges (2 km apart) and one flow meter at the basin outlet (Fig. 1). The simulation runs with the data collected by the two rain gauges during four recorded rain events. The simulated flow rate is compared with the one recorded by an installed level and speed meter, to test test the reliability of the simulations. Different modelling methods are used, with different attributions of recorded rain to the subnetwork area, and with different soil infiltration parameters, aiming to reduce variability and increase accuracy in the results.

The results provide valuable insight into the response of urban drainage networks to heterogeneous spatial fields of precipitation.

Limited impacts of salt-marsh restoration on hydrodynamic and sediment transport processes in the shallow microtidal Lagoon of Venice (Italy)

Alvise Finotello[1], Davide Tognin[2], Sebastiano Frasson[1], Andrea D'Alpaos[1]

(1) Dept. of Geoscience, University of Padova, alvise.finotello@unipd.it
(2) Dept. of Civil, Environmental, and Architectural Engineering, University of Padova

The Venice Lagoon possesses one of the planet's most fascinating and distinctive ecosystems, owing to its unique geographical location coupled with a long-lasting cultural heritage. Located in the northern reaches of the Adriatic Sea, this lagoon has undergone significant human-induced changes over time. Originally characterized by extremely shallow waters resulting from limited erosion from the sea and significant sediment deposition from major rivers such as the Piave, Sile, Brenta, and Bacchiglione, human interventions in past centuries (e.g., river diversion, excavation of navigable channels, construction of jetties at the Lagoon's inlets) produced significant deepening of the lagoonal bed through both direct and indirect effects (Luigi D'Alpaos, 2010). In addition, land reclamation efforts were initiated to convert salt marshes (i.e., low-lying vegetated wetlands periodically flooded by tides) into agricultural, residential, or aquacultural lands (Finotello et al., 2023).

Salt marshes are a defining feature not only of the Venice Lagoon but also of many low-lying temperate and subtropical coastal regions (Murray et al., 2022). Currently, extensive loss of salt marshes is occurring worldwide, and significant efforts are underway to conserve and restore these valuable ecosystems, along with the services they provide to the environment and society, such as blue-carbon sequestration, environmental remediation, shoreline protection, and habitat provision (Barbier et al., 2011). While it is undeniably valuable to restore salt marshes for ecological and economic reasons, most previous studies have not closely examined the co-benefits of marsh restoration on hydrodynamics and sediment-transport processes, which ultimately impact the morphodynamic evolution of coastal systems. In particular, it remains unclear whether marsh restoration can return the system to the conditions observed before marshes were degraded. The Venice Lagoon provides a unique opportunity to study this issue in detail given the availability of both extensive historical topobathymetric data and state-of-the-art numerical modeling techniques that enable investigating the morphodynamics of past, present, and future lagoon morphologies (Carniello et al., 2009; Finotello et al., 2023). Specifically, here we investigate the effects of marsh degradation and the potential impacts of future restoration projects at the scale of the entire tidal basin by means of numerical modeling techniques. We examine the hydrodynamic and sediment transport processes in three different configurations of the Venice Lagoon: the present one and those observed in 1932 and 1901. These two historical configurations serve as references to simulate the effects of marsh restoration projects aimed at restoring the total marsh area that existed at those times.

Our results demonstrate that marsh restoration alone will not suffice in fully returning the Venice Lagoon's hydro-morphodynamics to those observed at the beginning of the last century. This is because not only have salt marshes changed, but the overall lagoon morphology has also evolved, making marsh restoration projects essentially neutral with respect to current hydrodynamic and sediment transport processes within the lagoon.

While not diminishing the intrinsic significance of marsh restoration projects, the findings of this study specifically illustrate that marsh restoration may not provide a practical solution to address the long-standing issue of morphological degradation observed in Venice over the past century, also urging caution in considering the restoration of similar shallow-water back-barrier lagoons that are prevalent along coastlines worldwide.

References

Barbier E.B., Hacker S.D., Kennedy C., Koch E.W., Stier A.C., Silliman, B.R. (2011). The value of estuarine and coastal ecosystem services. *Ecological Monographs*, 81(2), 169–193.

Carniello L., Defina A., D’Alpaos L. (2009). Morphological evolution of the Venice lagoon: evidence from the past and trend for the future. *Journal of Geophysical Research: Earth Surface*, 114(4), 1–10.

D’Alpaos L. (2010). Fatti e misfatti di idraulica lagunare. La laguna di Venezia dalla diversione dei fiumi alle nuove opere delle bocche di porto. (L D’Alpaos, Ed.), Istituto Veneto di Scienze, Lettere e Arti (Vol. 1999). Venice: Istituto Veneto di Scienze, Lettere ed Arti.

Finotello A., Tognin D., Carniello L., Ghinassi M., Bertuzzo E., D’Alpaos A. (2023). Hydrodynamic feedbacks of salt-marsh loss in the shallow microtidal back-barrier Lagoon of Venice (Italy). *Water Resources Research*, 59(3), 32.

Murray N.J., Worthington T.A., Bunting P., Duce S., Hagger V., Lovelock C.E., et al. (2022). High-resolution mapping of losses and gains of Earth’s tidal wetlands. *Science*, 376(6594), 744–749.

Mapping the loss probability of pedestrians to improve the perception and communication of flood risk

Tommaso Lazzarin[1], Albert S. Chen[2], Daniele P. Viero[1]

(1) Dept. of Civil, Environmental, and Architectural Engineering, University of Padova, tommaso.lazzarin@phd.unipd.it
(2) Centre for Water Systems, University of Exeter

A proper evaluation and an effective communication of flood risk are important aspects to enforce flood preparedness and to reduce the impacts of future flooding events (Kreibich et al. 2017). In particular, communicating the expected flood risk to different categories of people (i.e., non-technician, of different age and formation) is recognized as a real challenge (Feldman et al., 2016). Flood maps showing the spatial distribution of the flow depth and velocity, that are typically used to represent flood scenarios, are unable to convey intelligible information on the associated hazard to the general public (Houston et al., 2019).

Any information, to be easily understandable to ordinary people, must be strongly connected with their practical experience and risk perception. Hence, an effective strategy is to communicate the danger associated to a given flooding condition with reference to human stability in floodwater. In this view, a number of hazard indexes, proposed in the last decades, express flood hazard for pedestrians by combining flow depth and velocity, based on available data or on conceptual models. Some of these hazard indexes suffer from a lack of proper physical foundation (Lazzarin et al., 2022). Others, primarily developed to identify only the critical threshold for human instability in floodwaters, were extended to rate intermediate flood hazard conditions by assuming a linear dependence of hazard on flow velocity. Considering that human stability in floodwaters is a matter of forces, which depend on the square of the velocity, such an extension is a gross oversimplification (Lazzarin et al., 2024).

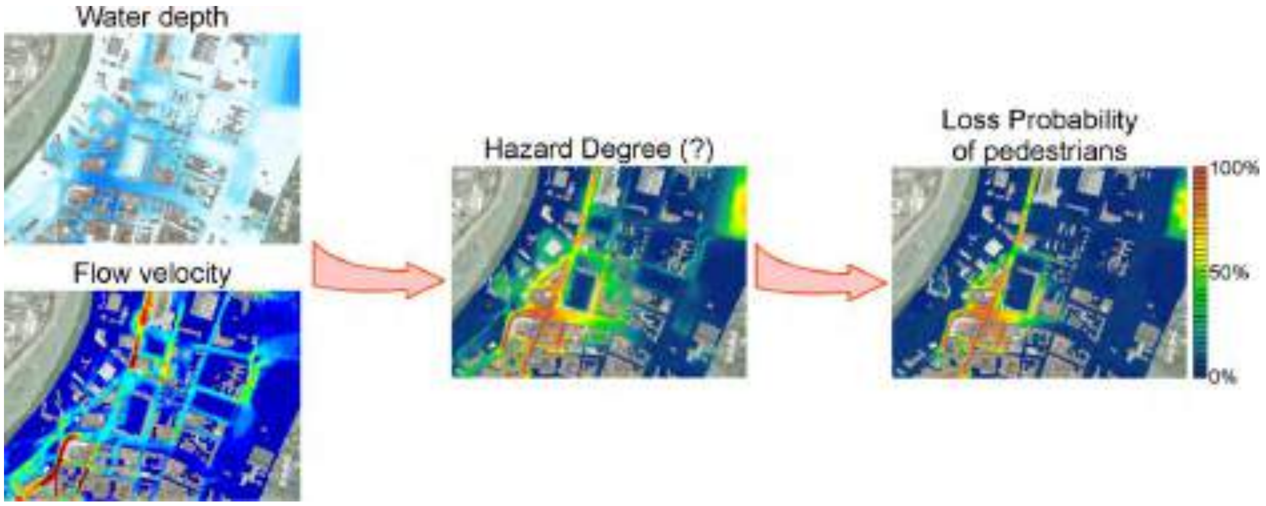


Figure 1 – Different strategies to map hydraulic hazard and risk.

To provide an unbiased perception of the real danger associated to flooding and to pursue an intelligible and effective way of communicating flood risk, we propose using the loss probability of people in floodwaters, *LP* (Lazzarin et al., 2024). Defined as the probability of a pedestrian to be swept away by floodwaters, *LP* varies between 0 and 100% (Figure 1), and accounts for both hazard and vulnerability in a physics-based and data-consistent fashion. Its spatial distribution can be easily computed as a function of water depth and velocity (Lazzarin et al., 2022; 2024).

A model application to a real case study highlights that all the different methods are able to correctly identify the endpoints of flood hazard, i.e., either no-hazard or extreme conditions. The main discrepancies between the use of previous hazard indexes and the loss probability, *LP*, emerge for intermediate hazard conditions. Particularly, in slow shallow waters, hazard indexes overestimate the risk perception, whereas *LP* correctly predicts low risk levels. On the other hand, *LP* identifies high risk conditions in slow and deep waters, for which hazard indexes generally provide a severe underestimation of the real danger. This last aspect is particularly important because deep floods are widespread in lowland areas.

In representing flood hazard, mapping the maximum water depths retains a definite value; being easily understandable, it provides a general picture of the flooded area in terms of both extent and severity. Besides that, the loss probability of pedestrians is an additional intelligible information; *LP* has an enhanced potential to discriminate a harmless nuisance flooding (Moftakhari et al., 2018) from a dangerous situation, which can be ascribed either to deep or fast flowing floodwaters. It is to be stressed that presenting flow depth and *LP* maps together is necessary to avoid the wrong perception that ‘no risk’ (i.e., *LP* ≈ 0) means ‘no damage’, i.e., to avoid generating false confidence in areas of low loss probability, where slow shallow waters can still produce extensive damage (possibility of entering the ground floor of buildings, reaching the door frame of vehicles, etc.).

References

Feldman, D., Contreras, S., Karlin, B., Basolo, V., Matthew, R., Sanders, B., et al. (2016). Communicating flood risk: looking back and forward at traditional and social media outlets. *International Journal of Disaster Risk Reduction*, 15, 43–51.

Houston, D., Cheung, W., Basolo, V., Feldman, D., Matthew, R., Sanders, et al. (2019). The influence of hazard maps and trust of flood controls on coastal flood spatial awareness and risk perception. *Environment and Behavior*, 51(4), 347–375.

Kreibich, H., Di Baldassarre, G., Vorogushyn, S., Aerts, J.C.J.H., Apel, H., Aronica, G.T., et al. (2017). Adaptation to flood risk: results of international paired flood event studies. *Earth’s Future*, 5(10), 953–965.

Lazzarin, T., Viero, D.P., Molinari, D., Ballio, F., Defina, A. (2022). Flood damage functions based on a single physics- and data-based impact parameter that jointly accounts for water depth and velocity. *Journal of Hydrology*, 607, 127485.

Lazzarin T., Chen A.S., Viero D.P. (2024). Beyond flood hazard. Mapping the loss probability of pedestrians to improve risk estimation and communication. *Science of the Total Environment*, 912, 168718.

Moftakhari, H.R., AghaKouchak, A., Sanders, B.F., Allaire, M., Matthew, R.A. (2018). What is nuisance flooding? Defining and monitoring an emerging challenge. *Water Resources Research*, 54(7), 4218-4227.

Assessing changes on sub-daily extreme rainfall in Italy with a non-stationary frequency analysis of convection-permitting model projections

Marco Lompi[1], Francesco Marra[2,3], Eleonora Dallan[4], Roberto Deidda[5], Enrica Caporali[1], Marco Borga[4]

(1) Department of Civil and Environmental Engineering (DICEA), University of Florence, marco.lompi@unifi.it
(2) Department of Geosciences, University of Padova
(3) Institute of Atmospheric Sciences and Climate, National Research Council of Italy
(4) Department of Land, Environment, Agriculture and Forestry, University of Padova
(5) Department of Civil, Environmental and Architecture Engineering, University of Cagliari

The intensity and frequency of extreme precipitation are changing in a warming climate. Assessing the possible change in extreme precipitation return levels is useful for adapting measures against increased flood risk. Changes in extreme precipitation are usually evaluated by analysing the climate projections from Regional Climate Models (RCM) with extreme value analysis methods. Nevertheless, the RCM resolution is too coarse to resolve convection, a critical driver of extreme sub-daily precipitation. Convection-Permitting Models (CPM) have finer resolutions that allow for the resolution of convection. Therefore, they have been demonstrated to be more accurate than RCM in describing the intensity of extremely short-duration events.

This study evaluates quantiles of precipitation extremes at the national scale using the Very High Resolution PROjections over Italy (VHR-PRO_IT, Raffa et al., 2023) as an input dataset. The projections are a downscaled product of the CMCC model at a convection-permitting scale of 2.2 km. The 1h-time resolution allows the analysis of the sub-daily annual maximum in two emission scenarios (RCP 4.5 and RCP 8.5). So far, this is the only CPM projection covering Italy in both emission scenarios with a continuous time series of 90 years from 1981 to 2070.

The methodology is based on the frequency analysis of the climate projections with the Simplified Metastatistical Extreme Value (SMEV) non-asymptotic approach (Marra et al., 2019), in which a two-parameter Weibull distribution describes the marginal distribution of the ordinary precipitation events and return levels are estimated explicitly considering the average number of yearly events.

Particularly, the methodology has been divided into two steps: first, a stationary SMEV with a moving window of 30 years has been fitted in 18 cities across Italy to check the dependence of the parameters in time; second, a non-stationary implementation of the SMEV (Vidrio-Sahagún and He 2022) is used to evaluate continuous changes in precipitation quantiles for different durations (1h, 3h, 6h, 12h and 24h) over the period 1981-2070 (1981-2005 historical + 2006-2070 future scenario). The Maximum Likelihood approach has been used in both steps to estimate the parameters.

In the first step, a bootstrap has been done to check if the signal of the changes in the parameters is greater than the noise due to the uncertainty in the sample. Figure 1 shows an example of the changes in the shape parameters in Florence in all the durations. The reduction in the shape parameters is associated with an increase in the most extreme events.

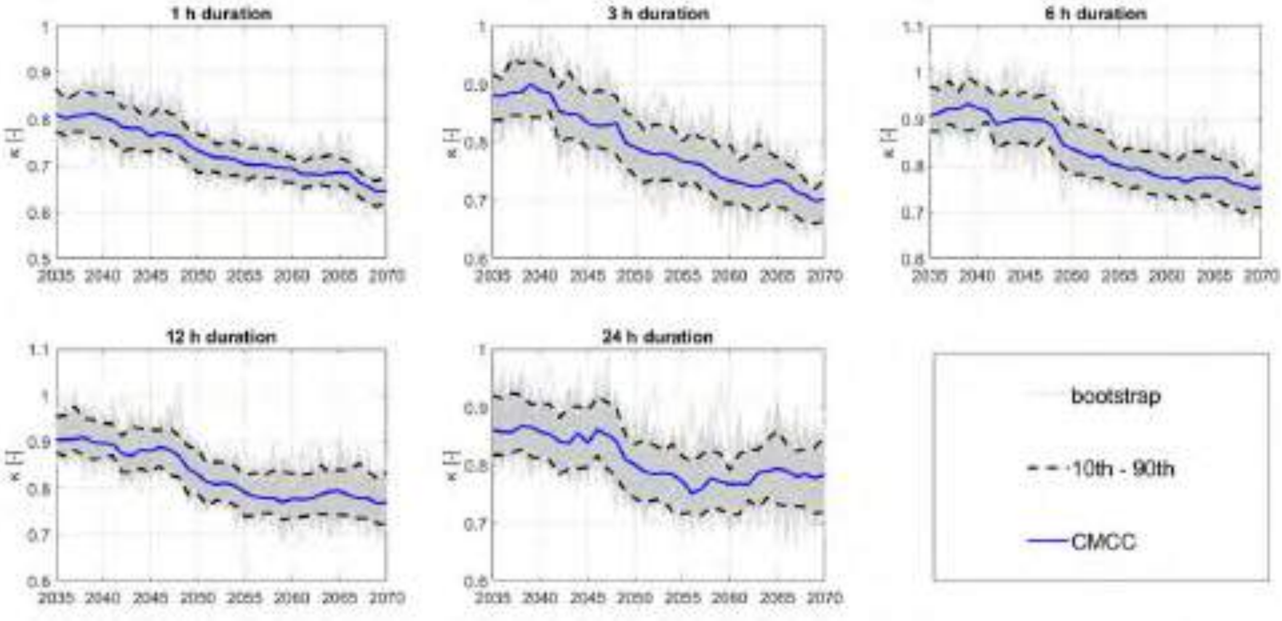


Figure 1 – Linear dependency of the shape parameter in all the durations for the RCP 8.5 future scenario. In the example, the changes in the shape parameter are shown for the city of Florence: in blue are the changes obtained for the time series of the model; in grey for the re-sampled time series of the bootstrap; the dashed black lines represent the 10th and 90th percentiles.

In the second step, three different models are compared: i) a stationary SMEV, with the two parameters constant in time; ii) a non-stationary SMEV model with the shape parameter kept constant and the scale parameter that changes linearly; iii) a fully non-stationary SMEV model in which both parameters are allowed to change linearly in time. The likelihood ratio test is used to assess the statistical significance of the dependence on time of the parameters.

The results of the likelihood ratio test show the areas in which significant changes in the distribution parameters and the return levels of extreme precipitation are projected. Moreover, the slope of the parameter and the projected changes in precipitation quantiles are shown. The maps show the areas with both increases and decreases of the return levels of the extreme precipitation for the two emission scenarios (RCP 4.5 and RCP 8.5), the precipitation durations (1h, 3h, 6h, 12h and 24h) and the considered return periods. The non-asymptotic approach allows the discussion of these results in terms of the main dynamic and thermodynamic drivers.

References

Marra F., Zoccatelli D., Armon M., Morin E. (2019). A simplified MEV formulation to model extremes emerging from multiple nonstationary underlying processes. *Adv. Water Resour.*, 127, 280-290

Raffa M., Adinolfi M., Reder A., Marras G.F., Mancini M., Scipione G., Santini M., Mercogliano P. (2023). Very High Resolution Projections over Italy under different CMIP5 IPCC scenarios. *Scientific Data*, 10, 238.

Vidrio-Sahagún C.T., He J. (2022). Hydrological frequency analysis under nonstationarity using the Metastatistical approach and its simplified version. *Adv. Water Resour.*, 166, 104244.

Sediment transport modelling in the design of flood-event scenarios

Laura Longoni[1], Monica Corti[1], Alessio Radice[1], Mirko Francioni[2], Monica Papini[1]

(1) Dipartimento di Ingegneria Civile e Ambientale, Politecnico di Milano, laura.longoni@polimi.it
(2) Dipartimento di Scienze Pure e Applicate, Università degli Studi di Urbino "Carlo Bo"

Natural hazards are widely recognized problems for human society are becoming more and more critical due to climate change. The presence of the mountain belts of the Alps and Apennines makes Italy one of the most exposed European countries to hydro-geomorphological hazards, as proven by casualties and large economic losses experienced every year in the country.

Urban settlements located at the downstream end of mountain catchments are highly prone to flash flood events in which sediment transport plays a significant role, as demonstrated by several recent studies (e.g., Longoni et al 2016, Radice et al 2012). It has been argued that stream morphological changes taking place over long periods may significantly change the river response to high flows. Moreover, it has been shown that in mountain regions the temporal scales of flow variation and morphological change can be similar to each other, resulting in a coupled process, where a sudden increase of river bed elevation may significantly increase the probability of outflow with inundation of the surroundings. During the past years, these natural calamities have increased in frequency. Carrara and Genova are only two examples of cities hit by floods characterized by sediment transport in 2014; the event of Senigallia in 2022 is another example.

International directives (like the European Directive on Floods) encourage the incorporation of sediment transport analyses into flood risk assessment, in recognition of the significant role played by sediment in flood hazard (Radice et al 2016).

In this research, we use a hydro-morphological model called SMARTSED (Gatti et al 2023) for the generation of flood-scenarios accounting for the role of sediment transport. Basins of different sizes are considered: two basins in northern Italy (the Caldone Basin in the pre-alpine area and the Tartano Basin in the Alpine area) and the basin that induced the flood in Semigallia are used in the simulations.

SMARTSED was developed by Politecnico di Milano. It is a physically-based model capable of simulating the effects of extreme rainfall events at catchments scale, taking into account relevant geological and geomorphological processes. This model is here used for a back analysis of real occurrences, but it can also forecast future risk scenarios in a climate change context using different time scales and modelling multiple hydraulic and geological processes that are active a basin. The software operates at a basin scale and simulates processes such as runoff transformation, surface runoff, erosion, sediment transport, and can recognize slopes susceptible to potential instability. Conceptually, the innovation of this model lies in the dynamic and non-aprioristic definition of flow cells that are automatically and dynamically identified a nd compose a flow network, unlike many similar models in the literature that statically predefine these cells. Additionally, leveraging global terrain databases, SMARTSED is capable of deriving granulometric composition (slopes) at a desired resolution through statistical downscaling (Gatti et al 2021). Required input data are of geographical and meteorological nature, often available for free from regional/national geoportals or global databases. Specifically, the model necessitates the digital elevation model (DEM) of any considered area, the watershed polygon, land use data (Corine Land Cover), rainfall and temperature data for the analyzed period, and geographic coordinates of relevant meteorological stations. The final model outputs encompass all variables related to simulated processes, such as water velocity, water and sediment height, snow height, distributed rainfall, infiltration rate, erosion-prone areas, evapotranspiration, surface runoff, liquid and solid discharge, and safety factor.

The event happened in Senigallia and, in general, in the whole Misa river catchments in 2022 is of particular interest not only for the damages that it determined, but also for the great amount of rainfall and the consequent erosion, which occurred in just one night. Rainfall height reached 400 mm in only one day in Cantiano (PU) and was beyond the ranges of the depth-duration curves currently used for the area. This event was interpreted as directly caused by climate change, as it was related to the development of a tropical storm in the Adriatic Sea, which is not common at these latitudes. This case shows in a clear way the impact that climate change can have on our territory in the next future.

References

F. Gatti, L. Bonaventura, A. Menafoglio, M. Papini, L. Longoni. (2023). A fully coupled superficial runoff and soil erosion basin scale model with efficient time stepping, *Computers & Geosciences,* 177, 105362.

Gatti F., Menafoglio A., Togni N., Bonaventura L., Brambilla D., Papini M., Longoni L. (2021). A novel downscaling procedure for compositional data in the Aitchison geometry with application to soil texture data. *Stoch. Environ. Res. Risk Assess.*, 35(6), 1223-1241

Longoni L., Ivanov V.I., Brambilla D., Radice A., Papini M., (2016). Analysis of the temporal and spatial scales of soil erosion and transport in a mountain basin. *Italian Journal of Engineering Geology and Environment* (IJEGE) - 16, 2, 17-30.

Radice A., Giorgetti E., Brambilla D., Longoni L., Papini M. (2012). On integrated sediment transport modelling for flash events in mountain environments. *Acta Geophysica*, 60, 191-213.

Radice A., Longoni L., Papini M., Brambilla D., Ivanov V.I. (2016). Generation of a design flood-event scenario for a mountain river with intense sediment transport. *Water*, 8, 597.

Evaluation of the accuracy of convection-permitting sub-daily extreme precipitation simulations over Italy

Paola Mazzoglio[1], Marco Borga[2], Marco Lompi[3], Francesco Marra[4,5], Eleonora Dallan[2], Roberto Deidda[6], Pierluigi Claps[1], Salvatore Manfreda[7], Valerio Noto[8], Alberto Viglione[1], Mario Raffa[9], Enrica Caporali[3]

(1) Department of Environment, Land and Infrastructure Engineering, Politecnico di Torino, paola.mazzoglio@polito.it
(2) Department of Land, Environment, Agriculture and Forestry, University of Padova
(3) Department of Civil and Environmental Engineering, University of Florence
(4) Department of Geosciences, University of Padova
(5) Institute of Atmospheric Sciences and Climate, National Research Council of Italy
(6) Department of Civil, Environmental and Architecture Engineering, University of Cagliari
(7) Department of Civil, Building and Environmental Engineering, University of Naples Federico II
(8) Department of Engineering, University of Palermo
(9) Regional Model and geo-Hydrological Impacts division, CMCC Foundation

Convection-permitting models have the potential to capture crucial processes in the climate system, presenting an opportunity to significantly enhance climate projections by providing more accurate representations of precipitation extremes.

In this work, we conduct an evaluation of the accuracy of sub-daily precipitation extremes obtained from VHR-PRO_IT (Very High-Resolution PROjections for ITaly) over the Italian peninsula, which are obtained with the downscaling of the CMCC global climate model at a convection-permitting scale (Raffa et al., 2023). Indeed, VHR-PRO_IT is generated through dynamic downscaling of the Italy8km-CM climate projection (spatial resolution of about 8 km; output frequency = 6 h; driven CMIP5 GCM = CMCC-CM) at about 2.2 km resolution under the IPCC RCP4.5 and RCP8.5 scenarios, employing the Regional Climate Model COSMO-CLM.

Gauged locations are used to assess the accuracy of VHR-PRO_IT in reproducing observed extremes. More specifically, the observed dataset used as ground truth for the comparison is I^2-RED (Improved Italian – Rainfall Extreme Dataset; Mazzoglio et al., 2020). In this work, 742 rain gauges with a minimum of 30 years of short-duration (1, 3, 6, 12, 24 h) annual maximum rainfall depths recorded in the period from 1980 to 2022 are used (Figure 1). The dataset covers the entire peninsula, although some areas are characterized by a lower rain gauge density due to the complex station relocation performed about 30 years ago during the dismantlement of the national hydrological service (SIMN, Servizio Idrografico e Mareografico Nazionale). Conversely, the dataset derived from the VHR-PRO_IT climate projections includes annual maxima from a 30-year time series, connecting the historical period (1981-2005) with 5 years of the RCP8.5 scenario (2006-2010) of the CPM.

Figure 1 – Location of the 742 rain gauges with at least 30 years of data in the 1980-2022 period.

The comparison is made by assessing biases between quantiles of annual maximum rainfall obtained from the two empirical cumulative distribution frequencies. The considered quantiles are 0.1, 0.25, 0.5, 0.75 and 0.9. The biases are shown with respect to the orography and the proximity to the sea, to analyze potential correlation with their geographical position.

Further work will be performed to assess and quantify local biases between L-moments and GEV distributions. Also in this case, evaluating their dependence on the geographic position, orography, and proximity to the sea.

References

Mazzoglio P., Butera I., Claps P. (2020). I^2-RED: a massive update and quality control of the Italian annual extreme rainfall dataset. *Water*, 12, 3308.

Raffa M., Adinolfi M., Reder A., Marras G.F., Mancini M., Scipione G., Santini M., Mercogliano P. (2023). Very High Resolution Projections over Italy under different CMIP5 IPCC scenarios. *Scientific Data*, 10, 238.

Advancing drought detection and management to improve the resilience of multisector systems under climate change

Martina Merlo[1], Matteo Giuliani[1], Yiheng Du[2], Ilias Pechlivanidis[2], Andrea Castelletti[1]

(1) Dept. Electronics, Information, and Bioengineering, Politecnico di Milano
(2) Hydrology Research Unit, Swedish Meteorological and Hydrological Institute (SMHI)

Drought is a slowly developing natural phenomenon that can occur in all climatic zones and propagates through the entire hydrological cycle with long-term socio-economic and environmental impacts. Intensified by anthropogenic climate change, drought has become one of the most significant natural hazards in Europe. Different definitions of drought exist, i.e. meteorological, hydrological, and agricultural droughts, which vary according to the time horizon and the variables considered. Just as there is no single definition of drought, there is no single index that accounts for all types of droughts. Consequently, capturing the evolution of drought dynamics and associated impacts across different temporal and spatial scales remains a critical challenge.

In this work, we first analyze different state-of-the-art standardized drought indexes in terms of their ability in detecting drought events at the pan-European scale, using hydro-meteorological variables from the E-HYPE hydrological model (Lindström et al. (2010)) and forced with the HydroGFD v2.0 reanalysis dataset (Berg et al. (2018)) over the period 1993-2018. Then, we investigate agreements and discrepancies between the events detected by these indexes and drought impacts recorded in the Geocoded Disasters (GDIS) dataset. Although some regions do not have documented drought records in the GDIS, critical droughts are identified in these areas according to the indexes. Such asymmetry can be explained by incomplete reporting in GDIS but also by some non-physical, hydro-meteorological factors influencing drought dynamics not adequately captured by standardized indexes. These findings suggest the need of adjusting the formulation of traditional drought indexes to better capture and represent drought-related impacts. Specifically, here we use the FRamework for Index-based Drought Analysis (FRIDA), a Machine Learning approach, originally proposed by Zaniolo et al. (2018), that allows the design of site-specific indexes to reproduce a surrogate of the drought impacts in the considered area, here represented by the Fraction of Absorbed Photosynthetically Active Radiation Anomaly (FAPAN). FRIDA builds a novel impact-based drought index combining all the relevant available information about the water circulating in the system identified by means of a feature extraction algorithm.

Our results reveal a general pattern among different indexes, that Southern England, Northern France, and Northern Italy are the regions with the highest number of drought events, whereas the areas experiencing longest drought durations are instead the Baltic Sea region and Normandy. Clustering the 35,408 European basins according to dominant hydrologic processes reveals that the variables mainly controlling the drought process vary across clusters. Similarly, we obtain diverse correlation between standardized drought indexes and the FAPAN in different clusters. Numerical results also show that, in one of the worst cases (cluster 10), the FRIDA index increases the correlation with FAPAN from 0.16 to 0.69. Lastly, the FRIDA indexes are computed for different climatic projections to investigate future trends in drought impacts. Results show divergence with respect to the trends of the standardized drought indexes, with correlation values below 0.30. In conclusion, these findings can contribute in advancing drought-related climate services by enabling the analysis of projected drought impacts.

References

Berg P., Donnelly C., Gustafsson D. (2018). Near-real-time adjusted reanalysis forcing data for hydrology. *Hydrology and Earth System Sciences*, 22(2):989–1000.

Lindström G., Pers C., Rosberg J., Strömqvist J., Arheimer B. (2010). Development and testing of the hype (hydrological predictions for the environment) water quality model for different spatial scales. Hydrology research, 41(3-4):295–319.

Zaniolo M., Giuliani M., Castelletti A.F., Pulido-Velazquez M. (2018). Automatic design of basin-specific drought indexes for highly regulated water systems. *Hydrology and Earth System Sciences*, 22(4):2409–2424.

The Venice Lagoon under the flood regulation: navigating challenges in preserving the city and its lagoonal ecosystem

Alessandro Michielotto[1], Davide Tognin[2], Riccardo Mel[3], Alvise Finotello[1], Luca Carniello[2], Andrea D'Alpaos[1]

(1) Dept. of Geosciences, University of Padova, alessandro.michielotto@phd.unipd.it
(2) Dept. of Civil, Environmental and Architectural Engineering, University of Padova
(3) Italian Institute for Environmental Protection and Research (ISPRA)

Coastal areas, such as deltas, estuaries and lagoons, are highly dynamic transitional environments shaped by the interplay of depositional and erosional forces. While providing a multitude of valuable ecosystem services, spanning from wave-energy dissipation to habitat provision and carbon sequestration (Barber et al., 2011), they also serve as important hubs, supporting larger populations than those in non-coastal areas (Small and Nicholls, 2003).

However, communities living along low-lying coastal environments are related to the hazards of the climate changes, for the rapidly rising sea levels and the intensification of the extreme events, which increase the flooding risk.

To reduce the risk of floods, more defensive structures (e.g., flood-gate barriers) were completed worldwide in the 2010s than in any prior decade (Orton et al., 2023). Here, we present a study on the first years of operation of the Mo.S.E. project, the mobile storm-surge barrier system activated in the Venice Lagoon in October 2020. The research aims to investigate, through the employment of the two-dimensional WWTM hydrodynamic model (Carniello et al., 2011), the impacts of the flood regulations, exploring the potential counter-effects of water level reductions on its valuable ecosystems.

During storm surges, floodgate barriers at the three lagoon inlets are raised, temporarily disconnecting the lagoon from the open sea (Mel et al., 2021), keeping water levels below a prescribed safety threshold. However, the intertwined action of wind waves and reduced water levels may generate an intensification of the erosional processes across the tidal flats. The reduced water levels negatively affect also salt-marsh sedimentation (Tognin et al., 2021). Although the erosional forces can increase the suspended sediment volume in the basin, lower water levels reduce in salt marsh flooding depths and duration (Figure 1), and the sediment deposition over marsh surfaces.

We also explore a hypothetical scenario considering an optimized flood regulation procedure, aimed at reducing the duration of flood-gate closures. Slightly higher water levels, prescribed by the optimized regulation, would allow sediment deposition over salt-marsh surfaces without compromising the preservation of urban areas from flooding.

Our findings offer valuable insights, underscoring the paramount importance of promoting effective defensive intervention policies. Our results might help to identify feasible solutions that better balance the preservation of coastal urban areas with the protection of natural coastal ecosystems.

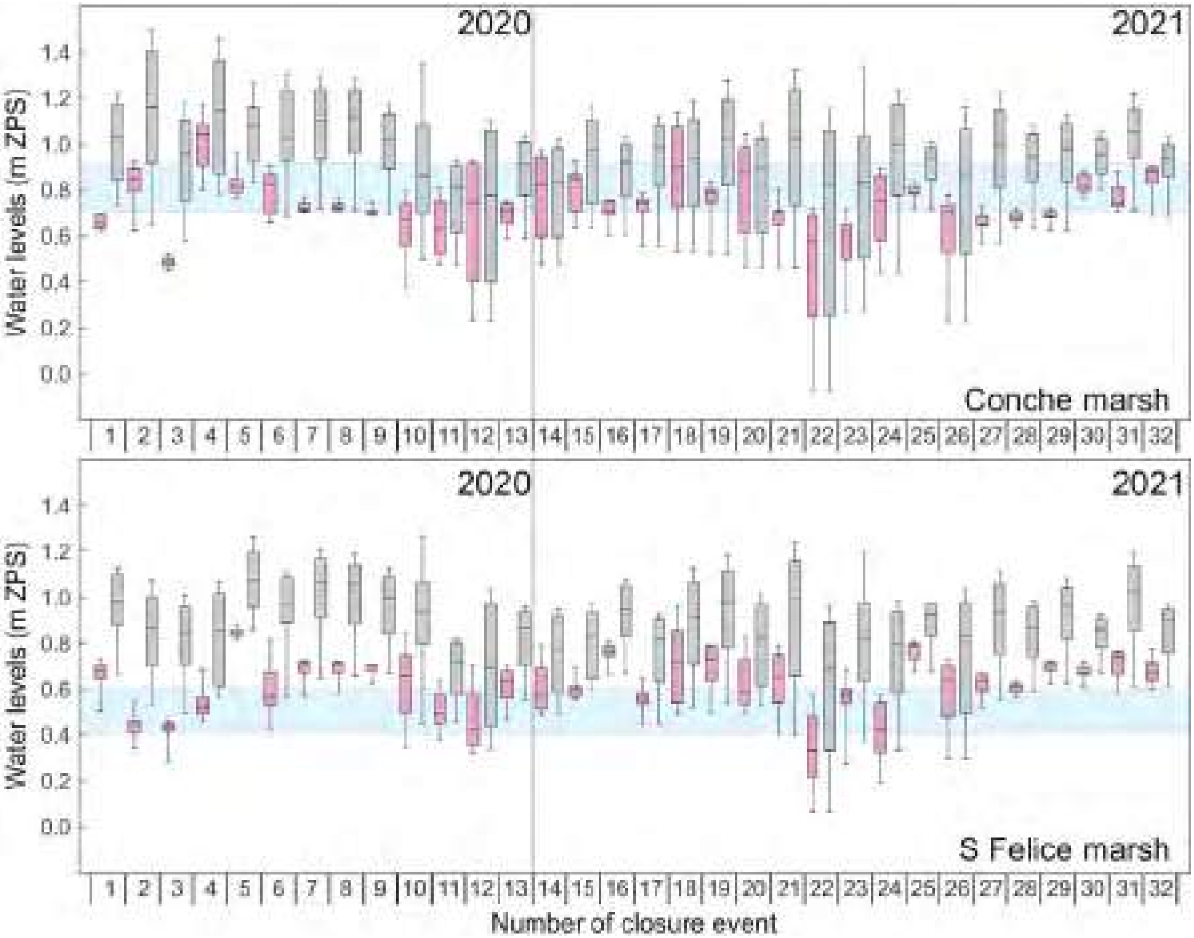


Figure 1 - Effects of water level reductions in Conche (southern lagoon) and San Felice (northern lagoon) marshes in the 2020 and 2021 years. The activation of the Mo.S.E. drastically reduces the water levels, thus limiting (or preventing) the salt marsh flooding. In pink: modelled water levels in the flood-regulated scenario; in grey: modelled water levels in the hypothetical open scenario; in light blue: salt marsh elevation range.

References

Barbier E.B., Hacker S.D., Kennedy C., Koch,E.W., Stier A.S., Silliman B.R. (2011). The value of estuarine and coastal ecosystem services. *Ecological Monographs*, 81(2), 169-193.

Carniello L., D'Alpaos A., Defina A. (2011). Modeling wind waves and tidal flows in shallow micro-tidal basins: Estuarine, Coastal and Shelf Science, 92, 263–276.

Mel R.A., Carniello L., D'Alpaos L. (2021). How long the Mo.S.E. barriers will be effective in protecting all urban settlements within the Venice Lagoon? The wind setup constraint. *Coastal Engineering*, 168.

Neumann B., Vafeidis A.T., Zimmermann J., Nicholls R.J. (2015). Future coastal population growth and exposure to sea-level rise and coastal flooding - A global assessment. *PLoS ONE*, 10(3).

Small C, Nicholls RJ. (2003). A global analysis of human settlement in coastal zones. *Journal of Coastal Research*, 19, 584–599.

Tognin, D., D'Alpaos, A., Marani, M., Carniello, L. (2021). Marsh resilience to sea-level rise reduced by storm surge barriers in the Venice Lagoon. *Nature Geoscience*, 14, 906-911.

60-years analysis of meteorological droughts in the western Po River basin

Emanuele Mombrini[1], Stefania Tamea[1], Alberto Viglione[1], Roberto Revelli[†]

(1) Department of Environment, Land and Infrastructure Engineering (DIATI), Politecnico di Torino, emanuele.mombrini@polito.it
(†) Deceased, 6 May 2023

Since the start of the 21st century, greater focus has been put on droughts and their wide range of environmental and socioeconomic effects, particularly in the context of climate change. This is especially true for the North-western region of Italy, comprising the Piedmont and Aosta valley, which have been affected in recent years by droughts that have had acute effects on water resources and water security in all sectors, including agriculture, energy and domestic use. The region also belongs to the Mediterranean hot-spot, characterized by faster than global average warming rates and higher vulnerability to their effects. Therefore, characterizing the observed changes and trends in drought conditions is of particular significance.

To this end, 60 years of precipitation and temperature data from the North West Italy Optimum Interpolation data set are used to calculate the drought indices SPI (Standardized Precipitation Index) and SPEI (Standardized Precipitation Evapotranspiration Index) at a short (3-month) and at a long (12-month) time scale. First, trend analysis on precipitation and temperature is performed, finding limited areas with significant precipitation decrease and, conversely, a general temperature increase over the region, with higher values found in the higher elevation areas. Changes in meteorological droughts are then evaluated, both in terms of drought indices trends and in terms of changes in the characteristics of drought periods, on both a local and regional scale. A relation between the altitude of the area and the observed changes is highlighted, with significant differences between the plain and mountainous portion of the region. The differences are mainly related to the observed trends, with the low-altitude part of the region displaying a tendency towards dryer conditions not in common with the mountainous area. Significantly, no trend is found at a region-wide level but is instead found when considering homogeneous areas defined by terrain ruggedness, which divides the flat, hilly and mountainous regions respectively (Figure 1).

Furthermore, changes in the number of drought episodes and in their severity, duration and intensity are found to be correlated with terrain ruggedness at all time scales: coherently with the trends in drought indices, significant decreases in the severity, duration and intensity of drought episodes are found in the alpine range, while increases are mostly found in the smoother low-lying areas.

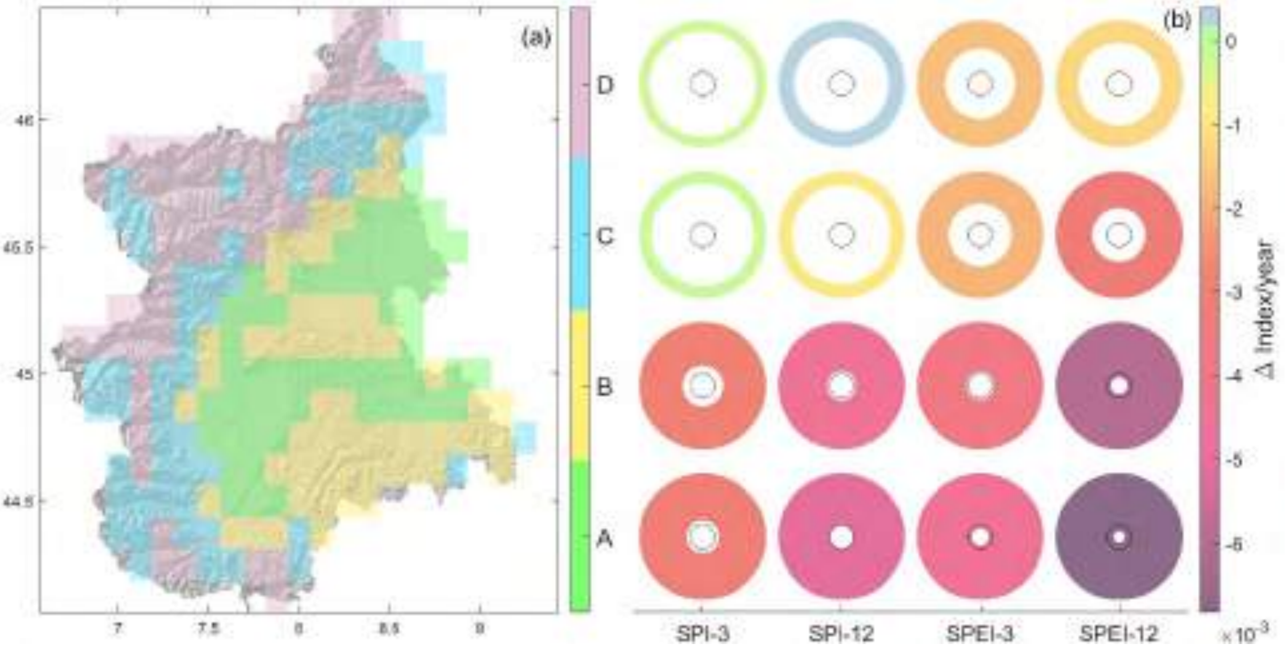


Figure 1 – (a) Representation of terrain ruggedness classes. (b) Trend analysis on drought indices calculated from data belonging to areas defined by terrain ruggedness inside cells. The color of the circles represents the slope coefficient of the trend, while the inner radius of the circles represents the significance of the trend (a smaller inner radius represents a more significant trend). The black circles denote a significance level of 5%.

Non-stationary simplified metastatistical extreme value approach: an application over the Rotian river catchment

Matteo Pesce[1], Eleonora Dallan[1], Francesco Marra[2,3], Marco Borga[1]

(1) Dept. of Land Environment Agriculture and Forestry, University of Padova, matteo.pesce@unipd.it
(2) Dept. of Geosciences, University of Padova
(3) Institute of Atmospheric Sciences and Climate (CNR-ISAC), National Research Council of Italy

Time-dependent precipitation frequency analyses were often hampered by the availability of relatively short data records, which result in large uncertainty in the estimation of extremes. The recently developed non-asymptotic statistical methods, based on fitting ordinary events rather than extreme events only, represent a potential solution to the problem of data scarcity and are finding wide application in literature under assumptions of stationarity. Recent studies adopted non-stationary schemes with non-asymptotic methods (e.g., Vidrio-Sahagún and He, 2022) and advocated their use over other methods for non-stationary frequency analysis of extreme precipitation. This study presents a non-stationary time-dependent approach for the statistical analysis of multi-duration precipitation extremes using simplified metastatistical extreme value (SMEV) approach. To this aim, we focus on a catchment in the Eastern Italian Alps, where trends in extreme precipitation where reported (Dallan et al., 2022) and which was impacted by the exceptional Vaia event in 2018. We provide an estimation of extreme return levels of precipitation in six stations in the neighborhood of the catchment and compare them with precipitation maxima observed during Vaia storm. The results show that using a non-stationary left-censored Weibull distribution, with both scale and shape parameters linearly dependent on time, allows to properly describe the observed trends of intense precipitation for different durations (Figure 1).

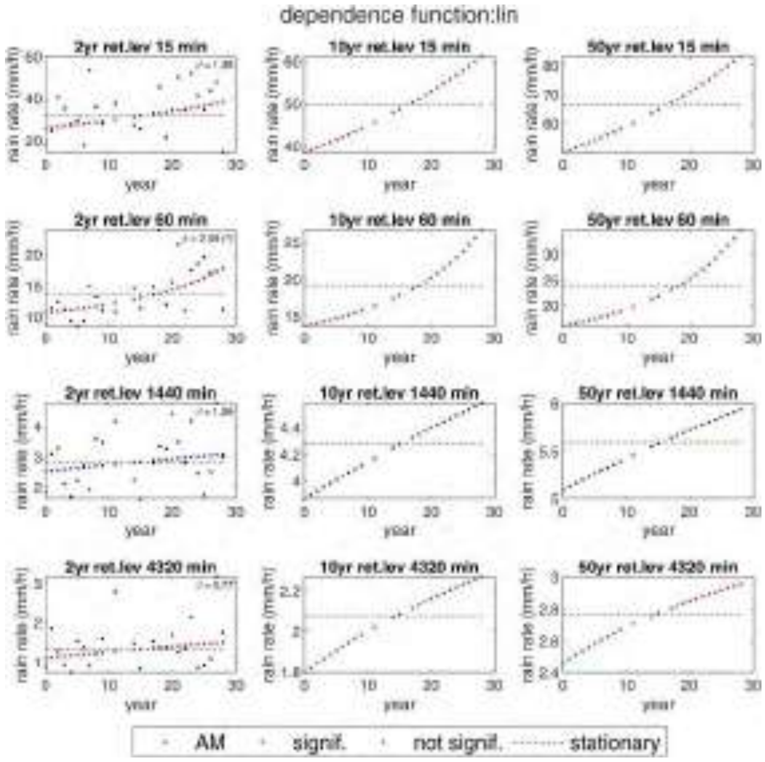


Figure 1 – Historical time series of different return levels (2-year, 10-year, 50-year) of precipitation intensity for different durations in Mezzana station, which is used as main reference for the hazard assessment of Vaia. Observed annual maxima are also reported, together with the 2-year return levels.

Our results suggest that the probability of observing events like Vaia increased over the past decades, leading to the need for updating local adaptation measures.

References

Dallan E., Borga M., Zaramella M., Marra F. (2022). Enhanced summer convection explains observed trends in extreme subdaily precipitation in the eastern Italian Alps. *Geophysical Research Letters*, *49*(5), e2021GL096727.

Vidrio-Sahagún C. T., He J. (2022). Hydrological frequency analysis under nonstationarity using the Metastatistical approach and its simplified version. *Advances in Water Resources*, *166*, 104244.

Integrated modelling for water resource management during droughts

Stefania Piazza[1], Andrea Galletti[2], Mariacrocetta Sambito[1], Manuel Roveri[3], Francesco Puoti[3], Anita Raimondi[4]

(1) Dept. of Engineering and Architecture, University of Enna "Kore", stefania.piazza@unikore.it
(2) Center for Climate Change and Transformation, Eurac Research
(3) Dept. of Electronics, Information and Bioengineering, Politecnico di Milano
(4) Dept. of Civil Engineering and Environmental Engineering, Politecnico di Milano

Drought periods make the water supply sometimes critical. Urban areas are particularly sensitive to water scarcity since they must meet the increasing demand for water to satisfy human needs due to the growing urban population all over the world. About 58% of the world population currently lives in cities; the trend is continuing to grow, and the United Nations (2018) expects that by 2050, it will be about 68%. On the other hand, water scarcity periods have been becoming more frequent, and the Intergovernmental Panel on Climate Change (Price et al., 2022) stated that if average global temperatures rise 3°C above pre-industrial levels, 170 million people are expected to experience extreme drought. Water scarcity provides several environmental, economic, socio-cultural, and health impacts since it can compromise a wide range of ecosystem services and may result in significant, long-term economic losses in a range of sectors. A substantial number of water distribution systems worldwide are operated as intermittent water supply systems, delivering water to consumers in irregular and unreliable manners. Intermittent water supply consumers commonly adapt to flexible consumption behaviours characterized by storing the limited water available during shorter supply periods in intermediate storage facilities for subsequent usage during more extended non-supply periods (Abhijith et al., 2023). In this context, it is urgent to define new strategies to improve the resilience of water supply systems. The use of alternative water resources, such as shallow waters, rainwaters, reclaimed waters, etc., can be of support to the traditional distribution networks. For example, rainwater harvesting is an ancient and well-known solution for drought risk mitigation with different levels of advanced technology associated with it (Raimondi et al., 2023). It involves several environmental and social benefits linked to the Sustainable Development Goals of the ONU Agenda 2030. It has been estimated that about 50% of water demand for non-drinking domestic use can be supplied by rainwater, and this is currently encouraged by laws and regulations.

Rainwater harvesting systems must be designed and managed to optimize water resource control under different climate and demand scenarios. In this sense, probabilistic modelling can be suitable for its versatility and multi-objective approach. The method enables the estimation of the probability distribution function of the variable of interest from the probability distribution function of the rainfall input and the roof characteristics. It can relate the storage volume to a return period, also considering the possibility of pre-filling from previous rainfall events and the retention time for water quality features. The integration of a probabilistic approach and a predictive model based on artificial intelligence can increase its potential and applications. Green-Tea is an integrated cloud-streaming platform for time-series exploration and forecasting as a service for environmental data (Puoti et al., 2023). Following the as-a-service approach, it provides useful insights into users demand for water supply, allowing them to leverage the exploration and forecasting/prediction abilities of machine and deep learning algorithms.

For the definition of the best practices and management rules to maximize the benefit, it is fundamental to estimate the vulnerability of the different users as a function of the socio-economic context and, at the same time, the strategically important sources of supply. To this end, it is essential to consider the use of models that integrate results from climate models, resource allocation models, and simplified network hydraulic models, considering losses, user behaviors, and water demand reduction strategies. The proposed methodology involves the analysis of the impact of water scarcity and self-adaptation strategies on water demand under intermittent flow conditions. This analysis was conducted on consumption data collected from a residential agglomeration in the metropolitan area of Palermo, in which the contribution that the private tanks of four single users (A, B, C, and D) and one condominium type (E) produce over the entire system was evaluated (Criminisi et al., 2009). A monitoring scheme was set up for all users, lasting 6 days, which involved measuring the pressure in the network every 15 minutes using a pressure meter installed upstream of the fiscal meter. The water volumes upstream and downstream of the user's private tank were measured through two class C meters (Q_{min}=15 [L/h], Q_{max}=5 [m3/h], sensitivity of 7-8 [L/h], pressure drop at Q_{max} of 1 bar, operating pressure of 16 bar) equipped with a pulse emitter and connected to a data logger, programmed to record data every minute. Finally, the water level in the tanks was acquired through a pressure cell level meter connected to a data logger which recorded data every 15 minutes (Figure 1).

Models for water distribution and quality evaluation can be useful to define key performance indicators for water resilience in urban areas in order to evaluate the impact of urban strategies with respect to the efficiency of water demand reduction, the implementation rate, the long-term mitigation capacity, the reactivity in the short term, and the overall cost.

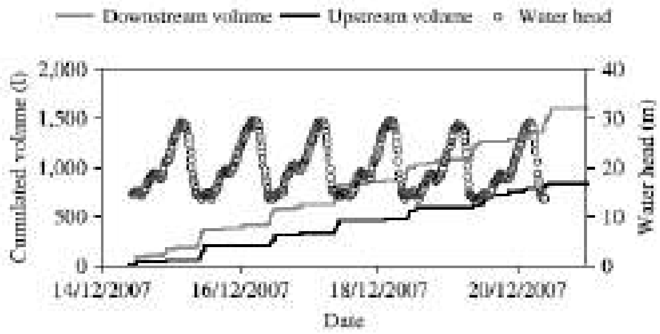


Figure 1 – Temporal trend of measured network water head and volume, downstream and upstream of the tank (household A).

References

Population Division of the UN Department of Economic and Social Affairs (UN DESA) (2018). *Revision of World Urbanization Prospects* produced.

Price J., Warren R., Forstenhäusler N., Wallace C., Jenkins R., Osborn T.J., Van Vuuren D.P. (2022). Quantification of meteorological drought risks between 1.5° C and 4° C of global warming in six countries. *Climatic Change*, *174*(1-2), 12.

Abhijith G.R., Naidu M.N., Boindala S.P., Vasan A., Ostfeld A. (2023). Analyzing the role of consumer behavior in coping with intermittent supply in water distribution systems. *Journal of Hydroinformatics*, 25(5), 1766–1787.

Raimondi A., Quinn R., Abhijith G.R., Becciu G., Ostfeld A. (2023). Rainwater harvesting and treatment: state of the art and perspectives. *Water*, 15(8),1518.

Puoti F., Falcetta A., Roveri M., Riva D., Chiggiato D. (2023). GreenTea: time-series exploration as-a-service for environmental science. *In 2023 IEEE Conference on Artificial Intelligence (CAI)*, 311-313, IEEE.

Criminisi, A., Fontanazza, C. M., Freni, G., and La Loggia, G. (2009). Evaluation of the apparent losses caused by water meter under-registration in intermittent water supply. *Water Science & Technology*, 60(9), 2373–2382.

Novel machine learning approaches for remote sensing image analysis in the context of water-related risks

Roozbeh Rajabi[1], Sebastiano B. Serpico[1], Silvana Dellepiane[1], Gabriele Moser[1]

(1) Department of Electrical, Electronic, Telecommunications Engineering, and Naval Architecture (DITEN), University of Genoa, roozbeh.rajabi@unige.it

Remote sensing, an ever-growing scientific discipline, involves acquiring information from various scenes without direct physical contact with surfaces. In our modern landscape, remote sensing has evolved into a powerful tool for monitoring and mitigating water-related risks, owing to the diverse range of missions and the substantial amount of data gathered through these advanced sensors. Within spoke VS1 water of RETURN project, remote sensing plays a crucial role in three activities including WP2: Flood risk, WP3: Drought risk, and WP4: Coastal flooding under environmental and climatic changes.

In the context of flood risk management under changing climate (WP2), aerial imagery serves as a crucial tool for extracting valuable information to be utilized in hydrological models for flood risk assessment. One notable aspect involves the extraction of floodborne objects, objects that can be carried by flood. This particular focus extends to various objects, encompassing urban elements such as cars and trash bins (Iqbal et al., 2022).

In this activity, our primary focus lies in vehicle detection within the Sampierdarena area of Genoa. We utilize aerial imagery provided by the Municipality of Genoa, having a spatial resolution of 10 cm. To achieve this goal, we leverage annotated datasets to fine-tune the pre-trained object detection deep networks like YOLO (Ammar et al., 2021). Subsequently, the trained network will be used to identify vehicles in the Genova dataset. Predicted outcomes will be manually investigated to correct any inaccuracies. In the final phase, we try to enhance our proposed methodology by incorporating innovative techniques from deep learning networks, such as feature pyramid networks (FPNs) and attention mechanism, with the ultimate aim of achieving more promising and accurate results.

In the realm of drought risk under environmental and climate changes (WP3), satellite remote sensing imagery is used for crop monitoring in large agricultural area within Po River basin in North Italy. To this aim FPAR (Fraction of Photosynthetically Active Radiation) time series calculated using VIIRS (Visible Infrared Imaging Radiometer Suite) sensor is used. The proposed methodology in this activity is mainly based on unsupervised clustering methods. Specifically, gaussian mixture model (GMM) is primarily used to cluster the time series data into winter and summer crops. Then, unsupervised deep learning methods like variational autoencoders will be considered to enhance the results (Lim et al., 2020). For validation purposes, European commission's joint research center vegetation maps is used.

In the context of addressing coastal flooding in response to environmental and climatic changes (WP4), the detection and monitoring the shoreline become crucial. The focus of this activity is on the coastal region of the Ligurian Sea, specifically around the city of Genoa, Italy. Sentinel-2 optical images with a spatial resolution of 10 m are employed for sea-land segmentation. To address this challenge, deep learning networks such as U-Net along with advanced segmentation loss functions will be utilized as the primary segmentation method (Heidler et al., 2022). Additionally, the fusion of Synthetic Aperture Radar (SAR) and multispectral data could be considered to enhance the accuracy of the obtained results.

The remote sensing datasets employed in the activities are outlined in Table 1. This table provides a summary of the application area, data type, and specifications of the remote sensing sensors utilized.

Table 1 – Remote sensing data types used in the activities.

Activity	Application	Problem in hand	Remote Sensing Mission Type	Sensor Name	Sensor Type	Spatial Resolution
WP2	Flood Risk	Object Detection	Airborne	-	RGB	10 cm
WP3	Drought Risk	Crop Monitoring	Satellite	VIIRS	Multispectral	500 m
WP4	Coastal Flooding	Shoreline Detection	Satellite	Sentinel-2	Multispectral	10 m
				Sentinel-1	SAR	5 m

Each activity presents its own set of challenges that need to be addressed in future work. In WP2, focused on aerial photo object detection, challenges include shadows in photos, small vehicle sizes, and limited spectral variability. These issues can be mitigated effectively by implementing shadow removal algorithms and creating a well annotated database. In WP3, the primary challenge lies in the lack of groundtruth data for the specified region of interest. This challenge can be tackled through the application of unsupervised and weakly-supervised algorithms. Lastly, in WP4, the dynamic nature of the sea-land boundary poses a challenge for shoreline detection. Employing deep learning techniques to learn the changes in shoreline can be a solution for this challenge.

References

Ammar A., Koubaa A., Ahmed M., Saad A., Benjdira B. (2021). Vehicle detection from aerial images using deep learning: a comparative study. *Electronics*, 10(7).

Heidler K., Mou L., Baumhoer C., Dietz A., Zhu X.X. (2022). HED-UNet: combined segmentation and edge detection for monitoring the Antarctic coastline. *IEEE Transactions on Geoscience and Remote Sensing*, 60, 1–14.

Iqbal U., Riaz M. Z. Bin, Barthelemy J., Hutchison N., Perez P. (2022). Floodborne objects type recognition using computer vision to mitigate blockage originated floods. *Water*, 14(17).

Lim K.L., Jiang X., Yi C. (2020). Deep Clustering With Variational Autoencoder. *IEEE Signal Processing Letters*, 27, 231–235.

Vegetation indices for plant water stress detection from satellite imagery

Amirarsalan Shahmohammadi[1], Matteo Rolle[1], Stefania Tamea[3]

(1) DIATI, Politecnico di Torino, amirarsalan.shahmohammadi@polito.it

Water stress is a form of abiotic stress that plants may undergo after a prolonged period of limited water availability in the soil and respond to by stomatal closure and reduced transpiration, leading to lower photosynthesis activity as an initial protective action. Monitoring agricultural lands for early symptoms of plant water stress is highly recommended in order to take appropriate measures in irrigation planning and to diminish the potential loss in crop yield. Remote sensing tools have been widely used for agricultural and vegetation monitoring, providing invaluable data on the physiological, biomechanical, and biochemical characteristics of plants on various spatial and temporal scales. Water stress can result in physiological alterations in plants, and thus influence the electromagnetic spectral characteristics of the plant, which are detectable by sensors aboard satellites, aircraft, drones, or embedded in devices used for field measurements. Accordingly, several vegetation indices (VIs) have been developed since the early 1970s to monitor the vegetation cover on earth using remotely sensed imagery, several of which have been specifically proposed for plant water stress detection (Gerhards et al., 2019; Safdar et al., 2023). VIs are usually simple mathematical relations of the spectral electromagnetic reflectance of plants within the visible and near-infrared range (400-1100 nm) of the electromagnetic spectrum. In practice, VIs use a wavelength sensitive to changes in the phenomenon of interest (i.e., water content) with respect to another wavelength insensitive to that phenomenon.

Following a thorough review of the literature, a list of 14 VIs for crop water stress was identified as the most widely used. Out of this list two VIs, (the Normalized Difference Moisture Index (NDMI), also known as the Normalized Difference Water Index (NDWI) (Gao, 1996), and the Crop Water Stress Index (CWSI)) were selected as most suitable to be applied directly on ready-to-use satellite imagery (highest level of postprocessing) while being almost independent of limiting factors such as different climates and species, water stress stage. NDMI utilizes near-infrared and shortwave infrared bands to display plants' moisture levels. The shortwave infrared band captures changes in both vegetation water content and spongy mesophyll structure within vegetation canopies, while the near-infrared reflectance is influenced by leaf internal structure and leaf dry matter content, but not by water content. By combining near-infrared and shortwave infrared measurements, it is possible to eliminate variations caused by leaf internal structure and leaf dry matter content, resulting in more accurate estimates of vegetation water content and thus water stress. NDMI between -0.2 and 0.4 is attributed to the water stress range of values. Canopy temperature can also be used as a water stress indicator, e.g. CWSI proposed by (Idso et al., 1981; Jackson et al., 1981) is based on the temperature difference between the leaf and the surrounding environment normalized with the temperature difference between well-watered plant and a fully closed stomata conditions. CWSI values above 0.4 indicate stressed vegetation.

The selected indices were applied to a specific case study to verify their potential. An area in northern Italy that experienced a severe drought period in 2022 was selected for this case study. For agricultural purposes, finer spatial and shorter temporal resolutions are more appropriate, given the plant dimensions and water content status that may vary on a daily basis. Therefore, Sentinel-2 and Landsat 8/9-Land Surface Temperature products, having spatial resolutions of 10 and 20 m and temporal resolutions of 5 and 8 days, respectively, were used to obtain the NDMI and CWSI in the area. Maize fields were selected, which is a major field in the area; hence, a lower bias exerted by different crops on the spectral signature is expected. Crop information, which is georeferenced and updated every year, was taken from the Piemonte Region, Agriculture division.

In comparison between the two indices, NDMI showed more promising results in detecting water stress in line with crop water content obtained from the Algorithm Theoretical-Based Document, on the SANP biophysical processor toolbox (Weiss and Baret, 2016). NDMI results were then compared to the fraction of Absorbed Photosynthetically Active Radiation (fAPAR), also obtained through the above toolbox, to check whether the two indices have comparable behaviors. Within the summer of 2022, fAPAR dropped both in spatial and temporal scales which is comparable with the water stress level indicated by NDMI (fig.1). However, in late June, the beginning of water stress according to NDMI, fAPAR remained high. To address this inconsistency, an effort is going on to develop a model for water stress throughout both the satellite data and soil-water balance dynamics.

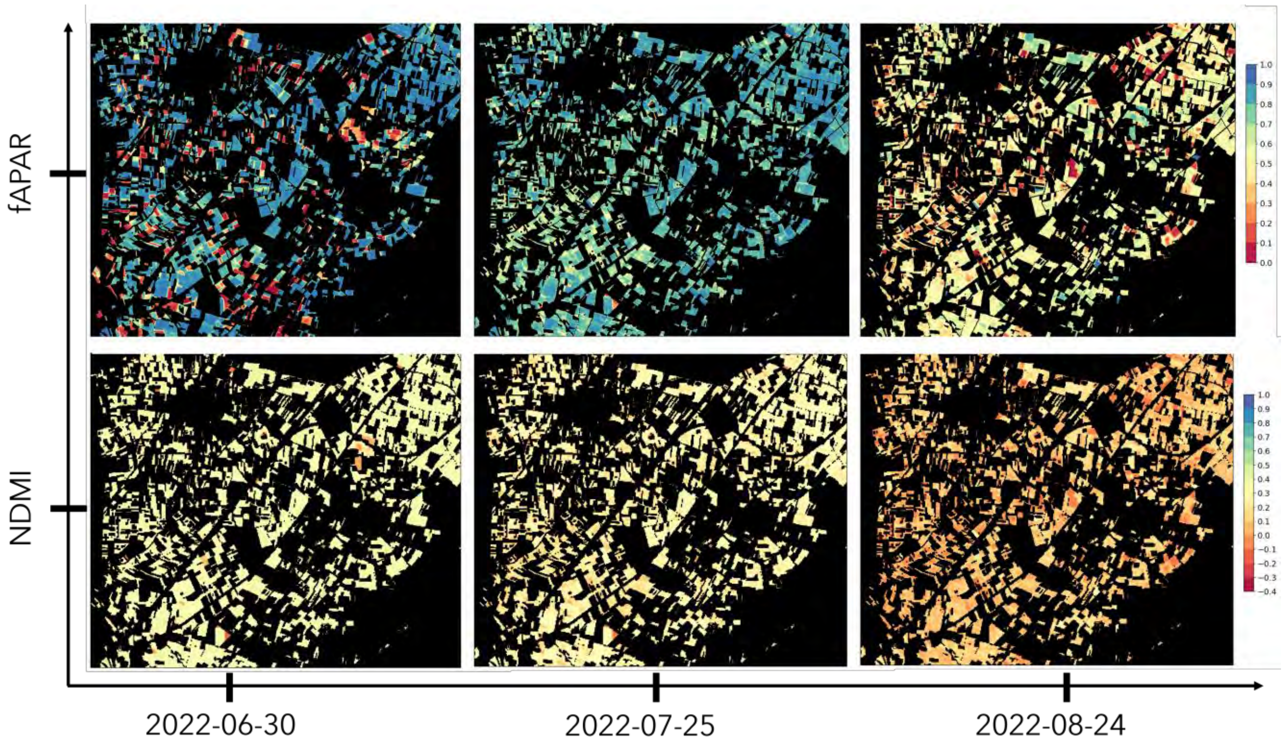


Figure 1 – fAPAR and NDMI spatio-temporal variations in the summer 2022 drought in Piemonte whereby fAPAR values range between 0 (no photosynthesis) and 1 (maximum photosynthesis), and for NDMI values in range of (-0.2-0.4) are attributed to water stress while values larger than 0.4 indicate green and not stressed vegetation.

References

Gerhards M., Schlerf M., Mallick K., Udelhoven T. (2019). Challenges and future perspectives of multi-Hyperspectral thermal infrared remote sensing for crop water-stress detection: a review. *Remote Sensing*, 11, 1240.

Safdar M., Shahid M.A., Sarwar A., Rasul F., Majeed M.D., Sabir R.M. (2023). Crop water stress detection using remote sensing techniques.

Gao B.C. (1996). NDWI - A normalized difference water index for remote sensing of vegetation liquid water from space. *Remote Sens. Environ.*

Idso S.B., Jackson R.D., Pinter P.J., Reginato R.J., Hatfield J.L. (1981). Normalizing the stress-degree-day parameter for environmental variability. *Agric. Meteorol.*

Jackson R.D., Idso S.B., Reginato R.J., Pinter P.J. (1981). Canopy temperature as a crop water stress indicator. *Water Resour. Res.*

Weiss M., Baret F., Jay S. S2ToolBox Level 2 products: LAI, FAPAR, FCOVER.

Analysis of the banquette dynamics by four years of videomonitoring acquisitions in an urban microtidal Mediterranean beach (Poetto beach, southern Sardinia, Italy)

Daniele Trogu[1], Sandro Demuro[1]

(1) Dept. of Chemical and Geological Sciences, University of Cagliari, d.trogu@unica.it

This work is part of the activities that the Coastal and Marine Geomorphology Group, of the University of Cagliari, is carrying out within the RETURN Project, VS1 - WP4.

Seagrass deposits on Mediterranean coasts are very common and these sedimentary structures, mostly made by leaves, roots, and rhizomes of Posidonia oceanica (L.) Delile are known as banquettes (Boudouresque et al., 1982; Simeone et al., 2013). The natural processes leading to their deposition and erosion events, however, have always been analysed in short monitoring periods. In this work we analysed a four-years images database coming from a high-resolution videomonitoring station installed above the promontory of an urban, microtidal and wave dominated beach, located in the Gulf of Cagliari, Italy, western Mediterranean, from September 2016 to September 2020. By the orthorectification of the images, we measured the cross-shore extension of banquettes in three transects of the beach and related these dynamics to wave and wind parameters (obtained from the Copernicus and ERA5 databases), looking for a correlation between the wave and wind climate and the dynamics of the banquettes, defined as their daily difference in cross-shore extension.

Our results showed that banquette deposition occurred during mild storms when floating leaf litter is present in the surf zone. Conversely, banquettes were not detected even during mild storm when leaf litter is not detected in the surf zone. The erosion or retreat of banquette occurred during more intense storm but, if there was litter in the surf zone, usually at the end of the storm a new banquette can be deposited. The presence or absence of floating leaf litter in the surf zone may therefore explain the low correlation value found between wave parameters alone and banquette cross-shore amplitude, as well as with its daily difference.

Offshore winds can also influence the banquette dynamics: under certain conditions of speed intensity, if no obstacles are present, the banquette may be removed offshore, supplying the litter in the surf-zone, or they may be covered by sediment. This latter process leads to build a sedimentary berm composed by vegetal rests and sand, that can also increase the beach resilience against the storms.

The permanence of the banquettes on the beaches also depends on their composition: when banquettes are intertwined with reeds, their removal by the waves does not occur even during intense storms and this sedimentary structure can protect the beach from flooding (Ruju et al., 2022).

References

Boudouresque C., Meinesz A. (1982). Découverte de l’herbier de Posidonies. Cahier du Parc National de Port-Cros 4, 1–79.

Simeone S., De Muro S., De Falco G. (2013). Seagrass berm deposition on a Mediterranean embayed beach. *Estuarine, Coastal and Shelf Science* 135, 171–181.

Ruju A., Buosi C., Coco G., Porta M., Trogu D., Ibba A., et al. (2022). Ecosystem services of reed and seagrass debris on a urban Mediterranean beach (Poetto, Italy). *Estuarine, Coastal and Shelf Science* 271, 107862.

Spoke VS2: Ground instabilities

Advanced satellite and aerial monitoring applications for the identification of ground instabilities in subaerial and shallow water environments

Benedetta Antonielli[1], Antonio Consentino[1], Matteo Del Soldato[2], Isabella Serena Liso[3], Claudia Masciulli[1], Paola Salmona[4], Elena Scacchia[1], Diego Di Martire[5] Francesca Bozzano[1]

(1) Earth Sciences Department, "Sapienza" University of Rome and CERI - Research Centre for Geological Risks, benedetta.antonielli@uniroma1.it
(2) Earth Sciences Department, University of Florence
(3) Department of Earth and Geo-Environmental Sciences, University of Bari
(4) Department of Civil, Chemical and Environmental Engineering, University of Genoa
(5) Earth Sciences Department, Environmental and Resources, Federico II University of Napoli

Ground instabilities detection involves gathering data on their occurrence, distribution, and intensity, which are crucial for disaster response planning. Existing inventories are key for preparing susceptibility and hazard maps, and the monitoring parameters, particularly surface displacement over time acquired by remote sensing (RS) methods, are fundamental for the detection of incipient or unknown deformation phenomena (landslide, sinkhole, and subsidence), and for updating the inventories. The most suitable RS technologies follow specific requirements related to the ground instability typologies in the subaerial environment, about the monitored size area, precision, reliability, temporal and spatial resolution, measurements density, deformation geometry, operability range, sensitivity to atmospheric noise, and budgetary constraints.

Satellite imagery such as Synthetic Aperture Radar (SAR) and optical (multispectral and hyperspectral) images, are commonly used for both large-scale and basin-scale analyses. Satellite SAR Interferometry (InSAR) has been long exploited for detecting and mapping slow-moving ground surface displacements and for updating inventories of many different natural or anthropogenic deformation phenomena. Since September 2022, a global screening of the European territory has been provided by the European Ground Motion Service (Copernicus Program) and more extensive exploitation of RS satellite data will be fostered by the new IRIDE satellite constellation, expected by 2026. The expert applications of large volumes of RS data represent an issue for the prompt exploitation of the retrieved information. In this regard, different post-processing approaches, machine learning (ML) modeling, artificial neural networks statistical analyses, and semi-automatic and automatic mapping methods at large scale have been recently proposed. In Figure 1 an outline of the RS data, methods, and applications for the analysis of ground instabilities is provided.

The automatic landslide mapping methods over wide areas, based on the InSAR data, use velocity thresholds or time series patterns combined with topographical and ancillary data (e.g. Festa et al., 2023) for an automatic clustering of moving areas. Then, a typological classification of the moving areas (Festa et al., 2023), or a ranking based on the risk (also considering the intersection of the landslides with critical infrastructures and urbanized centers) can be carried out, providing an important contribution to the risk management at the regional scale.

By leveraging a wealth of diverse datasets (e.g., SAR products, optical images, inventories, geological and engineering data), the application of supervised ML techniques can autonomously interpret complex patterns for clustering and classification tasks, that can be integrated into specific workflows designed to characterize and quantify the deformations.

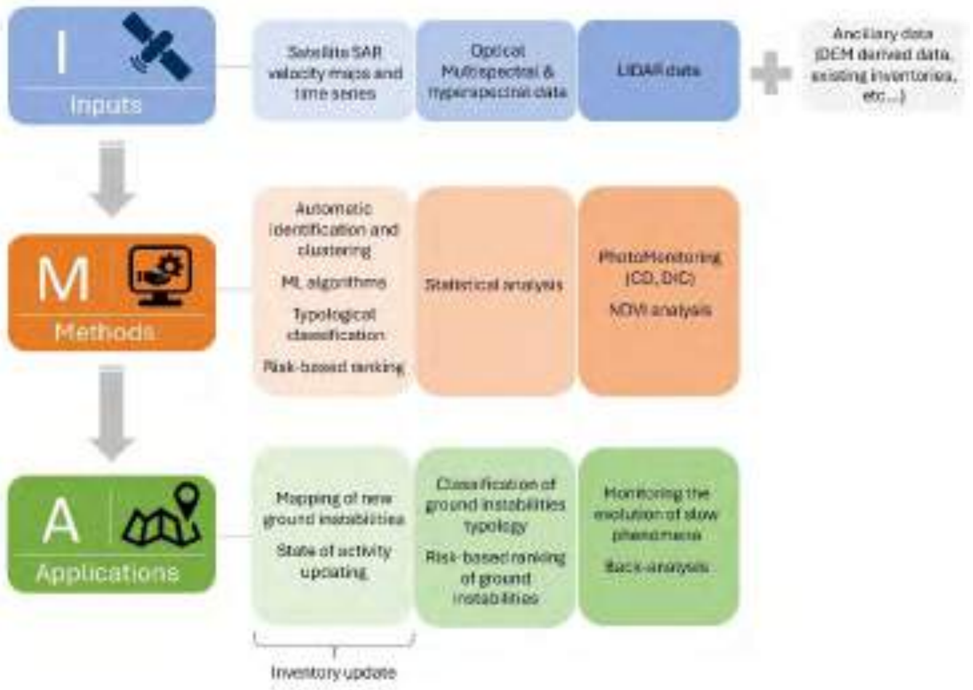


Figure 1 – Satellite and aerial monitoring data, methods, and application for the analysis of ground instabilities.

Regarding optical RS techniques, the advanced processing of images through PhotoMonitoring (PM) can detect and quantify the change or displacement of the terrain. PM algorithms yield displacement field maps (Digital Image Correlation - DIC) and maps of the ongoing changes (Change Detection - CD) with accuracy related to images' spatial, temporal, and radiometric resolution (Mazzanti et al., 2020). Optical-derived data (panchromatic, pan-sharpened, false-color composites) also facilitates landslide detection and mapping through visual inspection or analytical methods, and the Normalized Differential Vegetation Index (NDVI) from multispectral images contributes to mapping by assessing plant cover rates and spectral characteristics.

Imagery processing and classification are valuable input data also for the implementation of statistical analyses in GIS environment, widely employed for drafting instability and susceptibility maps at regional or catchment scale, and to point out the conditions where the event probability is higher. In this context, RS-derived instability maps are essential as ground truth. As regards predisposing and preparatory factors, NDVI maps are already employed, but further improvements should be carried out regarding other aspects, such as infrastructures, rain impervious areas, etc. This approach is expected to be very significant also for the statistical assessment of the influence of vegetation cover variation and health state on land instability changes in the short term.

Sinkhole detection and mapping are mainly achieved by aerial photographs and DEM-derived data interpretation, and their integration guarantees higher accuracy of the inventory map (Zumpano et al., 2019). InSAR velocity maps show subsiding reflectors whose likelihood to be precursors of sinkhole collapses is rated based on the integration with the susceptibility map (Esposito et al., 2021).

The monitoring of underwater ground movements in shallow water environments requires the accurate determination of water depth. Nowadays, active (LiDAR) and passive (multispectral) RS methods are considered the most advantageous options to rapidly acquire large datasets in coastal waters, lakes, and rivers. The increasing number of free and open-access satellite data (i.e. ICEsat-2, Sentinel-2, Landsat-8) is stimulating the use of RS methods to obtain low-depth bathymetries (Bernardis et al., 2023). The principal goal of RS applications in the study of submarine landslides is the frequent data repetition that allows for obtaining residual maps of the difference between successive bathymetric surveys. Repeated residual maps provide information about sediment movements that can be expressed in terms of volume, displacement, velocity, and acceleration. Those data have important practical applications for hazard maps, harbor management, dredging operations, and predicting channel infill and sediment budgets.

References

Bernardis M., Nardini R., Apicella L., Demarte M., Guideri M., Federici B., Quarati A., De Martino M. (2023). Use of ICEsat-2 and Sentinel-2 open data for the derivation of bathymetry in shallow waters: case studies in Sardinia and in the Venice Lagoon. *Remote Sensing,* 15, 2944.

Esposito C., Belcecchi N., Bozzano F., Brunetti A., Marmoni G. M., Mazzanti P., et al. (2021). Integration of satellite-based A-DInSAR and geological modeling supporting the prevention from anthropogenic sinkholes: a case study in the urban area of Rome. *Geomatics, Natural Hazards and Risk*, 12(1), 2835-2864.

Festa D., Bonano M., Casagli N., Confuorto P., De Luca C., Del Soldato M., et al. (2022). Nation-wide mapping and classification of ground deformation phenomena through the spatial clustering of P-SBAS InSAR measurements: Italy case study. *ISPRS Journal of Photogrammetry and Remote Sensing*, 189, 1-22.

Mazzanti P., Caporossi P., Muzi, R. (2020). Sliding Time Master Digital Image Correlation Analyses of CubeSat Images for landslide Monitoring: The Rattlesnake Hills Landslide (USA). *Remote Sensing*, 12, 592.

Zumpano V., Pisano L., Parise M. (2019). An integrated framework to identify and analyze karst sinkholes. *Geomorphology*, 332, 213–225.

Towards a national network of natural field laboratories for the study of ground instabilities

Chiara Colombero[1], Farbod Khosro Anjom[1], Gianmarco Marmoni[2], Guglielmo Grechi[2], Paolo Mazzanti[2], Davide Donati[3], Lisa Borgatti[3], Diego Di Martire[4], Giovanni Forte[4], Salvatore Martino[2], Francesca Bozzano[2]

(1) Dipartimento di Ingegneria dell'Ambiente, del Territorio e delle Infrastrutture (DIATI), Politecnico di Torino, chiara.colombero@polito.it
(2) Dipartimento di Scienze della Terra, Università di Roma La Sapienza
(3) Dipartimento di Ingegneria Civile, Chimica, Ambientale e dei Materiali, Università di Bologna,
(4) Dipartimento di Scienze della Terra, dell'Ambiente e Risorse, Università degli Studi di Napoli Federico II

Several geological and anthropogenic processes have high potential to damage rock masses over time, leading to their transformation into gravitational instabilities that, once triggered, can paroxistically fail over much shorter timeframes. Monitoring solutions, including multiparametric and multisensory systems, play a crucial role in mitigating risks and developing early warning strategies. Natural field laboratories equipped with these monitoring systems enable the testing of new technologies and data processing approaches for the analysis of predisposing factors, preparatory and trigger processes on a wide range of potential instabilities. Currently, significant emphasis is placed on understanding the role of diurnal or seasonal thermo- and hydro-mechanical effects in causing damage to rock masses. Within this context, the various research units engaged in the RETURN-VS2 project are presently conducting multiple long-term or temporary experimental activities in different Italian natural field laboratories.

The POLITO unit is focusing on the monitoring of different types of gravitational instabilities through passive seismic methods. Ambient seismic noise and microseismicity analyses can indeed be used to recognize irreversible modifications in site stability and failure precursors from an early-warning perspective. In addition, seismic parameters generally exhibit reversible variations related to the preparatory factors governing site stability. Reversible variations of seismic parameters as a function of the external air temperature fluctuations have been observed and quantified in several natural field laboratories, including the long-term monitored potentially unstable rock masses of Madonna del Sasso (VB) and Ormea (CN), and the slope at the top of the Bossea Cave (CN). The key role of temperature is also found to govern the reactivation of movements and possible collapses of the Gran Sometta Rock Glacier (AO). The research efforts of the unit are currently devoted to the application of machine learning techniques for the detection and classification of microseismic events to be read as failure precursors.

The SAPIENZA unit focuses its research on the impact of environmental forcings on rock block instabilities, pursuing a dual objective involving the continuous monitoring and data analysis of both periodic and episodic stressors and their resulting strain effects, together with rockfall detection, inventorying, and characterization. In the experimental field laboratories of Acuto (FR) and Poggio Baldi (FC), geotechnical, geophysical, and environmental monitoring, as well as remote surveys and photomonitoring applications, are carried out, respectively. At the AcutoFieldLab the collected data are used to infer the effect of temperature changes in 2D and 3D over the rock surface and across joints. In the Poggio Baldi landslide laboratory, the integration and comparison of technological devices like radar, laser scanners, and cameras with thermal, acoustic and pluviometric measurements contribute to the development of tailored magnitude-frequency relationships capable of supporting rockfall hazard analysis and deepen the understanding of rock instability precursor signals.

The UNIBO unit takes advantage of a combination of numerical modelling methods to investigate the role of various rock mass damaging processes and events on the long term stability of rock slopes (i.e., impact of seasonal groundwater table changes, thermal cycles and seismic events on the accumulation of brittle damage within a rock mass, as well as its spatial distribution and evolution with time). The San Leo plateau (FC) has been identified as an ideal site to conduct such investigations, based on the geological and geomechanical knowledge gained by the research unit over the past two decades, as well as the significant amount of monitoring data (from in-hole and surface extensometers logs, piezometric data, microseismic monitoring) collected along the years following the last major landslide event that affected the site in 2014.

The UNINA unit has been focusing on the monitoring of two mechanisms of rainfall-triggered landslides, which are typical and frequent in the sub-Apennine geological contexts:

1) fast and sudden slippages of thin pyroclastic covers resting on stiff and often fractured soft rock formations;
2) slow and intermittent sliding of even very thick complex formations which are often characterised by intense fissuring and softening.

In such mechanisms, the litho-stratigraphic predisposing factors are often hard to be characterized by conventional field and laboratory tests. Thus, the field monitoring of soil displacements and water content, the negative-to-positive pore pressure fluctuations, and the shallow atmospheric variables represent a fundamental requirement for calibrating and validating hydro-mechanical models, enabling to back-analyse the time-dependent slope movements and to predict their evolution, addressing mitigation countermeasures. In this framework, the unit will finalize the experimental characterization and monitoring of the field laboratories located in Pagani (SA) and Pietrapertosa (PZ).

The experience gained at each site is offered and shared within the project, with the goal of establishing a national network of natural field laboratories for the study of gravitational instabilities with the most advanced multisensory techniques of data acquisition and processing.

Towards the Proof of Concept: from single tools to tool chains. An example for co-seismic slope failures

Carlo Esposito[1], Maria Elena Di Renzo[1], Matteo Ferrarotti[1,2], Alessandro Peloso[3], Enrico Paolucci[4], Giovanni Forte[5], Salvatore Martino[1]

(1) Dept. of Earth Sciences and CERI – Research Centre for Geological Risks, "Sapienza" University of Rome, carlo.esposito@uniroma1.it
(2) Speri Società di Ingegneria e Architettura SpA
(3) ENEA - Italian National Agency for New Technologies, Energy and Sustainable Economic Development
(4) Dept. of Physics and Astronomy, University of Bologna
(5) Dept. of Civil, Construction and Environmental Engineering, University of Naples "Federico II"

One of the main goals of Spoke VS2 is to set up a methodological framework to simulate hazard scenarios due to ground instabilities in different contexts/environments and at different scales, based on know-how already acquired by participants. Specifically, Task 2.4.2 of WP2.4 aims to analyze and rationalize all the operational tools made available by the Partnership that deal with ground instabilities, and then organize them in a logical sequence able to simulate impact scenarios and considering predisposing factors as well as preparatory/triggering processes.

In this context, an effective example is represented by the "PARSIFAL" approach (e.g., Esposito et al., 2016; Martino et al., 2020); such a *Probabilistic Approach for Rating Seismically Induced slope FAiLures* has already been conceived as a sort of sequence of analytical actions – thus fitting the "philosophy" of tool chains – that allows the quantitative definition of scenarios of seismically-induced slope failures. Specifically, the framework of PARSIFAL is structured in three slots (Figure 1): 1) slope analysis, 2) slope stability, and 3) synthetic mapping of resulting scenarios.

The slope analysis (first slot) consists of partitioning the territory into kinematic units, which can be defined as areas prone to slope failures according to a specific mechanism. Three parallel procedures are proposed for first-time rock failures, first-time shallow earth slides, and reactivations of existing landslides, both in rock and earth slopes. First-time failure of rock slopes deals with different failure mechanisms (planar, wedge, or toppling). Geo-structural domains are drawn based on structural data, especially on the lithology, and number and orientation of bedding planes and joint sets. Regarding first-time shallow earth slides, only shallow translational slide mechanisms are considered, as they are particularly prone to be activated by seismic shaking on steep slopes. Reactivations correspond to existing, properly inventoried, landslides defined in terms of geometry and failure mechanism to allow consistent stability analyses.

The slope stability (second slot) is used to compute earthquake-induced displacements (if any) for evaluating the probability of exceedance with respect to an overall failure condition. In case no displacement can be calculated (e.g. for $PGA<a_y$), a safety factor (SF) provides the stability of the slope. External inputs require the assessment of seismic accelerations ($a_{h,v}$) and response spectra (RS) as a function of the seismic hazard results (SHA), for pseudostatic analyses and time-histories selection, respectively. Boundary hydraulic conditions are also required in terms of water pressure distributions (U) as a function of the rainfall hazard results (RHA). Both SHA and RHA results require external calls to the preferred method by the analyst, such as PSHA vs. DSHA for SHA, or Gumbel vs. GEV methods for RHA, as an example.

Finally, the integrated mapping of resulting scenario (third slot) aims at a comprehensive graphical representation of the slope stability conditions for different scenarios, corresponding to different seismic hazards and hydraulic conditions. For first-time failures in rock slopes, the elementary area is the cell unit; for first-time earth slopes, the elementary area is the slope unit, which represents a portion of slope with homogeneous aspect; for reactivations, the elementary area is the polygon unit, as reported in the landslide inventory. This comprehensive mapping requires that multiple associations between kinematic units and territorial units are solved in the case of rock slopes. Such a distinction is requested since several rock blocks, i.e. characterized by different size and/or failure mechanism, can correspond to the same territorial unit. In PARSIFAL, this problem is solved by computing a weighted and combined probability in case of multiple safety conditions and/or percentage of exceedance in terms of earthquake-induced displacements.

Since its first release, the Authors have highlighted how external tools can be experienced by users to provide specific inputs for the computational procedures (such as $a_{h,v}$, a_y, water pressure distributions, and so on). Then, in the renewed perspective offered by PE3 RETURN – VS2, the PARSIFAL methodology can be considered as the basic scheme where hints and tools provided by WP2 (predisposing factors) and WP3 (preparatory processes) can better frame and adapt to site-specific conditions slot 1 (slope analysis) and slot 2 (slope stability), respectively. In particular, since slot 1 consists in the susceptibility analysis for first-time failures, appropriate (i.e., meeting the requirements for the type, location, and scale of analysis) tools extracted from WP2 can be used for assessing the "intrinsic" proneness to slope failures. Similarly, specific tools from WP3 can be claimed to capture the effects of preparatory/triggering processes (e.g., intense antecedent or concurrent rainfalls), thus better simulating the combined scenario related to seismic shaking as well as other external forces in a multihazard-oriented perspective. Finally, among the planned improvements the tool chain should be completed by the recall of tools able to simulate kinematic parameters: the quantitative output of PARSIFAL cannot indeed neglect the "footprint" of displaced rock/earth masses in terms of runout and related velocity, as the latter is fundamental to properly assess the overall impact of a given ground instability.

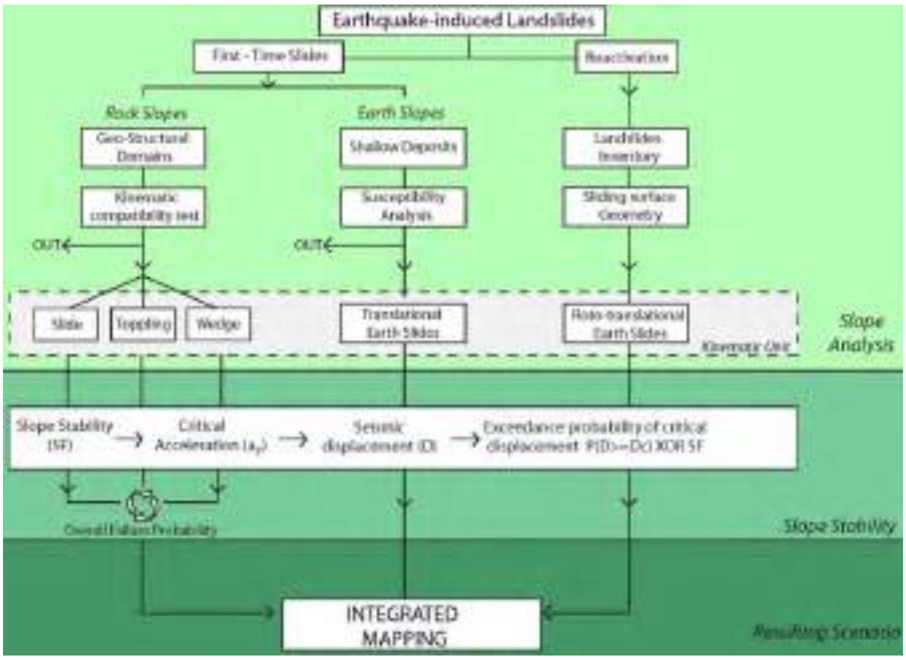


Figure 1 – Flow chart illustrating the multi-step PARSIFAL approach.

References

Esposito C., Martino S., Pallone F., Martini G., Romeo R. (2016). A methodology for a comprehensive assessment of earthquake-induced landslide hazard, with an application to pilot sites in Central Italy. In: Landslides and engineered slopes. Experience, theory and practice, *Taylor and Francis Inc*. 2: 869–877.

Martino S., Battaglia S., D'Alessandro F., Della Seta M., Esposito C., Martini G., Pallone F., Troiani F. (2020). Earthquake-induced landslide scenarios for seismic microzonation: application to the Accumoli area (Rieti, Italy). *Bull Earthquake Eng,* 18, 5655–5673.

The preparatory role of natural and anthropogenic wildfires on the occurrence of shallow landslides and their territorial distribution in view of effect scenarios conditioned by the temporal distance from fire events

Matteo Ferrarotti[1,2], Gian Marco Marmoni[1], Matteo Fiorucci[3], Divyeshkumar Rana[1], Hanieh Dadkhah[1], Ebrahim Ghaderpour[1], Carlo Esposito[1], Paolo Mazzanti[1], Gabriele Scarascia Mugnozza[1], Mara Lombardi[4], Davide Berardi[4], Anna Lei[5], Diego Di Martire[6], Jessica Maria Chicco[7], Giuseppe Mandrone[7], Salvatore Martino[1]

(1) Dept. of Earth Sciences, "Sapienza" University of Rome and CERI – Research Centre for Geological Risks; matteo.ferrarotti@uniroma1.it
(2) Speri Società di Ingegneria e Architettura SpA
(3) Dept. of Civil and Mechanical Engineering, University of Cassino and Southern Lazio
(4) Dept. of Chemical Engineering Materials Environment, "Sapienza" University of Rome
(5) Dept. of Architecture and Design, "Sapienza" University of Rome
(6) Dept. of Earth Sciences, Environment and Resources, "Federico II" University of Naples
(7) Interuniversity Dept. of Regional and Urban Studies and Planning, University of Turin

Landslides are a natural land-forming process and their interaction with humans makes them one of the most common geo-hazards. The so-called "destabilizing factors," which contribute to instability, are divided into "predisposing", "preparatory", and "triggering". Earthquakes and heavy rainfall, which usually act as triggers, are typically favored by a combination of predisposing factors and preparatory processes, that are investigated in PE3 RETURN – VS2, respectively, by WP2.2 and WP2.3. In particular, preparatory factors are dynamic and gradually reduce the slope's margin of stability without initiating the movement (Glade et Al., 2005).

Wildfires constitute, at the same time, a globally diffused natural hazard and one of the most relevant preparatory factors for shallow landslides, in view of cascading hazard scenarios. They are retained responsible for changes in watersheds' hydrologic and geomorphic response. Moreover, wildfires cause the denudation of hillslopes and the consequent reduction of the root strength, which mainly contributes to the soil cover stability (Figure 1; Abdollahi et Al., 2023). The magnitude and duration of the effects on the territory last for some years, depending on vegetation resistance and resilience. This kind of phenomenon can have natural causes, but human-induced ones usually carry a higher risk because they frequently affect areas near populated centers.

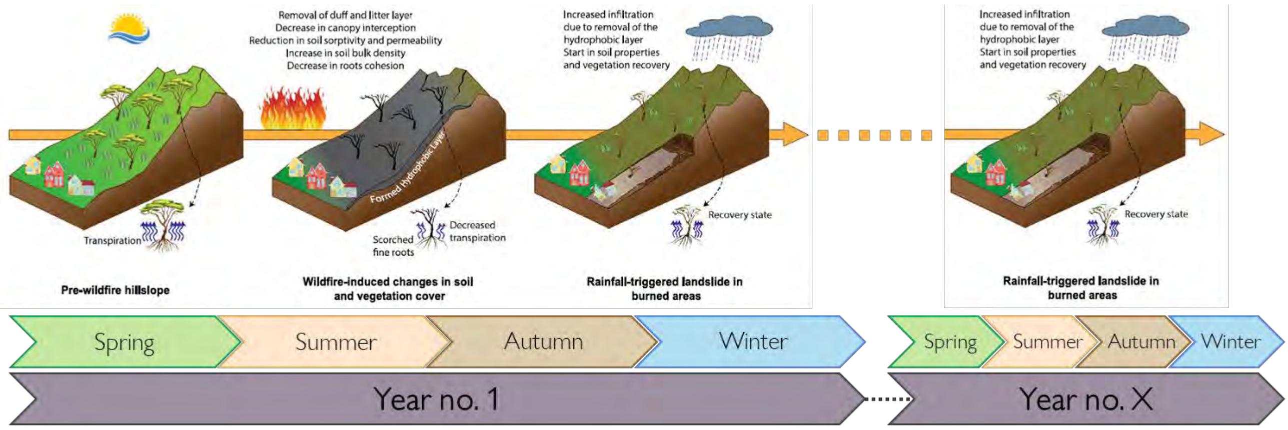


Figure 1 – Example of a time-dependent cascading hazard related to wildfires and landslides. A fire can prepare an area for shallow landslides for several years, with heavy rainfall possibly acting as a trigger throughout that time (mod. after Abdollahi et Al. (2023)).

The role of government and territorial management and defensible zones is crucial in reducing risk connected to wildfire and its effects, that present climate conditions and hypotheses of their changings could influence in relation to variations of temperature values as well as rainfall intensity, contributing to extensive fires impacting ecosystems and social risks like air pollution (Wasserman and Mueller, 2023).

The research presented here proposes a multidisciplinary approach to assess territory conditions before, during, and after wildfires, with a particular focus on ground stability, to quantify time-dependent scenarios of shallow landslides prepared by wildfires and triggered by different factors in a multi-hazard approach.

Anthropogenic factors significantly influence wildfires, as well as wildland-urban interface and socio-economic factors play key roles in wildfire management decisions. Despite limitations due to their resilience to complexities, wildfire ignition processes can be simulated using models like Poisson approaches, which can acknowledge wildfires' primarily human-induced and somewhat unpredictable nature, especially near combustible vegetation during certain periods (Li et al., 1999). Studies show strong correlations between computed fire weather indices and observed wildfire activities in various regions. Two main factors influence fire occurrences: the vegetational component at the time of ignition and the proximity of specific routes and networks. The analysis is based on observed wildfire events considered statistically independent and equiprobable. Poisson Probability Distribution aims to calculate the likelihood of a certain number of fire events within a specific time or area, assuming that the events are independent of each other and stationary over time. The purpose is to assess the probability of fires in an area. The results allow for representing wildfire hazard maps (see, for example, Berardi et al. (2023)).

In this context, having an inventory of wildfires and their effects, such as landslides, that is as complete as possible, is a crucial aspect of hazard analysis, since it collects validation points or events for both empirical and statistically based approaches. Multi-temporal land use/cover maps and landscape transformations, as well as historical documentation analysis and remote sensing techniques, are critical tools for reconstructing landscape transformations, including the occurrence and severity of wildfires and landslides. Furthermore, by weighing the amount and the type of vegetation loss during an event and tracking the process of hillslope denudation in the years that follow, they make it possible to evaluate the impact of each event over time. In particular, optical, radar, and multispectral satellite imagery, including Sentinel 1/2, Landsat, MODIS, and PlanetScope, are particularly helpful for reconstructing wildfire and landslide events, and also for identifying some of their useful features, such as land surface temperature (LST) and soil water content variations following a fire (Maffei et al., 2021).

Lastly, the influence of wildfires on shallow landslides is treated with an analytical/empirical approach. This involves conducting specific in situ and laboratory geotechnical tests on surface soil layers to determine the physical, hydraulic, and mechanical interactions between soil, vegetation, and fire, together with back-analysis approaches made possible by the aforementioned wildfire and landslide inventories and numerical simulations based on real data aimed at determining how wildfire can affect soil depth with significant increases in temperatures, thus influencing slope stability.

The final goal of this multidisciplinary research is the development of best practices for risk mitigation related to territorial and landscape management tools and plans, and fire extinguishing procedures, which is a topic strictly related to WP2.5.

References

Abdollahi M., Vahedifard F., Tracy F.T. (2023). Post-wildfire stability of unsaturated hillslopes against rainfall-triggered landslides. *Earth's Future*, 11(3), e2022EF003213.

Berardi D., Galuppi M., Libertà A., Lombardi M. (2023) Geostatistical modeling of wildfire occurrence probability: the case study of Monte Catillo natural reserve in Italy. *Fire*, 6, 11.

Glade T., Anderson M.G., Crozier M.J. (Eds.) (2005). Landslide hazard and risk (Vol. 807). *Chichester: Wiley*.

Li C.S., Lu J.C., Park J., Kim K., Brinkley P.A., Peterson J.P. (1999). Multivariate zero-inflated Poisson models and their applications. *Technometrics*, *41*(1), 29-38.

Maffei C., Lindenbergh R., Menenti M. (2021). Combining multi-spectral and thermal remote sensing to predict forest fire characteristics. *ISPRS Journal of Photogrammetry and Remote Sensing*, *181*, 400-412.

Wasserman T.N., Mueller S.E. (2023). Climate influences on future fire severity: a synthesis of climate-fire interactions and impacts on fire regimes, high-severity fire, and forests in the western United States. *Fire Ecol.,* 19, 43.

Data-driven microseismic event classification for the early warning of landslides

Farbod Khosro Anjom[1]*, Chiara Colombero*[1]

(1) Dept. of Environment, Land, and Infrastructure Engineering (DIATI), Politecnico di Torino, khosro-anjom.farbod@polito.it

Ambient seismic noise and microseismicity monitoring have been increasingly used in a wide range of applications, including hydrogeological assessments, fluvial seismology, and the monitoring of buildings, infrastructure, glacial bodies, and natural risk assessments. These methods are particularly beneficial for the assessment of natural risks associated with gravitational instabilities such as landslides and unstable rock masses. Various preparatory factors, such as heavy rainfall, fluctuations in temperature, seasonal changes, wind, and snowfall, progressively damage the rock formations. When these damages reach a critical point, the formations become unstable, and the timeframe for monitoring shortens dramatically. The continuous monitoring of potentially unstable sites through passive seismic methods involves the recording of seismic events from various natural and anthropogenic sources that are not always correlated to precursors of failure. Real-time systematic classification of passive events is therefore required for effective passive monitoring and for the analysis of the preparatory factors contributing to failure. The use of machine learning (ML) algorithms for passive event classification is still in its early stages, but some promising results have recently been demonstrated (Trani et al., 2022; Dokht et al., 2019). Using transfer learning techniques, which involve leveraging pre-trained machine learning models from the computer vision field, has proven to be very effective when applied to other disciplines. Here, we customize the AlexNet neural network, originally designed for object classification, to address passive event classification. We train the model on the labeled data recorded on the slope at the top of the Bossea Cave (CN, NW Italy). The limestone roof of the natural cave exhibits modifications in its stability that are related to temperature cycles, precipitation, and overall climate change, making it an interesting site for passive seismic monitoring. Several rock falls and local collapses have already been reported in historical times at the top of the biggest underground chambers of the cave.

For more than seven months, two broadband triaxial seismic stations placed above the cave continuously recorded passive seismic data, with a sampling frequency of 250 Hz. Using the short-time average over long-time average (STA/LTA) method, seismic events were detected and extracted from the continuous passive recordings. In total, 3455 events were detected, and the signals were converted into spectrograms (i.e., time-frequency representations) to analyze the spectral and temporal features of the events and identify their possible source. Based on a visual inspection of the spectrogram of the signals, Dabove et al. (2023) classified events into four categories (raindrops, rockfalls, earthquakes, and microseismic events potentially related to incipient thermal cracking). From the original dataset, 200 spectrograms were chosen at random and manually labeled for the categories under consideration.

As the input to the neural network, each spectrogram was prepared in a three-channel RGB format with a size of 227 × 227 × 3, and the category of the event (label) was considered as the output. The AlexNet's fully connected layer (last layer) was modified to respect four classes in the output rather than 1000 classes for object detection (Figure 1). The labeled data were divided into 150 training, 25 validation, and 25 test data sets, respectively. To optimize the hyperparameters, several training attempts were made. The model was trained with 20 mini-batches of data in each iteration and was trained for 100 epochs in 1 hour.

The final ML model achieved 100% accuracy on the training set and 92% on the validation set, promising good automatic pattern recognition of the passive data from spectrograms. In the future, we intend to use data sets from various sites for the training stage and define more comprehensive classes of passive events in order to be able to generalize the ML model to unseen data sets from various sites.

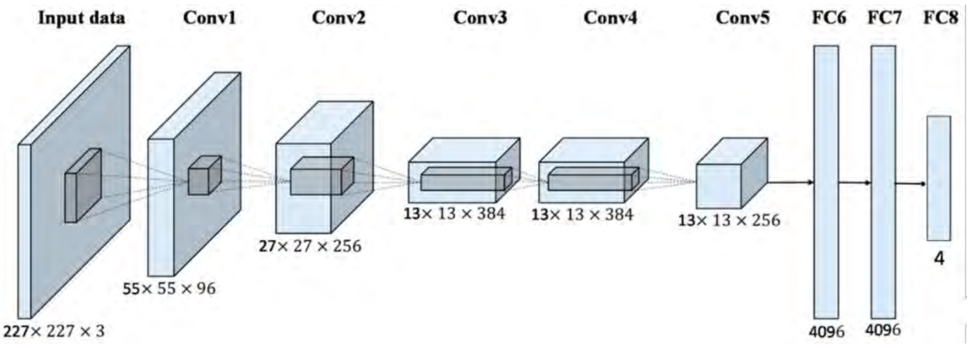


Figure 1: The architecture of the AlexNet model. The layer FC8 is modified for 4 classes of outputs instead of 1000.

References

Dabove P., Colombero C., Quaroni A.S. (2023). Towards the Monitoring of Underground Caves Using Geomatics and Geophysical Techniques: 3D Analyses and Seismic Response. *ISPRS International Journal of Geo-Information*, 12, 191.

Dokht R.M.H., Kao H., Visser R., Smith B. (2019). Seismic event and phase detection using time–frequency representation and convolutional neural networks. *Seismological research letters*, 90, 481-490.

Trani L., Pagani G.A., Zanetti J.P.P, Chapeland C., Evers L. (2022) Deepquake—an application of CNN for seismo-acoustic event classification in the Netherlands. *Computers & Geosciences*, 159, 104980.

Machine learning approaches for the assessment of ground instabilities. An overview of Return VS2 approach against existing literature

L. Nava[1], F. Catani[1], A. Rosi[1], K. Bhuyan[1], R. Tufano[2], G. Bausilio[2], P. Confuorto[3], E. Ghaderpour[4], D. Di Martire[2]

(1) Dept. of Geosciences, University of Padova
(2) Dept. of Department of Earth, Environmental and Resource Sciences, "Federico II" University of Naples, rita.tufano@unina.it
(3) Dept. of Earth Science, University of Florence
(4) Dept. of Earth Sciences, Sapienza University of Rome

The risks associated with ground displacements, such as landslides, subsidence, sinkholes, and liquefaction, are on the rise due to climate change. To effectively address these issues, it is crucial to enhance existing methodologies for fundamental tasks like data collection, monitoring, modeling, and prediction. Although remote sensing and Earth observation (EO) methods offer new possibilities in these domains, they pose challenges such as image noise, overlapping features and processes, low signal-to-noise ratio in emergency-acquired data, and the abundance of big data. Today, overcoming these challenges is feasible with the aid of Artificial Intelligence (AI)-driven tools (Ma and Mei, 2021). These tools include image analysis techniques for improved landslide detection, deep learning schemes for patch classification and object segmentation, and recurrent neural networks for uncovering hidden temporal relationships in monitoring time series. Machine Learning (ML) and Deep Learning (DL) methods employed in ground displacement studies have significantly advanced detection, involving pixel-wise classification and object-based algorithms, and monitoring of these processes. Monitoring tools extend to using DL for enhanced failure forecasting through time-series analysis (e.g. Ghaderpour et al. 2023a, b) and employing ML for advancing early warning systems to higher levels of accuracy. ML and DP methods can also be useful in understanding processes related to the importance of conditioning factors or exploring the relationships between causative and conditioning factors. Furthermore, even within a ML algorithm, different varieties exist, and their performances vary according to the study area and input data (Merghadi et al., 2020). Finally, even if ML and DL are becoming increasingly important in the support of numerical modeling development, calibration, and optimization (Guha et al., 2022), many challenges exist, like gaps in data and biases in the input training datasets which could potentially create biases and mislead the interpretation of the results. Therefore, the most effective ground deformation mapping and monitoring need supervision by both geologists and statisticians with the use of hybrid models and multiple datasets.

Ground displacement mapping, modeling, and monitoring are specifically investigated in Spoke VS2 of the RETURN project, concerning WP3 but with contributions that are useful for WP2 and WP4 as well.

The main aim is to document and show how the present-stage Return VS2 learning examples and derived rationales, developed during the first year of the project, cover the existing realm of application of AI methodologies, particularly ML and DL, to ground displacement hazard analysis. By providing practical toolchains, we try to contribute to establishing a framework for implementing ML and DL methods in ground displacement risk assessment and mitigation at the project scale. The objective of the Spoke VS2 is to empower decision-makers with data-driven insights, enhancing decision-making in areas such as land-use planning, infrastructure development, and emergency response for ground displacement risks. An essential aspect of this contribution is the facilitation of interdisciplinary collaboration, bridging the gap between domain-specific knowledge and advanced data analytics. This collaborative approach ensures a holistic perspective in hazard assessment and management, allowing for a smoother transition from conceptual modeling to logical/physical implementation of procedures in Proof of Concept (PoC), where ML and DL techniques may play a pivotal role. By comparing existing literature with VS2 ML/DL cases, the review identifies significant gaps in DL applications for landslides, subsidence, soil liquefaction, sinkholes, and submarine landslides. The scarcity of DL in this context hampers the potential of predictive models, limiting our ability to anticipate and mitigate the impact of these events on populations and infrastructure. Specifically, we underscore the deficiency in ML applications tailored for submarine landslides, emphasizing the need for interdisciplinary collaboration between oceanographers, geologists, and data scientists. Another critical gap identified is the absence of comprehensive ML/DL tools for multi-hazard assessment and runout estimation in the existing dataset of Learning Examples. The lack of dedicated tools for constructing risk scenarios further impedes the formulation of effective risk management plans. Additionally, this prevents decision-makers from obtaining sufficient data-driven insights, limiting their ability to make informed choices about aspects like land-use planning, infrastructure development, and emergency response—topics also addressed by other Return Spokes with special reference to TS1, TS2, TS3.

To address these gaps, we recommend prioritizing multi-hazard evaluation and risk scenario building in the next project phase. Integrated toolchains are deemed essential for assessing the cascading effects of various hazards and formulating effective risk management plans. We propose considering potential ML and DL methodologies during the PoC implementation phase, drawing from its content and relevant cited literature.

In summary, we present a guiding framework for the integration of AI methodologies into mass movement hazard mitigation, identifying and addressing critical gaps in current research and tool development.

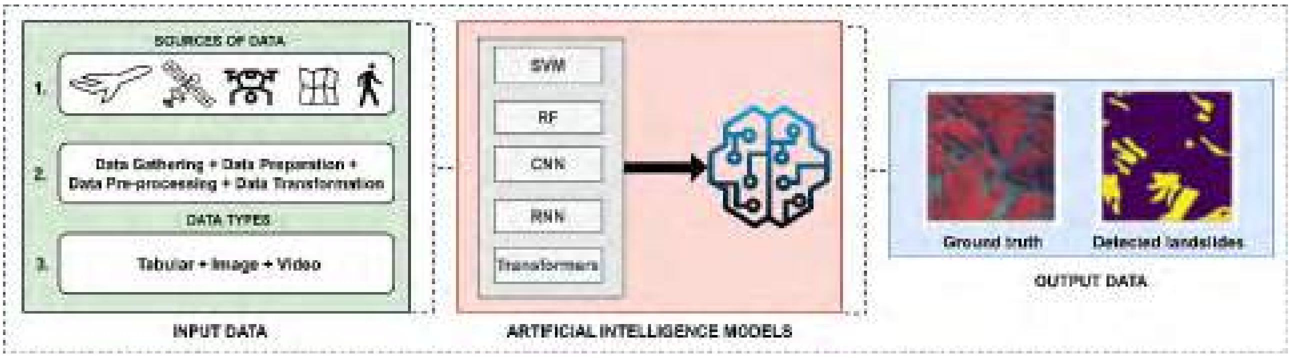


Figure 1 – General scheme for ground displacement detection and monitoring by EO and machine learning (modified from Catani et al., in press.). SVM= Support Vector Machine; RF= Random Forest; CNN= Convolutional Neural Network; RNN= Recurrent Neural Network.

References

Catani F., Nava L., Bhuyan K., Floris M. (in press). Artificial Intelligence applications for landslide mapping/monitoring on satellite EO data. In: "*Earth Observation Applications to Landslide Mapping and Monitoring*", 6, Elsevier, ISBN: 9780128238684.

Ghaderpour E., Mazzanti P., Scarascia Mugnozza G., Bozzano F. (2023). Coherency and phase delay analyses between land cover and climate across Italy via the least-squares wavelet software. *International Journal of Applied Earth Observations and Geoinformation*, 118, 103241.

Ghaderpour E., Masciulli C., Zocchi M., Marini R., Mastrantoni G., Reame F., Pantozzi G., Belcecchi N., Scarascia Mugnozza G., Mazzanti, P. (2022). Least-Squares Wavelet Analysis of Rainfalls and Landslide Displacement Time Series Derived by PS-InSAR. In International Conference on Time Series and Forecasting (pp. 117-132). Cham: Springer Nature Switzerland.

Guha S., Jana R., Sanyal M. (2022). Artificial neural network approaches for disaster management: A literature review. *Int. J. of Disaster Risk Reduction*, 81, 103276.

Ma Z., Mei, G. (2021). Deep Learning for Geological Hazards Analysis: Data, Models, Applications, and Opportunities. *Earth-Science Reviews*, 223, 103858.

Merghadi A., Yunus A. P., Dou J., Whiteley J., ThaiPham B., Bui D. T., Avtar R. & Abderrahmane B. (2020). Machine learning methods for landslide susceptibility studies: A comparative overview of algorithm performance. *Earth-Science Reviews*, 207, 103225.

Statistical methodology in GIS environment for the elaboration of dynamic ground instability susceptibility maps

Paola Salmona[1], Rossella Bovolenta[1], Bianca Federici[1], Ilaria Ferrando[1]

(1) Department of Civil, Chemical and Environmental Engineering (DICCA), University of Genova, rossella.bovolenta@unige.it

The UNIGE – DICCA working group aims to implement a tool, based on statistical analysis, to map ground instability susceptibility and its variations, following cumulate rainfall and vegetation coverage changes.

The starting point of this research work is a comparison in GIS environment between several influencing factors and the Italian actual instability repertory (ISPRA 2021, Marzocchi et al., 2016).

Through a workflow that joins bivariate analysis and logistic regression, a landslide susceptibility map is drawn and it is eventually divided into three classes, High, Medium and Low susceptibility.

Such methodology is expected to be tested on some learning areas, therefore implemented and improved in order to make it transferable to the Italian territory, also keeping into consideration the different types of ground instabilities and the availability and the quality of related data.

Presently, the work is in progress on:

- data reliability - identification of official, high-quality datasets and definition of specifications for data preprocessing, to be employed in different areas (i.e., time series and spatial interpolation of rainfall data)
- identification of consistent and scientifically justifiable classes for base data, either continuous (i.e. Digital Terrain Model) or discrete/descriptive data (i.e., land use);
- set-up of the resolution (for raster map) and the detail level (for vector data) adequate to the study areas extension, in order to find a balance between spatial generalization and complexity;
- identification, also from literature review, of specific factors specific for the different types of ground instability in order to customise the workflow for each considered type of instability (i.e. slope morphology, river erosion rate, etc.).

The first expected result is not only a static map describing the present ground instability susceptibility, but it is also the base map on which to observe the effects of the variations of two predisposing factors, rainfall and vegetation.

Regarding rainfall, it is described by means of the Climate Aggressivity index (Arnoldus Index – FMI Arnoldus, 1980). This parameter can be developed in two ways. The first one takes into consideration rainfall measures along thirty years, in order to calculate the average Climate aggressivity of an area. The second one is based on yearly and monthly time series, to point out how an extremely dry or rainy season can influence ground instability susceptibility (Di Lena et al., 2013).

Vegetation and related features are usually reported through regional cartography, above all land use or land cover maps but they are drafted by Regional Governments with different scales, criteria and procedures and are updated quite irregularly, generally less than once a year. In order to get content consistency it would be useful to apply to Regional maps the classification proposed in the Corine Land Cover, even if it is updated about every three years. An hypothesis to be developed, moreover, could be to integrate Regional cartography with Copernicus Normalized Difference Vegetation Index (NDVI) maps that are uniform, frequently updated and have a resolution consistent with the working scale.

Once input data are optimised, the actual statistical methodology is expected to be applied in a more favourable environment, reducing therefore the possibility of gross or systematic errors.

References

Arnoldus H.M.J. (1980). An approximation of the rainfall factor in the Universal SoilLoss Equation. In *Assessment of erosion - FAO Land and Water Devel. Div.* – Wiley & Sons, England, 127-132.

Bovolenta R., Federici B., Marzocchi R., Berardi R. (2016). A new GIS-based multivariate statistical analysis for landslide susceptibility zoning. *Landslides and Engineered Slopes. Experience, Theory and Practice* – Aversa et al. (Eds) Associazione Geotecnica Italiana, Rome, Italy.

Di Lena B., Antenucci F., Vergni L., Marian l. (2013) Analysis of the climatic aggressiveness of rainfall in the Abruzzo region. *Italian Journal of Agrometeorology*, 33–44.

Normalised Difference Vegetation Index 2016-present (raster 10 m), Europe, daily https://land.copernicus.eu/en/products/vegetation/high-resolution-normalised-difference-vegetation-index

Istituto Superiore per la Protezione e la Ricerca Ambientale ISPRA (2021). Inventario dei Fenomeni Franosi in Italia – IFFI. https://idrogeo.isprambiente.it/app/iffi

Spoke VS3: Earthquakes and volcanoes

Vulnerability assessment of rooftop telecommunication towers under seismic events

Alessandro Cardoni[1], Raffaele Tarantini[1], Andrea Calidori[1], Gian Paolo Cimellaro[1]

(1) Dept. of Structural, Geotechnical and Building Engineering, Politecnico di Torino, Corso Duca degli Abruzzi 24, Torino, 10129, Italy, alessandro.cardoni@polito.it

Telecommunication networks serve as essential infrastructures for urban areas, playing a crucial role in everyday tasks and emergencies such as earthquakes. Limited research has been conducted on the evaluation of the vulnerability of telecommunication towers on a broad scale. The majority of studies concentrate on analyzing the structural integrity of tall towers located in open areas when exposed to seismic events and strong winds. There is a lack approaches for assessing vulnerability and resilience on an urban scale, especially considering rooftop towers that are often subject to ageing and corrosion phenomena.

In this study, the seismic vulnerability assessment of 170 post antennas and 63 masts is performed representative of an urban physical infrastructure owned by a mobile network operator. The 233 analyzed antennas, situated atop various buildings, are considered fixed at the base. It is hypothesized that S235 steel was used for the poles, while the lattice towers were constructed using S275 steel elements. It is also assumed that the poles consist of circular hollow section (CHS) beams supporting three antennas each weighing 25 kg at the top, resulting in a total nodal load of 0.75 kN. The tower height, varies in a range from 2 to 6 m. According to NTC (2018), the slenderness ratio should not exceed 200, and the cross-section of the beams is designed accordingly. On the other hand, masts are composed of square base lattices with dimensions of 0.3x0.3 m, and each module has a fixed size of 0.3x0.5 m. The antennas mounted at the top impose a load of 0.75 kN, as in the pole structures. The total height of the towers ranges from 3 to 7.5 m. In this case, tower design is based on wind load resistance according to NTC (2018). The four main legs and horizontal braces have a Hollow Circular Section (total diameter of 42.4 mm, thickness of 2.6 mm), while primary braces are round bars with a diameter of 8 mm. Connections between all components are modeled as hinges. The four nodes at the junction of buildings and towers are considered fixed, while planes identified by horizontal braces act as rigid diaphragms.

A Finite Element (FE) model for each tower was developed using MATLAB. The poles were discretized into 25 elements, and the corresponding masses were applied at each node. Only bending deformability was considered. On the other hand, the masts were modeled as cantilever beams with deformability in both bending and shear. In this case, the FE model was constructed according to (Pozzati, 1972). The damping ratio was set at 5% for all towers. Seismic input was introduced as acceleration time histories, calculated at the top of each building by applying the seismic acceleration time history of the Norcia earthquake to the urban-scale FE model described in (Cardoni et al., 2022). Subsequently, multiple linear dynamic analyses were conducted to calculate the time histories of displacement at the upper nodes in both horizontal directions. Maximum displacements at the top and the corresponding drift ratios were then evaluated. Based on the results it is possible to observe that for a moderate intensity seismic input, rooftop towers and their components report no damage. Therefore, the future objective is to assess vulnerability and resilience indices of the entire urban network, introducing the effects of ageing through a corrosion model.

References

NTC (2018). Decreto Ministero Infrastrutture e Trasporti 17 gennaio 2018. Norme tecniche per le costruzioni. *G.U. n. 42 del 20/02/2018, suppl. ord. n. 8*.

Pozzati P., Ceccoli C. (1972). Teoria e tecnica delle strutture (Vol. 1). *Utet*.

Cardoni A., Borlera S.L., Malandrino F., Cimellaro G.P. (2022). Seismic vulnerability and resilience assessment of urban telecommunication networks. *Sustainable Cities and Society*, *77*, 103540.

Optimal design of FPS devices for isolated multi-span continuous deck bridges depending on the ground motion characteristics

Paolo Castaldo[1]*, Elena Miceli*[1]

(1) Dept. of Structural, Geothecnical and Building Engineering, Politecnico di Torino, paolo.castaldo@polito.it

This work examines the seismic performance of multi-span continuous composite or reinforced concrete (RC) deck bridges isolated with single concave friction pendulum system (FPS) devices. The aim is to evaluate the influence of ground motion characteristics on the optimal friction coefficient of the isolators by means of a non-dimensionalization of the motion equations. In agreement with (Jangid, 2008; Kunde and Jangid, 2006; Castaldo and Amendola, 2021), a six-degree-of-freedom (dof) model has been adopted, including 5 dofs for the lumped masses of the RC pier and 1 additional dof for the composite or RC deck, which is considered infinitely rigid. Two FPS devices are modelled, respectively, on top of the elastic RC pier and on the rigid RC abutment. The latter is modelled as a fixed support in order to include the interaction between the deck and the abutment. The velocity dependency of the FPS device behavior is taken into account according to (Mokha et al., 1990).

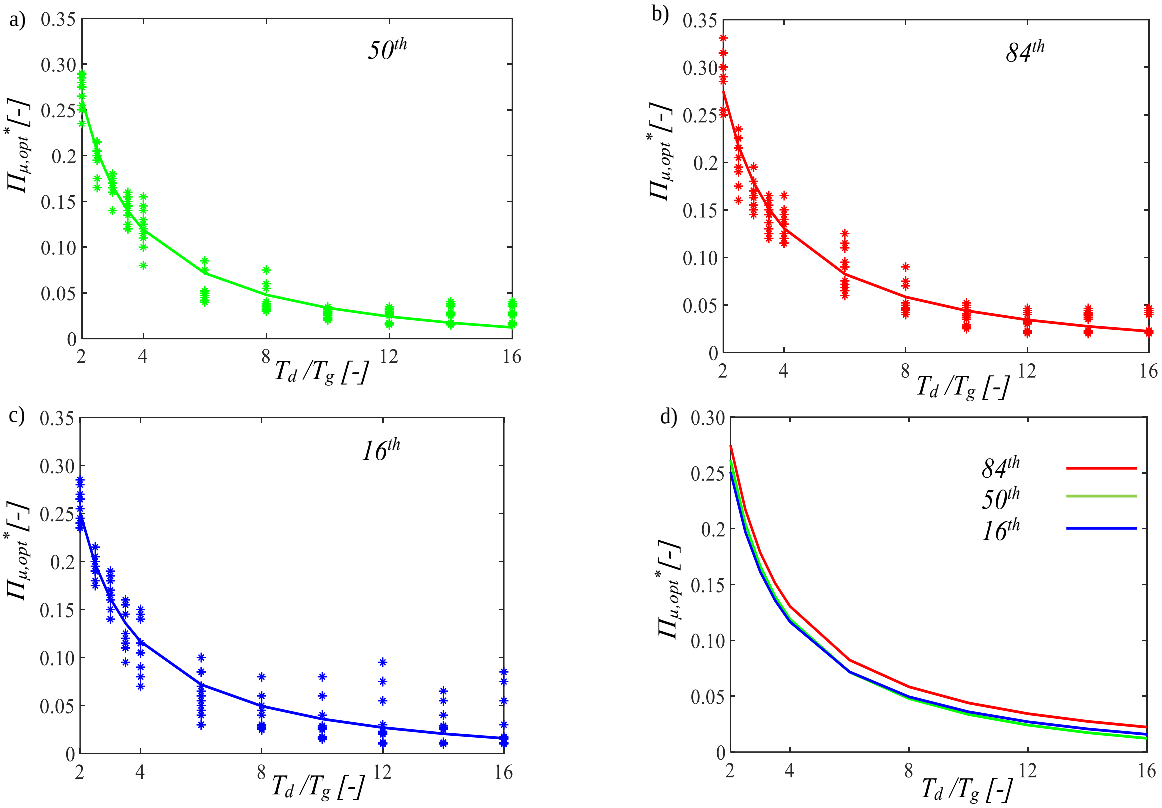


Figure 1 – Regression of the optimum normalized friction coefficient for both the FF and NF records related to a) the 50th percentile, b) the 16th percentile, c) the 84th percentile and d) all the percentiles.

To include the record-to-record variability, different sets of ground motions are considered, including both far-field (FF) records with different ranges of peak ground acceleration-to-velocity ratios (i.e., PGA/PGV) and near-fault (NF) inputs (Castaldo and Tubaldi, 2018). By including the PGA/PGV ratio, the non-dimensionalization of the motion equations with respect to the seismic intensity has been proposed.

Successively, a wide parametric analysis for different structural parameters (i.e., the pier period, the ratio between the deck period and the period associated to the ground motion input, the friction coefficient and the ratio between the mass of the deck and of the pier) is implemented. In this way, the normalized responses in terms of peak horizontal displacement of the pier and of the isolators are assessed. Finally, for each percentile of the seismic response (i.e., 16^{th}, 50^{th} and 84^{th}), a linear regression expression is evaluated in order to compute the normalized friction coefficient of the isolators with respect to the ratio between the deck period and the ground motion period as shown in Figure 1. These proposed expressions can be very useful for a preliminary design of the FPS devices to isolate multi-span continuous composite or RC deck bridges. Additionally, multivariate non-linear regression expressions are also provided to evaluate the seismic pier response. More details may be found in (Castaldo and Miceli, 2023).

References

Castaldo P., Amendola G. (2021). Optimal DCFP bearing properties and seismic performance assessment in nondimensional form for isolated bridges. *Earthquake Engineering and Structural Dynamics*, 50(9), 2442-2461.

Castaldo P., Miceli E. (2023). Optimal single concave sliding device properties for isolated multi-span continuous deck bridges depending on the ground motion characteristics. *Soil Dynamics and Earthquake Engineering*, 173, 108128.

Castaldo P., Tubaldi E. (2018). Influence of ground motion characteristics on the optimal single concave sliding bearing properties for base-isolated structures. *Soil Dynamics and Earthquake Engineering*, 104, 346-64.

Jangid RS. (2008). Stochastic response of bridges seismically isolated by friction pendulum system. *J Bridge Eng.,* 13(4), 319.

Kunde M.C., Jangid R.S. (2006). Effects of pier and deck flexibility on the seismic response of isolated bridges. *J Bridge Eng.,* 11(1), 109-121.

Mokha A., Constantinou M.C., Reinhorn A.M. (1990). Teflon Bearings in Base Isolation. I: Testing. *Journal of Structural Engineering*, 116(2), 438-454.

Scouring effects on dynamic response of caisson foundations

Sebastiano Foti[1], Mauro Aima[1], Andrea Ciancimino[1], Marlio Molina Manrique[1]

(1) Department of Structural, Geotechnical and Building Engineering (DISEG), Politecnico di Torino, sebastiano.foti@polito.it

Bridges over waterways are highly sensitive to hydraulic actions, especially foundation scour (Kirby *et al.* 2015). Foundation scour is the lowering of the riverbed level by water erosion, resulting in partial or complete exposure of bridge foundations. The loss of surrounding soil reduces the bearing capacity and stiffness of the foundation (e.g., Ciancimino et al. 2022b), with detrimental effects on the seismic performance of bridges (e.g., Foti *et al.* 2023). Due to the difficulty in detecting the presence of scour and the limited financial resources available for maintenance and repair, the condition of many bridges often remains unchanged for several years. However, scoured bridges may be exposed to new flood events or earthquakes, to which they may be more vulnerable due to the weakened support conditions. In this context, the impact of scour on the performance of bridge piers can be properly assessed using advanced numerical simulations and employing appropriate constitutive models to reproduce the soil response for a wide range of stress-strain conditions. Numerical modelling also allows for a rigorous representation of the problem geometry, to distinguish between general and local scour effects.

This contribution presents the results of a numerical study addressing the impact of different types of scouring on the seismic response of a bridge pier, which was carried out within Spoke VS3 of the RETURN project. Further details can be found in Molina Manrique (2023). The investigated structure consists of a single-degree-of-freedom system representing a 23 m tall reinforced concrete pier with a circular full section of diameter 3.2 m. The pier is supported on a cylindrical caisson foundation of diameter 8 m and height 10 m. The caisson is embedded for 9 m in medium dense gravelly sand. A sketch of the pier is shown in Figure 1a. The seismic response is investigated for the original configuration of the caisson foundation (referred to as "NS – Unscoured") and for two hydraulic scenarios. On the one hand, the foundation was subjected to general scour, in which the waterbed lowers uniformly, with a depth equal to 4 m ("GS – General scour"). On the other hand, local scour ("LS – Local scour") was simulated by importing the actual, asymmetric, morphology of a scour hole, obtained experimentally from a 3D scan in a hydraulic physical model test conducted to simulate the erosion processes under realistic and well-defined hydraulic scenarios (Ciancimino *et al.* 2022b). The use of the effective geometry of the scour hole has been shown to be effective in reproducing the mechanical response of the scoured foundation through numerical simulations (Ciancimino *et al.* 2022a).

In the numerical model, the pier column was modelled as elastic and the caisson was schematized with a rigid element, to focus on the performance of the soil-foundation system. The soil mechanical behavior was described by the pressure-dependent elastic-plastic multi-surface yielding (PDMY) model to account for the nonlinear behavior under cyclic loading and the depth dependence of stiffness in coarse-grained soils (Yang *et al.* 2003). The model was subjected to the acceleration time history recorded at the Northridge (1994) event, applied along the transversal direction of the bridge. The motion amplitude was scaled by factors 1, 2, 4, and 6, to address the influence of the ground motion intensity on the seismic performance of the pier.

Figure 1b presents the maximum acceleration recorded at the deck $a_{max,deck}$ for the three hydraulic conditions with increasing scaling factors. Figure 1c instead shows the results in terms of maximum rotation of the caisson foundation $\theta_{max,found}$. It is interesting to note that the maximum value of $a_{max,deck}$ is observed for the unscoured scenario, whereas it tends to decrease for the local and general scour foundations, especially when the model is subjected to large seismic inputs (Figure 1b). Such a response can be attributed to the base-isolation effect induced by the soil beneath the footing. As the scour process develops, the safety factor of the caisson foundation tends to decrease, bringing the soil response towards the highly non-linear regime, and in turn reducing the inertial actions transmitted to the superstructure. The downside of this "beneficial" effect is represented by a substantial increase of $\theta_{max,found}$ (Figure 1c). The reduction in foundation capacity due to scour implies larger rotations and displacements at the base of the model, especially for the pier subjected to general scour. This can be detrimental under large seismic loads, as it can lead to significant permanent accumulation of displacements or even eventual failure of the footing. These results may have important implications for the seismic retrofitting of existing bridges, requiring realistic modelling of the scour hole geometry with due consideration of scour processes.

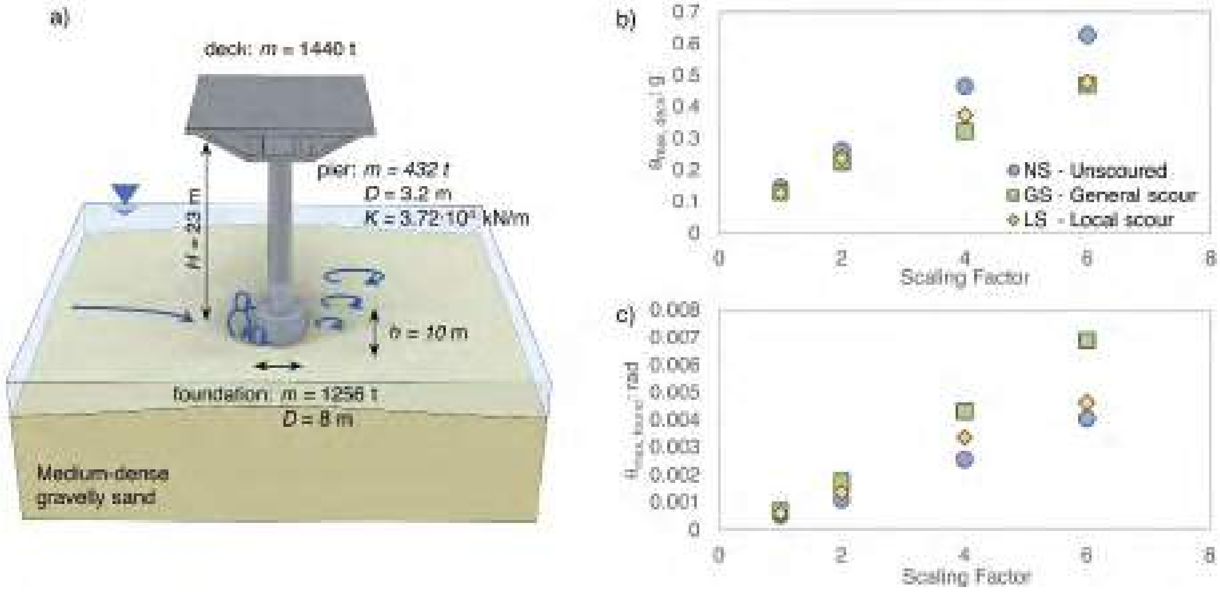


Figure 1 – Schematic representation of the case-study (a); results of the numerical simulations in terms of maximum acceleration (b) and rotation (c) at the deck for different scouring scenarios.

References

Ciancimino A., Anastasopoulos I., Foti S., Gajo A. (2022a). Numerical modelling of the effects of foundation scour on the response of a bridge pier. *Acta Geotechnica*, 17, 3697-3717.

Ciancimino A., Jones L., Sakellariadis L., Anastasopoulos I., Foti S. (2022b). Experimental assessment of the performance of a bridge pier subjected to flood-induced foundation scour. *Géotechnique*, 72, 998-1015.

Foti S., Aimar M., Ciancimino A., Giordano L. (2023). Influence of scour of foundations on the seismic performance of bridges. In *SECED 2023 Conference*. Cambridge, UK.

Kirby A., Roca M., Kitchen A., Escarameia M., Chesterton O. (2015). *Manual on scour at bridges and other hydraulic structures*, Ciria.

Molina Manrique M. (2023). *Scouring Effects on Dynamic Response of Caisson Foundations*, MS Thesis, Politecnico di Torino.

Yang Z., Elgamal A., Parra E. (2003). Computational Model for Cyclic Mobility and Associated Shear Deformation. *Journal of Geotechnical and Geoenvironmental Engineering*, 129.

Dynamic response of a liquefiable sand for shaking table testing by a large laminar shear box

Valentina Lentini[1], Mariangela Liuzzo[1], Giacomo Navarra[1], Maria Stella Vanessa Sammito[1]

(1) Dept. of Engineering and Architecture, University of Enna “Kore”, valentina.lentini@unikore.it

Soil liquefaction is a major cause of damage during earthquake. It can be defined as the transformation of a granular material from solid to a liquefiable state as a consequence of increase pore pressure and reduced effective stress. Thus, the evaluation of the excess pore pressure induced by shaking is important to predict the liquefaction behaviour of soils at a large scale. With this aim, a large biaxial laminar shear box has been designed for liquefaction studies at the Laboratory of Earthquake engineering and Dynamic Analysis (L.E.D.A.) of “Kore” University, Enna (Sicily, Italy) for 1g shaking table tests (Castelli et al., 2022).

The laminar box is rectangular in cross section and consists of 16 layers. Each layer is composed of two frames: an inner frame and an outer frame. The inner frame has an internal dimension of 2570mm by 2310mm, while the outer frame has an internal dimension of 2744mm by 2770mm. Each frame is made from hollow aluminium profiles with (30 x 80) mm^2 section and 2,0mm thickness. Between the layers, there is a 20mm gap making the total height 1600mm. The lowest layer is fixed on a steel base of dimensions 3274mm x 3276mm x 20mm.

To reinforce the base, a steel frame is installed between the base and the shaking table. The large laminar shear box at L.E.D.A. is shown in Figure 1.

Figure 1 - Laminar shear box at the Laboratory of Earthquake engineering and Dynamic Analysis (L.E.D.A.).

Cyclic direct simple shear (CDSS) tests, have been also performed by means of the CDSS device at the Soil Dynamics and Geotechnical Engineering Laboratory of the University “Kore” of Enna (Italy). The CDSS tests have been conducted for the geotechnical characterization of a liquefiable sand to be used in shaking table tests. The CDSS device is an advanced apparatus manufactured by Controls Group designed to allow a sample to be consolidated and then sheared under constant volume conditions simulating an undrained shear of a saturated specimen.

The apparatus includes a control and data acquisition system with two 5kN actuators that have internal displacement transducers. The standard sample is 70mm diameter. It is positioned on a pedestal and restrained by a rubber membrane and a series of slip rings. The CDSS tests have been conducted on very loose samples with a relative density of 15% considering a variability of ±3%.

The remoulding of the soil sample has been carried out by the wet method. Remoulded samples have been consolidated under an effective vertical stress, σ'_{v0}, of 50kPa. The series of rings induces an anisotropic condition on the soil samples during the consolidation phase. The cyclic shearing has been applied using sine waves with amplitudes equal to the cyclic shear stress, $\pm\tau_{cyc}$, and a frequency of 0,5Hz. The height of the samples has been kept constant during the shearing process using the active height control. The liquefaction onset can be determined based on the number of cycles, N_{liq}, required to reach a limiting double amplitude shear strain or a single amplitude shear strain. In this work, the liquefaction onset has been determined when the single amplitude of shear strain exceed 3%. The results of CDSS tests have allowed defining a curve of liquefaction resistance (LRC=Liquefaction Resistance Curve) obtained from the Cyclic Stress Ratio (CSR) and the number of cycles of liquefaction onset (N_{liq}).

Physical properties of the sand under consideration have been also obtained. In particular, for estimating maximum void ratio, e_{max}, a standard mold (volume of 2830cm^3) has been filled by a standard pouring device (diameter of 13mm) using the air pluviation technique. For evaluating the minimum void ratio e_{min}, the same mold has been placed on a vertically vibrating table. The procedure also involves a base plate and an appropriate surcharge weight (total weight required of 25,6 ± 0,2kg). The mold with the specimen has been vibrated for 8 ± ¼min at 60 ± 2Hz.

The physical properties of the sand under consideration are comparable to other sand in literature for liquefaction studies, e.g. Vietnam sand, Skopje Sand, Nevada 120 sand. Therefore, the outcomes of this study can also provide important information for calibration or validation of advanced constitutive model (Castelli et al., 2024) developed to simulate the liquefaction phenomenon to be employed in similar sandy soil.

References

Castelli F., Grasso S., Lentini V., Sammito M.S.V. (2022). Design of a Biaxial Laminar Shear Box for 1g Shaking Table Tests. *Geotechnics*, 467-487.

Castelli F., Grasso S., Lentini V., Sammito M.S.V. (2024). Assessment of liquefaction effects on dynamic soil structure interaction for the 1908 Messina and Reggio Calabria scenario earthquake. *Soil Dynamics and Earthquake Engineering*, 178, 108445, ISSN 0267-7261.

Analysis of active and fossil seismic structures near the city of Genova: a multidisciplinary study for the seismic risk assessment in low-seismicity regions

Michele Locatelli[1], Laura Crispini[1], Marco Scambelluri[1], Daniele Spallarossa[1], Laura Federico[1], Danilo Morelli[1], Paola Cianfarra[1], Davide Scafidi[1]

(1) Department of Earth, Environment and Life Sciences (DiSTAV), University of Genoa, michele.locatelli@edu.unige.it

Nowadays, one of the most challenging frontiers for the earth-science community is to better understand the source processes and wave propagation in heterogeneous rock media, parameters that play a fundamental role for the improvement of seismic risk assessments in densely populated areas. In this framework, the sector of the Voltri Massif (NW Italian Alps) located in the hinterland of the city of Genoa represents a natural laboratory to investigate (i) the interaction between rock faulting and fluid circulation during (potential) paleo-seismic activity and (ii) the detection, location, and source characterization of micro-earthquakes along tectonic lineaments developed inland and offshore the city (i.e., in the Ligurian Sea; Morelli et al., 2023). Our multi-scale and multidisciplinary study, part of the PNRR research program RETURN (Multi-risk science for resilient communities under a changing climate) will develop: (i) the structural and petrographic characterization of fault rocks (i.e., serpentinite breccias), (ii) the quantification of serpentinite carbonatization and its impact on the fault strength, and (iii) the analysis of the network of inland-offshore tectonic lineaments. This work, coupled with the analysis of historical seismic clusters, will be crucial to identify suitable areas for the deployment of high-resolution seismometers and for tracing the spatial-temporal evolution of micro-earthquakes and their static and dynamic source parameters.

The geological mapping of selected fault zones has revealed a multi-stage deformation history. Here, the older ductile structures (paragenesis: Atg + Ilm ± Chl ± Py ± Ccp, ascribed to the alpine-subduction and collision stages) are cut by steeply dipping fault planes NNE-SSW striking. The latter are characterized by multiple, anastomosed fault cores consisting of serpentinite-rich ultracataclasites, locally bound by chrysotile-rich shear bands. The textures (e.g., the serpentinite-rich ultracataclasites), the paragenesis of newly formed shear bands and associated veins (Ctl + Chl) and the orientation of these faults (NNE-SSW striking, subparallel to the Miocene-age lineaments detected in the Genoa Gulf; Morelli et al., 2023) suggest recent tectonic reactivation at the regional scale.

Future developments of the research project will include more detailed, high-magnification microscopy of selected samples (e.g., Field Emission SEM, EBSD and microprobe), regional scale morphotectonic characterization by satellite image analysis, and integration of field and seismic data. This will clarify the link between inland-offshore tectonic lineaments and the (low magnitude) seismicity of the area.

Abbreviations in the text:

Atg, antigorite; Ilm, ilmenite; Chl, chlorite; Py, pyrite; Ccp, chalcopyrite; Ctl, chrysotile.

References

Morelli D., Locatelli M., Corradi N., Cianfarra P., Crispini L., Federico L., et al. (2022). Morpho-structural setting of the Ligurian Sea: the role of structural heritage and neotectonic inversion. *Journal of Marine Science and Engineering*, 10(9), 1176.

Analyses of the infill panels performances in case of volcanoes and/or seismic events

Anna Marzo[1]*, Ivan Roselli*[2]*, Ivano Iovinella*[3]*, Lorenzo Moretti*[1]*, Alessandro Peloso*[4]*, Fernando Saitta*[2]*, Carlo Tebano*[3]*, Concetta Tripepi*[1]

(1) ENEA, CR Bologna, anna.marzo@enea.it
(2) ENEA, CR Casaccia (RM)
(3) ENEA, CR Portici (NA)
(4) ENEA, CR Frascati (RM)

The European Union aims to achieve climate neutrality by 2050 and created the European Green Deal (EGD, 2019) in order to contribute to the adaptation to the climate change and its consequences on the ecosystem. This plan intends to transform the European Union into a society with a modern, resource-efficient, and competitive economy. In this framework, it is of fundamental importance to intervene in residential buildings, which represent 43% of the final energy consumption. In fact, in Italy, approximately the 55% of residential buildings date back to the 1960s, 4% of which date back to before the 1919. Approximately the 25% of them have never undergone renovation work. In addition, these old buildings are characterized by low seismic capacity, having been built according to technical codes without or with few prescriptions against seismic loads. This vulnerability was evidenced in many past earthquakes (Carpani et al. 2012). In addition, recent Italian seismic events, also in case of moderate intensity, have caused many damages to the infill panels of RC buildings, only retrofitted for energy efficiency improvement. Therefore, an integrated approach to the coating systems interventions is compulsory, aimed at meeting a dual need: energy efficiency and seismic protection. From several years ENEA is involved in this mission within research projects (Baldi et al., 2020; Artioli et al., 2021) or through patents (Marzo and Tripepi, 2017; Artioli et al., 2018).

With reference to the volcanic risk, the typologies of both the infill walls and the coating retrofit may not be adequate to guarantee the required performances (mechanical resistance, temperature insulation, thermal resistance of the coating components, etc.) in the residential zones. Therefore, the evaluation of the behaviour of the infill walls in case of volcanic events in the areas where the population would not be evacuated (so-called yellow zone) is compulsory for adequate planning of efficiency measures.

For these reasons, within the Spoke VS3 of the RETURN project, in particular in the Tasks 6.2 and 6.3, the ENEA research team is investigating both the static and the dynamic behaviour of masonry infill panels. The goal of the research activity is to outline a proper methodology to manage the existing infill elements in reinforced concrete frames, undergone to seismic and/or volcanic loads. This methodology, starting from the knowledge of the main features, aims to achieve the more relevant combined systems for both energy efficiency and seismic safety. It is worth noting that the preliminary step is to define the pilot area, being the built characteristics closely related to the local features: typologies, loads, economical sources, performances, and so on. As a result of a research activity, the innovative mitigation/adaptation methods and techniques explored could be summarized in abacus and/or performance maps.

References

Carpani B., Indirli M., Marghella G., Marzo A., Gugliandolo A., Segreto M.A. (2012). Damage mechanisms in some residential building typologies during the Pianura Padana Emiliana Earthquake. *Energia, Ambiente e Innovazione* (EAI), 4-5(II), 105-118.

Baldi F., Gugliandolo A., Malvoni M., Ricci M., Segreto M.-A., Tallini A., Genova A., Romeo C., Marzo A., Rosselli I., Saitta F., Tripepi C. (*Report* RdS/PTR2020/070). Individuazione dei sistemi di integrazione impiantistica, studio degli ancoraggi, analisi finale di integrazione delle soluzioni standardizzate. Ricerca di Sistema Elettrico

https://www2.enea.it/it/Ricerca_sviluppo/documenti/ricerca-di-sistema-elettrico/adp-mise-enea-2019-2021/efficienza-energetica-dei-prodotti-e-dei-processi-industriali/report-rds_ptr_2020_070.pdf)

Artioli M., Beozzo S., Marzo A., Tripepi C. (*Report* RdS/PTR2021/134) . Tamponature con accumulo elettrico integrato: validazione in laboratorio. Ricerca di Sistema Elettrico (https://www2.enea.it/it/Ricerca_sviluppo/documenti/ricerca-di-sistema-elettrico/adp-mise-enea-2019-2021/tecnologie-efficienza-risparmio-edifici/report-rds_ptr_2021_134.pdf)

Marzo A., Tripepi C. Elemento di Rinforzo Antisismico in Fibra Naturale. *Brevetto* n. 102016000116158

Artioli M., Marzo A., Tripepi C. (2018). Elemento di tamponature con sistema di accumulo energetico integrato. *Brevetto* n. 102018000006280

Probabilistic hazard maps of dilute pyroclastic density current at Vesuvius volcano (Italy)

Daniela Mele[1], Pierfrancesco Dellino[1], Fabio Dioguardi[1], Roberto Sulpizio[1]

(1) Dipartimento di Scienze della Terra e Geoambientali, Università degli Studi di Bari Aldo Moro, daniela.mele@uniba.it

Pyroclastic density currents (PDC) are ground hugging gas-particle flows that can originate during a volcanic explosive eruption. Their devastating power is mainly related to velocity, dynamic pressure, particle volumetric concentration, and temperature.

In the volcanic history of Vesuvius, the pyroclastic density currents represented the more frequent event, and therefore, they are one major source of hazard in the Neapolitan area. This topic is investigated within Spoke VS3 of the RETURN project.

Probabilistic hazard maps were obtained by combining data of deposits of the explosive eruptions of the last six thousand years and interpolating data of impact parameters (velocity, density, particle volumetric concentration, temperature, dynamic pressure). The latter was calculated using a computer program, PYFLOW_2.0 (Dioguardi and Mele, 2018), which uses the sedimentological model of Dellino et al. 2008. The model links turbulent boundary layer shear flow theory with particle coupling to gas turbulence.

The obtained probabilistic hazard maps show the decay trend of the impact as a function of distance from the vent and allow depicting the expected damage (Figure 1). This outcome can help civil protection authorities to more precisely-implemented mitigation measures and communicate more effectively the risk to decision-makers and the population.

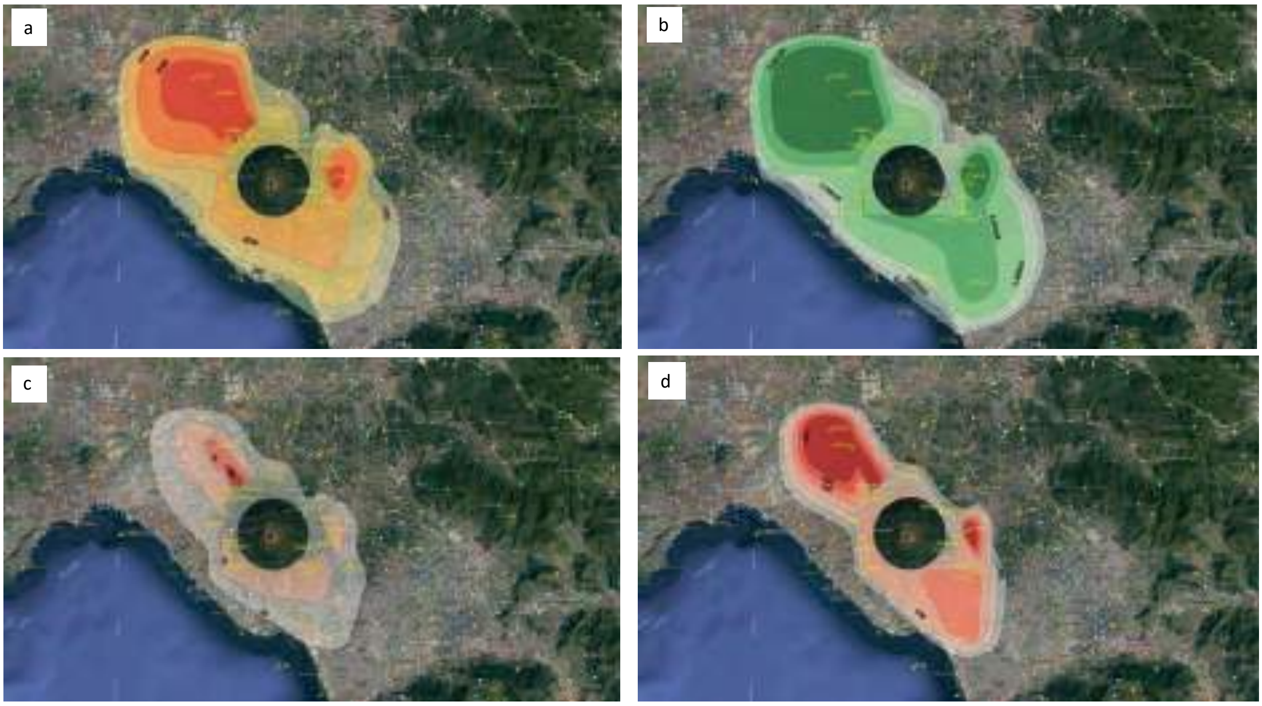


Figure 1 – Probabilistic hazard maps of (a) dynamic pressure (Pa), (b) particle volumetric concentration, (c) velocity (m/s) and (d) temperature (Kelvin).

References

Dioguardi F., Mele D. (2018). PYFLOW_2. 0: a computer program for calculating flow properties and impact parameters of past dilute pyroclastic density currents based on field data. *Bulletin of Volcanology*, 80, 28.

Dellino P., Mele D., Sulpizio R., La Volpe L., Braia, G. (2008). A method for the calculation of the impact parameters of dilute pyroclastic density currents based on deposit particle characteristics. *Journal of Geophysical Research: Solid Earth*, 113, B07206.

Refining age and ash dispersal of small- to medium-size explosive eruptions at Neapolitan volcanoes from high-resolution investigation of core C106 – eastern Tyrrhenian Sea

Paola Petrosino[1], Valentino Di Donato[1], Maria Rosaria Senatore[2]

(1) Dept. of Earth, Environment and Resources Science, University of Napoli Federico II, paola.petrosino@unina.it

Tephrostratigraphy involves the comprehensive study of sequences of tephra layers and their associated deposits, focusing on their distribution, stratigraphic relationships, and both relative and numerical ages through tephrochronology. This encompasses the definition, description, characterization, and dating of tephra layers conducted in both field and laboratory settings. In the central Mediterranean, employing a tephrochronological approach in the stratigraphic analysis of marine archives holds significant potential for reconstructing Late Quaternary volcanic activity in southern Italy. Particularly, this method proves valuable for vents where terrestrial records have been obscured due to erosional processes and caldera collapses. Marine successions, ranging from the shelf to the slope and deep basin, exhibit a preservative nature conducive to this type of analysis. The tephra framework and chronostratigraphy of erupted events in the region benefit significantly from contributions made by cryptotephra deposits—tephra not visible to the naked eye, typical of the marine conservative environment. Despite potential challenges such as post-depositional processes compromising preservation or isochron position(e.g. Abbott et al., 2018), cryptotephra serve as a powerful tool for detecting products of minor explosive events. This capability is particularly advantageous in resolving stratigraphic challenges posed by limited and scattered data at proximal sites, extending the reach of analysis far beyond the source.

Within spoke VS3 of the RETURN project, specifically in Task 3.2, we are leveraging the crucial role played by the investigation of marine successions to enhance our understanding of the dispersal patterns of volcanic products from Neapolitan volcanoes and their recurrence rates. This effort contributes to the ongoing refinement of volcanic hazard predictions. In this update, we present preliminary findings from core C106, retrieved at a depth of 292 meters offshore the mouth of the Sele River. The sediments of the core are mainly mad up of silt and constitute a continuous record from a basin site where the influence of reworking processes is deemed negligible. This core was previously examined by Buccheri et al. (2002) and Di Donato et al. (2009) within a multiproxy research framework, primarily focused on investigating paleoclimatic conditions during the last deglaciation in the southern Tyrrhenian Sea. The core reveals the presence of two macrotephra layers, occurring between 55 and 110 cm and at a depth of 563-565 meters. These layers have been identified as associated with the 79 CE Somma-Vesuvius eruption and the ca. 30 ka Y-3 Campi Flegrei marker tephra, as recognized by Munno and Petrosino (2004). In the current research, the core was sampled at 2 cm intervals, and the fractions residual after washing pretreatment at 60 and 100 microns underwent meticulous examination to identify the abundance of juvenile and lithic volcanic fractions. Sixty samples were specifically chosen from layers rich in juvenile content. The crystal component was subjected to detailed characterization, and the glass fraction underwent SEM-EDS analysis. To enhance the age model of the core, nine ^{14}C AMS age determinations were conducted on selected samples of mixed planktonic foraminifera. The core's chronological coverage extends over the past 33 ka, capturing a comprehensive timeframe. Throughout the analysis, 25 known eruptive events were successfully identified as proximal counterparts of the investigated cryptotephra layers (Figure 1). Additionally, several layers exhibited a diagnostic chemical composition, allowing for attribution to specific eruptive sources such as Campi Flegrei, Somma-Vesuvius, Ischia Island, and Etna. However, no reliable correlation with a previously known eruptive event emerged for these layers.

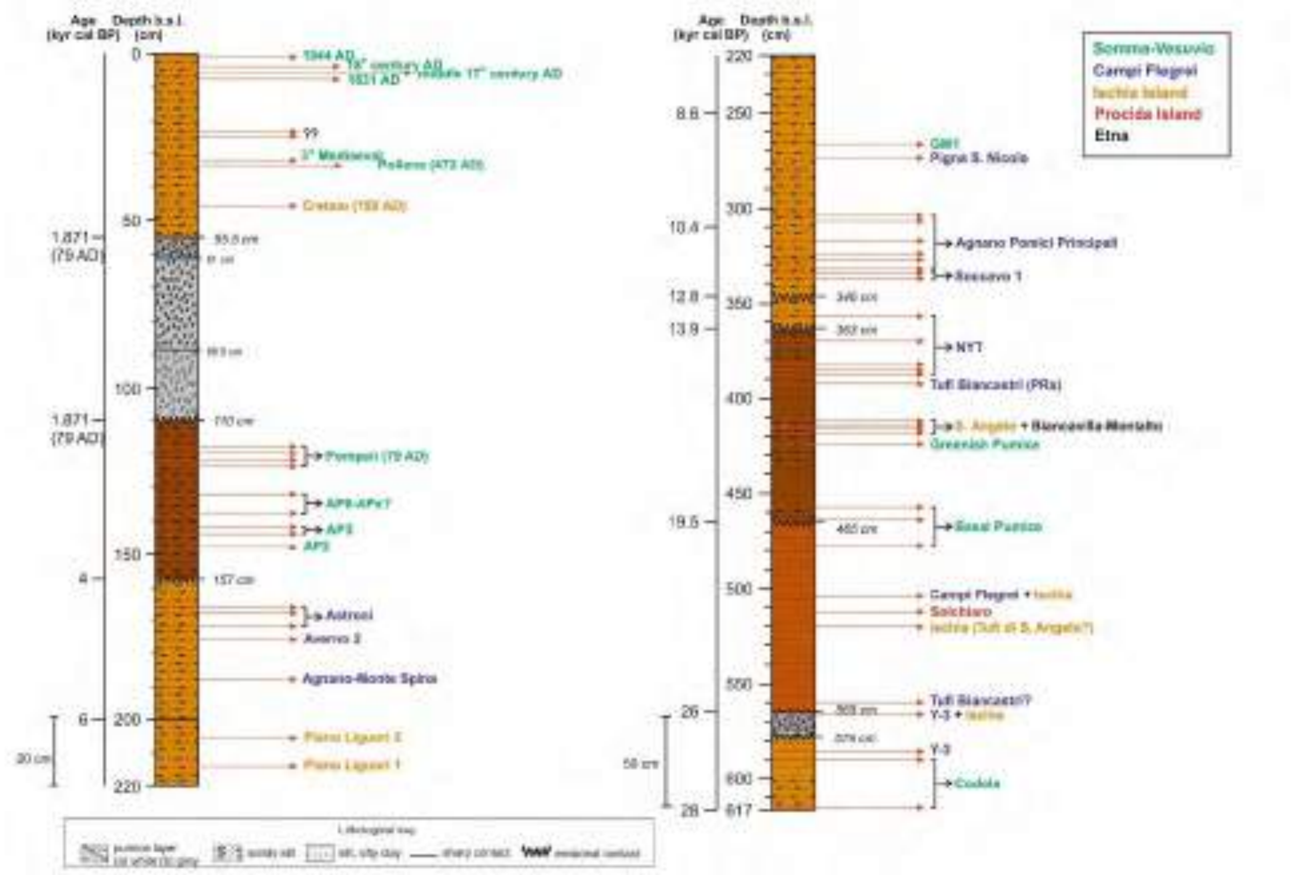


Figure 1 – Tephra and cryptotephra succession in marine core C106.

Despite being an ongoing project, the research has yielded several highly promising preliminary outcomes. These findings offer valuable insights into the refinement of the eruptive history of currently active sources, revealing evidence of previously undocumented eruptive episodes. The highly resolved age model established in the study allows for a more precise determination of the ages of eruptive events that were previously poorly constrained. One significant result for the RETURN project is the new understanding of the distal distribution of fine ash from various low-size eruptive episodes of the Neapolitan volcanoes, reaching and being detectable offshore the Sele River mouth, at a locations approximately 100 km away from the source. This insight is crucial for detailed hazard assessment, especially considering the unique characteristics of fine-grained ash, such as its ability to penetrate equipment, adhere to diverse surfaces, carry a high load of soluble salts, and pose a greater health hazard compared to coarser fractions (e.g. Wilson et al., 2012). Furthermore, the incorporation of ages from strongly correlated tephra layers as tie points for the age model, has strengthened the model itself, providing more robust temporal constraints for climatic variations. This aspect is particularly valuable for paleoclimatic reconstructions and for investigating potential cause-and-effect relationships between eruptions and climatic variations. Lastly, the detailed tephra lattice achieved in this study can be a valuable resource for Quaternary scientists, aiding in marine-continental correlation in the central Mediterranean for the last 33 ka.

References

Abbott P.M., Griggs A.J., Bourne A.J., Davies S.M. (2018). Tracing marine cryptotephras in the North Atlantic during the last glacial period: protocols for identification, characterisation and evaluating depositional controls. *Marine Geology*, 401, 81-97.

Buccheri G., Capretto G., Di Donato V., Esposito P., Ferruzza G., Pescatore T., et al. (2002). A high resolution record of the last deglaciation in the southern Tyrrhenian Sea: environmental and climatic evolution. *Marine Geology*, 186, 447-470.

Di Donato V., Esposito P., Garilli V., Naimo D., Buccheri G., Caffau M., et al. (2009). Surface-bottom relationships in the Gulf of Salerno (Tyrrhenian Sea) over the last 34 kyr: compositional data analysis of palaeontological proxies and geochemical evidence. *Geobios,* 42, 561-579.

Munno R., Petrosino P. (2004). New constraints on the occurrence of Y-3 Upper Pleistocene tephra marker layer in the Tyrrhenian Sea. *Il Quaternario*, 17, 11-20.

Wilson T.M., Stewart C., Sword-Daniels V.L., Leonard G.S., Johnston D.M., Cole J.W., et al. (2012). Volcanic ash impacts on critical infrastructure. *Physics and Chemistry of the Earth, Parts A/B/C*, 45–46, 5–23.

Ocean acidification caused by shallow volcanic CO_2 seeps in the Pozzuoli Bay, Campi Flegrei, Campania (Italy)

Andres Sandoval-Velasquez[1], Sara C. Diana[1], Flavia Migliaccio[2], Donato Giovanelli[2], and Alessandro Aiuppa[1]

(1) Department of Earth and marine Sciences, Università degli studi di Palermo, andreslibardo.sandovalvelasquez@unipa.it
(2) Department of Biology, Università degli studi di Napoli Federico II

One of the key objectives of Task T3.2.2 “Linking volcanoes and climate change” is to use volcano-related shallow water hydrothermal vents along the Italia coast to investigate (i) the dynamics of acidification in marine environment and their influence on ecosystems, and (ii) their potential use as proxy for man-related CO2 ocean acidification in time of global climate change. To do so, geochemical and microbiological characterizations have been initially performed in the geothermal area of Pozzuoli’s bay, Campania (Italy). We performed two sampling campaigns on June and July 2023 to investigate the impact of the hydrothermal vents on the column water. Water physico-chemical parameters were recorded from different selected points near the main emission from Secca delle Fumose. For sampling, we used an underwater CO2 sensor (HydroCTM, CONTROS System and Solutions, Kiel, Germany) in association with a multiparameter probe Hanna in order to study the vertical distribution of temperature, pH, and CO2 partial pressure (pCO2) of the selected points. The HydroC is a submersible measuring system that determines the partial pressure of CO2 in seawater (pCO2) using a nondispersive infrared spectrometer (Di Napoli et al., 2016). At the moment, 13 systematic vertical seawater profiles have been done at depths of 3, 6-8 and 10-13 m by each point. After acquisition, data was properly processed using the OCEAN DATA VIEW (ODV) software to subsequently generate preliminary maps showing the variability of pH and pCO2 around Secca delle Fumose (Fig. 1). As expected, points over Secca delle Fumose exhibit the lowest pH and the highest temperature and pCO2 with values around 6, 30°C and 9300 µatm, respectively. Comparing with the data obtained during the survey performed in 2015 by Di Napoli et al. (2016) who reported maximum temperatures of about 22 °C and pCO2 of 5025 µatm, our results show a clear increment in the dissolved volcanic CO2 of about 46%.

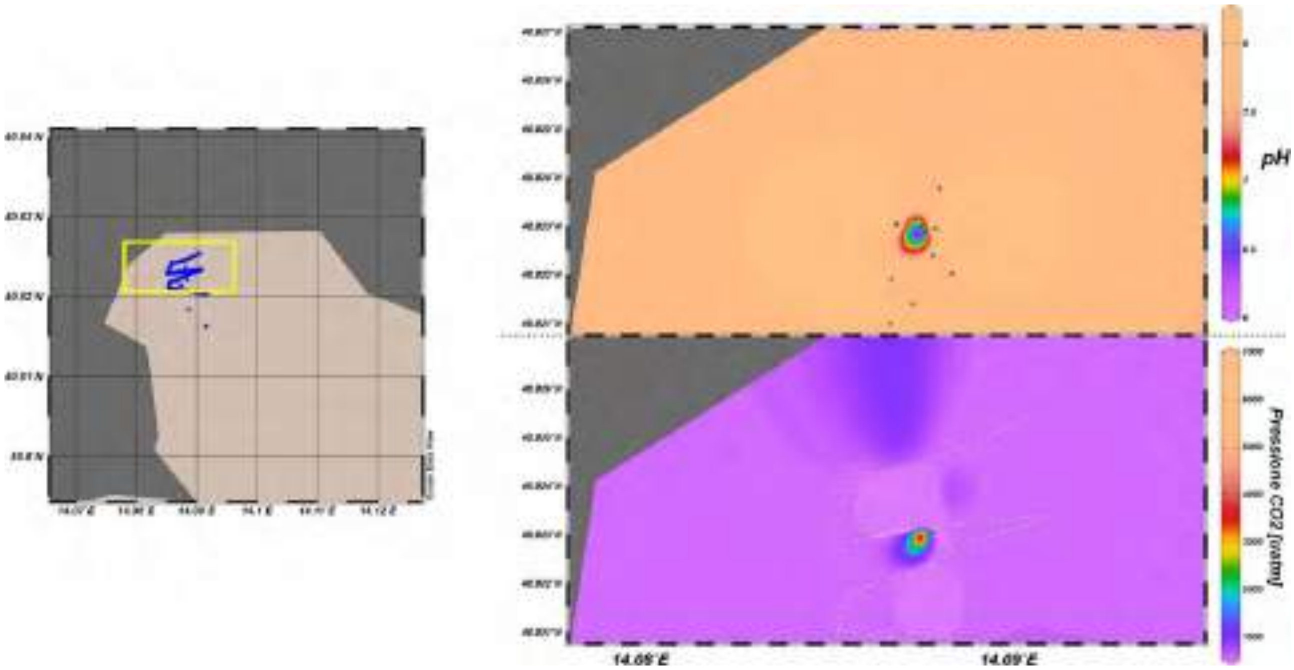


Figure 1 - Pozzuoli bay map; blue dots represent the different sampling points and the yellow square includes the magnified area observed in B and C. B) pH and C) pCO2 distribution around Secca delle Fumose; white dots represent sampling points.

References

Di Napoli R., Aiuppa A., Sulli A., Caliro S., Chiodini G., Acocella V., et al. (2016). Hydrothermal fluid venting in the offshore sector of Campi Flegrei caldera: a geochemical, geophysical, and volcanological study. *Geochem. Geophys. Geosystems*, 17, 4153–4178.

Linking active structures with seismogenic sources in tectonically polyphasic areas. A case study from the Martana Fault System (Central Apennines)

Gianluca Vignaroli[1], Riccardo Asti[1], Selina Bonini[1], Silvia Castellaro[2], Giulio Viola[1]

(1) Dipartimento di Scienze Biologiche, Geologiche ed Ambientali, Università di Bologna, gianluca.vignaroli@unibo.it
(2) Dipartimento di Fisica e Astronomia "Augusto Righi", Università di Bologna

In tectonically complex environments, incongruities between earthquake focal mechanisms and surface geological structures can lead to incorrect evaluation of the seismic hazard. This is particularly evident when considering active faults whose nucleation and growth have been shaped by diverse tectonic regimes over time. The complex surface expressions of fault systems that experienced a change in their kinematics in recent times pose challenges in accurately evaluating their potential to induce surface deformation during earthquakes. In the Northern Apennines, the inner Umbria-Marche region has been affected by extensional tectonics since the late Pliocene, following a contractional tectonic phase during the Apennines nappe stacking that started in the early/middle Miocene. Key example of major tectonic structure showing ambiguity between fault surface expression and the registered seismicity is the Martana Fault System in Central Apennines.

Within the Spoke VS3 of the RETURN project, we are applying an integrated, high-resolution approach to solve the tectonic evolution of the Martana Fault System (Figure 1) within its seismogenic framework. We are combining field observations and structural analyses to reconstruct the fault architecture and to unravel the local paleostress evolution through time. Our data show that the Martana Fault System accommodated significant extension and transtension during the late- post-orogenic evolution of the Central Apennines. Activation and reactivation of longitudinal and oblique structures resulted from the local compatibility between the orientation of the fault segments and the maximum stress axis resolved from the paleostress analysis.

These preliminary data represent fundamental geological pinpoints for the geophysical and geochronological investigations that we will carry out. Such a comprehensive workflow will eventually provide the base to build probabilistic models for the seismic response of fault zones in seismic hazard assessment protocols.

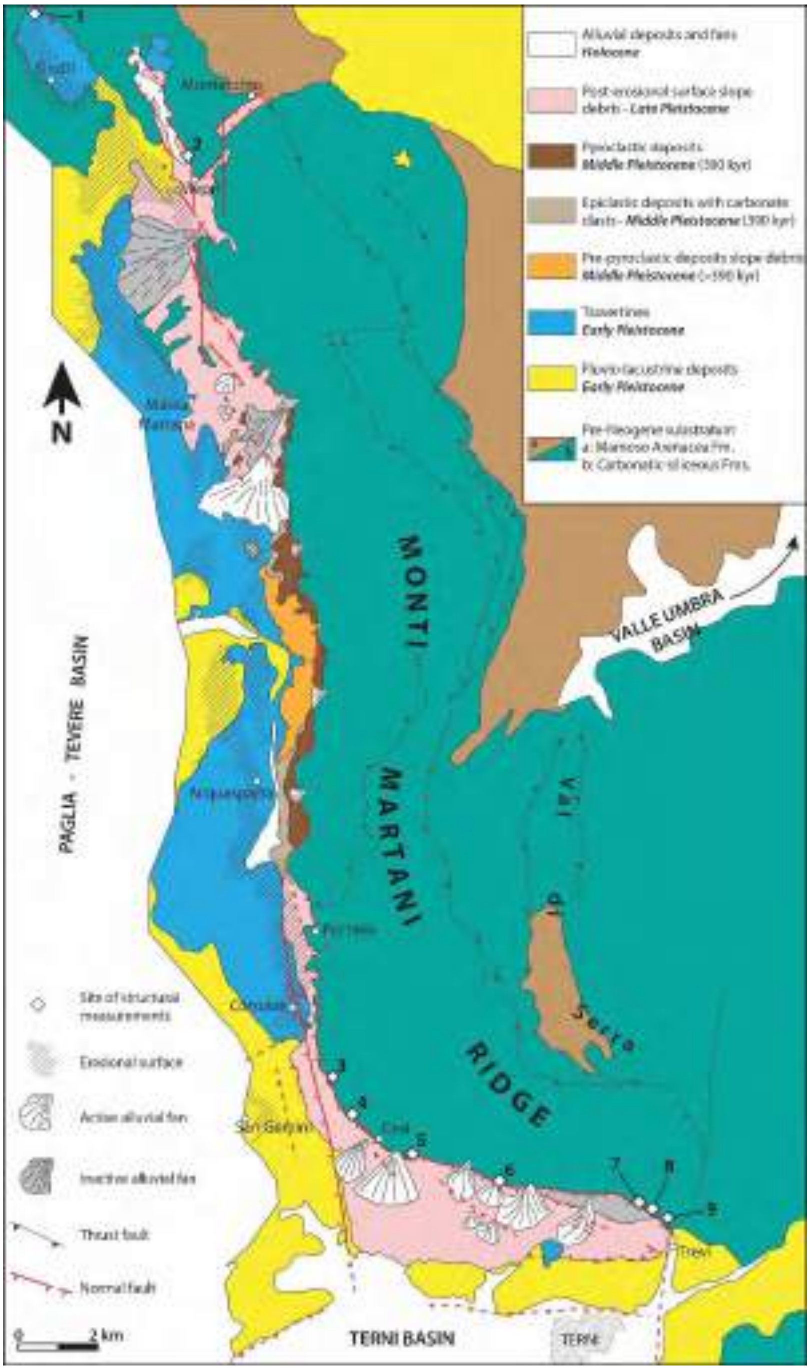


Figure 1 – Schematic geological map of the study area (redrawn and modified after Bonini et al., 2003).

References

Bonini M., Tanini C., Moratti G., Piccardi L., Sani F. (2003). Geological and archaeological evidence of active faulting on the Martana Fault (Umbria–Marche Apennines, Italy) and its geodynamic implications. *Journal of Quaternary Science*, 18, 695–708.

A methodology for multi-risk analysis: Santorini application

Giulio Zuccaro[1], Francesca Linda Perelli[1], Daniela De Gregorio[1], Mattia Federico Leone[2]

(1) Department of Structures for Engineering, University of Naples Federico II, francescalinda.perelli@unina.it
(2) Department of Architecture, University of Naples Federico II, Italy

A careful economic planning of mitigation and adaptation measures to be for a study area presupposes an accurate knowledge of the natural and anthropogenic phenomena that can generate damage to exposed elements (buildings, cultural heritage, and people). To pursue a reliable estimate of the expected damage, it is necessary to study the different phenomena of the area with a holistic-systemic approach, which allows the numerous variables of the problem to be considered in a multi-risk framework.

In case of volcanic eruptions, especially if of an eruptive type, the affected area can be damaged by a sequence of cascade events, which may or may not be connected by a cause/effect relationship, such as earthquakes, pyroclastic flows, ash fall, landslides, etc.

The concept of cascading effects and multi-risk is still a relatively recent research topic in the field of natural risk management; also, currently there are limitations both in the specific methodologies adopted and in the accumulated practical experience. In the context of EU-FP7 SNOWBALL project (Lower the impact of aggravating factors in crisis situations thanks to adaptive foresight and decision-support tools, 2015‑2017), a theoretical model for cascading effects analyses has been proposed and applied in the Santorini area (Zuccaro et al 2018).

Cascading effects are constituted by dynamic sequences triggered by natural and/or human events able to generate significant physical, social, or economic disruptions. These effects manifest in a complex and multidimensional way, evolving over time and being more closely linked to vulnerability than the hazards themselves. Low-level hazards, for instance, can trigger widespread cascading effects if vulnerabilities are widespread in the system or not adequately addressed in subsystems. Consequently, it is possible to isolate elements of the chain and consider them as individual disasters (subsystems).

The approach used to evaluate the cascading impact (Marzocchi et al. 2012) is outlined by considering specific fundamental components as the units of analysis. These components, depicted in Figure 3, include Space (s), Time (t), Hazards (H) within the chain, Initial Exposure (E), Initial Vulnerability (V), Dynamic Vulnerability (DV), Human Behavior Influence, and Damage (D). Space and Time serve as the reference framework for the other elements. Space is defined in relation to a Minimum Reference Unit, and time is referenced by individual instances characterizing each hazard in the 'cascading scenario time history,' originating from the triggering events at the initial time. Hazard, Exposure, and Vulnerability constitute the input data for the 'cascading effect problem' during the initial time (in peace time). The hazard consists of a singular timeline of events (referred to as cascading scenario time history) determined by specific criteria (e.g., probability of occurrence of time history, impact on a specific element at risk, stakeholder interests). Exposure involves grouping elements at the initial time t_0, aligning them with similar vulnerability under the influence of each hazard. Vulnerability represents the likelihood that a particular “vulnerability class” surpasses a specified damage level Di, given a hazard magnitude. Dynamic vulnerability signifies the gradual increase in vulnerability for exposed elements, dependent on the progression of the damaging process. The 'Damage' component serves as the output of the methodology, providing the distribution of damage on various exposed elements caused by cascading events. Human behavior plays a crucial role in influencing cascading effects, impacting the outcome, and acting as a variable affecting the effective implementation of preparedness actions.

Figure 1 illustrates the chronological sequence of a hypothetical cascading effects scenario triggered by the reactivation of Nea Kameni Volcano in Santorini (Greece), serving as a reference test case for the SNOWBALL project.

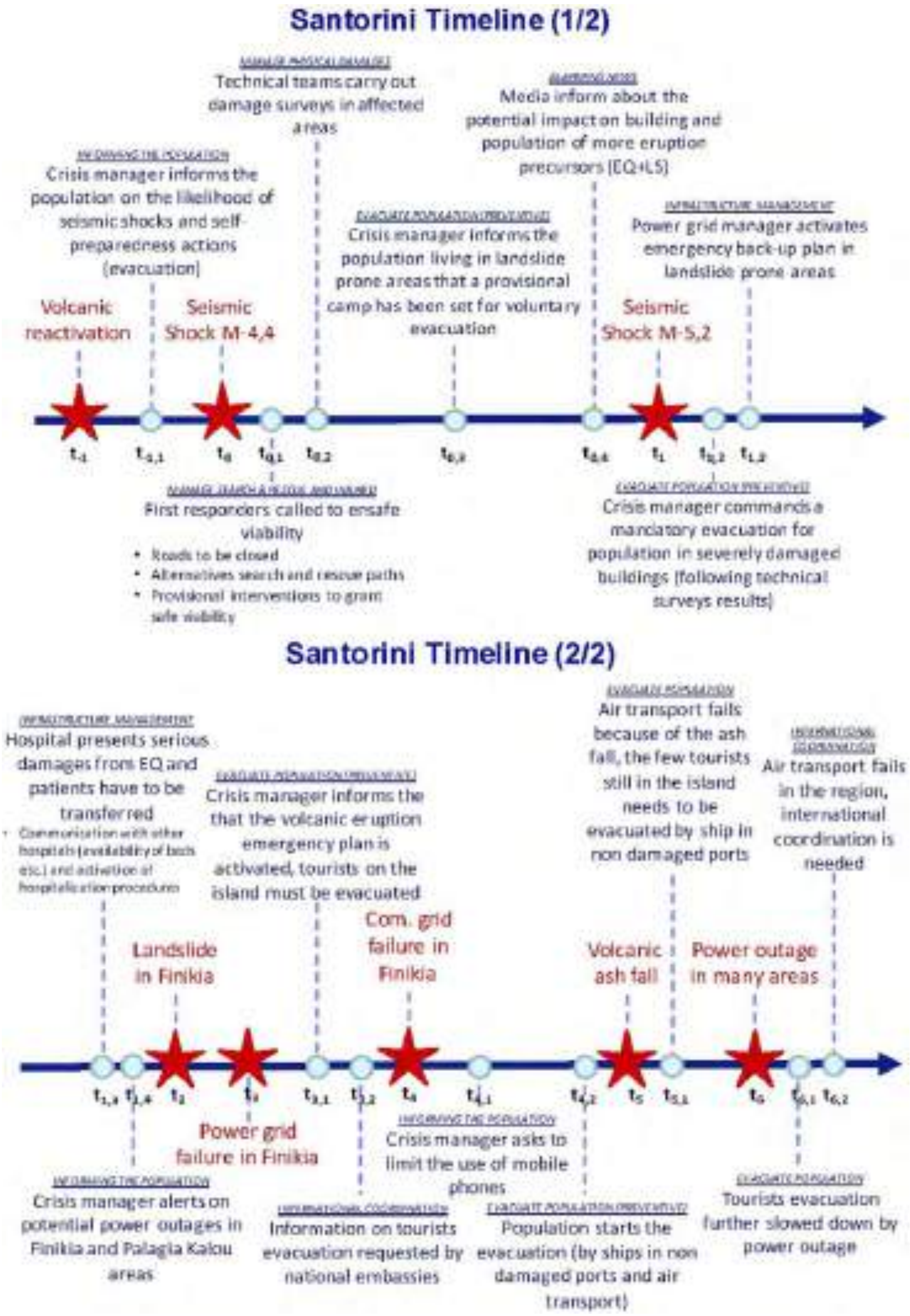


Figure 1. Timeline for the pilot application in Santorini, defined through workshops and interviews with local authorities, decision makers and service providers

Throughout this timeline, crucial decision points have been identified through 'scenario building' workshops involving key representatives from local authorities, civil protection officials, and managers of critical infrastructures in Santorini. Multiple timelines can be linked to the specific scenario event tree, allowing for variations that do not alter the sequence of cascading effects but involve modifications related to the 'time' and/or 'human behavior' factors. The 'decision points' signify significant timestamps in the evolution of cascading effects, where these variables are likely to influence the ultimate scenario outcome.

Future developments envisage replicating the methodology validated on the Santorini case study in the Campi Flegrei area, the object of study within the RETURN project.

References

Zuccaro, G., De Gregorio, D., & Leone, M. F. (2018). Theoretical model for cascading effects analyses. *International journal of disaster risk reduction*, 30, 199-215.

Marzocchi, W., Garcia-Aristizabal, A., Gasparini, P., Mastellone, M. L., & Di Ruocco, A. (2012). Basic principles of multi-risk assessment: a case study in Italy. *Natural hazards*, 62, 551-573.

Spoke VS4: Environmental degradation

Improving the assessment of the contamination levels of a river catchment basin accounting for the dilution effect generated by fluvial transport. The case study of Sarno River in Campania

Stefano Albanese[1], Annalise Guarino[1], Antonio Iannone[1], Lucia Pacifico[1]

(1) Dept. of Earth, Environmental and Resource Sciences, University of Napoli Federico II, stefano.albanese@unina.it

A geochemical prospection is a valuable tool for studying the influence of the geological context on the composition of river sediments and determining the existence of natural or anthropogenic geochemical anomalies in a river basin. Several indices have been proposed in the scientific literature to assess the environmental quality of sediments and the ecological status of catchments. Among these indices, the contamination factor (CF), based on applying a ratio between raw geochemical compositions in sediments and a value assumed to be the reference for the undisturbed conditions (background/baseline), is one of the most widely historically used.

However, when calculating CF values, reference values are often determined without taking into account the possible influence of river dynamics on the variability of the sediment. In fact, the composition of a stream sediment sample results from the mixing/dilution process affecting the loose materials proceeding from the upstream catchment and depends on the geochemical and mineralogical features of the bedrock, mainly if it is chemically or physically weathered.

In mineral exploration, the Sample Catchment Basin (SCB) method uses the location of the samples and the terrain's physical characteristics to determine the average upstream area contributing to the sediment composition; the extension of the geological units within each SCB is then used to determine sample-specific background values to detect the presence of any local geochemical anomaly.

This study's primary purpose was to evaluate whether applying the dilution effect correction to determine background levels could also improve the performance of some pollution indices, favouring a more effective and accurate assessment of environmental degradation in a river basin.

The Sarno River, known for its susceptibility to pollution from urban and industrial sources, served as a relevant case study. Specifically, 96 stream sediment samples were used, and the SCB method was applied to define the catchment of each sample. Background concentrations for seven potentially toxic elements (i.e., As, Cd, Cr, Cu, Hg, Pb and Zn) were estimated by calculating their weighted average content based on the area fractions of the lithologic units falling in each sample catchment (Carranza, 2009; Dominech et al., 2022). The values derived from this process were then used as a reference for assessing the CF of the river bed in correspondence with individual sampling points.

The CF values were calculated and mapped using "undiluted" and "dilution-corrected" background values. For the "undiluted" background, a unique value retrieved from Albanese et al. (2013) was used for all the samples.

A comparative analysis was completed on the determined CF values to assess whether applying the SCB method can determine sensitive changes in the spatial and statistical distribution of the CF values and correspondingly improve index performance.

Preliminary outcomes of the comparison process show that the spatial distribution of CF based on a "dilution-corrected" background reduces the spatial dispersion of the contaminated areas, improving the reliability of the index (Fig. 1).

This study provides a methodological benchmark for future research focusing on environmental risk assessment of river sediments.

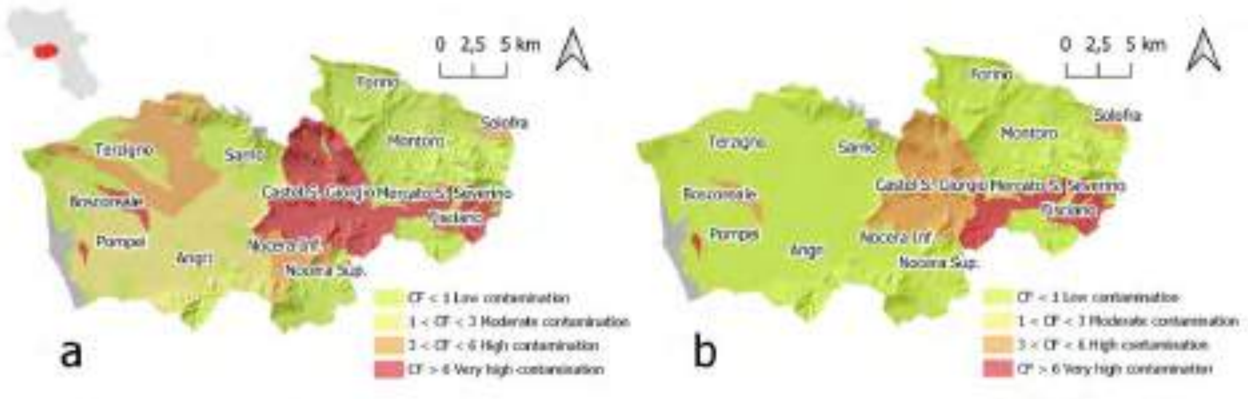


Figure 1 – Chromium (Cr) CFs spatial distribution based on a) "undiluted" and b) "dilution-corrected" background values.

References

Carranza E.J.M. (2009). Chapter 5: Catchment Basin Analysis of Stream Sediment Anomalies. In: *Handbook of Exploration and Environmental Geochemistry*, Volume 11. Geochemical Anomaly and Mineral Prospectivity Mapping in GIS. Elsevier Science B.V., 115-144.

Dominech S., Yang S., Aruta A., Gramazio A., Albanese S. (2022). Multivariate analysis of dilution-corrected residuals to improve the interpretation of geochemical anomalies and determine their potential sources: The Mingardo River case study (Southern Italy). *Journal of Geochemical Exploration*, 232, 106890.

Albanese S., Iavazzo P., Adamo P., Lima A., De Vivo B. (2013). Assessment of the environmental conditions of the Sarno river basin (south Italy): a stream sediment approach. *Environmental Geochemistry and Health*, 35, 283–297.

Phytostabilization long term trial in an abandoned Sardinia Mine

Chiara Alisi[1], Tommaso Calandrelli[1], Giovanni De Giudici[2], Daniela Medas[2], Giada Migliore[1], Patrizia Paganin[1], Flavia Tasso[1]

(1) ENEA-Casaccia
(2) Dept. of Chemical and Geological Science, University of Cagliari, gbgiudic@unica.it

Ingurtosu mine site (Sardinia, IT) was one of the largest and most productive of sphalerite and galena mines in Sardinia. Today it is part of the Geological and Mining Park and in 1997 it became one of the UNESCO network of Geo-parks. The mine is inserted in a highly natural environmental and landscape context. The peak of productivity was the period between the 19th and 20th centuries, and the plants closed in 1969.

The scarce prevention during the extraction activity and following closure led to a considerable environmental impact. Under the European Project UMBRELLA, in September 2011 a field trial was set up in the abandoned mine in order to design a phytoremediation process, assisted by plant growth promoting bacteria (PGPB).

A preliminary characterization of the field was carried out through a hydro-geo-chemistry survey, a bioprospection for microbiology and botany, heavy metal content and mobility analysis.

Following a greenhouse experiment (Wernitznig et al., 2014) a toolbox was established by the endemic pioneer plant *Euphorbia pithyusa* L. associated with a bacterial consortium (UI), composed by ten selected native strains, metal-tolerant and good PGP.

The field experiment considered 9 conditions tested in triplicate on the 27 subplots it was divided. The different treatments were applied singly or in combination: bioaugmentation with bacterial consortia, mycorrhizae and the commercial mineral amendment Viromine™, a by-product of the bauxite industry which is widely used for environmental remediation processes due to its metal-trapping capacity.

About three years later (December 2014), a second bioaugmentation was performed with a modified consortium (USMI), obtained with new PGP strains isolated from the microbial community that had spontaneously evolved in the meantime. In addition, the native species *Juncus maritimus* Lam. was added to the association.

The field management was minimal, minimal irrigation and bacteria dispersion were performed with the water taken from the Rio Naracauli, which flows under the experimental site and which carries a load of 40 kg of zinc per day. Only sporadic inspections have been performed from 2015 to 2022.

Survival of plants in relation to soil metabolic activity, microbial biodiversity (Sprocati et al., 2014) and other biochemical and microscopic parameters (Medas et al., 2015) were the parameters observed.

Microbial community was monitored over the time through biochemical (EcoPlate, BIOLOG SystemTM) and molecular profiling. The cultivable bacterial fraction was isolated from the rhizosphere, identified by sequencing of rDNA16S and characterized for PGP functions: auxin production, N2 fixation, PO4 mobilization and production of siderophores.

An early assessment, carried out 5 months after the first inoculum proved that subplots, which underwent bioaugmentation, retained the best metabolic activity with a high functional diversity, supporting the decision to proceed with the field trial (Sprocati et al. 2014).

In the first two years, a general gradual decrease in the plant survival was observed. In the plots treated with bioaugmentation the plant survival was 20% higher than controls. Later on, as a result of a very dry season, without any irrigation, the control plants survival felt close to 0%, while 20% of the plants assisted by bacteria survived and recovered over time, unlike the controls. These differences in the survival and resilience of plants were reflected in the physiological soil profile -at the community level- presenting a much higher metabolic activity, measurable over time, in the plots treated with bioaugmentation.

The results of molecular and biochemical profiles in soil samples collected from June 2014 to March 2016 indicated that the bioaugmentation contributed to the development of a more specialized community, consisting of few species better adapted to the extreme conditions.

At a distance of 12 years from the beginning of the trial, some of the introduced plants *E. pithyusa* and *Juncus maritimus* are established and other new spontaneous plants have settled (mainly *Rumex* sp. and *Helichrysum* sp.). These plants proved to effective in the uptake of Zn and other metals in the rhizosphere and the roots by biomineralization process that led to formation of hydrozincite and hemimorphite, which in turn represent a potential secondary mineral deposit.

Reference

Wernitznig S., Adlassnig W., Sprocati A.R., Turnau K., Neagoe A., Alisi C., et al. (2014). Plant growth promotion by inoculation with selected bacterial strains versus mineral soil supplements. *Environ Sci Pollut Res*, 21, 6877–6887.

Sprocati A.R., Alisi C., Pinto V., Montereali M.R., Marconi P., Tasso F., et al. (2014). Assessment of the applicability of a “toolbox” designed for microbially assisted phytoremediation: the case study at Ingurtosu mining site (Italy). Environ Sci Pollut Res 21(11):6939-51.

Medas D., De Giudici G., Casu M.A., Musu E., Gianoncelli A., Iadecola A., et al. (2015). Microscopic processes ruling the bioavailability of Zn to roots of Euphorbia pithyusa L. Pioneer plant. *Environmental Science and Technology*, 49(3), 1400–1408.

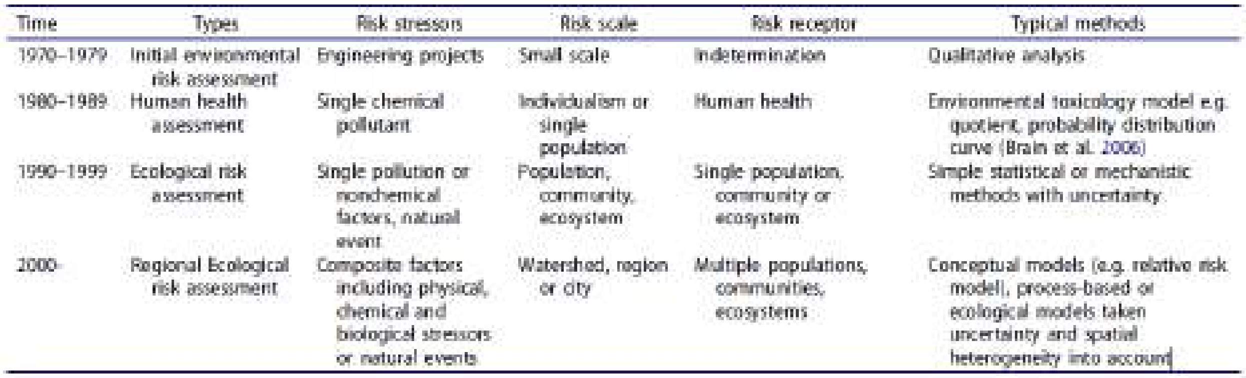
Ecological Risk Assessment: principles and methodologies

Elisa Chiara Bizzotto[1]*, Silvia Breda*[1]*, Petra Scanferla*[1]

(1) Fondazione Università Ca' Foscari, elisachiara.bizzotto@unive.it

Ecological Risk Assessment (ERA) is defined as an iterative process that evaluates the likelihood that adverse ecological effects are occurring or may occur as a result of exposure to one or more stressors (USEPA, 1992).

In the field of toxicology, risk assessment methods were introduced in the mid-20th century, with initial focus on the evaluation of the effects of chemicals on human health; methodologies were then extended also to environmental assessments to cover the effects on ecological receptors and ecosystems (Tarazona and Ramos-Peralonso, 2023); more recently, the ERA approach has been used also at wide spatial scales, dealing with various environmental issues (e.g. for the assessment of contaminated sites, but also regional risk and of urban ecological risk) (Fig. 1).



Time	Types	Risk stressors	Risk scale	Risk receptor	Typical methods
1970–1979	Initial environmental risk assessment	Engineering projects	Small scale	Indetermination	Qualitative analysis
1980–1989	Human health assessment	Single chemical pollutant	Individualism or single population	Human health	Environmental toxicology model e.g. quotient, probability distribution curve (Brain et al. 2006)
1990–1999	Ecological risk assessment	Single pollution or nonchemical factors, natural event	Population, community, ecosystem	Single population, community or ecosystem	Simple statistical or mechanistic methods with uncertainty
2000-	Regional Ecological risk assessment	Composite factors including physical, chemical and biological stressors or natural events	Watershed, region or city	Multiple populations, communities, ecosystems	Conceptual models (e.g. relative risk model), process-based or ecological models taken uncertainty and spatial heterogeneity into account

Figure 1 – Different development states for ecological risk assessment (Hua et al., 2017).

In Europe, two terminologies, environmental risk assessment and ecological risk assessment are used, frequently considered as synonyms, although conceptual differences exist. Specifically, the environmental risk assessments cover all potential adverse effects on the environment as well as humans exposed through the environment, while the ecological risk assessment focuses on the specific effects on ecosystems. Unlike human health assessments, the goal of ecological risk assessments is to protect the population or ecosystem and not the "individual" (effects on individuals within populations in animal/human risk assessment vs effects on individuals, populations, ecosystem integrity and/or ecosystem services in ecological risk assessment). As a result, the endpoints for ecological risk assessments are broad and are population-specific, such as reproduction impairment, population growth, mortality etc (OECD, 2018, EFSA 2019).

Under the context of the RETURN Project (Spoke VS4 – Task 4.4.2), a summary of the main ERA principles and methodologies will be developed, with a special focus on procedure for the ERA of combined exposure to multiple chemicals (also referred to as 'chemical mixtures') and evaluations about the influence of climate change on the ERA paradigm. The presentation will summarize the main content and topics that will be evaluated, with the aim to encourage discussion and synergies within the RETURN project.

References

US Environmental Protection Agency (USEPA) (1992). Framework for ecological risk assessment (EPA 630/R-92/001). February 1992.

Tarazona J.V., Ramos-Peralonso M.J. (2023) in S. Harper. Risk Assessment, Ecological, Editor(s): Philip Wexler, Encyclopedia of Toxicology (Third Edition), *Academic Press*, 2014, ISBN 9780123864550.

Hua L, Shao G, Zhao J (2017). A concise review of ecological risk assessment for urban ecosystem application associated with rapid urbanization processes, *International Journal of Sustainable Development & World Ecology*, 24:3, 248-261.

EFSA Scientific Committee, More SJ, Bampidis V, Benford D, Bennekou SH, Bragard C, Halldorsson TI, Hernandez-Jerez AF, Koutsoumanis K, Naegeli H, Schlatter JR, Silano V, Nielsen SS, Schrenk D, Turck D, Younes M, Benfenati E, Castle L, Cedergreen N, Hardy A, Laskowski R, Leblanc JC, Kortenkamp A, Ragas A, Posthuma L, Svendsen C, Solecki R, Testai E, Dujardin B, Kass GEN, Manini P, Jeddi MZ , Dorne J-LCM and Hogstrand C (2019). Guidance on harmonised methodologies for human health, animal health and ecological risk assessment of combined exposure to multiple chemicals. *EFSA Journal,* 17(3), 5634.

OECD (2018). Considerations for Assessing the Risks of Combined Exposure to Multiple Chemicals, Series on Testing and Assessment No. 296, Environment, Health and Safety Division, Environment Directorate.

Effects of combined stressors on the ecosystem functioning in the Grado-Marano lagoon

Margherita Burini[1], Laura Baldassarre[1], Federica Nasi[1], Lisa Sandri[1], Annamaria Albanese[1], Sonia Manzo[2], Tamara Cibic[1]

(1) Section of Oceanography – OGS, mburini@ogs.it
(2) PROTER – ENEA

This activity is part of Spoke VS4 (Environmental Degradation; T 4.4.1) and aims at expanding the knowledge related to the risks affecting the Grado-Marano lagoon, particularly those deriving from the combined effects of oxygen depletion and mercury, i.e., one of the major contaminants in this lagoon (Figure 1c). The Grado-Marano lagoonal system represents one of the most important transitional environments along the coastline of the northern Adriatic Sea (Acquavita *et al.*, 2012). Despite the anthropogenic pressures exerted on this coastal environment by the presence of several surrounding urban areas and industrial activities (Covelli *et. al.*, 2006), the lagoon is one of the best conserved wetlands in the whole Mediterranean area (Acquavita *et al.*, 2012). Among the contaminants affecting the lagoon, mercury (Hg) is a major health concern (Emili *et al.*, 2014). This element is known to exert neurotoxic and genotoxic effects on humans once transformed into the bioaccumulable organometallic form monomethylmercury (MeHg) (Bettoso *et al.*, 2023). The lagoon experiences occasional hypoxic/anoxic conditions, as a consequence of high organic matter loads and nutrient concentrations, combined with strong late summer water stratification. This latter represents one of the key factors controlling *in situ* MeHg production at the sediment–water interface. To verify how this lagoon ecosystem responds to the synergistic effect of hypoxia and contamination, two experimental field studies will be carried out in two selected areas, one in the eastern and one in the middle part of the lagoon, which are contaminated by Hg to a different extent. The prolonged period of segregation from the oxygenating seawater will be induced by artificially secluding small portions of the lagoon using enclosures. Thus, the worst-case scenario will be simulated, *i.e.*, the experiment will be performed in high temperature conditions (climate change scenario) and in an organic-enriched shallow area. To artificially isolate the shallow areas, 18 mesocosms (~0.8 m^3 each) will be positioned in three replicate clusters to study the short-term (few hours) and long-term (few days) effects on planktonic and benthic communities at different trophic levels (prokaryotes, microalgae, consumers). According to the experimental design described in Baldassarre *et al.* (2023), the mesocosms are made up of a cylindrical galvanized iron frame (Ø approx. 100 cm) covered by a transparent nylon cylinder (Figure 1b); they will be aligned in three rows (corresponding to three experimental replicates: R1, R2, R3 – Figure 1a) along transects with similar depth (<80 cm). Mesocosms have an opening on both the lower and upper sides (Figure 1b), so as to allow the passage of vertical flows between the two boundary layers (water/air and water/sediment) and prevent horizontal water flows (interior/exterior of the mesocosms), mimicking the segregation of the lagoon from the oxygen-enriched seawater when the water column is in hypoxic or anoxic conditions. Sampling will be carried out at five times: t0-t4, lasting almost 100 hours (Figure 1a). The oxygen concentration, temperature and salinity will be continuously recorded by a multiparameter probe both inside and outside the enclosures. In addition, through passive samplers, the presence of several organic and inorganic pollutants will be estimated continuously along the whole course of the experiment. A possible increase in the efflux of nutrients from the sediments towards the water column will be evaluated; the concentration of chlorophyll-*a* and phaeopigments in the water column will be analyzed to identify possible phytoplankton blooms. The prokaryotic community composition, abundance and structure of phytoplankton and microzooplankton will also be evaluated in the water column. At each experimental time, inside three replicate mesocosms and, in parallel, in one external site, the physical-chemical characteristics of the surface sediments will be determined too, along with the abundance and diversity of microphytobenthos and macrozoobenthos. Prokaryotes, microphytobenthos, macrozoobenthos will be identified both through classical taxonomy and through molecular techniques. Furthermore, following the induced hypoxia, the bioturbation activity of invertebrates within the mesocosms will also be investigated and the concentration of mercury and methylmercury in different matrices will be determined. Finally, to assess to what extent the combined stressors affect the main biological processes and the overall lagoon pelagic-benthic coupling, the community respiration, primary production, prokaryotic heterotrophic C production, and some degradative enzymatic activities will be evaluated in the water and surface sediments.

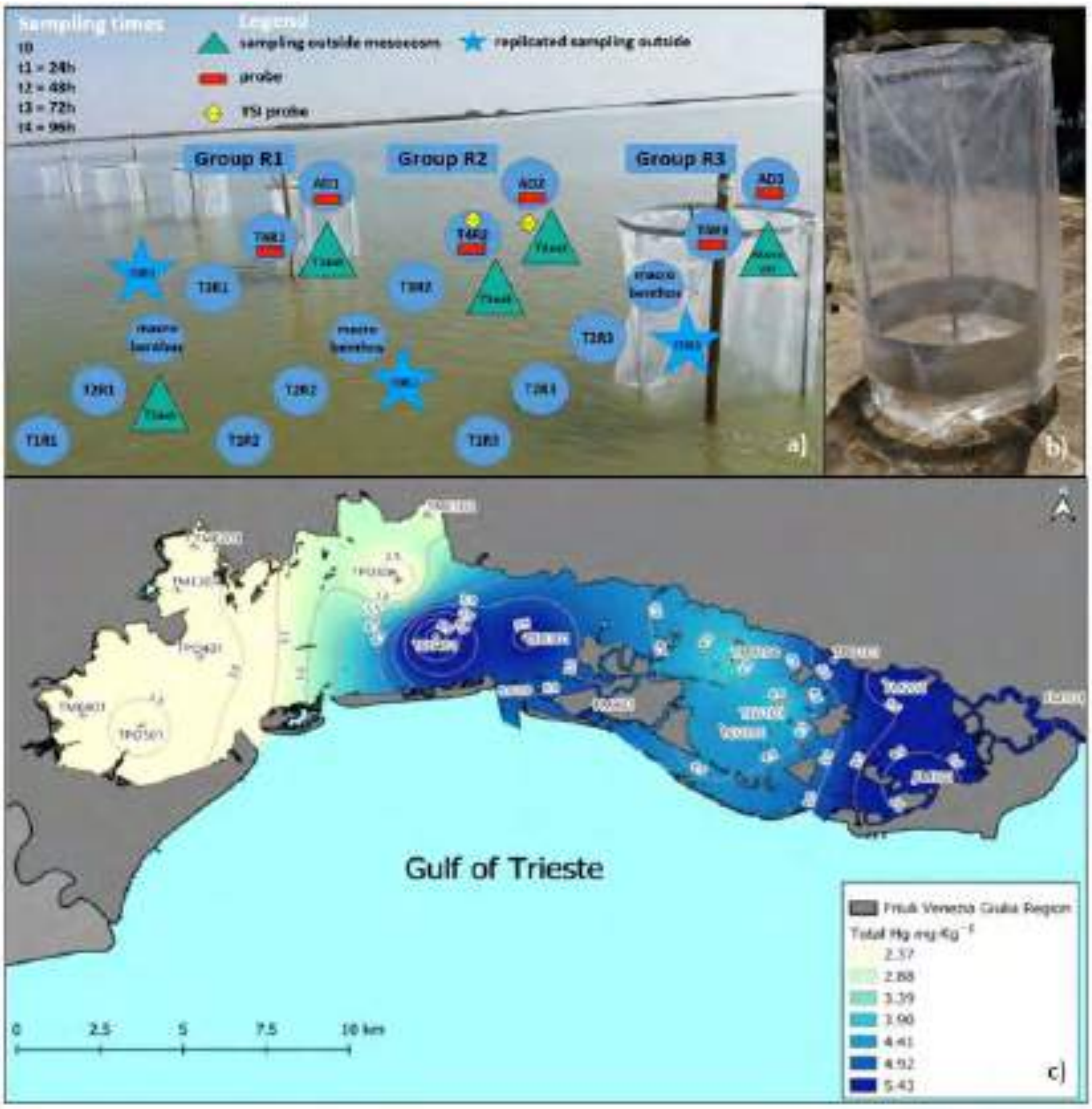


Figure 1 - (a) Experimental design: 18 mesocosms placed in 3 groups of 6 to assure sampling in 3 replicates per 5 experimental times; (b) Detail of the mesocosms; (c) Spatial distribution of total Hg in surface sediments of the GML was obtained by IDW (Inverse Distance Weighted) interpolation (adapted from Bettoso et al., 2023).

References

Acquavita A., Covelli S., Emili A., Berto D., Faganeli J., Giani M., et al. (2012). Mercury in the sediments of the Marano and Grado Lagoon (northern Adriatic Sea): sources, distribution and speciation. *Estuarine Coastal and Shelf Science*, 113, 20-31.

Baldassarre L., Natali V., De Pascale F., Vezzi A., Banchi E., Bazzaro M., et al. (2023). The impact of MOSE (Experimental Electromechanical Module) flood barriers on microphytobenthic community of the Venice Lagoon. *Microorganisms*, 11(4), 936.

Bettoso N., Pittaluga F., Predonzani S., Zanello A., Acquavita A., (2023). Mercury levels in sediment, water and selected organisms collected in a coastal contaminated environment: the Marano and Grado Lagoon (Northern Adriatic Sea, Italy). *Applied Sciences*, 13(5), 3064.

Covelli S., Fontolan G., Faganeli J., Ogrinc N. (2006). Anthropogenic markers in the Holocene stratigraphic sequence of the Gulf of Trieste (northern Adriatic Sea). *Marine* Geology, 230, 29-51.

Emili A., Carrasco L., Acquavita A., Covelli S., (2014). A laboratory-incubated redox oscillation experiment to investigate Hg fluxes from highly contaminated coastal marine sediments (Gulf of Trieste, Northern Adriatic Sea). *Environ. Sci. Pollut. Res.*, 21(6), 4124-33.

Use of passive sampling techniques for chemical, physical and ecotoxicological analysis of seawater at various marine locations throughout Italy

Laura Caiazzo[1], Marco Capello[2], Tamara Cibic[3], Laura Cutroneo[2], Marina Di Carro[4], Valentina Esposito[3], Irene Geneselli[2], Emanuele Magi[4], Maria Rita Montereali[1], Luisa Parrella[5], Simona Schiavo[5], Salvatrice Vizzini[6], Sonia Manzo[5]

(1) ENEA Casaccia Research Centre, Rome, laura.caiazzo@enea.it
(2) Department of Earth, Environment and Life Sciences, University of Genoa
(3) Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS)
(4) Department of Chemistry and Industrial Chemistry, University of Genoa
(5) ENEA Portici Research Centre
(6) Dipartimento di Scienze della Terra e del Mare, Università degli Studi di Palermo

Passive samplers represent an innovative monitoring tool for the time-integrated measurement of bioavailable contaminants (i.e., inorganic and organic compounds) in water and sediment (Vrana et al., 2005). These devices are proving to be reliable, robust and cost-effective and can be very useful for a proper evaluation of the ecotoxicological impact.

Our group's goal within the Italian PNRR project "Return" is to monitor seawaters at several locations throughout Italy, specifically Genoa harbour (in collaboration with DISTAV AND University of Genoa, WP3), Panarea, Vulcano, Grado-Marano lagoon and Sarno mouth. These are very interesting sites since they are characterized by different kinds of contaminations at each location. In harbours, a wide range of anthropogenic chemicals may be present due to all the waterways connected to industrial and harbor activity and city and sewage discharges. River-mouths and lagoons serve as natural laboratories for assessing the impact of plastic/bioplastic and priority metal mixtures, as well as representing land anthropic stresses exerted on rivers. In the Aeolian Islands, the presence of secondary volcanism phenomena, with emanation of steam and other volcanic gases, causes seawater acidification and possible contamination from plastic and heavy metal leaching processes.

Passive Samplings have been already exposed beginning in December 2023 in Genoa harbour (Figure 1), while in the other sites, samplings will begin around next spring, with samplings being conducted generally once a season.

Figure 1 – Passive samplings in Genoa harbour.

Organic chemicals will be sampled by Semi-Permeable Membrane Device (SPMD) and Polar Organic Chemical Integrative Sampler (POCIS) for lipophilic and hydrophilic compounds, respectively, and will be deployed for 21 days (Huckins et al., 1990; Alvarez et al., 2004). Besides, Diffusive Gradients in Thin films (DGT) will be deployed for 7 days for metals and mercury sampling (Schintu et al., 2008; Vrana et al., 2005). When combined with the detection through high sensitivity and selectivity instrumentation at our disposal, such as GC-MS, LC-MS/MS, Hg-Analyzer and ICP-MS, this will enable the thorough assessment of the system studied.

On passive sampler extracts (polar, non-polar) a battery of three bioassays with organisms belonging to different trophic levels (Aliivibrio fischeri, Artemia salina, Dunaliella tertiolecta) will be applied for the detection of ecotoxicological effects at the investigated locations.

Alongside the PS, sediment and water sampling will be also conducted at the end of the PS deployment. The detection of pollution at concentrations lower than ng/L will be possible thanks to the synergy of active and passive sampling systems. Physical measurements will be combined with water and sediment samplings, specifically temperature, conductivity, pH and oxygen, using a multiparametric probe (CTD).

The time-integrated data from these devices and the ecotoxicological characterization will be used to complement chemical monitoring and to improve the risk assessment of chemical pollution.

Reference

Alvarez D.A., Petty J.D., Huckins J.N., Jones-Lepp T.L., Getting D.T., Goddard J.P., Manahan S.E. (2004). Development of a passive, in situ, integrative sampler for hydrophilic organic contaminants in aquatic environments. *Environmental Toxicology and Chemistry*, 23, 1640–1648.

Huckins J.N., Tubergen M.W., Manueera J.K. (1990). Semipermeable membrane devices containing model lipid: a new approach to monitoring the bioavailability of lipophilic contaminants and estimating their bioconcentration potential. *Chemosphere*, 20, 533-552.

Schintu M., Durante L., Maccioni A., Meloni P., Degetto S., Contu A. (2008). Measurement of environmental trace-metal levels in Mediterranean coastal areas with transplanted mussels and DGT techniques. *Marine Pollution Bulletin*, 57, 832–837.

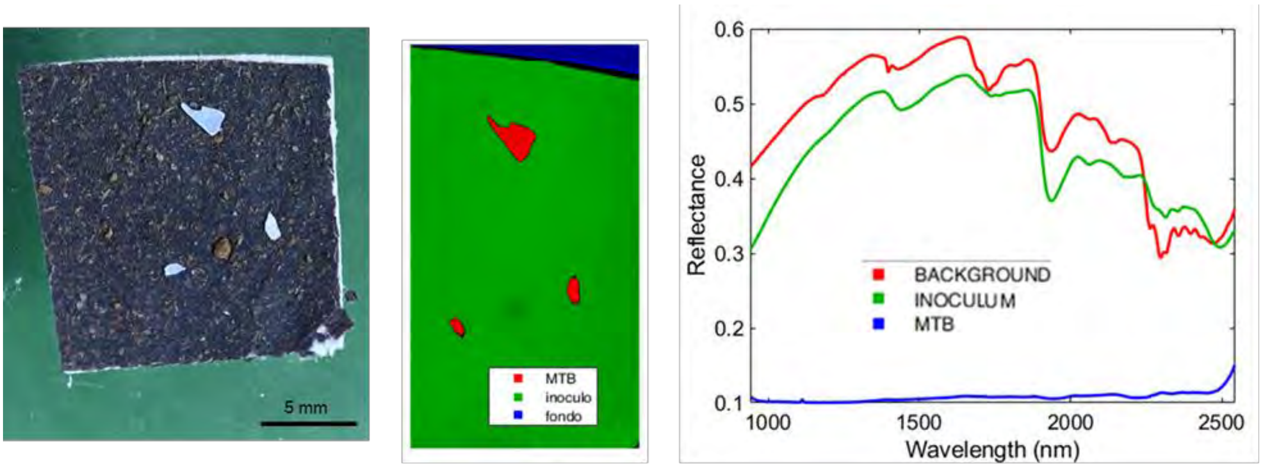
Vrana B, Mills G.A., Allan I.J., Dominiak E., Svensson K., Knutsson J., Morrison G., Greenwood R. (2005). Passive sampling techniques for monitoring pollutants in water. *Trends in Analytical Chemistry*, 24, 10.

Classification of Mater-Bi® bioplastics in anaerobic sludge by SWIR hyperspectral imaging

Giuseppe Capobianco[1], Marica Falzarano[2], Giuseppe Bonifazi[1], Alessandra Polettini[2], Raffaella Pomi[2], Andreina Rossi[2], Silvia Serranti[1]

(1) Department Chemical Engineering, Materials and Environment, Sapienza University of Rome
(2) Department of Civil, Constructional and Environmental Engineering, Sapienza University of Rome

Bioplastics have entered everyday life as a potential sustainable substitute for commodity plastics. One of the most common blends on the market is Mater-Bi® (MB), a family of polymeric compounds based on TPS and commercialized with different chemical formulations depending on the used co-polymer (Bracciale et al., 2020). In this scenario, an innovative approach based on hyperspectral imaging (HSI) was developed to monitor commercial starch-based MB disposable bioplastic behavior during anaerobic digestion. To test the applicability of the technique, hyperspectral images of samples composed of MB fragments dispersed in anaerobic sludge to simulate MB monodigestion were acquired in the short-wave infrared range (SWIR: 1000-2500 nm). A chemometric approach was then developed to analyze HSI data (Figure 1). In more detail, Principal Component Analysis (PCA) was applied for data exploration, followed by the implementation of a classification model based on Partial Least Square-Discriminant Analysis (PLS-DA) able to identify MB in the sludge. The achieved results demonstrated the possibility to recognize and monitor the presence of MB in the anaerobic sludge and evaluate the quality of the biodegradation.



a b c

Figure 1 – Mater-Bi® mixed with inoculum, source image (a); false color image with set classes: Mater-Bi® flakes (red), inoculum (green) and background (blue) (b) and average raw reflectance spectra acquired in the SWIR range (1000-2500 nm) of the 3 classes.

References

Bracciale M.P., De Gioannis G., Falzarano M., Muntoni A., Polettini A., Pomi R., et al. (2024). Disposable Mater-Bi® bioplastic tableware: characterization and assessment of anaerobic biodegradability. *Fuel*, 355, 129361.

On the detection of bioplastic content in marine water using analytical and spectroradiometric techniques

Laura Corbari [1], Giuseppe Ciraolo[1], Marcella Barbera[2], Massimiliano Salamone[2], Daniela Piazzese[2]*

(1) Department of Engineering, University of Palermo, laura.corbari@unipa.it
(2) Department of Sea and Earth Sciences, University of Palermo

The long-term sustainability of bio-based polymers is now being considered due to their comprehensive range of potential impacts. Understanding the degradation of various biopolymers in marine environments is crucial for assessing their environmental impact, biodegradability, material selection, ecological consequences, and policy decisions. This knowledge can significantly contribute to the development of sustainable solutions for addressing marine pollution and protecting marine ecosystems.

Given the growing demand for bio-based polymers in the global market, it is imperative to investigate their real behaviour and degradation under diverse environmental conditions. For this purpose, we designed an experimental plan to study the degradation of commercially produced PLA-based materials under simulated marine conditions. Microcosms were set up, containing seawater, PLA bags, and PLA containers inoculated with selected microorganisms from a marine environment. The bioplastic materials in the microcosms served as the sole food source for the microorganisms. After 60 days, seawater from the microcosms was collected to identify possible hydrolysis degradation products using orbitrap technology.

Since preliminary investigations suggest that lactic acid is the final degradation product of PLA, we are currently optimizing the method for extracting lactic acid from seawater. Specifically, we are testing the efficiency of lactic acid extraction using Solid-Phase Extraction (SPE). Seawater solutions containing known concentrations of lactic acid are being used, and recovery tests are being conducted with two different types of SPE cartridges to determine the best extraction method. Additionally, vitality tests on microorganisms in the microcosms have been conducted to assess the suitability of the bioplastic substrate as a food source.

Furthermore, an indoor laboratory experiment was performed to spectrally characterise the bioplastic materials. The spectral reflectance of the samples was measured using the FieldSpec 4 Hi-Res spectroradiometer by ASD (Analytical Spectral Devices). This instrument acquires spectral signatures over the full solar reflected spectrum (350 – 2500 nm). The samples were spectrally characterized inside a white box illuminated using two lamps that simulate solar irradiance. The lamps were rotated upward, illuminating the samples with diffuse light.

The spectra of bioplastic materials (PLA caps and PLA bags) were collected and obtained by stacking three layers of cups and five layers of bags to ensure their opacity. The samples were spectrally characterized twice: the first time when they were uncontaminated, and the second time after 60 days. The aim was to examine any structural changes that may occur during the degradation process.

An example of the spectra collected, referring to the cups acquired at T0 and T60, is shown in Figure 1.

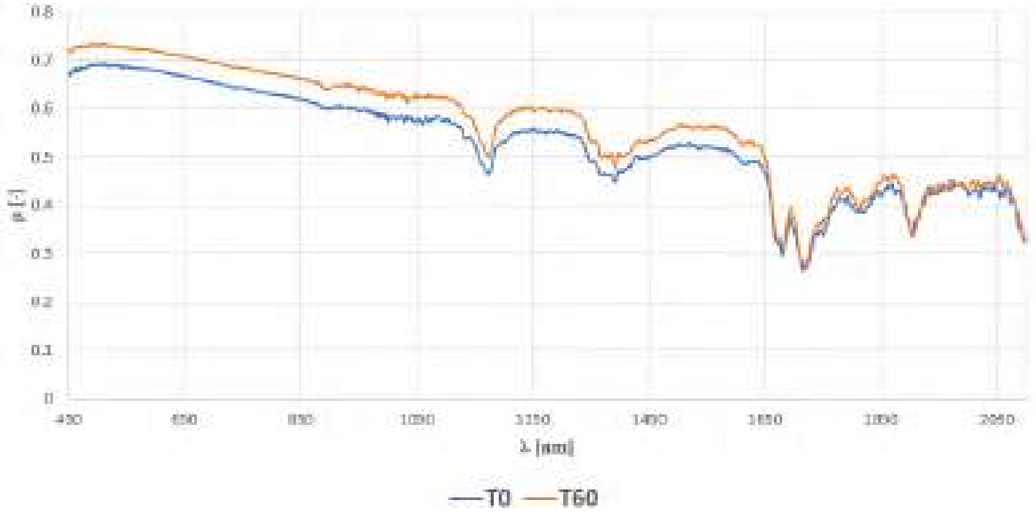


Figure 1 – Spectra of the cups acquired at T0 and T60.

The results are currently in the analysis phase; nevertheless, it is apparent that the signature at T60 has experienced a variation, resembling an upward shift, in comparison to the T0 case.

In conclusion, our research aims to meet the urgent need for understanding the degradation of biopolymers in marine environments, especially those based on PLA. Through the characterization of these materials and the assessment of their behaviour under simulated conditions, we strive to provide valuable data to the realm of marine sustainability and waste management. The insights gained from this study will play a pivotal role in developing sustainable solutions to address marine pollution and safeguard marine ecosystems.

Reference

Corbari L., Maltese A., Capodici F., Mangano M.C., Sarà G., Ciraolo, G. (2020). Indoor spectroradiometric characterization of plastic litters commonly polluting the Mediterranean Sea: toward the application of multispectral imagery. *Scientific Reports,* 10(1), 19850.

Gewert B., Plassmann M.M., MacLeod M. (2015). Pathways for degradation of plastic polymers floating in the marine environment. *Environmental science: processes & impacts*, 17(9), 1513-1521.

Karlsson T.M., Grahn H., van Bavel B., Geladi P. (2016). Hyperspectral imaging and data analysis for detecting and determining plastic contamination in seawater filtrates. *Journal of near-infrared spectroscopy*, 24(2), 141-149.

Serranti S., Fiore L., Bonifazi G., Takeshima A., Takeuchi H., Kashiwada S. (2019). Microplastics characterization by hyperspectral imaging in the SWIR range. In: *SPIE Future Sensing Technologies,* 11197, 134-140. SPIE.

Proposal of new environmental monitoring protocols for emerging contaminants in the pilot site of the Port of Genoa

Laura Cutroneo[1], Barbara Benedetti[2], Laura Caiazzo[3], Marina Di Carro[2], Laura Gaggero[1], Irene Geneselli[1], Emanuela Magi[2], Sonia Manzo[4], Maria Rita Montereali[3], Luisa Parrella[4], Simona Schiavo[4], Marco Capello[1]

(1) Department of Earth, Environment and Life Sciences, University of Genoa, laura.cutroneo@edu.unige.it
(2) Department of Chemistry and Industrial Chemistry, University of Genoa
(3) ENEA Casaccia Research Centre, Rome
(4) ENEA Portici Research Centre, Portici (Naples)

As part of the RETURN (multi-Risk sciEnce for resilienT commUnities undeR a changiNg climate) Project funded by the Italian PNRR –National Recovery and Resilience Plan, the University of Genoa, with the DISTAV and the DCCI Departments, participates in several research lines among the various ones proposed within the project (www.fondazionereturn.it) and has planned to carry out some research activities, using the Port of Genoa (Italy) as an open-air laboratory, in order to produce new environmental monitoring plans, sampling protocols and laboratory methodologies. These research activities will make use of the collaboration of research institutions involved in other research lines within RETURN, such as ENEA of Rome and Portici (Naples).

Within the Project, this large Working Group will focus on the research and identification of "natural geological" and emerging pollutants in seawater and bottom sediments.

The Port of Genoa was chosen as the Pilot Site because it is involved (or will be involved in the coming months) in several major activities of construction of maritime and land infrastructures, and as “storage site” for excavated and dredged sediments and rocks, i.e. (a) the new breakwater of the port, which will rest on seabed up to 50 m deep and will allow the entrance of latest generation ships inside the port (the breakwater construction is controlled by the Environmental Monitoring Plan drawn up by the DISTAV of the University of Genoa and based on the Descriptors of the Marine Strategy Framework Directive); (b) the highway bypass “Gronda”, which above all avoids heavy traffic on the motorway that passes through Genoa; (c) the sub-port tunnel which will connect the east to the west of the city, bypassing the center; (d) the mountain rail tunnel “Terzo Valico” which will allow a fast rail connection between the Port of Genoa and northern Italy and Europe.

Geographically speaking, the Port of Genoa is located at the top of the Ligurian Sea, an extremely dynamic area from both an atmospheric and marine point of view. This makes the Port of Genoa an interesting "scientifically active" area where the evolution of meteorological, marine, and environmental conditions tests the skills of anyone who works there. Among these, there are also the members of the working groups of the PNRR RETURN Project who deal with the physical and biogeochemical monitoring of sediments and waters of the port during the dredging activities and the construction of the new breakwater, currently underway.

The Port of Genoa collects the waters of two important streams (Bisagno and Polcevera) and numerous minor streams which develop on lithotypes peculiar for their chemistry (the green rocks), including ophiolitic rocks (basalts, gabbros and serpentinites) and sedimentary rocks (mostly lime schists and shales), making port waters and sediments a scientifically interesting and continuously evolving area. The construction of the motorway bypass “Gronda” includes the dumping of drilling mud and sediment from green rocks directly into the harbour via a slurry pipeline, which could therefore discharge a significant amount of chrysotile (more generally, asbestos fibres) into the port environment. Furthermore, the Port of Genoa also receives run-off water from the Genoa streets and some city sewage discharges, which input organic and inorganic chemical components (metals, organic microcontaminants, drugs, pesticides, etc.) and micro- and macroplastics into the sea.

Ports can represent a sink of ecotoxic metals (EM) and sediments favour their dissolution and transfer into the water column, mainly during dredging activities. Some EMs (e.g. As, Pb, Cd, Fe, Zn, Cu) can be toxic even at low concentrations due to bioconcentration and biomagnification in the food chain, and affect marine biodiversity not only in ports, but also in neighbouring areas. Therefore, maintaining good quality standards of port waters is not only important, but is also necessary for the survival of biodiversity and the protection of marine ecosystems (Cecchi et al., 2023).

In recent years, the Port of Genoa has been a pilot site for several European projects (in the framework of the INTERREG Italy-France Maritime 2014-2020 and Life+ programs): SEDITERRA (Cecchi et al., 2020), GEREMIA (Cecchi et al., 2021; Reboa et al., 2023), SPlasH! and SPlaH & Co (Cutroneo et al., 2020), SINAPSI, FIBERS (Militello et al., 2019). Results of these projects will be capitalized in RETURN activities.

The actors of this new monitoring activities will deal with particular emerging pollutants (not included in the Descriptors of the Marine Strategy Framework Directive applied to the monitoring of the new breakwater of the port), namely asbestos fibres and similar, and a vast range of possible organic molecules such as pharmaceuticals, pesticides, herbicides, endocrine disruptors, glyphosate and AMPA, perfluorinated compounds (PFAS). The matrices that will be investigated will be bottom sediments, port waters, and biota, and the sampling techniques will start from the use of already consolidated instruments (Niskin bottle for water sampling, Van Veen grab for sediment, POCIS for organic compounds, and DGT for heavy metals) trying, where possible, to optimize their application to the chemical compounds studied. Ecotoxicological analysis techniques will be applied to the sediments to complete the analysis of their degree of pollution.

Here we will report the methodologies applied to the researches and the first results of the researches descripted above.

Acknowledgments

The Authors would like to thank the Port System Authority of the Port of Genoa for having granted the use of the port areas as pilot site where the activities described above can be developed.

References

Cecchi G., Cutroneo L., Di Piazza S., Vagge G., Capello M., Zotti M. (2020). From waste to resource: mycoremediation of contaminated marine sediments in the SEDITERRA Project. *Journal of Soils and Sediments* 20: 2653-2663.

Cecchi G., Cutroneo L., Di Piazza S., Besio G., Capello M., Zotti M. (2021). Port Sediments: Problem or Resource? A Review Concerning the Treatment and Decontamination. *Microorganisms* 9(6): 1279.

Cecchi G., Cutroneo L., Di Piazza S., Rosa E., Zotti M., Capello M. (2023). Myco-Barriers as Sustainable Tool for Port Seawater Decontamination from Metals. *Journal of Marine Science and Engineering*, 11, 1117.

Cutroneo L., Reboa A., Besio G., Borgogno F., Canesi L., Canuto S., et al. (2020). Correction to: Microplastics in seawater: sampling strategies, laboratory methodologies, and identification techniques applied to port environment. *Environmental Science and Pollution Research* 27(16), 20571.

Militello G.M., Sanguineti E., Yus González A., Mantovani F., Gaggero L. (2019). The concentration of asbestos fibers in bulk samples and its variation with grain size. *Minerals,* 9(9), 539.

Reboa A., Besio G., Cutroneo L., Geneselli I., Gorbi S., Nardi S., et al. (2023). The EU Interreg Project “GEREMIA” on waste management for the improvement of port waters: results on monitoring the health status of fish as bioindicator. *Environmental Science and Pollution Research*.

Combined use of potassium ferrate and surfactant for the remediation of hydrocarbons contaminated soil

Federica De Marines[1], Marco Capodici[1], Gaetano Di Bella[2], Giovanni Vinti[1], Daniele Di Trapani[1], Gaspare Viviani[1]

(1) Department of Engineering, University of Palermo, federica.demarines@unipa.it
(2) Faculty of Engineering and Architecture, University of Enna "Kore"

Non-aqueous phase liquids (NAPLs), deriving from improper management or discharge of petroleum products and organic solvents, represent a serious risk of contamination due to their persistence and mobility (Gupta and Yadav, 2020). Generally, they are constituted by hydrophobic organic substances, such as petroleum hydrocarbons, which tend to be trapped in the soil pores, becoming a long-term source of contamination (Huo et al., 2020). In situ chemical oxidation (ISCO) is a widely used remediation technique for the reclamation of contaminated soil and aquifers due to its treatment speed. However, since oxidation reactions generally occur in the aqueous phase, the efficiency of the technique is limited by the availability of NAPL (Xu et al., 2022). To overcome this limitation, research has focused on the combined ISCO and surfactant technology (Bouzid et al., 2021); this is a promising strategy attributed to the high efficiency of desorption and solubilization of contaminants. However, the interactions between surfactants, oxidants and contaminants have not been fully understood. In recent years, a new oxidant, i.e. potassium ferrate (K_2FeO_4), has gained attention for ISCO application. Ferrate (Fe(VI)) has been widely used in drinking water treatments; however, its use for environmental remediation represents an emerging field (Kumar Rai et al., 2018).

This topic is investigated within Spoke VS4 of the RETURN project.

In this context, the aim of the study was to investigate the feasibility of the combined use of potassium ferrate (Fe(VI)) and an anionic surfactant (SDBS) for the remediation of a real soil artificially contaminated by diesel-fuel. The tests, designed to simulate an ISCO treatment, were conducted in Slurry mode (100 g of soil and 500 mL of solution) by mean of Jar Test with a duration of 48 hours. Specifically, the concentration of oxidant and surfactant, as well as dosing times, were evaluated in terms of their effectiveness in solubilizing and oxidizing Total Petroleum Hydrocarbons (TPH). Two scenarios were analyzed: the first where Fe(VI) and SDBS were dosed simultaneously, and the second where Fe(VI) was dosed 24 hours after SDBS. Additionally, the effect of both compounds on the residual soil phytotoxicity was examined. Furthermore, a water control test was conducted, representing the blank control.

The results obtained from the blank control showed only moderate extraction of TPH from the soil (~30%) and a volatilization percentage of 10%. In the samples treated with Fe(VI) and SDBS, on the other hand, results indicated an increase in TPH removal efficiency with an increase of both the oxidant and surfactant dosage. In more details, results from first scenario showed that the dosage of ferrate (VI) ensures a good TPH oxidation performance, which increases with its concentration, allowing to achieve values close to 70%. Furthermore, the surfactant further increased the efficiency of TPH removal from the soil, reaching overall yields of approximately 75%. From the analysis of the results achieved in the second scenario, it was found that, starting from the lowest dose of ferrate and SDBS, removal efficiencies increased significantly (>70%) compared to the first scenario. In particular, SDBS maximized the extraction rate of TPHs from the solid matrix, facilitating their transition into the liquid phase and making them more readily oxidizable in the subsequent Fe(VI) dosage. In fact, in this case, oxidation rates increased from 65% to 80%. The main results are shown in Figure 1

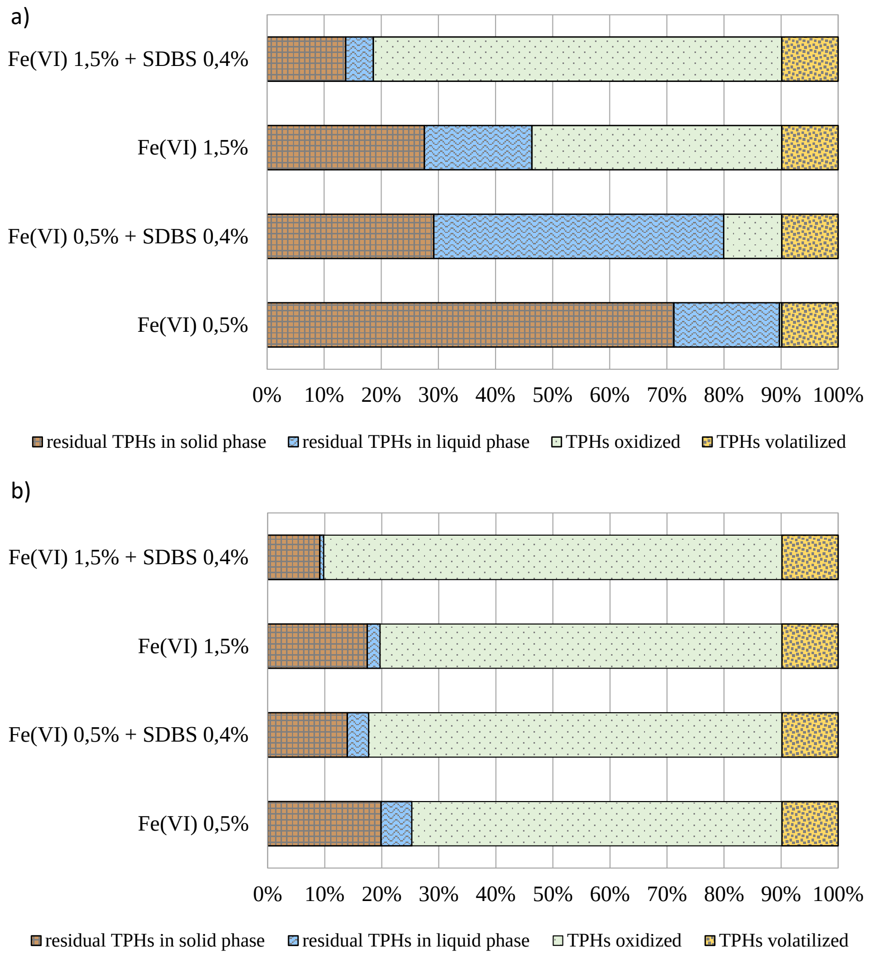


Figure 1 – TPHs mass balance after treatment in the first (a) and second (b) scenario.

References

Bouzid, I., Pino Herrera, D., Dierick, M., Pechaud, Y., Langlois, V., Klein, P.Y., Albaric, J., Fatin-Rouge, N., 2021. A new foam-based method for the (bio)degradation of hydrocarbons in contaminated vadose zone. *J. Hazard. Mater*. 401, 123420.

Gupta, P.K., Yadav, B.K., 2020. Three-Dimensional Laboratory Experiments on Fate and Transport of LNAPL under Varying Groundwater Flow Conditions. *J. Environ. Eng*. 146, 1–10.

Huo, L., Liu, G., Yang, X., Ahmad, Z., Zhong, H., 2020. Surfactant-enhanced aquifer remediation: Mechanisms, influences, limitations and the countermeasures. *Chemosphere* 252.

Kumar Rai, P., Lee, J., Kailasa, S.K., Kwon, E.E., Tsang, Y.F., Ok, Y.S., Kim, K.H., 2018. A critical review of ferrate(VI)-based remediation of soil and groundwater. *Environ. Res*. 160, 420–448.

Xu, J.C., Yang, L.H., Yuan, J.X., Li, S.Q., Peng, K.M., Lu, L.J., Huang, X.F., Liu, J., 2022. Coupling surfactants with ISCO for remediating of NAPLs: Recent progress and application challenges. *Chemosphere* 303, 135004.

Adsorption of lanthanides ions onto geopolymer and Neapolitan yellow tuff

Fulvio De Paola[1], Mauro Iuliano[1], Gaetano De Tommaso[1], Oreste Tarallo[1], Fabio Montagnaro[1], Marco Balsamo[1], Gabriella Pinto[1]

(1) Department of Chemical Sciences, University of Naples "Federico II", fulvio.depaola@unina.it

Adsorption processes are commonly used in water treatment to remove emerging pollutants, as rare earth elements (REE). REEs are a set of seventeen chemical elements, specifically the fifteen lanthanides plus yttrium. They are widely used in medical applications (Dancey et al. 2000) and various industrial and technological processes, but it is important to note that prolonged exposure to these elements can have a negative impact on human health, potentially causing pulmonary embolisms and lung cancer. The study examined the extraction of specific REE elements from aqueous solutions using natural solid phases, including Neapolitan yellow tuff (NYT) and a synthetic organic hybrid geopolymer. Metakaolin-based geopolymers are solids with a structure like tectosilicate. They are typically prepared by treating an aluminosilicate material with an alkaline solution of sodium silicate (Davidovits 2011). Additionally, the incorporation of a silicone component, such as polydimethylsiloxane (10% w/w), has been shown to result in materials with improved mechanical and thermal properties (Roviello et al. 2013).

Both solids have different adsorption sites: permanent charge site, silanol and aluminol groups with acid-base behavior on the surface. Potentiometric measurements were carried to define both the protolythic equilibria and the point of zero charge (ZCP) of the solids, which represents the pH at which the surface charge is zero.

The study of adsorption kinetics provides information on the stages involved in the interaction of solids with ions. Measurements are carried out by preparing suspensions of the analyte in $NaClO_4$ as ionic medium, at different concentrations.

The kinetic data were evalutated using various models, including the pseudo-first and second-order models, as well as the intraparticle diffusion model (Ho et al. 1999). Kinetic measurements indicate that process follows the pseudo-second-order kinetic model.

Adsorption isotherms were obtained as function of the concentration of the target analyte. The suspensions were stirred for a sufficient time to allow equilibrium between the phases to be reached in a thermostated environment. Adsorption isotherms were also utilized to evaluate the removal efficiency using the Langmuir and Freundlich models. Experimental data are interpreted with Langmuir model.

To complete the study of adsorption temperature-dependent measurements made it possible to derive the thermodynamic parameters (ΔG^0, ΔH^0, ΔS^0) as well as the activation energy (E_A) of the process. Experimental data show that the extent of adsorption increases with temperature, indicating that the process is endothermic. The positive values of ΔH^0 are a consequence of the dehydration of the ions during the adsorption process. This process requires a lot of energy, which exceeds the heat released by the adsorption reaction. The positive values of ΔS^0 can be attributed to an increase in disorder in the solid–solution interface, as a consequence of the dehydration of the adsorbed ion. The results can be interpreted in terms of ion exchange between lanthanaides ions with permanently charged sites and with acid–base sites (silanol and aluminol).

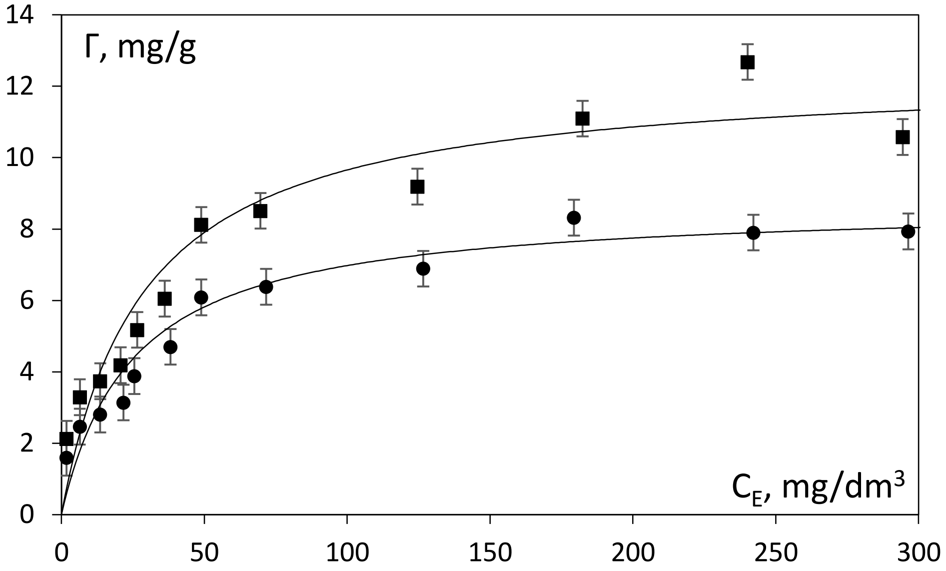


Figure 1 – Amount of adsorbed Yttrium(III) ions per gram (Γ) of geopolymer (squares) and Neapolitan yellow tuff (circles) as a function of equilibrium concentration (C_E) at 25 °C in 0.1 M $NaClO_4$ (solid concentration of 3.5 g/dm^3).

References

Dancey J.E., Shepherd F.A., Paul K., et al. (2000). Treatment of non resectable hepatocellular carcinoma with intrahepatic ^{90}Y-microspheres. *Journal of Nuclear Medicine*, 41(10), 1673–1681.

Davidovits J. (2011). Geopolymers: structure, processing, properties and industrial applications. *Geopolymer: Chemistry & Applications, 3rd edition.*

Roviello G., Ricciotti L., Ferone C., Colangelo F., Cioffi R., Tarallo O. (2013). Synthesis and characterization of novel epoxy geopolymer hybrid composites. *Materials*, 6, 3943-3962.

Stumm W., Morgan J.J. (1992). Chemistry of the solid-water interface: processes at the mineral-water and particle-water interface in natural systems. *John Wiley & Son Inc., 3rd edition.*

Ho Y.S., McKay G. (1999). Pseudo-second order model for sorption processes. *Process Biochem.*, 34, 451-465.

Preliminary design of a new soil column test for physical simulation of infiltration and evaporation processes

Andrea Dominijanni[1], Guido Musso[1], Vincenzo Sergio Vespo[1]

(1) Department of Structural, Geotechnical and Building Engineering (DISEG), Politecnico di Torino, andrea.dominijanni@polito.it

Within the VS4 “Environmental Degradation”, and, more specifically, the WP5 on “Prevention and Remediation” – TASK 5.4, research activity has been undertaken to develop innovative technologies for the cover systems of contaminated sites and waste disposal facilities.

The primary purpose of cover systems is to minimize both water infiltration into the contaminated material and the migration of volatile pollutants into the atmosphere. The three primary requirements for cover systems are (Hauser et al., 2001):

- to minimize infiltration into the waste or the contaminated soil and percolation from the waste or the contaminated soil to groundwater;
- to isolate the wastes or the contaminated soil from receptors and control movement by wind or water;
- to control gaseous emissions.

In particular, the research focuses on the physical, hydraulic and mechanical properties that control the performance of evapotranspiration covers, which consist of thick layers of natural soils or recycled soil-like materials, able to store water during rainy periods and release the accumulated water back into the atmosphere according to an evapotranspiration process.

Evapotranspiration covers use two natural processes to control infiltration into the waste: (1) the soil provides a water reservoir, and (2) natural evaporation from the soil plus plant transpiration (evapotranspiration or ET) empties the soil water reservoir. These covers are inexpensive, practical, and easily maintained biological systems that may be expected to remain effective over extended periods of time, perhaps centuries, at low cost (Hauser et al., 2001).

In addition, the research will evaluate the possible combination of evapotranspiration covers with geosynthetics, such as drainage geocomposites, geomembranes and geosynthetic clay liners, to optimize the overall performance, also accounting for the possible stresses caused by climate change. The environmental impacts of the considered cover systems will be compared to quantify the degree of sustainability in engineering projects involving contaminated sites and landfills. Sustainability analysis will take into account emissions (greenhouse gases), consumption of nonrenewable resources, and overall impacts on human health in order to determine which design option yields the least negative impact on these categories.

A current limitation in using cover systems, including an evapotranspiration layer, is mainly related to the difficulty in understanding infiltration and evaporation processes and, consequently, in predicting the performance of this solution. To overcome such a limitation, the research activity has been planned to provide theoretical and experimental insight into the coupled thermo-hydro-mechanical phenomena that control infiltration and evaporation processes through porous media.

It has been previously shown that evaporation is governed by complex boundary conditions and by the thermo-hydraulic properties of the porous medium, which impact the evaporation rate and the moisture profile within the soil (Wilson et al., 1994; Guida et al., 2023).

On the other hand, infiltration is controlled by the precipitation rate and hydraulic properties of the soil with respect to both air and water (Siemens et al., 2014; Aimar et al., 2023).

On the basis of such findings, a new laboratory apparatus has been designed. This apparatus consists of a soil column placed over a weight scale and equipped with matric potential sensors, soil moisture probes, time domain reflectometers and thermistors placed at different heights along the column. Two different hydraulic circuits have been considered at the bottom of the soil column to simulate (1) a constant hydraulic head condition and (2) a free drainage condition. At the top of the soil column, three possible boundary conditions may be adopted: (1) a constant hydraulic head, (2) a simulated rainfall and (3) an imposed temperature and thermal flux by using an infrared lamp. The scheme of the new apparatus is shown in Figure 1.

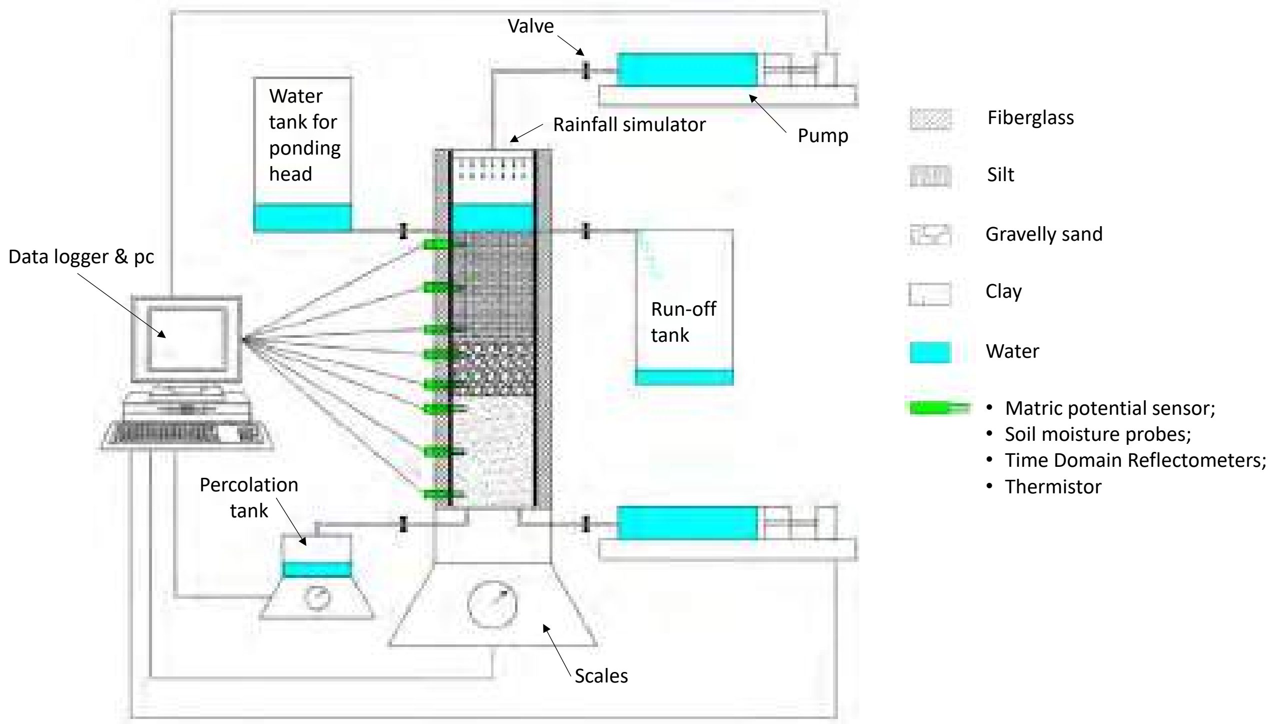


Figure 1 – Scheme of the new laboratory apparatus for the thermo-hydraulic analysis of infiltration and evaporation processes.

The test results will be interpreted using a coupled thermo-hydro-mechanical numerical model that takes into account the flow of both the water and air phases (Aimar et al., 2023; Guida et al., 2023). After the calibration based on the laboratory experimental results, the model will be used to predict the expected performance in field applications.

The construction of the new apparatus and the conduction of a series of preliminary tests will be the next step in the research activity.

References

Aimar M., Della Vecchia G., Musso G. (2023). One phase vs two-phase modelling of infiltration processes. In: Ferrari A., Rosone M., Ziccarelli M., Gottardi G. (eds.). *Geotechnical Engineering in the Digital and Technological Innovation Era*. CNRIG 2023. Springer Series in Geomechanics and Geoengineering. Springer, Cham.

Guida G., Vespo V.S., Musso G., Della Vecchia G. (2023). The role of hydraulic and thermal properties of soil in evaporation: a numerical insight. *Environmental Geotechnics*, 1-18.

Hauser V.L., Weand B.L., Gill M.D. (2001). Natural covers for landfills and buried waste. *Journal of Environmental Engineering*, 127(9), 768-775.

Siemens G.A., Take W.A., Peters S.B. (2014). Physical and numerical modeling of infiltration including consideration of the pore-air phase. *Canadian Geotechnical Journal*, 51(12), 1475-1487.

Wilson G.W., Fredlund D.G., Barbour S.L. (1994). Coupled soil–atmosphere modelling for soil evaporation. *Canadian Geotechnical Journal*, 31(2), 151–161.

An integrated approach to assess the combined effects of climate change and contamination on habitat-forming species under future scenarios

Valentina Esposito[1], Michela D'Alessandro[1], Sonia Manzo[2], Simona Schiavo[2], Mariarita Montereali[2], Giovanna Ciluffo[3], Geraldina Signa[3], Agostino Tomasello[3], Federica Cassetti[3], Marta Greco[3], Salvatrice Vizzini[3]

(1) National Institute of Oceanography and Applied Geophysics - OGS, vesposito@ogs.it
(2) ENEA SSPT PROTER
(3) Dept. of Earth and Marine Science, University of Palermo

Photosynthesizing and habitat-forming organisms, such as seagrasses and macroalgae, may take on the role of creating *refugia* from unfavorable or harmful conditions associated with global change, thanks to their ability to sequester carbon and the complexity of the microhabitats they create (Falkenberg et al., 2021). In addition, they play key ecological, physical, and economic roles (Vassallo et al., 2013) providing diverse ecosystem services (provision of food and raw materials, nursery for species of economic interest, coastal protection, and carbon storage). While these roles are widely recognized, environmental degradation and future abiotic conditions (global climate change and contamination) may alter the persistence of the original habitat itself as well as its influence on the surrounding environment.

Against this background, some of the actions proposed within task 4.1 of the Spoke VS4 of the RETURN project, aim to assess the combined effects of global change (warming and acidification) and sulfide and heavy metal contamination on habitat-forming species and on structural and functional diversity of their associated communities, to better understand the ability of these species to function as stress alleviators and, by maintaining consistent morphology and phenology, to support biodiversity and associated ecosystem services.

At this scope, the shallow volcanic vents in the Aeolian Archipelago have been chosen as natural laboratories to conduct field experiments on seagrasses (*Cymodocea nodosa* and *Posidonia oceanica*) and the macroalgae *Ericaria brachycarpa*. Indeed, coastal volcanic areas share several similarities with projected global and climate change scenarios in marine systems (high temperature and CO_2, with consequent low pH, and high load of toxic chemicals such as sulfides and trace metals) (Dahms et al., 2018), consequently allowing the investigation of the short- and long-term responses at different hierarchical levels of the biological and ecological organization (species, communities, and ecosystems).

At the Vulcano vent the combined effect of seawater acidification and trace metal contamination will be investigated on the coastal fish community. In detail, the influence of fish trophic and behavioral traits on total mercury (THg) accumulation under acidified conditions will be assessed. To this end, basal sources and fish associated with *Cymodocea nodosa* seagrass meadows were compared for THg levels under low and ambient pH conditions.

Further investigations will be conducted in Panarea island (Figure 1) and specifically at 4 shallow hydrothermal systems (Bottaro crater, Hot/cold, campo 21, black point) characterized by different physico-chemical conditions and by the presence of the seagrass *Posidonia oceanica* and/or the macroalga *Ericaria brachycarpa* to evaluate the combined effects of acidification, temperature, sulfides and trace metals. Control sites have been identified in the coastal area of Salina island, where no hydrothermal activity has been observed so far, so that depth, seawater chemical features, sediment grain size and exposure are comparable to the targeted shallow systems (impacted sites) of Panarea island.

Abiotic matrices (seawater and/or sediments) will be analyzed to evaluate the occurrence, the extent and the potential impact of the stressors. Passive samplers will be also deployed to estimate bioavailable metals. These analyses, together with the analysis of available literature, will allow the physical and chemical characterization of the study sites. Samples will be collected in summer and autumn 2024 at sites affected by volcanic activity and at control sites and will be analyzed in laboratories of the research team (ENEA, OGS ECCSEL NatLab Italy of Panarea island, University of Palermo). Different competencies of the research group will be integrated to elucidate the response to combinations of multiple stressors (warming and/or acidification and/or metal contamination) by analyzing i) structural (density, biomass) and physiological features in macrophytes and macroalgae and ii) structural and functional diversity in their associated communities.

Given that climate change is considered an important driver of environmental degradation and that it often acts in combination with other stressors (i.e., chemical toxics), this study will contribute to the understanding of how future scenarios of change may trigger the loss of important habitats with expected consequences on the provision of ecosystem services from which people depend on.

Figure 1 – underwater pictures showing hydrothermal emissions of Panarea island and the two target species (P. oceanica and E. brachycarpa).

References

Dahms H.U., Schizas N.V., James R.A., Wang L., Hwang J.S. (2018). Marine hydrothermal vents as templates for global change scenarios. *Hydrobiologia*, 818, 1-10.

Falkenberg L.J., Scanes E., Ducker J., Ross P.M. (2021). Biotic habitats as refugia under ocean acidification. *Conservation Physiology*, 9(1), coab077.

Vassallo P., Paoli C., Rovere A., Montefalcone M., Morri C., Bianchi C.N. (2013). The value of the seagrass *Posidonia oceanica*: A natural capital assessment. *Marine Pollution Bulletin*, 75, 157–167.

Distribution, contamination sources and risk assessment of priority organic pollutants in the soils of a heavily contaminated river basin: the case study of the Sarno River Basin (Southern Italy)

Annalise Guarino[1], Antonio Iannone[1], Lucia Rita Pacifico[1], Stefano Albanese[1]

(1) Dept. of Earth Sciences, Environment and Resources, University of Naples Federico II, annalise.guarino@unina.it

The Sarno River Basin, located in the southwestern portion of the Campania Plain between the Somma–Vesuvius volcanic complex and the carbonatic formations of the Southern Apennine Chain, is one of the most polluted river basins in Europe due to widespread industrialization and intensive agriculture.

The Basin apart from being severely contaminated by potentially toxic elements (PTEs) (Cicchella et al., 2014), attributable to both anthropogenic and natural sources, is also characterized by the presence of high concentrations of some priority organic pollutants, such as polycyclic aromatic hydrocarbons (PAHs), organochlorine pesticides (OCPs) and polychlorinated biphenyls (PCBs).

These organic compounds are the most common soil contaminants, especially in highly industrialized and anthropized areas due to their use in various processes linked to human activities (e.g., agricultural practices, industrial processes, mining activities, vehicular traffic). Although they can be often found in combination in the soils, these substances have different composition and have different origins and fates in the environment.

The aim of this work is the assessment of the geochemical-environmental conditions of the Sarno River Basin. The work is based on selected PAHs, OCPs, and PCBs and it considers their concentrations and distribution patterns in topsoils to determine the nature of their potential pollution sources and the risk level to which the local population is exposed.

For this purpose, over an area of about 500 km^2 a total of 42 soil samples were collected, following the FOREGS procedures (Salminen et al., 1998), to determine the content of several organic compounds. For characterizing the geochemical conditions of the area, cartographic elaborations were created for selected variables, to have a clear view of the spatial distribution patterns of the analysed contaminants, and a univariate statistical analysis was carried out, aimed at identifying the main indices that characterize the distribution of the data. Subsequently, an analysis was carried out to establish the emission source of the analyzed contaminants, following a different method for each group of contaminants considered.

As regard PAHs, in order to discriminate the emission sources, as suggested by Tobiszewski and Namiesnik (2011), diagnostic ratios are taken into consideration. The use of these ratios is based on the thermodynamic stability of the PAHs molecules, since during low temperature (petrogenic) processes (e.g., wood burning) LMW PAHs are usually formed, while high temperature (pyrogenic) processes (e.g., combustion of fuels in engines) emit HMW compounds.

For OCPs the ratios between the parent compound and its metabolites are used as pollution sources indicators (Jiang et al., 2009). Because some OCPs tend to degrade over time in other metabolites and since the technical pesticides (i.e., DDT, HCH, chlordane, endosulfan) used, mainly in agricultural practices, are composed by a precise percentage of the different molecules, the ratio between the parent compound and its metabolites can help identify whether the concentrations found in soil are attributable to fresh or historical use of these substances.

It is difficult to establish the correlation between the PCB congener profiles and the sources, especially in the condition of multi-sources, because the distributions of PCBs could be influenced by the soil characteristics, the stability of different PCB congeners, and the function of emission sources. However, the dominant component of PCBs could be used to identify the source of PCBs (Yu et al., 2014).

References

Cicchella D., Giaccio L., Lima A., Albanese S., Cosenza A., Civitillo D., De Vivo B. (2014). Assessment of the topsoil heavy metals pollution in the Sarno River Basin, south Italy. *Environ. Earth Sci.*, 71, 5129–5143.

Jiang Y.F., Wang X.T., Jia Y., et al. (2009). Occurrence, distribution and possible sources of organochlorine pesticides in agricultural soil of Shanghai, China. *J Hazard Mater*, 170, 989–997.

Salminen R., Tarvainen T., Demetriades A., et al. (1998) FOREGS Geochemical Mapping Field Manual. Geological Survey of Finland, *Espoo Guide* 47.

Tobiszewski M., Namiesnik J. (2011). PAH diagnostic ratios for the identification of pollution emission sources. *Environ Pollut*, 162, 110–119.

Yu Y., Li Y. X., Shen Z. Y., Yang Z., Mo L., Kong Y., et al. (2014). Occurrence and possible sources of organochlorine pesticides (OCPs) and polychlorinated biphenyls (PCBs) along the Chao River, China. *Chemosphere*, 114 (22), 136–143.

Environmental risk due to micropollutants release: the contribution of wet-weather discharges in urban catchments

Jessica Ianes[1], Beatrice Cantoni[1], Enrico Ulisse Remigi[2], Fabio Polesel[2], Luca Vezzaro[3], Manuela Antonelli[1]

(1) Department of Civil and Environmental Engineering (DICA), Politecnico di Milano, manuela.antonelli@polimi.it
(2) DHI A/S
(3) Department of Environmental and Resource Engineering (DTU Sustain), Technical University of Denmark

Wet-weather discharges from integrated urban wastewater systems (IUWS) represent a threat for surface waters. When the system capacity is reached during rain events, a mixture of stormwater and untreated wastewater is discharged to surface water through Combined Sewer Overflows (CSOs), along the sewer system, and/or through the Bypass (BP) at the inlet of Wastewater Treatment Plant (WWTP). The loads of discharged contaminants are highly variable in time and space (Petrie, 2021), making it difficult to correctly monitor and assess the environmental risk for a specific catchment. However, wet-weather impact is strongly addressed by the revision of the Urban Wastewater Treatment Directive (EU Commission, 2022), that requires the assessment of discharged volumes, concentrations, and loads.

The present work aims at assessing the impact of 12 micropollutants present in wet-weather discharges on receiving surface water, by using an archetype IUWS, defined through a stochastic approach. Monitoring data were gathered from literature to characterize yearly discharges and to predict the chronic risk posed by micropollutants. The estimated environmental chronic risk from wet-weather discharges was compared against that posed by WWTP effluent. This work was developed within the Spoke VS4 (WP3) of the RETURN project and described in detail in Ianes et al. (2023).

The archetype IUWS included several CSOs, BP at the inlet of the WWTP, the WWTP effluent and a river as receiving water. These *i-th* elements (CSOs, BP, effluent, river) were characterized in terms of both water quantity (discharged volume and river flowrate) and quality (concentrations of *j-th* micropollutant), each one defined by a probability distribution, to consider data inherent variability. Various percentiles were extracted from these probability distributions for the parameterization of the archetype IUWS.

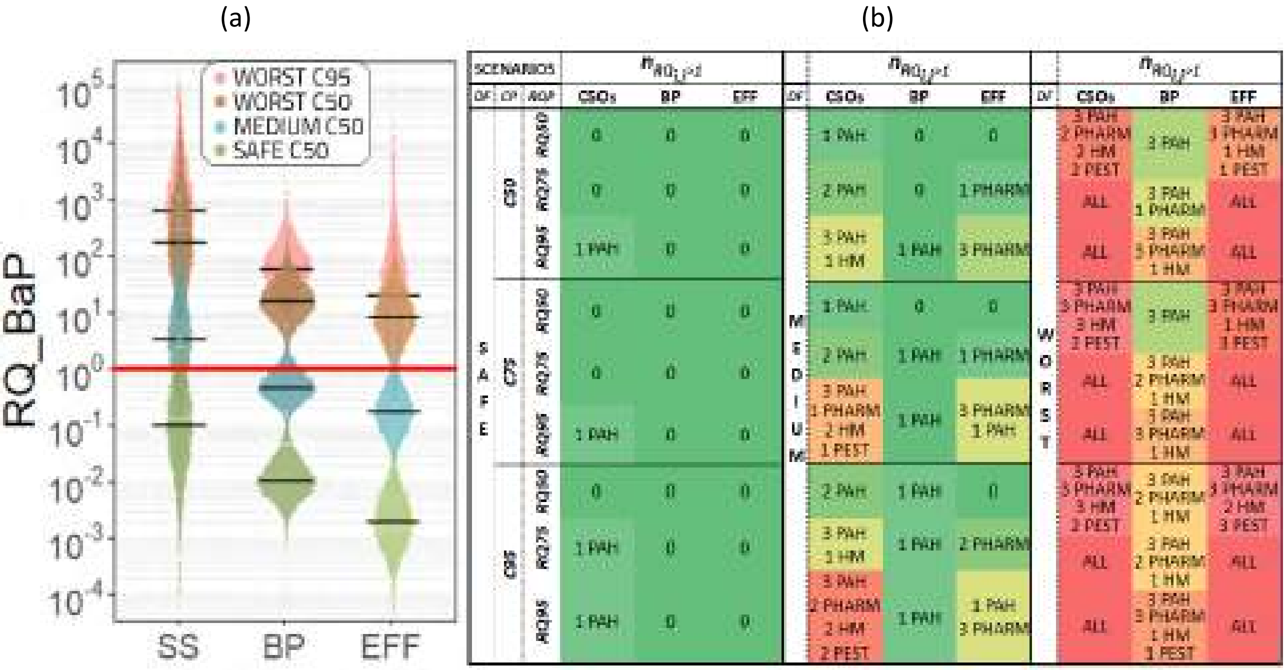
Six scenarios were identified related to climate changes: three pollution levels were accounted using the distributions for the 50th, 75th, 95th percentiles (C50, C75, C95) of the micropollutants concentration distributions; three dilution scenarios (Safe, Medium, Worst) were derived from the distributions of the river dilution factor.

The chronic risk for the river was assessed in each scenario through the Risk Quotient (RQ), calculated using annual loads and the uncertainty analysis, as risk posed by: (i) the *j-th* micropollutant in the *i-th* discharge ($RQ_{i,j}$), (ii) all micropollutants in the *i-th* discharge (RQ_i), and (iii) the *j-th* micropollutant in all discharges (RQ_j).

Percentiles of both micropollutants concentration and RQ are usually arbitrarily chosen, leading to different risk estimations. Conversely, non-default values of the river dilution factor allow to evaluate the climate change impact that may result in lower dilution.

The choice of different micropollutants concentration percentiles did not determine significant differences in RQ values, while the choice of the dilution factor can strongly impact the risk assessment outcome. For example, for Benzo(a)Pyrene (BaP, Figure 1a) median RQ values were found to be less than 10 times higher from C50 to C95 scenario, while values are up to 10,000 times higher from Safe to Worst scenario. Therefore, an accurate risk assessment requires to correctly quantify the hydraulic variables of the IUWS (specifically the dilution factor), as neglecting the impact of dilution and assessing only the discharged concentrations might lead to significant risk overestimation.

As to micropollutants exceeding the risk threshold of RQ=1 ($n_{RQi,j}$>1) in Figure 1b, the higher risk is posed by Polycyclic Aromatic Hydrocarbons (PAH), with BaP as the most relevant, mainly present in CSOs and BP. Pharmaceuticals (PHARM) represent the second class of concern for surface water, being the effluent the main source, while wet-weather discharges contribute to the risk only in the Worst scenario. The third class of concern is Heavy Metals (HM), with high risk in Worst scenario related to CSOs. Pesticides (PEST) pose the smallest risk both in Medium and Worst scenarios, with Diuron being the most critical compound.



SCENARIOS			$n_{RQ_{i,j}>1}$				$n_{RQ_{i,j}>1}$				$n_{RQ_{i,j}>1}$		
DF	CP	RQP	CSOs	BP	EFF	DF	CSOs	BP	EFF	DF	CSOs	BP	EFF
SAFE	C50	RQ50	0	0	0	MEDIUM	1 PAH	0	0	WORST	3 PAH 2 PHARM 3 HM 2 PEST	3 PAH	3 PAH 3 PHARM 1 HM 1 PEST
		RQ75	0	0	0		2 PAH	0	1 PHARM		ALL	3 PAH 1 PHARM	ALL
		RQ95	1 PAH	0	0		3 PAH 1 HM	1 PAH	3 PHARM		ALL	3 PAH 3 PHARM 1 HM	ALL
	C75	RQ50	0	0	0		1 PAH	0	0		3 PAH 3 PHARM 3 HM 2 PEST	3 PAH	3 PAH 3 PHARM 1 HM 3 PEST
		RQ75	0	0	0		2 PAH	1 PAH	1 PHARM		ALL	3 PAH 2 PHARM 1 HM	ALL
		RQ95	1 PAH	0	0		3 PAH 1 PHARM 2 HM 1 PEST	1 PAH	3 PHARM 1 PAH		ALL	3 PAH 3 PHARM 1 HM	ALL
	C95	RQ50	0	0	0		2 PAH	1 PAH	0		3 PAH 3 PHARM 3 HM 2 PEST	3 PAH 2 PHARM 1 HM	3 PAH 3 PHARM 2 HM 3 PEST
		RQ75	1 PAH	0	0		3 PAH 1 HM	1 PAH	2 PHARM		ALL	3 PAH 2 PHARM 1 HM	ALL
		RQ95	1 PAH	0	0		3 PAH 2 PHARM 2 HM 2 PEST	1 PAH	1 PAH 3 PHARM		ALL	3 PAH 3 PHARM 1 HM 1 PEST	ALL

Figure 1 – (a) $RQ_{i,j}$ for BaP due to each discharge. (b) Number of exceedances of the risk threshold for each discharge in each scenario (DF: dilution factor scenarios, CP: pollution level scenarios) per micropollutant class.

In conclusion, this study proposes an approach for decision makers to evaluate the contribution of wet-weather discharges in affecting the aquatic ecosystem on a long-term perspective, comparing the chronic risk with those posed by WWTP effluent during dry-weather. A proper risk evaluation can support the planning and design of the most appropriate mitigation measures.

However, site-specific monitoring campaigns are needed to detect the specificity of the discharged pollution in each catchment, and a larger spectrum of micropollutants should be investigated. Moreover, to address the possibility of the presence of acute risk, it is fundamental to address the dynamic of the discharge. For this reason, we performed 7 monitoring campaigns on a WWTP bypass (chosen for accessibility reasons) and effluent, collecting multiple samples during the same event. We found strong differences within the same event and across events, with higher concentrations discharged during smaller rain events.

References

EU Regulation 2020/741 (2022). Proposal for a directive of the European Parliament and of the Council concerning urban wastewater treatment (recast). Off. J. Eur. Union 0345, 1-68.

Ianes J., Cantoni B., Remigi E., Polesel F., Vezzaro L., Antonelli M. (2023). A stochastic approach for assessing the chronic environmental risk generated by wet-weather events from integrated urban wastewater systems. *Environ. Sci.: Water Res. Technol.*, 9(12), 3174-3190.

Petrie B. (2021). A review of combined sewer overflows as a source of wastewater-derived emerging contaminants in the environment and their management. *Environ. Sci. Pollut. Res.*, 28, 32095-32110.

LiDAR-based modeling of wildland fire behaviour and bark beetle outbreaks interaction: new perspective for Italian catchments

Luca Mauri[1], Emanuele Lingua[1]

(1) Department of Land, Environment, Agriculture and Forestry, University of Padova, luca.mauri@unipd.it

Forest fires, windstorm and bark beetles outbreaks nowadays represent a relevant issue for European forests. In this regard, local stakeholders are actually facing with critical circumstances both concerning the implementation of efficient silvicultural management of forest stands affected by such issues. The storm Vaia occurred in 2018 in northeastern Italy created an unexpected scenario for Italian Alps. Following the windthrow produced by the storm, bark beetles proliferated from the downed logs, therefore moving to the neighbour standing forest and modifying the characteristics and the availability of forest fuel. In this context, the development of remote sensing techniques and tools such as Light Detection and Ranging (LiDAR) and Unmanned Aerial Vehicle (UAV)-based data acquisition, together with wildfire behaviour models, allow researchers to perform detailed estimation of forest fuels, necessary to simulate fire behaviour over disturbed forested areas over time. The prediction of key factors related to wildfire risk (e.g., fire type, rate of spread, flames lengths) is useful in estimating fire behaviour also in those areas affected by bark beetles outbreaks. In this connection, new methods able to overcome notable limitations in forest fire simulations is nowadays needed. The interaction between bark beetles outbreaks and wildland fire dynamics are therefore investigated focusing on a forested catchment (Veneto region, Italy) affected by the VAIA storm, and therefore involved in a widespread bark beetle outbreak. Extensive field data collection and fire behaviour models were coupled with high-resolution LiDAR and UAV-based analysis, to compare wildfire behaviour before and after beetle outbreak. Results could enrich the amount of information available for local administration of the Alpine region, in order to find effective interventions and management options for the areas affected by similar natural disturbances over time.

Recent trends on environmental degradation: a bibliometric analysis

Nada Mzid[1], *Fabio Terribile*[1,2]

(1) Department of Agriculture, University of Naples Federico II, nada.mzid@unina.it
(2) CRISP Research Center, University of Naples Federico II

In the current years, environmental degradation challenge has been actively debated. European ecosystems are facing the threat of environmental degradation, in addition to the climate change impacts causing continuously and gradually adverse effects on ecosystems conditions (Barbu et al., 2017). With the further development of environmental degradation-related scientific studies and research, accurate, high-resolution, and up-to-date datasets were spotted as urgent and essential (Ivits et al., 2018). Furthermore, cloud-based global remote datasets accompanied by the rise of progress in algorithm and modelling research, have considerably strengthen the application potential of earth observation systems for environmental degradation studies (Iordache et al., 2022; Stroppiana et al., 2021).

Here in view of RETURN (Spoke VS4, WP4.2) we have attempted to assess: (i) the main current sources of environmental degradation as observed by scientific literature, and (ii) a synoptic evaluation about the scale of observation and the spatial extent of environmental degradation processes.

To investigate this expectation, a scientific study (presented and discussed within the Deliverable DV4.2.1) was carried out highlighting the patterns of the academic bibliography on environmental degradation following two steps. Firstly, a preliminary bibliometric analysis was carried out devoted to examine the main drivers of environmental degradation. Subsequently, a synoptic evaluation of the outcoming results analyzing sources and scale of land degradation, thus demonstrating the critical trade-off between spatial extent and spatial resolution, was performed. To extract the necessary data for this analysis and for the construction of a database of papers, the Scopus database was used. We selected search terms related to the proposed theme based on two major dimensions: the environmental problem and the geographic region of interest. These search terms were required to occur in the paper’s title, abstract, or keywords for all available publications. From the listed papers, we focused on Article, Conference paper, Review, Book chapter, and Book, and we excluded the remaining document types. We also excluded the papers published before 2016 and focused on the range time 2016-2023. A total of 19,748 documents were generated and analyzed. The bibliometric analysis to measure documents information was conducted using both VOSviewer and a software package *bibliometrix* based on R language.

Cluster analysis – based on keywords related to the environmental degradation research - presented four principal clusters: The first main group of clusters is principally associated with studies in wastewater, wastewater treatment, microplastics, toxicity and pesticides. The second general category of cluster is mainly concerning the monitoring of dynamic changes of forest degradation (deforestation) based on remote sensing. The third main category of cluster is in relation with the research of environmental degradation and sustainable development of land resources. The fourth group of clusters englobe a summary of keywords from the above-mentioned categories. The latter analysis is investigated in detail within the Deliverable 4.2.1 of the RETURN project.

Afterwards we generated a more detailed analysis separating environmental degradation processes occurring over terrestrial and marine ecosystems. On the base of this, we produced a small focus on key examples of environmental degradation of particular interest in RETURN, namely plastics, wildfire, pathogens, and eutrophication. In addition, we plotted the resulting papers into the following sections, which are of a special interest for RETURN project, namely Database, Mapping, Transport Model, and Innovative Modelling approaches.

Finally – in view of RETURN project – we had produced a synoptic scheme highlighting how the different RETURN VSs, TSs, DS and VS4 themes are placed altogether with respect to spatial resolution (or support of measurements) and spatial extent.

References

Barbu A.D., Dejean F., Sporer M., Tomescu M., Böttcher H., Förster H., et al. (2017). Trends and projections in Europe 2017. Tracking progress towards Europe's climate and energy targets. European Environment Agency Report.

Iordache M.D., De Keukelaere L., Moelans R., Landuyt L., Moshtaghi M., Corradi P., et al. (2022). Targeting plastics: machine learning applied to litter detection in aerial multispectral images. *Remote Sensing*, 14, 5820.

Ivits E., Verzandvoort S., Hessel R., Wösten H., Tóth G., Weynants M., et al. (2018). Land degradation knowledge base: policy, concepts and data. *European Topic Centre on Urban, Land and Soil Systems Report*.

Stroppiana D., Bordogna G., Sali M., Boschetti M., Sona G., Brivio P. A., et al. (2021). A fully automatic, interpretable and adaptive machine learning approach to map burned area from remote sensing. *International Journal of Geo-Information*, 10, 546.

Effects of chronic PFAS exposure on mitochondrial antioxidant defences in a freshwater fish species (*Squalius Cephalus*) from the Veneto region

Sara Pacchini[1], Giacomo Vanzan[1], Elisabetta Piva[1], Sophia Schumann[1], Paola Irato[1], Andrea Bottacin Busolin[2], Andrea Marion[2] and Gianfranco Santovito[1]

(1) Dept. of Biology, University of Padova, sara.pacchini@phd.unipd.it
(2) Dept. of Industrial Engineering, University of Padova

Since its discovery in 2013, the Veneto region has been affected by one of the most extensive PFAS contaminations in the world, originated by a fluorochemical plant in the province of Vicenza, active since the late 1960s (WHO, 2017). PFAS are highly persistent in the environment due to their chemical properties. Exposure to environmental stressors can affect animals' physiology, in many cases inducing a response from the organism at the level of the antioxidant system (Wielsøe et al., 2015). PFAS can bioaccumulate and biomagnify along food webs, affecting ROS production at the molecular level, hence unbalancing the cellular redox equilibrium (Piva et al., 2022). This may result in cell death, DNA damage, altered enzymatic function, and consequent oxidative damage to the entire organism. To protect cells from these damages, organisms have evolved various antioxidant multi-enzymatic systems (Bonato et al., 2020). Therefore, variations in the content and the activity of antioxidant enzymes are useful as biomarkers for oxidative stress caused by contaminants in marine organisms, enabling the evaluation of potential risks for aquatic ecosystems and biota (Pacchini et al., 2023).

The present study aims to evaluate the possible effects of chronic exposure to different environmental concentrations of PFAS and the induced physiological responses in a freshwater fish species: *Squalius cephalus* which populates the Veneto rivers. To this end, molecular and biochemical analyses were carried out, to evaluate a few oxidative stress biomarkers in the kidney.

The fieldwork activity was carried out in March 2021: ten specimens of *Squalius cephalus* were sampled by electrofishing from three rivers in Vicenza characterized by three different levels of PFAS contamination (very low, low and high). After the sampling, fish were immediately anesthetized and euthanized with an overdose of essential clove oil. The kidney was extracted and frozen in liquid nitrogen to be stored at -80 °C until laboratory analyses.

Expression analyses were performed at the transcriptional level of genes coding for four mitochondrial isoforms (*sod2, gpx4, prdx3, prdx5*) of antioxidant enzymes, evaluating the mRNA accumulation by real-time qPCR.

The results (Figure 1) suggest that exposure to PFAS at sufficiently high concentrations (low polluted site) leads to an activation of gene transcription of all mitochondrial proteins considered. The further increase in environmental concentration (highly polluted site) produces a further increase only in *prdx3*, which can be considered a key enzyme in antioxidant defenses in response to PFAS contamination. Otherwise, *gpx4* expression levels return to control values, indicating a downregulation that may reflect an energy saving strategy, useful for implementing the action of other components of the antioxidant system.

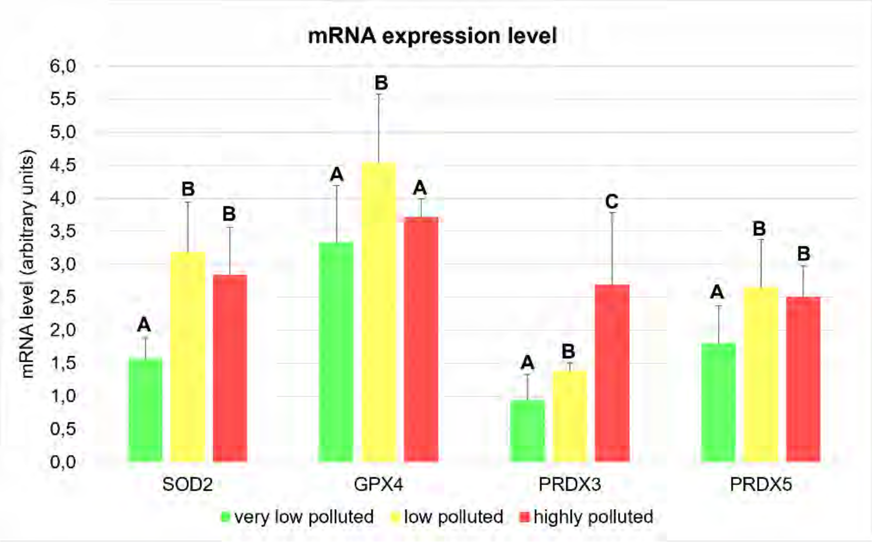


Figure 1 - mRNA accumulation levels of the target antioxidant enzymes. Values are indicated as mean concentrations ± SD. Different letters correspond to significant statistical differences ($p < 0.005$) among different sites.

Afterwards, these data were correlated with two indicators of cellular damage: Lipid Peroxidation (LPO) and Advanced Oxidation Protein Products (AOPP) formation.

Regarding the LPO results, the statistical analysis reported a p-value >0.05, therefore the differences between the sites are not statistically significant. This implies that the cellular damage caused by PFAS toxicity is not detected in lipids, which remain unaltered in the three differently polluted sites.

In relation to the AOPP results, we noticed that, regardless of the extent of contamination of the “low” and “highly polluted” sites, the same oxidation of proteins occurs. We deduced that, as proteins are the major targets of PFAS toxicity, even a smaller quantity of pollutants is sufficient to cause damage to them.

In conclusion, we observe a qualitative response which is reflected in the involvement of different components of the antioxidant system, but also quantitative in relation to different levels of environmental contamination. Exposure to PFAS increases the rate of ROS formation, both of O_2^-, as demonstrated by the increase in *sod2* expression, and of H_2O_2, as demonstrated by the activation of the scavenger enzymes of this ROS (*gpx4, prdx3, prdx5*).

References

WHO Regional Office for Europe (2017). Keeping our water clean: the case of water contamination in the Veneto Region, Italy. https://www.who.int/europe/publications/i/item/9789289052467.

Wielsøe M., Long M., Ghisari M., Bonefeld-Jørgensen E. C. (2015). Perfluoroalkylated substances (PFAS) affect oxidative stress biomarkers in vitro. *Chemosphere*, 129, 239–245.

Piva E., Schumann S., Dotteschini S., Brocca G., Radaelli G., Marion A., Irato P., Bertotto D., Santovito G. (2022). Antioxidant Responses Induced by PFAS Exposure in Freshwater Fish in the Veneto Region. *Antioxidants*, 11(6).

Bonato M., Corrà F., Bellio M., Guidolin L., Tallandini L., Irato P., Santovito G. (2020). PFAS environmental pollution and antioxidant responses: an overview of the impact on human field. *International Journal of Environmental Research and Public Health*, 17(21), 21.

Pacchini S., Piva E., Schumann S., Irato P., Pellegrino D., Santovito G. (2023). An experimental study on antioxidant enzyme gene expression in Trematomus newnesi (Boulenger, 1902) experimentally exposed to Perfluoro-Octanoic acid. *Antioxidants*, 12(2), 2.

Multiple ingestion exposure routes for alkylphenols: an integrated human health risk assessment including drinking water and crops' food

Luca Penserini[1], Beatrice Cantoni[1], Elena Sezenna[1], Sabrina Saponaro[1], Manuela Antonelli[1]

(1) Department of Civil and Environmental Engineering (DICA), Politecnico Milano, manuela.antonelli@polimi.it

The scarcity of clean freshwater is becoming a major issue for present and future generations, especially in densely urbanized areas. The increasing pollution is a potential threat to public health, leading to cross-contamination among interconnected compartments such as freshwater and soil. This cross-contamination could be severe with contaminants of emerging concern (CECs) originating from anthropic activities, which have been globally detected in surface water, groundwater and soils. CECs are not completely removed by wastewater treatments plants and may persist in both surface water and groundwater, used as sources for drinking water. Furthermore, when these water sources, along with reclaimed wastewater, are used for irrigation, CECs can be directly uptaken by crops intended for human consumption or accumulate in soil, eventually translocating to crops over time (Delli Compagni et al., 2020). Hence, both drinking water and edible crops are critical pathways for human exposure to CECs, whose combined effect needs further investigations.

Currently, health risk assessments are limited to single exposure sources without considering the multiple exposure routes to which humans are subjected, even if recent European regulations encourage the application of risk-based approaches aimed at the preventive control of health risk. In addition, the adopted risk assessments are primarily deterministic, offering incomplete insights, especially for CECs. In fact, CECs are characterized by substantial knowledge gaps in their presence, fate and toxicology, which cannot be properly accounted by deterministic approaches. A fully stochastic approach would be recommended, since it would enable to consider the uncertainties inevitably associated to both CEC concentrations measurement and toxicological characterization (Cantoni et al., 2021).

Among CECs, bisphenol A (BPA) and nonylphenol (NP) are of particular interest in this broad perspective, representing one of the major exposure sources for humans. In fact, BPA and NP adversely affect immune and renal systems, respectively, and have been frequently detected in freshwater and drinking water, but also in packaging used for drinking water and food.

In this framework, we proposed an integrated procedure to quantitatively assess health risk from alkylphenols due to the multiple exposure from the consumption of both drinking water and food, considering the relevant inter-connected environmental compartments. In detail, the risk was assessed computing the probabilistic Benchmark Quotient (BQ), considering the uncertainties related to the variability of contaminant concentrations and percentages of censored data. We showed the potential of this approach in quantitatively apportioning the risk between contaminants and sources, making it useful as a tool for supporting monitoring campaign and prioritizing mitigation measures. This work was developed within the Spoke VS4 (WP3 and WP4) of the RETURN project. The detailed work is described in Penserini et al. (2023).

The developed procedure includes several steps. Firstly, the analyzed system boundaries were defined, considering all the compartments involved in the CECs transport from sources to the end-user, as shown in Figure 1a. The investigated exposure route was the oral ingestion, focusing on tap water and food, specifically cereals, fruits and vegetables, as exposure sources. The model for the quantitative chemical risk assessment, proposed by Penserini et al. (2022), was applied to evaluate the multiple exposure to the two contaminants. As for the exposure assessment step, BPA and NP concentration data were retrieved from literature for each compartment. Then, in the hazard assessment step, the toxicological characterization was taken from the literature. Finally, exposure and hazard assessment steps were combined in the risk characterization step, to quantitatively estimate human health risk for BPA and NP, including uncertainty analyses to account for knowledge gaps and provide decision makers with the confidence level of the risk estimation.

Results (see Figure 1b) indicate that, despite the human health risk due to NP is noteworthy, the estimated risk from BPA is significantly higher, with higher risk associated to the consumption of food from edible crops than from tap water. Hence, BPA is undoubtedly a contaminant to be prioritized, especially through mitigation actions aimed at its prevention and removal from food. The uncertainty analysis enabled to properly consider availability and quality of CECs data, especially as regards their physical-chemical behavior and toxicity, providing the degree of confidence for the estimated risk, which is a key factor for informed decisions. Besides, this procedure permits to both (i) provide indications for future monitoring campaigns to better evaluate the CECs fate in different compartments, and (ii) explore intervention strategies to be adopted to reduce the overall risk.

However, further research is needed to identify metabolites and potentially harmful by-products generated in the environment, which might cause different or additional risks. Moreover, it will be beneficial to systematically extend this developed procedure to other CECs to support their prioritization.

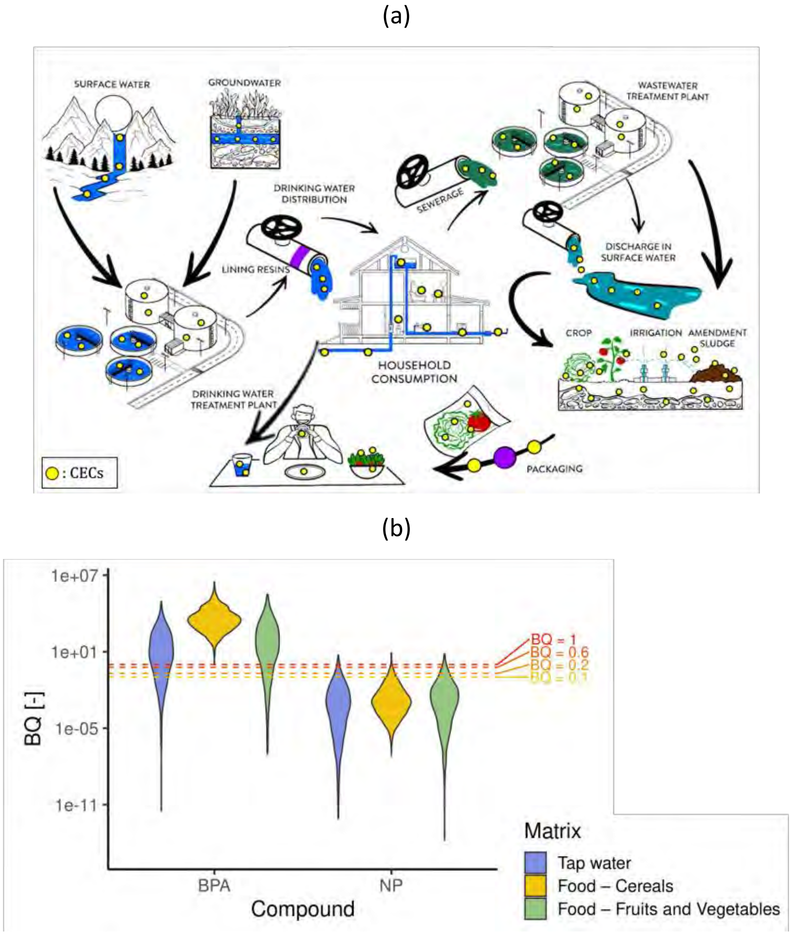


Figure 1 – (a) Conceptual scheme of the investigated system, including the environmental compartments and the exposure sources; (b) Estimated BQ distributions for each exposure source.

References

Cantoni B., Penserini L., Vries D., Dingemans M.M.L., Bokkers B.G.H., Turolla A., et al. (2021). Development of a quantitative chemical risk assessment (QCRA) procedure for contaminants of emerging concern in drinking water supply. *Water Res*., 194, 116911, 1-10

Delli Compagni R., Gabrielli M., Polesel F., Turolla A., Trapp S., Vezzaro L., et al. (2020). Risk assessment of contaminants of emerging concern in the context of wastewater reuse for irrigation: an integrated modelling approach. *Chemosphere*, 242, 125185.

Penserini L., Cantoni B., Vries D., Turolla A., Smeets P.W.M.H., Bokkers B.G.H., et al. (2022). Quantitative chemical risk assessment for mixtures: application to alkylphenol mixtures and phthalate mixtures in tap and bottled water. *Environ. Int.,* 165, 107294, 1-10.

Penserini L., Cantoni B., Gabrielli M., Sezenna E., Saponaro S., Antonelli M. (2023). An integrated human health risk assessment framework for alkylphenols due to drinking water and crops' food consumption. *Chemosphere*, 325, 138259, 1-9.

Consequences and risk modeling of NaTech in industrial environments

Marco Ravina[1], Federico Urbinati[1], Marta Brignone[1], Deborah Panepinto[1]

(1) Department of Environment, Land and Infrastructure Engineering, Turin Polytechnic

This work is conducted within the framework of Task 4.5.5 of the RETURN project. The objective is to harmonize and integrate strategies to improve the quality management of the environmental matrixes in a complex industrial context, characterized by potential impacts on the environment and on human health due to NaTech hazards. In this work, the possible consequences of NaTech events on a complex industrial plant are considered. Particular attention is paid to the risk to the health of workers potentially present in the production plant. The consequences of a NaTech event on possible production processes involving hazardous substances are simulated, assessing the resulting environmental impacts, with particular regard to atmospheric emissions and the related risk to human health. By means of both established and innovative mathematical models, various modes of industrial accidents involving the release of hazardous substances on the ground and into the atmosphere are simulated. To this end, an existing industrial plant is considered as an example case study. A potential damaging event resulting from a NaTech event is applied to this scenario. In order to define the type of triggering event, a literature search has been conducted on the main existing NaTech databases. The results include the representation of the consequences of a NaTech event in terms of risk and environmental indices, with a view to contributing to the development of a possible integrated prevention methodology.

Nanocellulose-based solutions for water treatment

Laura Riva[1], Ilaria Corsi[2], Alessandra Gallo[3], Chiara Battocchio[4], Carlo Punta[1]

(1) Dept. of Chemistry, Materials and Chemical Engineering "G. Natta", Politecnico di Milano, laura2.riva@polimi.it
(2) Dept. of Physical, Earth and Environmental Sciences, University of Siena
(3) Dept. of Biology and Evolution of Marine Organisms, Stazione Zoologica Anton Dohrn
(4) Dept. of Science, Roma Tre University

The growing and urgent demand for water and wastewater decontamination from a wide range of pollutants asks for the development of more effective and safe technologies. In this context, the design of manufactured nanomaterials (MNM) for an efficient water treatment is attracting more and more interest due to their promising adsorption performances. At the same time, MNM also raise concerns due to their potential (eco)toxicity and the uncertainty related to their final fate. For this reason, a safer-by design strategy is recommended in developing new MNM, which should combine a high decontamination efficiency with verified eco-safety (Corsi et al., 2020). A first step in this route consists into the proper choice of starting material for the production of MNM (Corsi et al., 2018). The goal of this work is to show an overview of our recent findings on how nanocellulose, simply derived from biomass as renewable source, can represent a sustainable and eco-safe solution for developing new MNM with high sorption performances for water treatment (Figure 1). 2,2,6,6-Tetramethypiperidinyloxyl (TEMPO)-oxidized cellulose nanofibers (TOCNF), bearing carboxylic groups on the C6 position of some glucopyranose units, have been produced from different sources and their eco-safety has been verified by an *in vivo* acute study with marine mussels *Mytilus galloprovincialis* (Rusconi et al., 2024).

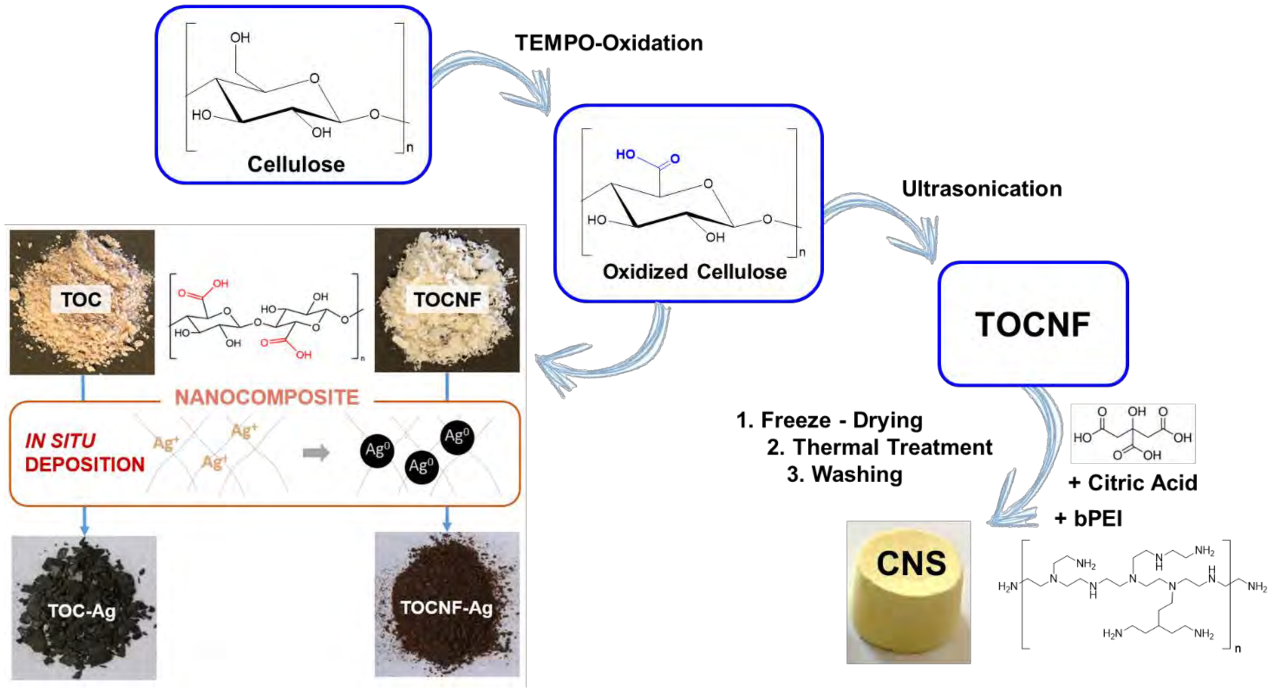


Figure 1 – Design of cellulose-based manufactured nanomaterials.

Cellulose nanofibers have been successfully used as suitable supports for silver nanoparticles, providing nano-composites with enhanced sorption performances towards heavy metals. In our recent study we focused on Cd^{2+} as a model, to study the interaction mechanism between silver-decorated cellulose nanofibers and bivalent metals exploiting advanced spectroscopic and microscopic techniques, including XPS, XAS, EDX and FESEM (Riva et al., 2024).

TOCNF were also used as building blocks for the design of nanostructured cellulose-based materials, obtained by thermal cross-linking with branched polyethylenimine. These systems, which have extremely attractive properties including a high exposed surface area due to their porous network, have proved to be extremely efficient in environmental remediation towards different categories of contaminants. In order to support a non-impacting *in-situ* application in water environment, their eco-safety was demonstrated considering the marine microalga *Dunaliella tertiolecta* and the Mediterranean mussel *Mytilus galloprovincialis* species, toward which no genotoxic effects were observed (Fiorati et al., 2020). Recent studies on the behavior of these porous cellulose-based materials in presence of extremely sensitive marine species, such as sea urchins, allowed us to identify potentially toxic components and to optimize the production process to limit their toxicity. The results obtained underline the importance of the choice of building-block and the eco-design process for materials intended for environmental remediation purposes (Esposito et al., 2023).

All the topics described are investigated within Spoke VS4 of the RETURN project.

References

Corsi I., Fiorati A., Grassi G. (2020). Nanomaterials for the Detection and Removal of Wastewater Pollutants. *Elsevier,* Chapter 14, 383-405.

Corsi I., Fiorati A., Grassi G. (2018). Environmentally Sustainable and Ecosafe Polysaccharide-Based Materials for Water Nano-Treatment: An Eco-Design Study. *Materials*, 11, 1228.

Rusconi T., Riva L., Punta C. (2024). Environmental safety of nanocellulose: an acute *in vivo* study with marine mussels *Mytilus galloprovincialis*. *Environmental Science Nano,* 11, 61-77.

Riva L., Dotti A., Iucci G. (2024). Silver Nanoparticles Supported onto TEMPO-Oxidized Cellulose Nanofibers for Promoting Cd^{2+} Cation Adsorption. *ACS Appl. Nano Mater.*

Fiorati A., Grassi G., Pastori N. (2020). Eco-design of nanostructured cellulose sponges for sea-water decontamination from heavy metal ions. *J. Clean. Prod.,* 246, 119009.

Esposito M. C., Russo G. L., Riva L. (2023). Nanostructured cellulose sponge engineered for marine environmental remediation: Eco-safety assessment of its leachate on sea urchin reproduction (Part A). *Environmental Pollution*, 334, 122169.

Litter distribution in marine and coastal sediments: case studies from Apulia region

Angela Rizzo[1,2], Giuseppe Bonifazi[3], Giuseppe Capobianco[3], Eleonora Gorga[3], Daniela Mele[1], Giovanni Scardino[1,2], Vincenzo De Santis[1,2], Isabella Lapietra[1], Marco La Salandra[1], Stefania Lisco[1,2], Serena Liso[1], Antonella Marsico[1,2], Giuseppe Mastronuzzi[1,2], Mario Parise[1,2], Silvia Serranti[3], Giovanni Scicchitano[1,2], Angelo Sozio[1]

(1) Dept. of Earth and Geo-environmental Sciences, University of Bari Aldo Moro, angela.rizzo@uniba.it
(2) Interdepartmental Research Centre for Coastal Dynamics, University of Bari Aldo Moro
(3) Dept. of Chemical Engineering, Materials and Environment, Sapienza University of Rome

The accumulation of litter (micro and macro items) in different marine and coastal matrices represents a global issue with dangerous effects on ecosystems and human health. This study is aimed at illustrating preliminary results from ongoing activities focused on the assessment of beach litter (BL) items on sandy beaches and microplastic (MPs) in marine sediments from Apulian coastal areas. Standard monitoring techniques used for the BL identification and classification consist of in-situ visual surveys carried out following international guidelines. Although direct surveys allow the assessment of the BL distribution along the investigated site, they are time-consuming and only allow to cover limited coastal stretches. Recently, innovative and multi-disciplinary approaches have attempted to address these limitations. In this context, a growing number of studies are exploiting the use of aero-photogrammetric surveys, coupled with GIS post-processing tools, for the assessment of BL pollution. Unmanned Aerial Systems (UASs) are often used to acquire images that can be used to evaluate the BL items' density and the potential relationships between coastal morphodynamic processes and BL distribution along the beach profile.

In this study, BL distribution is analazyed based on multi-approaches surveys carried out along the Adriatic coast of the Apulian Region. Several aero-photogrammetric flights were carried out to obtain RGB georeferenced orthomosaics on which manual image screening is performed (Phase 1 in Figure 1). Furthermore, morphodynamic analyses were also performed in GIS environment to define the recent shoreline evolution and analyze the potential influence of coastal processes in the accumulation of BL items along the beach profile (Phase 2 in Figure 1). Eventually, a machine learning-based algorithm was also tested to evaluate the accuracy of BL automatic identification.

The visual screening results for the Torre Guaceto beach (Brindisi) showed that artificial polymers/plastic turned out to be the most frequently represented object (up to approximately 80% of the total identified items), followed by glass and textiles. The shoreline evolution analysis highlighted a general retreat trend, with rates up to 1.4 m/yr. The upper limit of the fixed vegetation also resulted to be affected by retreat process, up to 3 m. The integrated analysis of the results allowed to state that the zone between the embryo dune and the foredune limit, gathered the highest density of BL items (Rizzo et al., 2023). This zone is relatively little affected by marine processes and therefore BL items tend to lay for a longer period. In addition, these objects can constitute accretion cores for small embryo dunes which, in turn, will tend to increase the risk of burial for BL items. Eventually, the application of a machine learning-based procedure for the BL litter identification highlighted that, although there is still the need to increase the overall performance, the proposed algorithm proved to be a suitable tool for instance segmentation and classification (Scarrica et al., 2022; Sozio et., 2023). Further exploitation of this innovative approach will be aimed at developing an effective coastal monitoring system to be used for the tailored management of coastal sites.

An innovative approach based on a ground hyperspectral sensor for macroplastic litter monitoring (Phase 3 in Figure 1) on coastal sediments was also tested at Torre Guaceto beach (Brindisi) (Bonifazi et al., 2023a).

The results demonstrated as hyperspectral imaging (HSI) working in the near infrared range (NIR: 1000-1700 nm) combined with machine learning can be a valid tool for in situ recognition of polymers constituting marine plastic litter, which is fundamental to identify pollution sources and to support the implementation of mitigation measures.

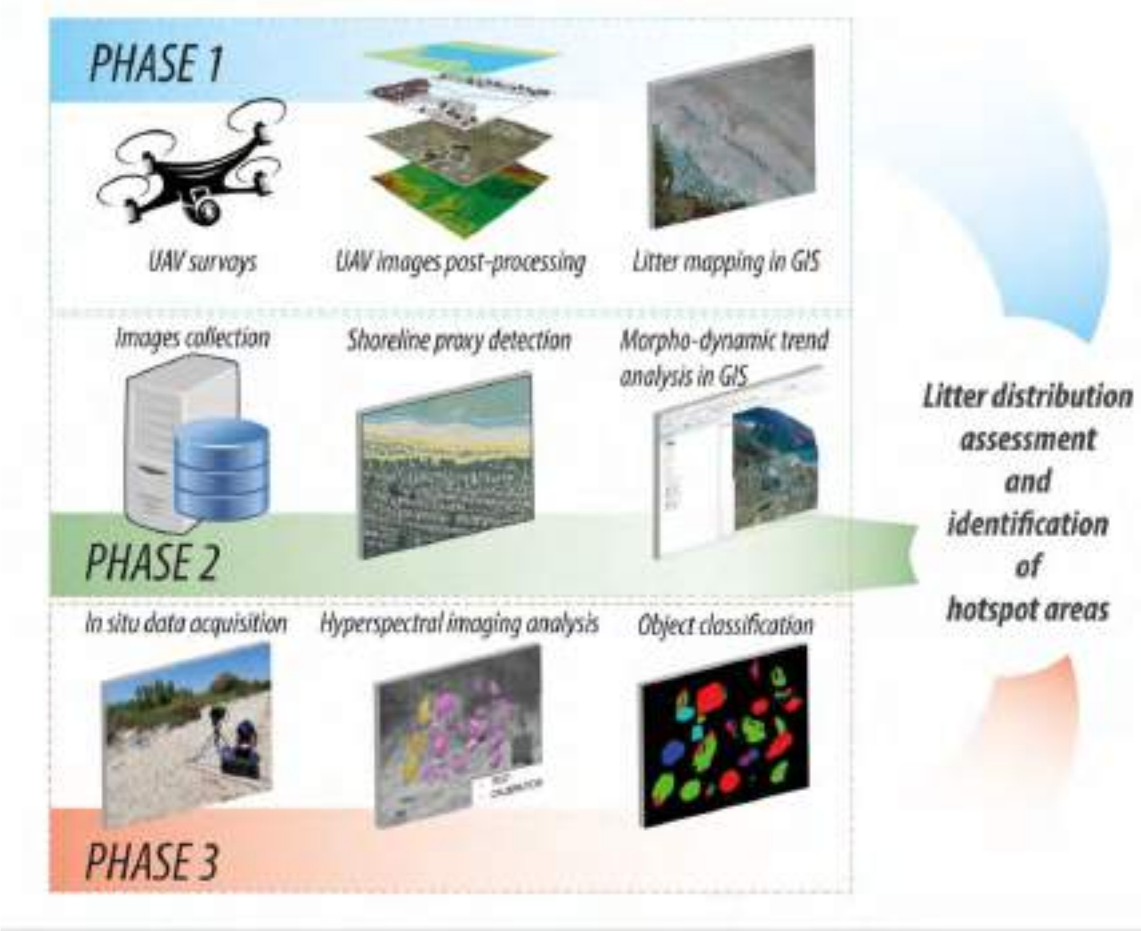


Figure 1 – Schematization of the methodological approaches applied for the BL identification, classification, and distribution along the investigated coastal sector.

Regarding MPs analysis in marine and coastal sediments, samples were collected in both emerged (Torre Guaceto - Brindisi) and submerged (Gulf of Taranto and Bari) environments. Collected samples were then analyzed in the laboratory to carry out particle size analysis and, in some cases, micro-Fourier-Transform Infrared spectroscopy and micro-RAMAN analysis (Cofano et al., 2023). Preliminary results showed that a large amount of MPs in the sea-bottom originates from textile fibers. Ongoing activities are focused on the application of emerging procedures based on the application at lab-scale of HSI technology working in the SWIR range (1000-2500 nm) (Bonifazi et al., 2023b), building classification models able to identify MPs directly on the collected marine (Mar piccolo basin, Taranto) and coastal sediment (Torre Guaceto, Brindisi) samples, in order develop a fast and effective automatic recognition strategy.

Further activities will be aimed at integrating available datasets to provide a set of guidelines for the effective characterization of marine and coastal areas contaminated by artificial polymers/plastics and to contribute to the overall coastal sustainable protection offering useful tools for the identification of the most vulnerable zones requiring priority management actions.

References

Bonifazi G., Capobianco G., Cocozza P., Mastronuzzi G., Rizzo A., Serranti S. (2023a). Identification of plastic debris on beaches by ground-based hyperspectral imaging. In: *Book of abstracts from International conference ECDS 2023: Emerging Concepts & Design For Sustainability, Villers-sur-Mer, Calvados, France (8-11 October 2023)*, 73-74.

Bonifazi G., Capobianco G., Serranti S. (2023b). Fast and effective classification of plastic waste by pushbroom hyperspectral sensor coupled with hierarchical modelling and variable selection. *Resources, Conservation and Recycling,* 197, 107068.

Cofano V., Mele D., Lacalamita M., Di Leo P., Scardino G., Bravo B., et al. (2023). Microplastics in inland and offshore sediments in the Apulo-Lucanian region (Southern Italy). *Marine Pollution Bulletin*, 197, 115775.

Rizzo A., Sozio A., Anfuso G., La Salandra M. (2023). The use of UAV images to assess preliminary relationships between spatial litter distribution and beach morphodynamic trends: the case study of Torre Guaceto beach (Apulia Region, Southern Italy). *Geografia Fisica e Dinamica Quaternaria*, 45, 237–250

Scarrica V.M., Aucelli P.P., Cagnazzo C., Casolaro A., Fiore P., La Salandra M., et al. (2022). A novel beach litter analysis system based on UAV images and Convolutional Neural Networks. *Ecological Informatics*, *72*, 101875.

Sozio A., Scarrica V.M., Aucelli P.P., Scicchitano G., Staiano A., Rizzo A. (2023). Comparing Meanshift/SVM and Mask-RCNN algorithms for beach litter detection on UAVs images. In: *2023 IEEE International Workshop on Metrology for the Sea; Learning to Measure Sea Health Parameters (MetroSea)*, 483-487.

Impact of biodegradable and unbiodegradable microplastics on soil quality and ecotoxicity

Giorgia Santini[1], L. Santorufo[1], G. Maisto[1]

(1) Dipartimento di Biologia, Complesso Universitario di monte Sant'Angelo, Università degli studi di Napoli Federico II, giorgia.santini@unina.it

Microplastics (MPs) represent emergent pollutants in terrestrial ecosystems and exert impacts on soil properties, affecting key soil ecological functions. In agroecosystems, plastic mulching is one of the main sources of plastic residues in soils. The research aimed to evaluate the effects of two types (biodegradable: B-MPs; un-biodegradable: NB-MPs) of MPs, from plastic mulching, at different concentrations (0.5, 1 and 2% d.w.) on soil quality and phytotoxicity. To achieve the aims, mesocosm trials were set up using 35 pots where MPs and soil were mixed and spinach were grown. The soils were analyzed for pH, concentrations of organic C, total C and N, DNA yield, microbial respiration (Resp) and activities of hydrolase (HA), dehydrogenase (DHA), β-glucosidase (β-glu) and urease (U). The abundances of eubacterial (16S rDNA) and fungal (18S rDNA) DNA were quantified by qPCR. To assess the overall quality of the soil, an integrated soil quality index (SQI) was calculated. The phytotoxicological assays were performed using Sorghum saccharatum L. and Lepidium sativum L. as test organisms and performed on soil mixed with MPs. The results inherent to the abiotic properties of the differently exposed soils showed that C was statistically higher in soils exposed to B-MPs than in the control in contrast to the other properties, which showed no statistically significant variations. The biotic properties in particular Resp and eubacterial abundance were significantly lower as the treatment concentration increased while β-glu had a completely opposite trend showing a significant increase as the treatment increased. Phytotoxicity through L. sativum L. is significantly decreased for all treatments compared to the control; while that through S. saccharatum L. is significantly increased for all treatments. Overall, no statistically significant differences were found in the SQI between treatments (C, NB-MPs and B-MPs). In conclusion, B-MPs seem to have the greatest influence on the biological properties of the soil, in particular on the microbial community and related activities, although there is no significant evidence on the overall quality of soils.

Sustainability of contaminated sites remediation: benchmarking in the international contest

Petra Scanferla[1], Silvia Anna Frisario[2], Silvia Breda[1], Giulia Meneghin[1], Rachele Ciacciarelli[2]

(1) Fondazione Università Ca’ Foscari, petra.scanferla@unive.it
(2) Eni Rewind spa

The European Commission has identified soil as a priority in terms of vision towards zero pollution by 2050 (EC, 2021a) and has published the EU Soil Strategy which promotes sustainable management and moves towards a sustainability assessment of redevelopment and remediation (EC, 2021b). Therefore, the activities of reclamation and recovery of degraded areas are inserted as opportunities for urban and industrial regeneration and need to be evaluated in terms of sustainability starting from *ISO 18504:2017 -Soil quality-Sustainable Remediation*, which collects and systematizes what has been elaborated by more than twenty years of applied research in this field. The recovery and regeneration of contaminated sites, brownfield and mining sites represents a significant challenge for its environmental, social and economic impacts and, therefore, the associated decision-making process still strives to find sustainable solution. In the last decade, several guidelines, procedures and tools have been developed at both national and international level to enhance the principles of sustainability within the decision-making process and implement what has been defined as "Sustainable Remediation", namely "The process of management and remediation of a contaminated site, aimed at identifying the best solution, which maximizes the benefits of its implementation from an environmental, economic and social point of view, through a decision-making process shared with stakeholders".

In order to define a framework to assess the sustainability of the remediation, which is one of the topics investigated within Spoke VS4 , WP5 – “Prevention and remediation” of the RETURN project, a preliminary study has been developed to describe the Italian and the international contexts regarding the regulatory and technical approach to manage the contaminated areas. This study has shown that in many countries, sustainability evaluation instruments (guidelines, assessment frameworks, tools) for reclamation projects are available in all countries analyzed (Italy-IT, France-FR, Germany-D, UK, Netherlands-NL, Denmark, Sweden, Norway Finland and USA).

Many countries (FR, D, UK, NL, DK, S, N) have a regulatory which included sustainability assessment of the projects at an advanced level using tools that consider all aspects of sustainability (environmental, social, economic), other countries, such as FIN and USA, required the application of sustainability criteria as optional or at a qualitative level (qualitative indicators).

The Italian regulatory framework stands out for the absence of national statutory procedures for the analysis of environmental, social and economic sustainability of reclamation projects. In Italy, the voluntary and effective application, by “problem owners” of the ISO 18504:2017 for selecting the most sustainable remediation strategy may represent a significant element to promote the regulatory evolution and the acceleration of the remediation in our country.

References

EC (2021a). Pathway to a Healthy Planet for All - EU Action Plan: “Towards Zero Pollution for Air, Water and Soil”. EC COM(2021) 400 final.

EC (2021b). EU Soil Strategy for 2030 - Reaping the benefits of healthy soils for people, food, nature and climate. COM(2021) 699 final.

Plastic leachate impact in aquatic environment

Simona Schiavo [1], Sara Accardo [1,2], Maria Rita Montereali [3], Laura Caiazzo [3], Sonia Manzo[1]

(1) ENEA CR PORTICI, simona.schiavo@enea.it
(2) Department of Science and Technology, Parthenope University of Naples
(3) ENEA CR CASACCIA

The widespread of environmental pollution from chemicals of diverse sources poses a significant threat to both human well-being and ecosystems. The adverse effects caused by such a pollution are not only related to the episodic exposure to single chemicals, but rather to simultaneous and prolonged exposure to many diverse chemicals.

More attention is paid to plastics, an emerging contaminant, that represent potential physical and chemical threats since their impact is linked not only to mechanical injuries but also to the leaching of chemicals. In particular, the use of plastics and poor waste management have led a global concern due to their wide dispersion in water environments.

Bioplastics are promoted as an alternative to conventional petroleum-based nonbiodegradable plastics. However, whether biodegradable plastics are successfully tackling the problem is questionable as laboratory and field studies showed contrasting outcomes. Today, it remains unclear whether biodegradable formulations are advantageous to reduce plastic impact compared to conventional polymers. Bioplastics and plant-based materials are marketed as sustainable alternatives to conventional plastics. However, little is known with regard to the chemicals they contain and the safety of these compounds.

Given the continuous rise in global production and consumption of plastic products, coupled with their enduring presence in the environment, there is a heightened concern regarding the influence of plastic materials on natural habitats. From this perspective, the overarching goal of this research was to comprehensively assess the ecotoxic effects induced by polymeric materials and in particular of the chemicals released, across different environmental context. To this aim, the evaluation of the ecotoxicological impacts of plastic polymer leachates with diverse chemical compositions and properties: polyethylene, polypropylene, polystyrene, polylactic acid) were assessed. This was achieved through a multidisciplinary approach that integrates chemical analysis and ecotoxicity tests. Leachate were obtained according to Italian and European Standard procedure (EN 12457-2 2002). Chemical characterization of the plastic leachates, focusing on metal and organic content, was conducted using ICP-MS and GC-MS analytical techniques. Ecotoxicological assays were performed with diverse model organisms belonging to saline or freshwater environments (*V. fischeri* bioluminescence inhibition test), Cladocera (*D. magna* acute immobilization test and chronic reproduction test) and plants (phytotoxicity with *Sinapis alba, Sorghum saccharatum, and Lepidium sativum* and *Vicia faba* chronic test), for freshwater matrix, and zooplankton (*Artemia salina* acute and chronic test) and marine microalgae (*Dunaliella tertiolecta* growth inhibition oxidative stress, and DNA damage) for seawater matrix. All results were integrated into a synthetic index by TBI procedure (as reported in Manzo et al., 2008).

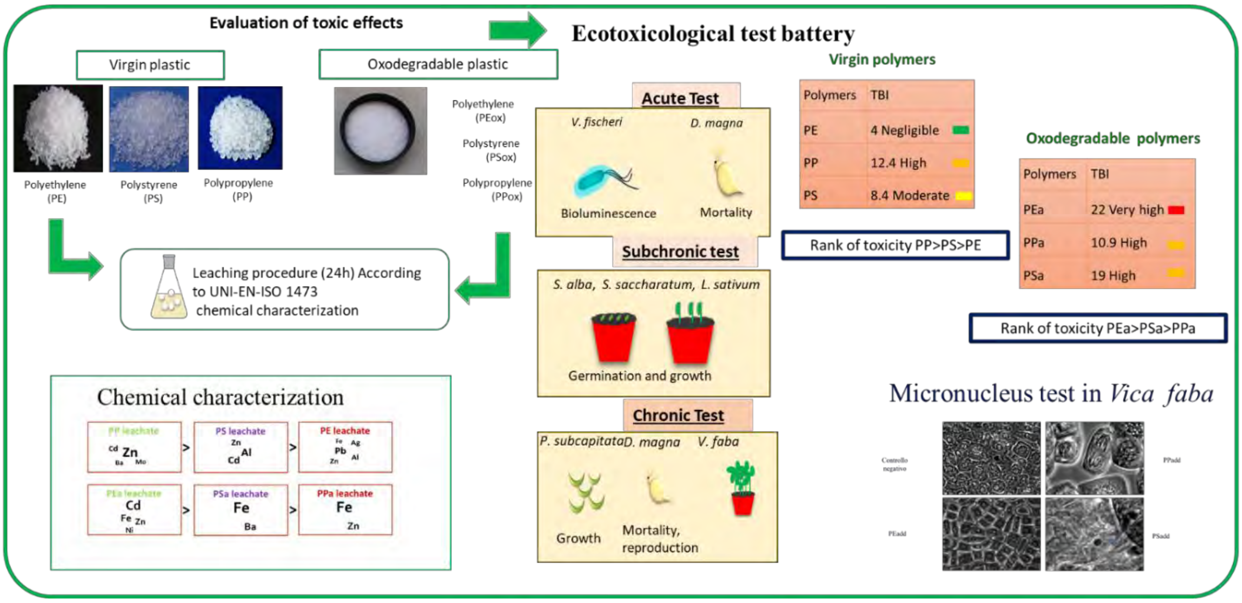


Figure 2 - Experimental design of ecotoxicological and chemical assessment.

This study demonstrated that virgin plastic pellets could be responsible of serious toxicological effects. Polypropylene toxicity could be related to solvents (methanol, oil, cyclohexane) used in its production, whereas Polystyrene toxicity was probably due to the depolymerization, occurring in water, followed by styrene release, while the mild toxic effects of Polyethylene, and its temporary biostimulation, could be attributable to the thermoregulatory additives present in the polyethylene resins. The results of cyto-geno endpoint highlighted that the presence of reactive oxygen species and DNA damages could be related to genotoxic effects, found only for PP., from Transition, post transition and alkaline earth metals, metalloids, and non-metals in all leachates were found to be comprised from 0.5 to 83.5 µg/L. Therefore, the observed toxic action might reasonably be attributable to the synergic presence of metals and polymer specific chemicals. Regarding the oxo-degradable polymers, their adverse effects appear to be mainly ascribable to a high metals content, since no other chemical difference was evidenced. Moreover, the oxo-degradable additive seems to share the onus of the observed ecotoxicological effect with other leachable component of the plastic polymers. Additional observations are ongoing upon effects linked to PLA exposure.

Nanoremediation of contaminated aquifers

Rajandrea Sethi[1], Carlo Bianco[1], Tiziana Tosco[1], Alessandro Casasso[1], Monica Granetto[1]

(1) Department of Environmental Engineering (DIATI), Politecnico di Torino, rajandrea.sethi@polito.it

Groundwater contamination is a pervasive problem, posing significant risks to human health and ecosystems. In this context, nZVI particles have emerged as a potent solution, offering unprecedented opportunities for in situ groundwater remediation (Figure 1, Sethi et al. 2019; Tosco et al. 2014). Their efficacy is attributed to their nanoscale size, which endows them with a high surface area-to-volume ratio, enhancing their reactivity with a range of contaminants. This quality makes nZVI particles particularly effective in reducing contaminants through both chemical reduction and also sorption processes. The unique reactivity of these nanoparticles is further augmented by their ability to be injected in aqueous slurries directly into contaminated aquifers, thus enabling targeted source treatment and plume remediation.

The synthesis and characteristics of nZVI are central to understanding their reactivity and application. The particles are typically synthesized to have a core of zerovalent iron, enveloped by an oxide layer. This configuration is crucial as the oxide layer evolves over time, influencing the longevity and reactivity of the particles. The surface passivation or the sufidation of the particles are critical factors in determining the efficacy of the remediation process and the longevity of the reagents.

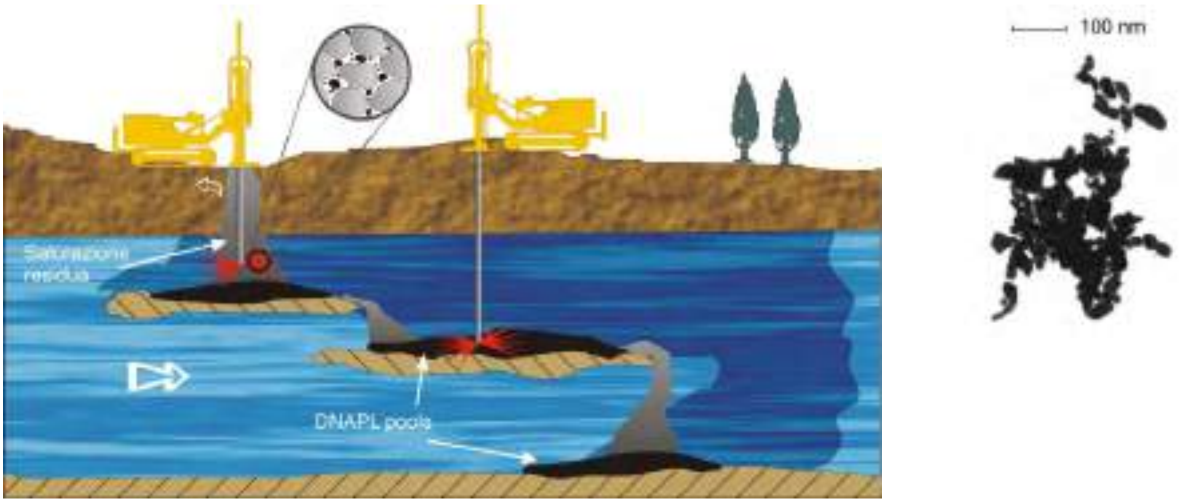


Figure 1 – In-situ injection and electron micrograph of zerovalent iron nanoparticles.

Despite the advantages, the application of nZVI in groundwater nanoremediation presents challenges, particularly in terms of colloidal stability and mobility within subsurface environments. The stability of nZVI against aggregation is essential to maintain its high reactivity and ensure effective transport through porous media. Advances in surface modification techniques, including the use of biopolymers, were studied at Politecnico of Torino and its spin-off Delta Nova showing promise in enhancing both stability and mobility. A recent patent developed by the Groundwater Engineering Group allows a controlled distribution and deposition of the particles in order to generate controlled reactive zones in groundwater bodies.

The complex interactions involved in the transport of nZVI in porous media, such as physical filtration, straining, and physico-chemical interactions, necessitate a comprehensive understanding to optimize in situ application. Modeling the transport and fate of nZVI particles in subsurface environments is another critical aspect of this research. Various models, including modified advection-dispersion equations and sophisticated simulation tools like MNM1D/3D (Bianco et al. 2016) was developed by our group to predict the behavior of nZVI in porous media. These models incorporate factors such as porosity, permeability, and fluid viscosity, which are essential in designing effective remediation strategies (Figure 2, Bianco et al. 2023).

In conclusion, nZVI particles represent a frontier in nanoremediation, offering a powerful tool for groundwater treatment. Their unique properties, coupled with ongoing advancements in stability, mobility, and field application techniques, hold the promise of improving environmental remediation practices.

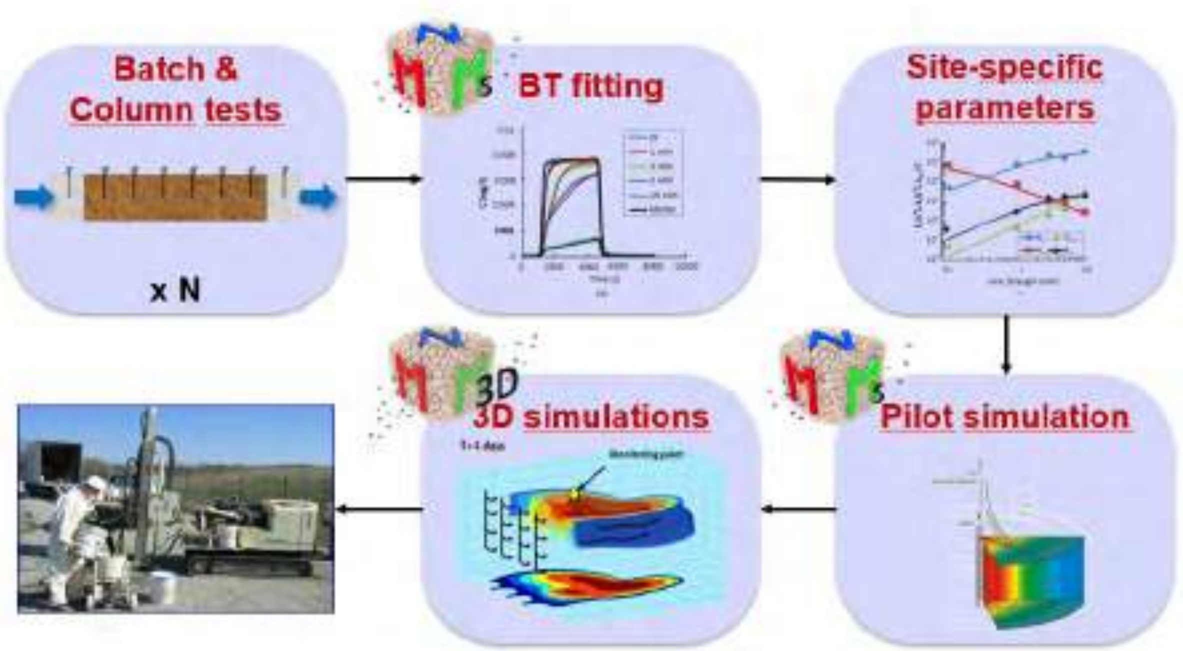


Figure 2 – Model assisted design of a remediation intervention by nZVI nanoremediation.

References

Sethi R., Di Molfetta A. (2019). Groundwater Engineering. A technical approach to hydrogeology, contaminant transport and groundwater remediation. *Springer Tracts in Civil Engineering*.

Tosco T., Petrangeli Papini M., Cruz Viggi C., Sethi R. (2014). Nanoscale zerovalent iron particles for groundwater remediation: a review. *J. Clean. Production*.

Bianco C., Mondino F., Casasso A. (2023). Improved delivery of nanoscale zero-valent iron particles and simplified design tools for effective aquifer nanoremediation. *Water*.

Bianco C., Tosco T., Sethi R. (2016). A 3-dimensional micro-and nanoparticle transport and filtration model (MNM3D) applied to the migration of carbon-based nanomaterials in porous media. *Journal of Contaminant Hydrology.*

Bio-electrochemical remediation of soil polluted by 2,4-dichlorophenoxyacetic acid

Annalisa Vacca[1], Michele Mascia[1], Laura Mais[1]

(1) Dept. of Mechanical, Chemical and Materials Engineering, University of Cagliari, annalisa.vacca@unica.it

Microbial fuel cells (MFCs) have been proposed as energy saving bioremediation technique, thanks to many advantages including eco-friendly, cheap, and easy operation and sustainability (Abourached et al., 2014). The application of this technique in soil remediation (SMFCs) has been used for the removal of both organic compounds and heavy metals from polluted soils (Abbas et al., 2021). Usually, the SMFC is a membrane less MFC in which the anaerobic anode is buried in the soil and connected via external circuit to cathode suspended in the overlying water (Gustave et al., 2019). In the buried anodic soil, organic matter is oxidized by microorganisms (usually electrogens) along with power generation (Li et al., 2017). The electrons generated from the oxidation are transferred through the external circuit to the cathode for the reduction of an electron acceptor (usually O2) (Chakraborty et al., 2020). Finally, the electrons continuously flow from the anode to the cathode through external circuit and produce electricity.

In this work SMFCs test have been performed using the herbicide 2,4-dichlorophenoxyacetic acid (2,4D) as model pollutant. The experimental set-up is reported in figure 1 a. The frequency of consumption and feeding cycle in the SMFC operating under fed-batch conditions has been assessed with growth curves and polarization/Power curves (Figure 1 b); the organic substrate adopted during the tests was sodium acetate. In the remediation tests, fixed amounts of soil were polluted with different concentrations of 2,4D. The remediation was assessed measuring the residual concentration of herbicide at fixed time. Samples of soil were withdrawn from the SMFCs in different reaction zones; namely near the bioanode, near the biocathode and in the middle. The herbicide was extracted by Soxhlet method using acetonitrile and was quantified by HPLC measurements. As a comparison, also the natural degradation of the herbicide was studied. The removal of 2,4D measured in different zones of the cell are reported in figure 1 c after 3 weeks.

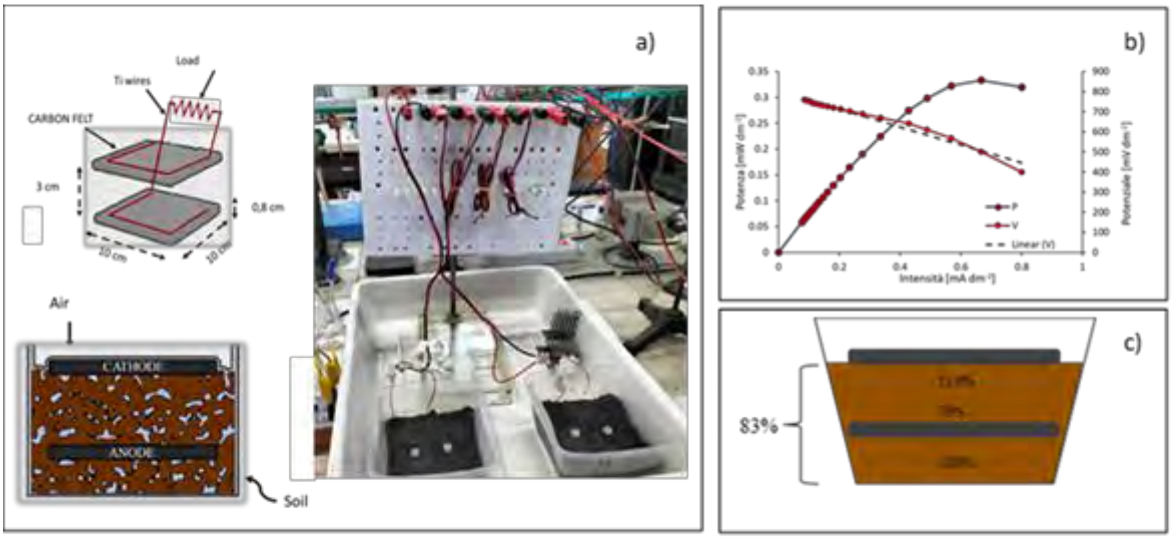


Figure 1 – a) Experimental set-up; b) polarization and power curves of SMFCs; c) percentages of removal of 2,4D in the cell.

A mathematical model of the SMFCs was implemented considering the chemical, physical and biological phenomena involved in the remediation. The parametrization of the model is ongoing based of the experimental data of removal of herbicide measured during the first set of tests with SMFCs.

References

Abourached C., Catal T., Liu H., (2014). Efficacy of single-chamber microbial fuel cells for removal of cadmium and zinc with simultaneous electricity production. *Water Res*., 51, 228-233.

Abbas S.Z., Rafatullah M., (2021). Recent advances in soil microbial fuel cells for soil contaminants remediation. *Chemosphere,* 272, 129691.

Gustave W., Yuan Z.F., Sekar R., Ren Y.X., Liu J.Y., Zhang J., et al. (2019). Soil organic matter amount determines the behavior of iron and arsenic in paddy soil with microbial fuel cells. *Chemosphere,* 237, 124459.

Li X., Wang X., Weng L., Zhou Q., Li Y. (2017). Microbial fuel cells for organic contaminated soil remedial applications: a review. *Energy Technol.,* 5, 1156-1164.

Chakraborty I., Sathe S.M., Khuman C.N., Ghangrekar M.M. (2020). Bioelectrochemically powered remediation of xenobiotic compounds and heavy metal toxicity using microbial fuel cell and microbial electrolysis cell. *Mater. Sci. Energy Technol.,* 3, 104-115.

Assessing spread and distribution of antimicrobial resistance and potential pathogenic bacteria in the Gulf of Trieste: a combined metagenomic approach

Gianpaolo Zampicinini[1]*, Viviana Fonti*[1]

(1) Division of Oceanography, National Institute of Oceanography and Applied Geophysics - OGS, gzampicini@ogs.it

Among emerging contaminants in the marine environment, microbial pollutants such as pathogenic bacteria and gens conferring antibiotic resistance (antibiotic resistance genes, ARGs) are increasingly recognized as a potential threat. Due to the increasing anthropogenic pressure and to their direct connection to the land, marine coastal environments have the potential of disseminating and promoting the establishment of ARGs and opportunistic pathogens in the aquatic microbial communities, with the cascade effects of promoting the spread of antimicrobial resistance (AMR), and exposing millions of people to health risks (e.g. through food and recreational activities).

The present study, in the context of Spoke VS4 (Environmental Degradation) of the PNRR-RETURN project, aims to assess presence, prevalence and distribution of microbial pollutants in the Gulf of Trieste (GoT) using high throughput sequencing (HTS) of bulk DNA extracted from the whole marine microbial community. To this end, sediment, and surface and bottom water samples are being collected every two months over one year at seven locations in the GoT: the Isonzo river mouth, the port of Monfalcone, the long-term sampling station LTER-C1 near the Miramare Marine Protected Area, the port of Trieste, the Barcola shore, the area affected by the discharge of Trieste-s urban wastewater treatment plant, and a location offshore of Trieste (Figure 1).

Taxonomic characterization of the samples' prokaryotic communities will be performed by high throughput sequencing of the 16S rDNA marker gene (metabarcoding) using the Oxford Nanopore platform. Long read metabarcoding allows sequencing the whole 16S gene (1500 bp), providing improved taxonomic resolution and pathogen detection compared to short-read metabarcoding, limited to targeting specific marker regions. Nanopore sequencing also allows real time data output, enabling rapid characterization of a community, although with a lower sequence accuracy and taxonomic resolution.

ARGs detection will be performed after high throughput sequencing of samples' whole community DNA ("shotgun" sequencing) using the Illumina platform. ARGs can be searched: 1) directly in the short reads obtained from sequencing, or 2) after assembling the reads into metagenomes or scaffolds. Assembly from short reads is computationally intensive, requiring in most cases high performance computing (HPC clusters). Both methods will be used, since they allow detection of different ARG classes. Bioinformatic pipelines for ARG screening include reference based methods (AMRFinderPlus, RGI, Abricate), well suited at identifying known ARGs, and deep learning (DeepARG, fARGene) or structural homology modeling (PCM) approaches, that can potentially identify unknown ARG candidates. With the exception of PCM, all pipelines for post-assembly screening are included in funcscan (https://nf-co.re/funcscan/1.1.4), a portable, integrated pipeline built with the Nextflow scripting language that manages the different tools and their environments, packaged in Docker or Singularity images. The pipeline is deployed on the Galileo 100 HPC cluster (CINECA). Metagenome assemblies will be generated with SPAdes (https://github.com/ablab/spades); to minimize workflow dependent biases all datasets will be assembled using the same tool and parameters.

Association of ARGs with plasmids and insertion sequences will be assessed, since they allow ARGs to be transferred to other bacteria.

The results of this study will be also investigated considering the environmental variables (such as the fluxes of organic materials and their terrigenous origins) and the Gulf circulation, with the final scope of improving our understanding of the ecological processes involved in the spread and distribution of microbial pollution in coastal marine environments.

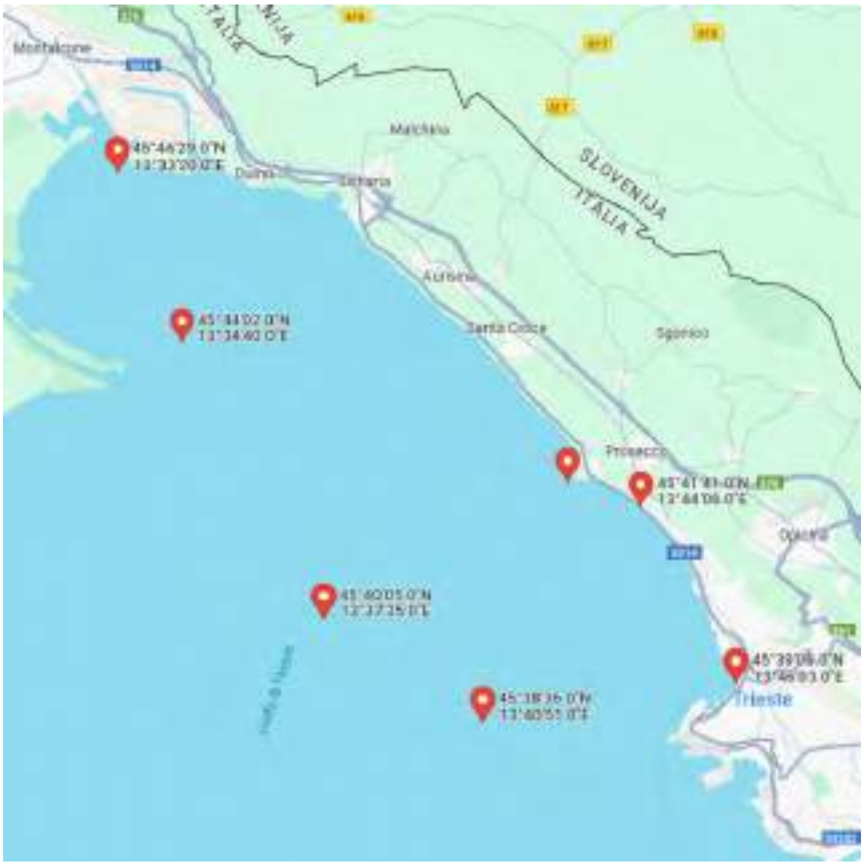


Figure 1 - Sampling locations in the gulf of Trieste.

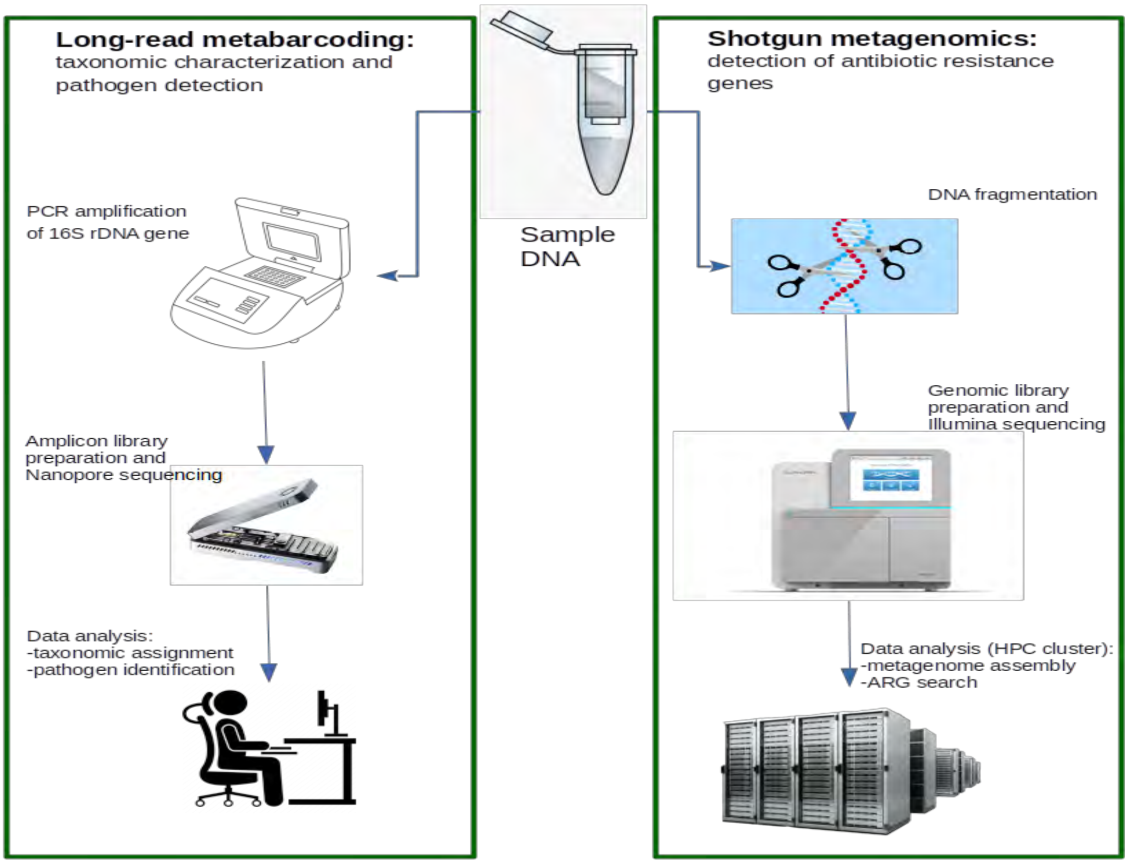


Figure 2 – Sample analysis workflow; left panel: taxonomic characterization and pathogens detection; right panel: antibiotic resistance genes screening.

References

Bengtsson-Palme J., Abramova A., Berendonk T. U., et al. (2023). Towards monitoring of antimicrobial resistance in the environment: For what reasons, how to implement it, and what are the data needs? *Environment International*, 178, 108089.

Ewels P., Peltzer A., Fillinger S., et al. (2020). The nf-core framework for community-curated bioinformatics pipelines. *Nat Biotechnol.*, 38:276–278.

Hatosy SM, Martiny A.C. (2015). The ocean as a global reservoir of antibiotic resistance genes. *Appl Environ Microbiol*, 81, 7593–7599.

Han, R., Qi, J., Xue, Y., et al. (2023). HycDemux: a hybrid unsupervised approach for accurate barcoded sample demultiplexing in nanopore sequencing. *Genome Biol*, 24, 222.

Ruppé E., Ghozlane A., Tap J., et al. (2018) Prediction of the intestinal resistome by a novel 3D-based method. *Nature Microbiol.*, 4, 112-123.

Spoke TS1: Urban and metropolitan settlements

Retrofitting through the loss-based earthquake engineering approach

Gianni Bartoli[1]*, Federico Gusella*[1]

(1) Dept. of Civil and Environmental Engineering of Florence, University of Florence, gianni.bartoli@unifi.it

The economic impacts, due to damage and disruption of recent earthquakes suggested a conceptual way of designing to mitigate their effects. This approach is the Performance-Based Earthquake Engineering (PBEE) (Priestley et al. 1997), that is integrated in the seismic guidelines, which relates required building performance to several seismic hazard levels. The necessity to integrate the monetary loss and downtime into the PBEE of structures characterizes the Loss-Design Earthquake Engineering (LDEE) (Cornell et al. 2020). This improvement in the design approach is strictly connected to the society's needs for informed decision making in the face of seismic demand. The evaluation of the cost and benefit of seismic protection is not only a very interesting and challenging problem from a scientific point of view, but it can also have a very large economic impact. This design approach depends on both the owner's desire for sound judgment on the costs and benefits of seismic protection and on the society's needs for informed decision making when facing the seismic effects and the uncertainty of earthquake resistant capacity of structures. Moreover, the new design procedure must be combined with a logical explanation of the rules of the approach to practitioners (Krawinkler et al. 2004). Performance assessment implies that the consequences (e.g. expected annual loss) for the structural, non-structural, and content systems are computed and compared to specified performance targets (Calvi et al. 2021).

The goal of the research is to provide recommendations to designers for the assessment of the effective capacity of retrofitting interventions to reduce the seismic risk of buildings. The proposed design procedure consists of (a) specifying performance targets (e.g. acceptable dollar losses, capital to invest, reduction of expected annual loss) and associated seismic hazard, and (b) deriving engineering parameters and in particular, the target fragility curves, related to those damages with the greater impact on the expected annual loss. The identification of the target fragility curves in turn allows to identify proper retrofitting interventions to reduce the seismic risk. With the goal of promoting the design procedure in the common practice, closed-form equations are developed, and a case-study is investigated.

References

Calvi, GM., O'Reilly GJ., Andreotti G. (2021). Towards a practical loss-based design approach and procedure, Earthquake Engng Struct Dyn. 50:3741‑3753.

Cornell CA., Krawinkler H. (2000). Progress and challenges in seismic performance assessment. PEER Center News. 3(2), 1-2.

Priestley MJN., Kowalsky MJ. (2000). Direct displacement-based design of concrete buildings. *Bull. N. Z. Soc. Earthq. Eng.*, 33(4), 421-444.

Krawinkler, H., Miranda E. (2004). Performance-Based Earthquake Engineering. In: Bozorgnia, Y., and Bertero, V.V. (eds.), Earthquake Engineering: From Engineering Seismology to Performance-Based Engineering. Boca Raton, FL: CRC Press.

Identification, analysis and evaluation of building risk

Roberto Castelluccio, Lorenzo Diana, Mariacarla Fraiese, Rossella Marmo, Veronica Vitiello

(1) Department of Civil, Building and Environmental Engineering, University of Naples Federico II, roberto.castelluccio@unina.it

The risk management process includes risk identification, analysis, and evaluation. In urban systems, buildings are certainly vulnerable assets and exposed to exogenous risks, but they can become hazards when, in relation to their vulnerability, they affect people's safety, cause inefficiencies, increase downtime and huge economic losses. Therefore, it is important to manage the risks arising from the vulnerability of buildings in order to mitigate the impacts on the community of geophysical, hydrological, meteorological and environmental events. The authors proposed the definition of a *Building Risk*, which is the probability that a hazardous event, caused by the vulnerability of the technical elements of the envelope, will cause damage to the urban system. That said, the *Building Risk* fits perfectly into the multi-risk analysis of urban systems. The authors aim to define a method and a tool for the management of the risks associated with the technical elements of the building envelope, having recognized that these elements are vulnerable to events, even of low intensity and high frequency, which are common in urban and metropolitan contexts (Castelluccio et al., 2022). For example, extreme weather events or low-intensity earthquakes that do not impact structural elements can cause damage to architectural and plant elements with unacceptable consequences also for urban safety (DPC, 2009). The authors' goal requires, first of all, the identification of the causes and the description of potential hazardous events; the analysis of the probability of occurrence of such hazardous events and the determination of the damages associated to them; the assessment of risk thresholds and risk prevention or mitigation mechanisms. First, the authors identified the technical elements of the envelope that are most vulnerable to the set of environmental risks considered by the Return project, and then introduced a classification system of the same technical elements that takes into account the parameters that characterize the propensity to suffer damage (i.e. their vulnerability) in the face of certain exogenous events (geophysical, hydrological, meteorological, environmental, etc.). The introduction of Technological Unit Classes in the "Return taxonomy" represents an expansion of the well-known GED4ALL (Silva et al., 2022) which considers the vulnerability of the technical elements of the envelope and the related hazard on the urban areas of reference. The authors then analyzed the consequences associated with damage to the technical elements of the enclosure, including economic losses, service disruptions, and threats to human safety (NIST, 2012). For the third category, which is of particular interest because it relates to the safety and protection of life, two measures of damage have been proposed, such as obstruction of escape routes and injuries to people. The synoptic framework for characterizing the vulnerability of the elements to different events is currently being developed (Figure 1), based on constructive characteristics, materials, shape, and degradation. It is possible, indeed, to determine the characteristics of the technical elements that determine their lower vulnerability to different exogenous and hazardous events. From the relationship between the different construction types and the hazardous scenarios, it will therefore be possible to derive design rules that take into account the particular environmental exposures and the risk scenarios connected to them. For example, if an urban area is particularly subject to strong winds, the design choices must direct the designer of the recovery or new construction intervention towards the proposal of materials and construction elements that are not very vulnerable to the erosive action, the sail effect and the drag action. The characterization of the multi-hazard vulnerability matrix, constructed by means of comparisons, will allow local administrations to manage the *Building Risk* through urban planning and building policies aimed at increasing urban safety and functionality through the reduction of exposure and vulnerability of the technical elements of the building envelope.

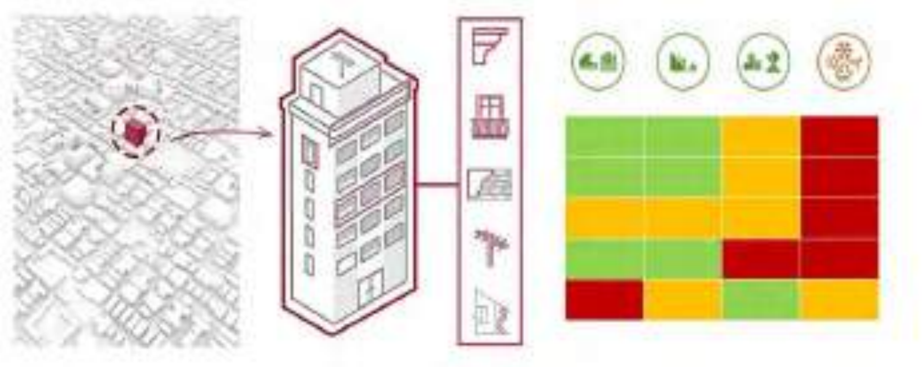


Figure 1 – An illustrative example of the matrix of building elements vulnerability to a set of hazards.

References

Castelluccio R., Fraiese M., Diana L., Vitiello V. (2022). L’identificazione del Rischio Edilizio come fase necessaria per la gestione degli scenari multi-rischio. In: Colloqui.AT.e 2023. In Transizione: sfide e opportunità per l’ambiente costruito, Bari.

Dipartimento della Protezione Civile (2009). Linee guida per la riduzione della vulnerabilità di elementi non strutturali arredi e impianti. Presidenza del Consiglio dei Ministri, Roma.

National Institute of Standards and Technology (2008). Recommendations for improved seismic performance of non-structural components. US Department of Commerce, Gaithersburg.

V. Silva, S. Brzev, C. Scawthorn et al. (2022). A building classification system for multi-hazard risk assessment. *International Journal of Disaster Risk Science*, 13, 161–177.

Spatial indicators and strategic approaches for increasing territorial resilience

Ilaria Cazzola[1]*, Grazia Brunetta*[1]*, Benedetta Giudice*[1]*, Manuela Rebaudengo*[1]*, Angioletta Voghera*[1]

(1) Dipartimento Interateneo di Scienze, Progetto e Politiche del Territorio (DIST), Politecnico di Torino, ilaria.cazzola@polito.it

The concept of resilience, though extensively discussed across various disciplines, often encounters challenges in translating theory into practical applications. This research carried out within the framework of Work Package 4 - Task 4.1 - Comprehensive Risk Management for urban settlements, strives to contribute to the operationalization of resilience. The objective is to propose methods and tools for measuring territorial and urban resilience with a focus on climate-related events.

The research adopts a site-specific approach, utilizing spatially explicit indicators to evaluate and predict the impacts of climate-related events on urban systems. A key outcome will be the development of a reference catalogue of progress indicators to systematize current best practices, thereby serving as a repository of case studies. The overarching goal is to enhance resilience by incorporating considerations of multi-vulnerability into climate adaptation strategies. The approach is place-based, involving the creation of models and indicators to monitor the effectiveness of climate adaptation strategies.

The research path consists of several stages:

- Indicator Selection:

  Conducting an in-depth review of existing literature in urban planning, climate adaptation, and risk management to identify key progress indicators relevant to territorial resilience.

- Good Practice Collection:

  Analyzing good practices in territorial resilience to extract insights and strategies applicable to diverse contexts. These practices are then tailored to the specific case study and aligned with identified indicators.

- Case Study Application:

  Applying the selected indicators and best practices to the case study to facilitate a comprehensive assessment of territorial resilience. This step involves data collection, analysis, and interpretation to provide insights into the current state of resilience and potential areas for improvement.

- Guideline Formulation:

  Developing guidelines for building territorial resilience, creating a practical framework for stakeholders involved in territorial planning and design.

- Testing through Living Lab:

  Validating the framework through a living lab experience, testing its effectiveness in real-world scenarios with stakeholders' collaboration.

At the current moment, as a first tangible output, the research will present a list of spatially explicit indicators that will be applied and tested in three distinct case studies that represent past and ongoing collaborations with external institutions. They are located in the territory of the Metropolitan City of Turin and, more specifically, along the course of the Po River: Sangone River, Stura River, and Moncalieri Municipality.

This comprehensive framework aims to bridge the gap between theoretical understanding and practical implementation, ensuring the relevance and applicability of territorial resilience in specific urban contexts.

References

Beltramino S., Scalas M., Castro Rodriguez D.J., Brunetta G., Pellerey F., Demichela M., et al. (2022). Assessing Territorial Vulnerability. Testing a multidisciplinary tool in Moncalieri, Italy. *TEMA*, 15(3), 355-375.

Voghera A., Giudice B. (2020). Defining a social-ecological performance to prioritize compensatory actions for environmental regeneration. The experimentation of the environmental compensation plan. *Sustainable Cities and Society*, 61, 102357.

Voghera A., Giudice B. (2019). Evaluating and Planning Green Infrastructure: a strategic perspective for sustainability and resilience. *Sustainability*, 11(10), 2726.

Disaster risk reduction and climate mitigation and adaptation for the Italian context: towards the selection and validation of best practices across plans and urban projects

Silvio Cristiano[1], Isabella Trabucco[1], Carlo Pisano[1]

(1) Department of Architecture, Università degli Studi di Firenze, silvio.cristiano@unifi.it

The ongoing climate emergency is adding up to the multiple risks to which cities and regions are expected to be subject in the present 21st century, with parallelly galloping urbanisation specifically stressing urban and metropolitan systems. In an overall objective to define strategies for risk management in those urban and metropolitan settlements, with a focus on the Italian context, information is required to support decision-making with suitable approaches, performance indicators, and best practices, able to be diversified across plans (urban and metropolitan scale) and urban projects (neighbourhood/district scale). Building on and feeding back to more preliminary outcomes of other project tasks and work packages of Italian extended partnership "RETURN - multi-Risk sciEnce for resilienT commUnities undeR a changiNg climate", with special regard to its spoke dedicated to urban and metropolitan settlements, a scientific roadmap and its first available results will be presented, dealing with the selection and validation - through appropriate performance indicators - of existing best practices on Disaster Risk Reduction and Climate Mitigation and Adaptation across urban plans and projects, towards the creation of a repository of European solutions, opportunely assessed and, if need be, adapted to the Italian context. Physical, geological, ecological, social, and technical aspects will be all considered, among others. This will be put in relation with prospective urban systemic transformations, and related additional actions, including multi-side and multi-risk mitigation and adaptation measures, with the additional objectives to to design solutions and measures to increase the resilience and carbon neutrality of urban and metropolitan systems to climate change, to define pathways for adaptation and mitigation to climate change also through the transformation of governance systems, and to define a roadmap for the urban-metropolitan systemic transition to climate neutrality also aligning with other ongoing initiatives (e.g. Mission Climate Neutral City by the European Commission, International Energy Agency, United Nations, etc.).

Multi-risk mitigation and energy efficiency measures at building and neighborhood scale to increase urban resilience

Maria Teresa De Risi[1], Maria Polese[1], Marco Gaetani D'Aragona[1], Marco Di Ludovico[1], Silvia De Angeli[2], Serena Cattari[3], Abbas Fathiazar[2], Dora Francese[1], Bruna di Palma[1], Paola Galante[1], Federica Visconti[1], Marialuce Stanganelli[1], Marilena Bosone[1], Angelo Picariello[1], Enrico Maria Oliva[1]

(1) University of Naples Federico II, mariateresa.derisi@unina.it
(2) University of Genova

Italian urban systems face significant exposure to various hazard sources. Thus, enhancing the resilience of these systems from a comprehensive, multi-hazard perspective is not merely a challenge but an absolute necessity for stakeholders. Although seismic hazards are a prominent concern across all municipalities, the impact of other natural and anthropogenic hazards varies based on the geographical location of each urban area. Recent events have underscored the vulnerability of Italian cities to flood hazards (pluvial, fluvial, and coastal), as well as pollution.

Moreover, in the context of strengthening interventions for buildings, it is nowadays imperative to integrate energy efficiency measures and sustainable technologies and materials. This should be done while considering the entire life cycle of both as-built and retrofitted building stock. The primary advantage of integrated intervention methods lies in their capacity to mitigate risks arising from multiple hazards while concurrently optimizing certain overhead costs and implementation-related expenses, by exploiting synergies between single hazard measures. However, a crucial factor to consider is the possibility of adverse effects resulting from the interaction of risk reduction measures, which may introduce potential trade-offs among various strategies for risk reduction.

Considering these challenges, we aim at the development of design criteria for multi-risk mitigation and energy efficiency measures at both building- and neighborhood- scale, with a focus on seismic, flood, and environmental hazards, as well as climatic hazards, specifically heat waves.

First, building archetypes will be defined - based on a series of characteristics as reported in the brand-new “RETURN taxonomy”. After the as-built assessment in terms of expected annual losses for the selected archetypes, «packages» of combined multi-hazard and energy efficiency interventions will be defined for the selected building archetypes analyzing potential synergies and drawbacks between single hazard measures. The definition of the most suitable «packages» of combined measures will be facilitated by the creation of a ‘Multi-hazard Mitigation Measures Catalogue’. In this catalogue, each measure is categorized using different attributes to facilitate easy navigation, understanding, and selection. These attributes include hazard specific performance criteria, as well as attributes related to energy efficiency, life cycle cost, environmental impacts, limitations, applicability, and potential synergies and drawbacks with other methods.

Some real word case studies will be investigated at different scales, from building to city scale, to identify virtuous practices of prevention, adaptation, and mitigation of architectural solutions for climate change. These findings will then be used to enhance and refine the selected measures within the packages.

Some of the identified packages of measures, best-integrated within the multi-risk field, will be "virtually" implemented at the building- or the neighborhood- level, and a post-intervention loss assessment will be carried out in a multi-variable cost-benefit analysis context, aiming at elaborating policy makers-oriented tools for the selection of the best strategies to improve urban resilience.

Enhancing climate resilience: generating future weather files for typical and extreme conditions

Milad Heiranipour[1], Fabio Favoino[1], Stefano Avesani[2], Miren Juaristi Gutierrez[2]

(1) Department of Energy, Polito University, milad.heiranipour@polito.it
(2) Institute for Renewable Energy, Eurac Research

Incorporating climate change considerations into the design decision process is imperative. The climate crisis introduces critical challenges in the built environment, encompassing issues such as overheating, heightened health risks, and the urgent need to curtail carbon emissions. Our initiative transcends mere acknowledgment to actively address these challenges head-on. Through the evaluation of building resilience under extreme conditions like heat waves, our goal is to combat overheating and bolster safety.

Our approach involves the utilization of comprehensive weather data, generated through dynamical downscaling. This enables us to establish robust simulation parameters, ensuring that our analyses and decisions are rooted in a profound understanding of the evolving climate. By focusing on the synthesis of building resilience under extreme conditions, we strive to develop adaptive solutions that not only withstand the impacts of climate change but also contribute to a substantial reduction in our carbon footprint. The significance of implementing this extensive database of future weather files in Politecnico di Torino is underscored by our commitment to actively engage with the challenges posed by climate change in the built environment.

This proposal aims to implement a robust methodology for generating future weather files using dynamical downscaling. Specifically, we focus on typical and extreme conditions, such as heat waves. Our objective is to provide researchers with valuable inputs for conducting thermal resilience analyses in the built environment. By developing this innovative approach, we empower researchers to assess and enhance building resilience under diverse climate scenarios, ultimately contributing to the advancement of impactful climate adaptation research.

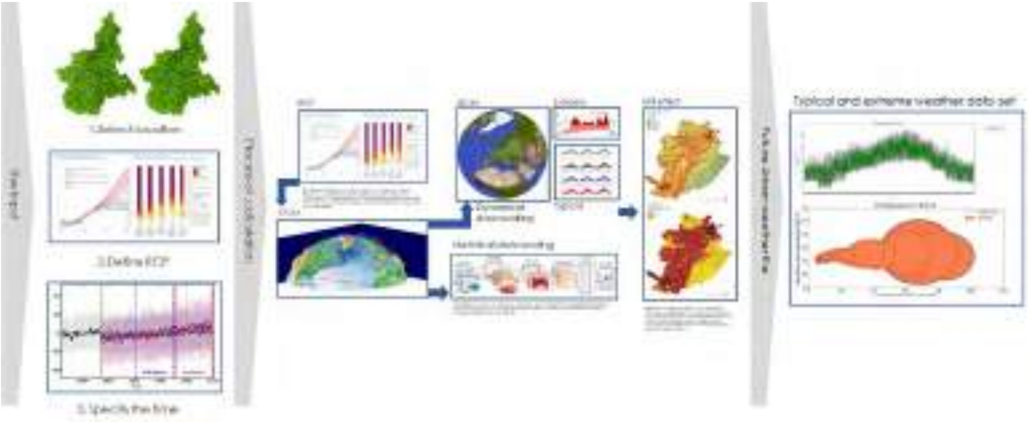


Figure 3 - Process of future weather data.

A flexible methodological approach to ground resilience-oriented planning policies

Federica Isola[1], Sabrina Lai[2], Federica Leone[3], Corrado Zoppi[4]

(1) Dept. of Civil and Environmental Engineering and Architecture, University of Cagliari, federica.isola@unica.it

Following the European Environment Agency (2019), "land take" can be understood as the phenomenon wherein urban areas, with their impermeable surfaces, encroach upon agricultural or forested areas. The most severe manifestation of land take is soil sealing, an irreversible process driven by building activities and infrastructure construction where pervious land covers, characterized by the presence of soil and vegetation, are replaced by impervious artificial materials such as asphalt and concrete. Land cover dynamics, such as land take, modify soil characteristics, hydrogeological processes, and vegetation structure, and are therefore strongly connected with landslides, i.e., with the downward and outward movement of rocks and soils. Moreover, by causing the loss of natural and seminatural ecosystems, land take and soil sealing bring about the loss of multiple ecosystem services, i.e., the benefits that ecosystem supply to human beings. Some ecosystem services are relevant to the RETURN project because they contribute to reducing hazards and risks in urban and metropolitan areas; labeled "regulating ecosystem services", these include local temperature regulation, urban flood risk mitigation, coastal protection.

The relation between land cover changes and landslides has been studied by various authors (among many, Pisano et al., 2017, Hao et al., 2022), yet the relation between land take and landslide hazard is still under-researched. Therefore, such relation is here assessed to understand to what extent land-taking processes increase landslides, and it is investigated by taking as a case study the catchment basin that includes the town of Sassari, and by coupling spatial analyses and inferential models. This analytical framework is also applied within Spoke TS1 of the RETURN project to analyze, in quantitative and spatially explicit terms, the relationship between hazards related to climate change in urban and metropolitan areas, such as heat waves, and the provision of multiple ecosystem services supplied by green areas (WP3, task 5.3.4), therefore paving the way for identifying place-specific policy recommendations to improve the local environmental quality (WP4, task 5.4.3), and in turns, the quality of urban life.

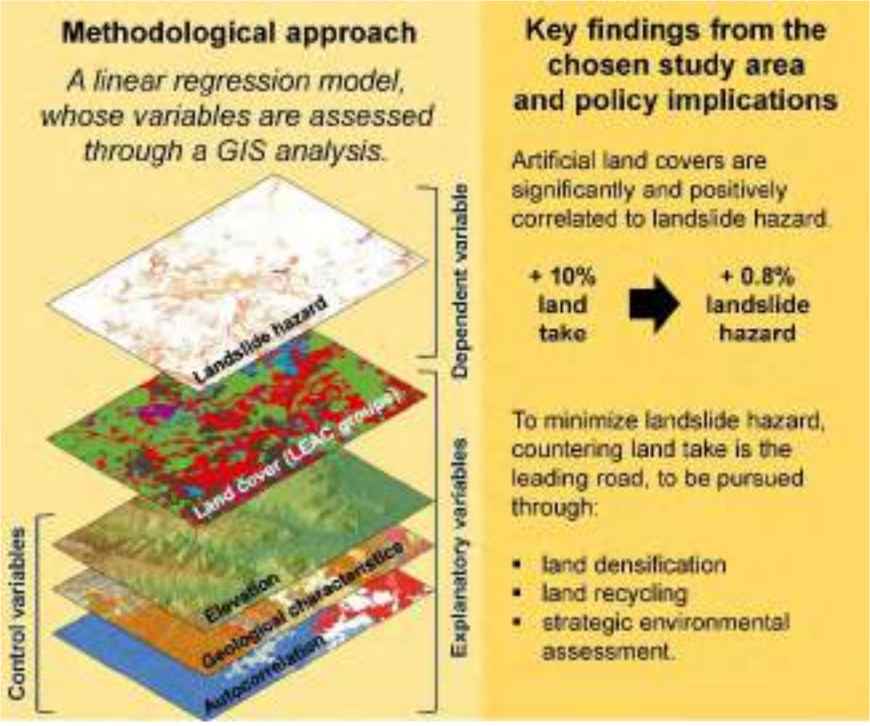
The relation between land take and landslide hazard is assessed through a regression model that relates the level of landslide hazard to a set of land cover variables that includes artificialized land, i.e., land taken up through urbanization processes, and a set of covariates that represent the main land cover types within the Land and Ecosystem Accounting (LEAC) taxonomy (Figure 1). Spatial units for the analysis are 300-m square cells, and the model operationalizes as follows:

$$LH = \alpha_0 + \alpha_1 L\_TAKE + \alpha_2 ARA + \alpha_3 PMF + \alpha_4 FOR + \alpha_5 GRSH + \alpha_6 DEPOQ + \alpha_7 VOLSE + \alpha_8 ELEV + \alpha_9 HGLAGGED$$

where, in each cell:

- LH = landslide hazard.
- L_TAKE = land take.
- ARA = arable land.
- PMF = pastures and mosaic farmlands.
- FOR = standing forests.
- GRSH = natural grasslands, sclerophyllous vegetation, and heathlands.
- DEPOQ = quaternary deposits.
- VOLSE = volcanic sedimentary rocks.
- ELEV = average elevation.

- HGLAGGED = spatially lagged dependent variable controlling for LH’s spatial autocorrelation.



A linear regression model, whose variables are assessed through a GIS analysis.

Artificial land covers are significantly and positively correlated to landslide hazard.

To minimize landslide hazard, countering land take is the leading road, to be pursued through:

- land densification
- land recycling
- strategic environmental assessment.

Figure 1 – Graphical representation of the methodological approach (left-hand side); main result and overview of the policy implications (right-hand side).

The estimates of the coefficients α_i show the correlations between landslide hazard and the LEAC land cover types and, particularly, the interdependence of LH and the size of land take.

For a full overview of the results and of the policy implications, the reader can refer to Isola et al. (2023). The most important finding is that a significant and positive correlation is identified between the land take-related covariate (L_TAKE) and the variable associated with landslide hazard (LH) namely, a 10% increase in L_TAKE is associated with a 0.8% increase in LH. Therefore, as far as land covers and their effects on landslide hazard are concerned, controlling land-taking processes is the main road to mitigating the hazard.

On this premise, three main groups of policy implications, respectively concerning land densification, land recycling, and strategic environmental assessment (SEA), can be identified (Figure 1). As for land densification, it implies that land is developed within existing settlements to take advantage of existing infrastructure without using undeveloped land, hence land recycling strategies and compact urban models should be promoted in the case study area, and they could be supported through appropriate financial or regulatory tools, also including, flexible and performance-based zoning regulations. The last policy implication concerns SEA, a mandatory appraisal planning tool in EU countries, which can pave the way for the integration, within spatial plans, of measures aimed at preventing or minimizing land take.

The flexible methodological approach here proposed as a tool to support decision-making processes provides an already developed example of how the research activities within Spoke TS1 of the RETURN project can be carried out to analyze the relationship between the provision of multiple ecosystem services and climate-related hazards in urban and metropolitan areas, and to ground place-specific policy recommendations.

References

European Environment Agency (2019). The European Environment—State and Outlook 2020. Knowledge for Transition to a Sustainable Europe. *Luxembourg: Publications Office of the European Union*. ISBN 978-92-9480-090-9.

Hao L., van Westen C., Rajaneesh A., Sajinkumar K.S. Martha T.R., Jaiswal P. (2022). Evaluating the relation between land use changes and the 2018 landslide disaster in Kerala, India. *Catena*, 216, 106363, 1–13.

Isola F., Lai S., Leone F., Zoppi C. (2023). Assessing the relation between land take and landslide hazard. Evidence from Sardinia, Italy. In: Gervasi, O., Murgante, B., Rocha, A.M.A.C., Garau, C., Scorza, F., Karaca, Y., Torre, C.M. (eds.) Computational Science and Its Applications – ICCSA 2023 Workshops. ICCSA 2023, Athens, July 3-7. Lecture Notes in Computer Science, 14106, 642–658. *Cham: Springer*.

Pisano L., Zumpano V., Malek Ž., Rossokopf C.M. (2017). Parise, M. Variations in the susceptibility to landslides, as a consequence of land cover changes: A look to the past, and another towards the future. *Science of the Total Environment*, 601–602, 1147–1159.

A building taxonomy for multi-hazard assessment

Sergio Lagomarsino[1], Roberto Castelluccio[2], Serena Cattari[1], Silvia De Angeli[1], Donatella de Silva[2], Carlo Del Gaudio[3], Lorenzo Diana[2], Francesca Ferretti[4], Emidio Nigro[2], Giuseppe Piccardo[1], Massimiliano Pittore[5], Maria Polese[3], Luca Pozza[4], Margherita Rago[1], Gerardo Verderame[3]

(1) DICCA, University of Genoa, Genoa, Italy, sergio.lagomarsino@unige.it
(2) DICEA, University of Naples Federico II
(3) DIST, University of Naples Federico II
(4) DICCAM, University of Bologna
(5) EURAC Research

Existing taxonomies are poorly suited to multi-hazard analysis and mainly biased toward the seismic risk and the structural vulnerability. These classifications do not provide useful information to perform a proper multi-hazard assessment. Moreover, they are not able to cover the specific classes of technological elements of the building envelope as well as the specific sub-systems that compose them, as one of the significantly hit components by external hazards.

For these main two reasons, faceted taxonomies seem to be more proper to reach the expected goals of an integrated multi-risk study for resilient communities and cities. Therefore, a new taxonomy for buildings (named "Return Taxonomy") have been developed, starting from the GED4ALL taxonomy as a reference and a basis (Silva et al. 2022). The proposed taxonomy has been developed to accomplish the following goals:

- Provide a comprehensive description of the building from a multi-hazard perspective, including additional characteristics useful to perform assessments and make decisions for hazards other than seismic (e.g., fire, flood, heavy rains, heatwaves etc.).
- Harmonize the taxonomy on buildings with the contents of Italian regulations and standards [Italian UNI Norm 8290 – 1:1981 Edilizia residenziale. Sistema tecnologico. Classificazione e terminologia (Tran. Housing buildings. Technological System. Classification and Terminology)].
- Consider the role of the entire set of technical components of the building envelope.

Compared to GED4ALL, the Return Taxonomy provides: 1) an organization of the attributes, with the collection into "attribute groups"; 2) the addition of attributes to the original list, particularly aimed to multi-hazard assessment; 3) slight modifications to attributes, keeping as much as possible the compatibility with GED4ALL.

The Return Taxonomy can be considered a reliable starting taxonomy for allowing a harmonized description of sub-systems composing a building, aiming to contemplate the action of multiple hazards on the entire building. The list of the attributes is shown in Figure 1, collected into homogenous groups as follows:

a) Occupancy
b) Building Features
c) Vertical Structural System
d) Building Configuration and Regularity
e) Building Horizontal Diaphragms
f) Hydrological aspects
g) Foundation and Soil Conditions
h) Fire Building Performance
i) Building Envelope
j) Building Exterior Technical Elements

Figure 1. Return Building Taxonomy: Attributes Groups, attributes, and sub-attributes.

The new attributes that have been added are:

- Att. 4 Average Plan Surface;
- Att. 6 Gravity Load System that provides information on the gravity loads structural system;
- Att. 8 Partition Walls that provides information on the characteristics and connection efficiency of partition walls to the vertical structure;
- Att. 13 Ceilings that considers also the role of ceilings (as suspended or false ceilings) and its connection efficiency to the horizontal structure;
- Att. 17 Soil class concerning the soil class of the foundation soil;
- Att. 18 Topography of the area;
- Att. 22 Cornice Construction technique;
- Att. 23 Balcony Construction Technique;
- Att. 24 Household Drain system material. The three last attributes are related to the characteristics of exterior technical elements.

The main modifications of existing attributes are collected into two main categories:

(i) Reorganization of attributes

- Att. 3 Number of stories that now provides information exclusively concerning the height of the structure and the number of stories below ground;
- Att. 7 Lateral Load-resisting System that now includes the information concerning the main direction of the building, the materials of the lateral load system, and the role of the infills when they are present;
- Att. 9 Building position in the block,
- Att. 10 Plan Regularity,
- Att. 11 Elevation Regularity,
- Att. 21 Openings/windows that, compared to GED4ALL, stand out as independent attributes.

(ii) Modification of existing attributes

- Att. 1 Occupancy that includes information on the present and original function of the building, the occupancy of the ground floor, the number of occupants, and the cultural heritage value of the building;
- Att. 2 Age of Construction that provides information concerning the construction period, the age of retrofit interventions, the state of maintenance of the building, the decay of material and the presence of pre-existing damage;
- Att. 5 Material Type that gives details on the material of the vertical structural system;
- Att. 14 Roof Shape that includes information on the presence and position of thermal/acoustic insulation, water protection and covering, on the presence of standing-out elements and the related slenderness, dimension, and material;
- Att. 19 Fire Safety that is structured in a more extensive manner;
- Att. 20 Exterior Walls that includes the presence and position of thermal/acoustic insulations, the presence of decorations and moldings, and the role of finishings.

Starting from such a holistic framework, the interoperability of the proposed taxonomy, easily tailorable at varying the building features and hazards, ensures to easily handle information, allowing to assess the multi-hazard impacts on urban systems as well.

References

Silva V., Brzev S., Scawthorn C., Yepes C., Dabbeek J., Crowley H. (2022). A Building Classification System for Multi-hazard Risk Assessment. *Int J Disaster Risk Sci*, 13, 161–177.

Ecosystem services and green infrastructure for resilient cities

Sabrina Lai[1], Federica Leone[1], Corrado Zoppi[1]

(1) Dept. of Civil and Environmental Engineering and Architecture, University of Cagliari, sabrinalai@unica.it

A methodology to characterize a green infrastructure (GI) in urban and metropolitan (U/M) areas is identified which supports the supply of multiple ecosystem services (ESs), while also ensuring ecological connectivity among U/M landscape patches, to provide policy makers with recommendations to improve the quality of a GI. Multifunctionality relates to functions that the U/M landscape performs or should support (Hansen and Pauleit, 2014), whereas connectivity concerns the identification of ecological corridors (ECs), i.e., connected patches of habitats that support wildlife movement (D'Ambrogi and Nazzini, 2013). Building upon previous studies (Isola et al., 2022) and in-depth analyses of environmental, landscape and socio-cultural contexts, a set of criteria for defining the landscape suitability to support a GI and a set of criteria for identifying ECs will be selected.

The first set of criteria accounts for the functions that a GI should perform and will be assessed through environmental indicators identified based on previous studies (Lai et al., 2018, 2021) that model and spatially assess provision of the following ESs: preserving levels of habitat quality suitable to support life cycles of wild plants and animals; micro and regional climate regulation through mitigation of land surface temperature; agricultural crop production and harvested wood; preservation of endangered species or habitats and areas relevant for conservation purposes; maintenance of elements that are attractive for nature-based recreation; maintenance of landscape characters that support local identity, cultural heritage, and tourism. Accordingly, the concept of cultural ESs can support the relevance of tangible and intangible heritage to urban regeneration.

The second set of criteria accounts for aspects that characterize ECs. Each criterion and/or indicator will be mapped through geographical analyses and techniques. Once nodes and ECs are identified, the suitability of ECs to be part of the GI will be assessed. The deliverables offered by the activities could be as follows: a detailed report on the implementation of the methodological framework aimed at identifying the GIs located in U/M contexts, e.g., within the metropolitan area of Cagliari, and a spatially explicit (GIS-based) representation of such taxonomies and of the determinants of the spatial layout of the ESs supply and of the characteristics of the ECs.

Secondly, correlations between the spatial taxonomies of impacts generated by climate-related risks (e.g., heat waves and islands and/or air pollution) are detected and analyzed within the metropolitan area of Cagliari, to assess how the multifunctional supply of ESs by the GI can contribute to mitigating climate-related impacts. Among such key ESs are carbon capture and storage capacity (CCSC) or heat regulation in U/M areas. Detailed analysis of the correlations between the identified taxonomies will be performed, as well as an environmental analysis of their characteristics and distinctive features. Within Spoke TS1, WP3 of the RETURN project, this activity is included under Task 5.3.4 ("Integrated multi-risk urban impact assessment and forecasting at variable scale") as "Modeling ecosystem services contribution to multi-risk mitigation in human settlements" (5.3.4.4) and, as such, it feeds into deliverable DV 5.3.4, concerning the definition of "Multi-hazard impact and risk modelling and rapid forecasting methodology".

Moreover, such methodological approach, whereby spatial modeling and inferential analysis are coupled, will be integrated into the planning tools at the U/M level, taking into account the influence of ESs on human well-being. For this reason, setting up protocols to incorporate cultural ESs into the spatial planning, while avoiding the application of undifferentiated parameters disconnected from the local identity, is fundamental.

This will lead to identifying place-specific policy recommendations to improve the environmental quality of the GI identified in the metropolitan area of Cagliari, and, consequently, its resilience against climate-related hazards and risks.

Within Spoke TS1, WP4 of the RETURN project, the deliverable of this research-action process will be a Guidelines Handbook that identifies the technical development of the logical framework of a Strategic environmental assessment (SEA) process aimed at generating a U/M Masterplan based on a strategic and operational structure aimed at substantially increasing the U/M quality of life through the system of ESs delivered by a U/M GI. The SEA process (recall activity "implementation of the strategic environmental assessment approach in order to increase the quality of urban life based on the enhancement of services provided by urban ecosystems") will develop from a strategic device inspired by the New European Bauhaus initiative, in line with deliverable DV 5.4.4 (Concept guidelines, design proposals and assessment protocols to monitor urban integrated resilience in compliance with NEB – New European Bauhaus principles) of Task 5.4.3 (Green transition towards resilient and regenerative urban eco-districts) of WP4 (Mitigation and adaptation for more resilient and livable cities) of Spoke TS1 (Urban and metropolitan settlements), WP4, of the RETURN project.

Figure 1 provides a graphical representation of how the proposed activities contribute to DV 5.3.4 and DV 5.4.4.

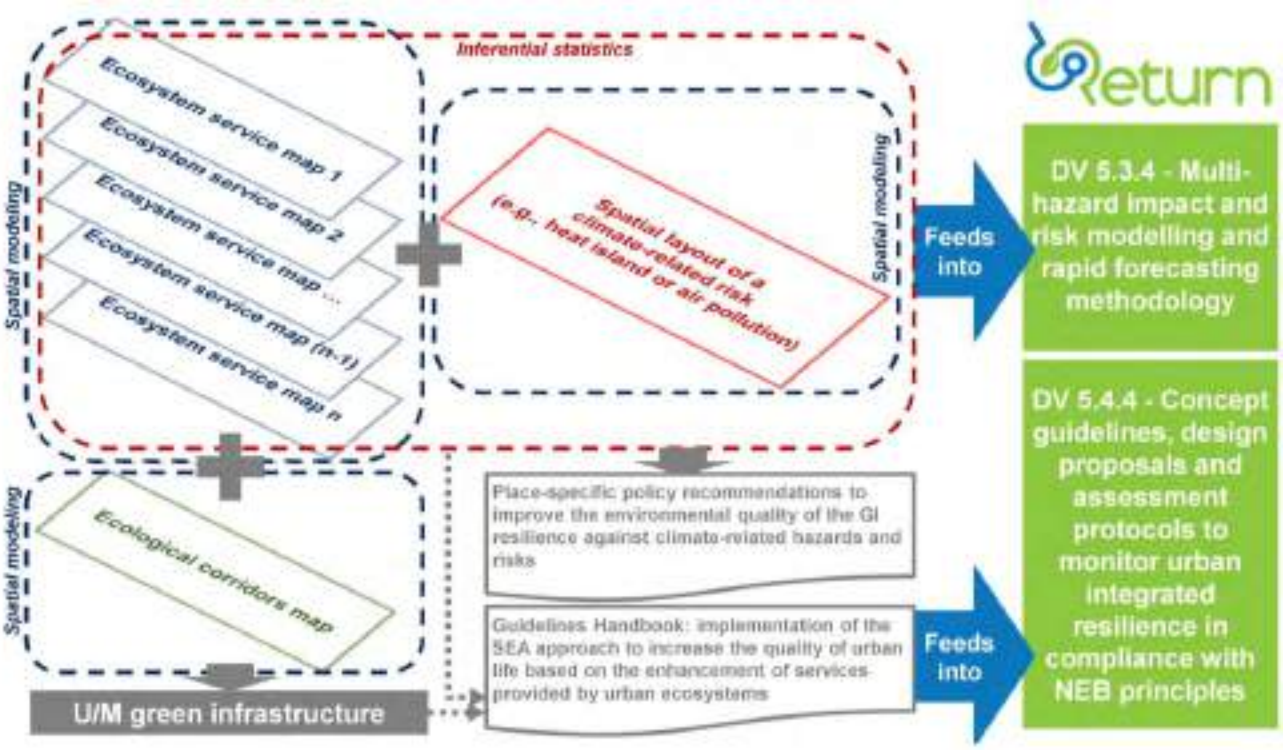


Figure 1 – Overall methodological approach and how it feeds into Deliverables 5.3.4 and 5.4.4.

References

D'Ambrogi S., Nazzini L. (2013). Monitoraggio ISPRA 2012: La rete ecologica nella pianificazione territoriale [ISPRA 2012 Monitoring: the ecological network within spatial planning]. *Reticula*, 3, 1–5. Available online: https://www.isprambiente.gov.it/files/pubblicazioni/periodicitecnici/reticula/Reticula_n3.pdf (accessed on 7 January 2024).

Hansen R., Pauleit S. (2014). From multifunctionality to multiple ecosystem services? A conceptual framework for multifunctionality in green infrastructure planning for urban areas. *AMBIO*, 43, 516–529.

Isola F., Lai S., Leone F., Zoppi C. (2022). Strengthening a regional green infrastructure through improved multifunctionality and connectedness: Policy suggestions from Sardinia, Italy. *Sustainability*, 14, 9788.

Lai S., Leone F., Zoppi C. (2021). Land surface temperature and land cover dynamics. A study related to Sardinia, Italy. *TeMA, Journal of Land Use, Mobility and Environment*, XIII, 3, 329–351.

Lai S., Leone F., Zoppi C. (2018). Implementing green infrastructures beyond protected areas. *Sustainability*, 10, 3544.

Systemic approach and multi-scalar urban knowledge: urban hotspot and critical context identification

Mario Losasso[1], Maria Fabrizia Clemente[1], Antonio Sferratore[1], Sara Verde[1]

(1) Department of Architecture, University of Naples Federico II, losasso@unina.it

The number of natural disasters is dramatically increasing in terms of frequency and intensity with severe impacts on urban areas. These disasters, directly and indirectly, compromise the urban balance with cascading, composite, and aggregate effects on population, energy networks, infrastructure, health system, etc. The co-presence of multi-hazard conditions can lead to tipping points, potentially upsetting the balance of urban settlements. In recent years, there has been a growing awareness of the necessity to understand, explore, and manage multiple risks that affect assets, resources and people.

Aiming to reach a thorough understanding of how and where to apply strategies and actions for adaptation, vulnerability and exposure reduction, and resilience enhancement, the contribution aims to define - through a systemic approach - criteria for the identification of urban critical context where the complex relationship among vulnerability, hazard and exposure leads to multi-risk conditions.

Urban settlements are complex systems made by physical, social and ecological components. These components have specific functions and are organized in hierarchical levels (de Rosnay, 1977). Given this complexity and the multitude and diversity of phenomena in urban and metropolitan settlements, it's crucial to adopt innovative systemic and multi/inter-disciplinary knowledge approaches (Losasso, 2013).

In this context, a critical urban context can be identified as a complex system that fails to ensure the expected performances across various dimensions. Analysing the connection between assets in these areas – such as built-up features, road traces, geomorphologic conditions, natural boundaries, critical infrastructures, green systems, socio-economic conditions, etc. – and certain key factors in environmental, governance and socio-economic terms supports the identification of the level of criticality to multi-risk conditions.

Through an analytical methodology applied to urban settlements, a knowledge model is developed, integrates soft, hard, and demographic systems. This model is aligned to national regulatory guidelines, such as National Climate Change Adaptation Strategy (MATTM, 2015) and Climate Change Adaptation Plan (MASE, 2023). The analysis aims to identify connections between settlement design principles and processes of construction and formation of the built space in the functional, socio-productive and urban identity response. This involves gathering both quantitative data of the physical system and qualitative data of a synthetic nature, along with other non-measurable aspects (Bologna et al., 2021).

In urban critical contexts, where exposure, vulnerability, and immaterial assets pose significant risks, the concept of hotspot areas emerges as crucial. These areas, marked by high risks, can be identified through index and indicator systems, as well as modelling and simulations. Recognizing these hotspot areas within urban critical contexts is essential to support decision makers in multi-risk scenarios. The term "urban hotspot" was defined through a literature review, with various authors contributing to the definition of spatial and analytical criteria to outline hotspot areas. Since 2001, the World Bank's Disaster Management Facility (Dilley et al., 2005) has been conducting a global scale multi-hazard risk analysis, identifying key "hotspots" where disaster risks are notably high. This initiative aims to provide information and methods for prioritizing disaster risk reduction and making informed decisions on development investment. Accounting for climatic hazards (drought, flood, storms) and natural hazards (landslides, earthquakes, eruptions) DMF identifies disaster risk hotspots on a global scale based on criticality levels associated to simple indicators (mortality risk and economic losses).

The identification of settlement contexts and hotspot areas, characterized by the concentration or overlap of detected risks and impacts, makes the application of counter measures (adaptation, vulnerability and exposure reduction, and resilience enhancement strategies and actions) a priority.

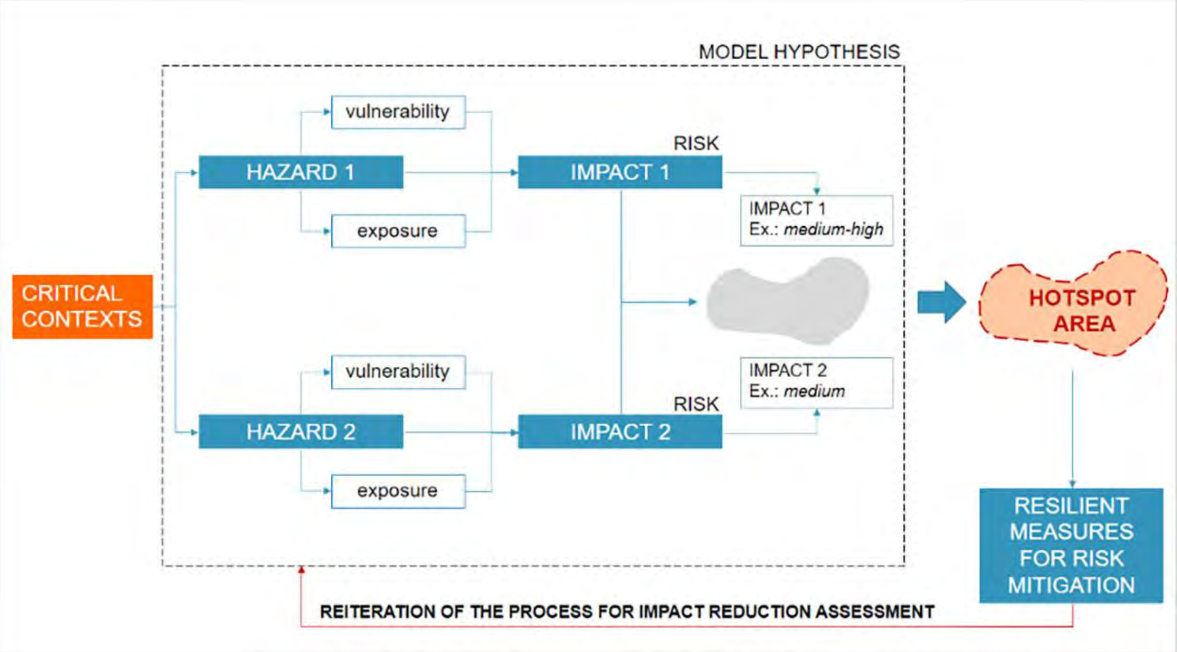


Figure 1 – Process definition and model hypothesis to outline hotspot areas in critical contexts. The application of strategies and actions for risk mitigation (adaptation, vulnerability and exposure reduction, and resilience enhancement) should be tested to assess impact reduction.

References

Bologna, R., Losasso, M., Mussinelli, E., Tucci, F. (Eds.) (2021). Dai distretti urbani agli eco-distretti. Metodologie di conoscenza, programmi strategici, progetti pilota per l'adattamento climatico/ From Urban Districts to Eco-districts. Knowledge Methodologies, Strategic Programmes, Pilot Projects for Climate Adaptation. Santarcangelo di Romagna: Maggioli.

de Rosnay, J., (1977). Le macroscope: Vers une vision globale, *AC*. ISBN 10: 8472880176

Dilley, M., Chen, R.S., Deichmann, U., Lerner-Lam, A.L., Arnold, M., Agwe, J., Buys, P., Kjestad, O., Lyon, B., Yetman, G. (2005). Natural Disaster Hotspots. A global Risk Analsys. *Disaster Risk Management Series*, n.5. Washington D.C.: The World Bank, Hazard Management Unit.

Losasso, M. (2013). Progettazione ambientale e caratteri della disciplina architettonica. In Rigillo, M. (Ed.), Oltre la siepe. Scenari di ricerca per il progetto ambientale. Napoli: *Editoriale Scientifica*, 237-241.

MASE - Ministero dell'Ambiente e della Sicurezza Energetica (2023). PNACC – Piano Nazionale di Adattamento ai Cambiamenti Climatici. Available at: https://www.mase.gov.it/sites/default/files/PNACC_DOCUMENTO_DI_PIANO.pdf [05 January 2024].

MATTM – Ministero dell'Ambiente e della Tutela del Territorio e del Mare (2015). *Strategia Nazionale di Adattamento ai Cambiamenti Climatici.* Available at: https://www.mase.gov.it/sites/default/files/archivio/allegati/clima/documento_SNAC.pdf [10 october2023].

Geosphere risk-related factors in urban areas: a perspective from a 3D-modelled geological subsurface

Daniele Maestrelli[1], Paola Vannucchi[1]

(1) Dept. of Earth Sciences, University of Florence, daniele.maestrelli@unifi.it

The relevance of the geo-morphological system in urban areas becomes increasingly pronounced, especially in light of the growing vulnerability to diverse natural hazards, intensified by factors such as climate change and rapid urbanization. The geological composition of a region, encompassing elements such as soil structure, rock formations, and the presence of fault lines, plays a direct role in determining its susceptibility to various hazards.

For instance, areas situated on soft or loosely packed soils face heightened vulnerability to seismic activities, primarily due to the phenomenon of soil liquefaction. Similarly, the existence of specific rock types can predispose a region to elevated risks of landslides or erosion. Technological advancements and improved data collection methods have significantly enhanced our capacity to comprehend and apply geological and geomorphological insights in urban planning.

In the first instance, urban areas can be characterized through a general scenario that outlines the primary geo-morphological features as categorized in the taxonomy. As an exemplification, we have chosen the following scenario:

Flat inland settlement in a tectonic-origin basin surrounded by mountainous reliefs with the presence of a river. Built fabric: Historic center characterized by compact fabric; widespread residential fabric of recent expansion adjacent to transportation infrastructure on a territorial scale. Risks: Geophysical risks of seismic type with site amplification, liquefaction, soil stability, hydraulic risks with the presence of sudden floods, climatic risks with heatwaves and heavy rains, biological risks with atmospheric and soil pollution.

Taking as an example this scenario, we can elucidate the geo-morphological features that expose urban settlements to hazard. We propose an exploration of risk-related factors inherent to the above described context, a scenario that aligns well with numerous urban settlements in the Italian peninsula, prominently exemplified by the city of Florence. As a reference point for this illustration, Florence is intricately connection with neighboring cities such as Prato and Pistoia. Situated in a tectonic basin, termed a "semi-graben" in geological terms (Neuendorf, 2005), Florence faces exposure to tectonic (normal) faults along its northern periphery.

Moreover, the basin, including the city of Florence, is intersected by the Arno River and its tributaries. This complex geographical setting gains added significance as the Florence basin serves as a pivotal economic hub, accommodating crucial infrastructures and cultural tourism. The interconnected nature of these elements underscores a profound association with the geo-morphological sphere.

The geology of the Florence urban settlement (Figure 1a) is in fact characterized by the presence of Quaternary tectonic boundary faults (associated with secondary transversal faults) which have the potential to elevate seismic hazards. Consequently, the city faces a high level of exposure to this risk. Additionally, the presence of the Arno River exposes Florence to significant flood risk, a fact corroborated by historical events such as the 1966 flood (Coli et al., 2013). Despite the city being located in the basin, the presence of boundary scarps associated with the faults introduces the possibility of landslide risk (Morelli et al., 2021). Furthermore, owing to its specific morphology, the basin is susceptible to climatic risks, particularly those associated with heat-waves (Morabito et al., 2012). Given Florence's status as a substantial productive district, the urban settlement is also exposed to biological risks linked to contaminants and air pollution (Palli et al., 2008).

As demonstrated by the Florence example, accurately characterizing the urban area within its geo-morphological context is paramount for precisely quantifying multi-risk exposure. In this context, a crucial tool for enhancing this characterization, and serving as the initial step in constructing a digital twin, is a 3D digital model of the subsurface (see Figure 1b). This model not only offers a comprehensive view of the subsurface but also aids in elucidating the relationships with surface elements vulnerable to multi-risk scenarios.

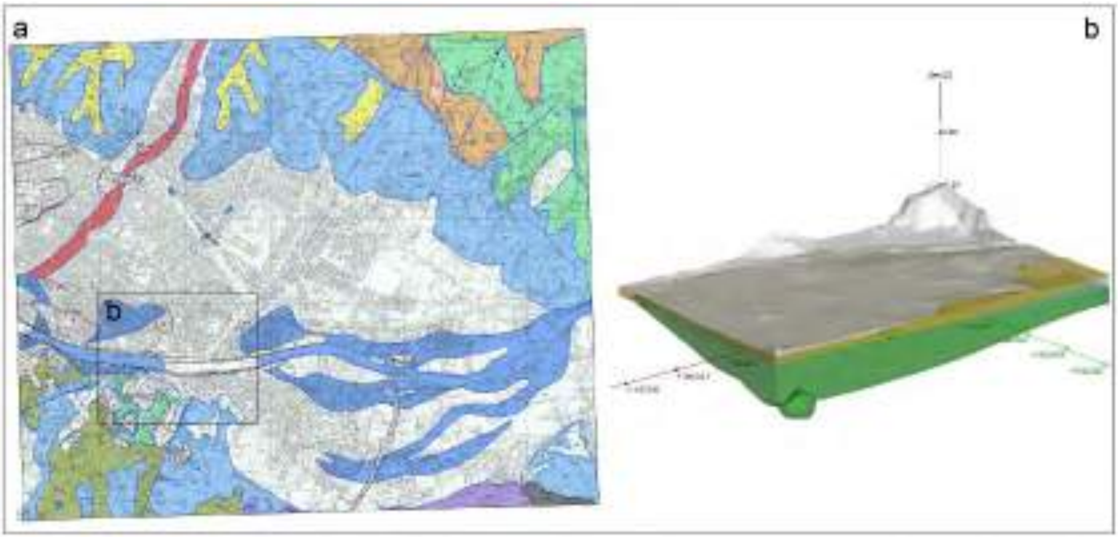


Figure 1. a) The Florence urban settlement as depicted in the 1:10.000 Tuscany geological map (CARG 1:10.000 section n. 275040). The city of Florence well fits with the hypothetical urban settlement proposed in the Scenario n. 5. b) An example of 3D geo-model produced for a portion of the Florence urban area. The 3D model highlights the subsurface stratigraphy and structural setting.

References

Coli, M., Brugioni, M., & Montini, G. (2013, September). Florence and its floods: anatomy of an hazard. In Proceeding of (Ed.), *18th International Conference on soil mechanics and Geotechnical Engineering* (workshop of Geotechnical Engineering for conservation of cultural heritage and historical site).

Morabito, M., Profili, F., Crisci, A., Francesconi, P., Gensini, G. F., & Orlandini, S. (2012). Heat-related mortality in the Florentine area (Italy) before and after the exceptional 2003 heat wave in Europe: an improved public health response?. *International journal of biometeorology*, 56, 801-810.

Morelli, S., Pazzi, V., Tofani, V., Raspini, F., Bianchini, S., & Casagli, N. (2021). Reconstruction of the slope instability conditions before the 2016 failure in an Urbanized District of Florence (Italy), a UNESCO world heritage site.

Understanding and Reducing Landslide Disaster Risk: Volume 1 Sendai Landslide Partnerships and Kyoto Landslide Commitment 5th, 449-455.

Neuendorf, K. K. (2005). Glossary of geology. Springer Science & Business Media.

Palli, D., Saieva, C., Munnia, A., Peluso, M., Grechi, D., Zanna, I., ... & Masala, G. (2008). DNA adducts and PM10 exposure in traffic-exposed workers and urban residents from the EPIC-Florence City study. *Science of the Total Environment*, 403(1-3), 105-112.

Towards redevelopment of contaminated decommissioned sites through the application of circular economy principles

Giulia Meneghin[1], Petra Scanferla[1], Silvia Breda[1], Antonio Sellitri[1]

(1) Fondazione Università Ca' Foscari, giulia.meneghin@unive.it

Circular economy represents a new model of production and consumption aimed at the minimization of waste through an efficient use of resources. The application of circular economy principles represents one of the most important contributions to policies on sustainable development, in consistency with the commitments adopted under the Paris Agreement on climate change and related to the Sustainable Development Goals (SDGs) of the 2030 Agenda. In this context, it is necessary to create an objective model that should be able to measure the circularity of a given process through the assessment of specific indicators. A national technical standard on circular economy was recently published in order to create a common strategy for monitoring circular processes in organisations.

The UNI/TS 11820 "Measuring circularity - Methods and indicators for measuring circular processes in organizations" – available from November 2022 – is the new national standard that anticipated the publication of the ISO specification (ISO/WD 59020), only available in draft. The standard aims to provide a method and a taxonomy of indicators for assessing, through a rating system, the level of circularity of an organization or group of organizations, including public institutions, regardless of type, size and the supplied products or the provided services. The national standard provides a set of circularity indicators that can be applied at both the micro level (single organisation) and the meso level (group of organisations). The set is composed of 71 indicators grouped into six categories, encompassing material resources, energy and water, waste and emissions, logistics, products and services, and human resources, assets, policies and sustainability. The indicators are also divided into core (that must be filled in), specific (of which at least 50% has to be filled in) and rewarding indicators (for which filling in is not compulsory). The indicators are also defined by a quantitative, semiquantitative or qualitative scale. In general, the level of circularity is defined with a measurement system on a 100 basis that has no minimum threshold for circularity.

Information obtained from the study of such technical standards are also applicated in the field of remediation of contaminated sites in order to apply the best solutions in a circular and sustainable way. Activities, resources (water, energy, materials, human resources, etc.) but also the specific remediation technologies are the main objective of the circularity assessment for the remediation of contaminated sites.

These topics are investigated in Spoke TS1 of the RETURN project. This task will apply circular economy principles on an urban metropolitan scale in order to reduce risk exposure. The main goal is to define strategies, actions, principles, and policies for a sustainable resources' management. Such elements should be applied to critical urban contexts characterised by the presence of multiple risk situations, in order to develop the concept of a resilient city and to improve the habitability of urban spaces.

The assessment of circular metabolism in urban settings for multirisk contexts also involves the remediation and redevelopment of contaminated decommissioning sites in a specific critical urban context. Knowledge concerning the application of the circular economy may be useful in order to develop a new methodology applicable to the remediation of contaminated decommissioning sites through the use of specific indicators to enhance the redevelopment of an urban context from a circular and a sustainable perspective.

References

UNI/TS 11820 (2022). Misurazione della circolarità – Metodi ed indicatori per la misurazione dei processi circolari nelle organizzazioni.

ISO/WD 59020 (2023). Circular economy — Measuring and assessing circularity.

Recognition of the minimum urban system to improve multi-hazard recovery by exploiting participatory planning approaches

Soheil Mohammadi[1], Serena Cattari[1], Francesca Pirlone[1], Giorgio Boni[1], Ilenia Spadaro[1], Fabrizio Bruno[1,2], and Silvia De Angeli[1]

(1) Dept. of Civil, Chemical and Environmental Engineering, University of Genoa, soheil.mohammadi@edu.unige.it
(2) Higher University School IUSS

Damages to urban structures caused by consequent or interacting natural hazards create a complex and challenging post-disaster environment. Many functions provided by the affected structures are disrupted and consequently, systemic processes, including recovery, are impaired and delayed. Despite its criticality, recovery is the least explored phase in the disaster management framework, specifically from a pre-disaster perspective, in terms of planning and actions for better recovery before disasters occur. Planning for recovery is a critical aspect to promote resilient rebuilding of communities. Engaging stakeholders in the recovery planning process is not only beneficial for accurately identifying recovery needs but also for incorporating diverse perspectives into the development of recovery plans.

This research develops and applies the concept of the ‘minimum urban system’ (MUS), as the subset of physical assets of the urban system to be preserved to ensure continuing recovery efforts after a disaster. The MUS must be determined considering the relative socio-economic importance of the urban assets as well as their contribution to the whole urban system's performance. Given this context, the goal of this work is to establish a methodological framework that combines participatory planning techniques with quantitative data analysis to model the urban system in three spatial scales (macro, meso and micro), and ultimately identify its most crucial components and their interdependencies as the MUS.

First, the main results of a critical review of existing literature and guidelines on disaster recovery have been provided with the twofold aim of identifying current gaps and providing the layout to develop the framework. Then, the socio-economic importance of diverse buildings and urban structures have been measured at the macro, meso and micro scales by a series of indicators. These indicators have been generated integrating outcomes from: 1) a participatory Fuzzy Cognitive Mapping (FCM) with stakeholders to identify crucial urban functions and their interdependencies and 2) an analysis of quantitative physical and socio-economic data characterizing the urban system and its constituent elements across the three spatial scales.

A preliminary identification of the crucial urban functions necessary for initiating and progressing the recovery process has been performed through focus groups involving disaster risk management experts and mayors from various parts of Europe. Then, a FCM has been implemented in the city of Sanremo, in the western part of the Liguria Region, Italy. A group of participants from different sectors created individual cognitive maps, which were then aggregated into a single map. This aggregated map was analyzed using voting mechanisms and network analysis to determine the most important and impactful urban functions and interdependencies contributing to recovery in their municipality.

The assets contributing to each functionality have been identified and characterized exploiting available cartography and statistical data. The influence of the multi-hazards vulnerability of each asset has been evaluated by imposing multi-hazard risk scenarios of consecutive earthquakes and floods and considering their interaction in terms of exposure and vulnerability.

The developed modeling framework will represent the basis for the implementation of a quantitative tool for decision-makers to support urban planning and address the optimal investment alternatives to increase the system’s resilience under a limited budget.

Storyline-based approach for multi-risk assessment of urban and metropolitan areas

M. Pittore[1], A. Zaccaria[2], C. Marciano[3], M. Polese[2], G. Tocchi[2], C. Griffo[1], A. Pirni[3], S. Terzi[1], S. De Angeli[3], F. Ferretti[4], L. Pozza[4], S. Cattari[3], S. Lagomarsino[3], D. Sivori[3], D. Di Bucci[5], G. Verderame[2], C. Visconti[2], C. Del Gaudio[2], M. Di Domenico[2], M.T. De Risi[2], G. Piccardo[3], F. Canepa[3], M.G. Badas[6], S. Lai[6], C. Zoppi[6], F. Leone[6], P. Bragato[7], G. Bartoli[8], F. Gusella[8], A. Crespi[1]

(1) EURAC Research - Bolzano, massimiliano.pittore@eurac.edu
(2) University of Naples Federico II
(3) University of Genova
(4) University of Bologna
(5) Civil Protection Department
(6) University of Cagliari
(7) OGS – Istituto Nazionale di Oceanografia e di Geofisica Sperimentale
(8) University of Firenze

The RETURN project aims at developing a consistent framework for the assessment of multiple risks of urban and metropolitan areas, under changing and non-stationary conditions. Due to the wide range of natural, environmental and anthropogenic hazards threatening urban areas and the related risks, a pragmatic approach to identify risk scenarios is fundamental. In this context, the concept of risk storylines is introduced, referring to a defined, plausible combination of events, their consequences and the factors possibly affecting these elements, as well as the physical, socio-ecological and functional elements at risk (Shepherd et al. 2018; March et al. 1991, Sillmann et al. 2021). A storyline-based approach is proposed in the framework of the WP 5.3 activities as a methodology for the multi-risk assessment of urban environments, by including multiple hazards, with their possible interactions, and all the exposed urban assets with the objective of evaluating the socio-economic impacts. A graphical representation of a risk storyline is an impact chain, highlighting the causal relationships between events and their impacts on the analyzed context. In this way, complex multi-risk processes can be considered in a consistent framework for a number of hazards, i.e., meteorological, hydrological, geohazards, environmental, societal hazards, etc. (UNDRR-ISC 2021). In this work, the methodology will be illustrated with reference to a specific storyline, presented with the impact chain in Figure 1, including alternative hazard and vulnerability modelling strategies. Advantages and disadvantages of the method will be analyzed, also with reference to the possible metrics usable for measuring impacts. In the RETURN project, the collaboration between the different Spokes can effectively contribute to the generalization of the proposed storyline-based approach.

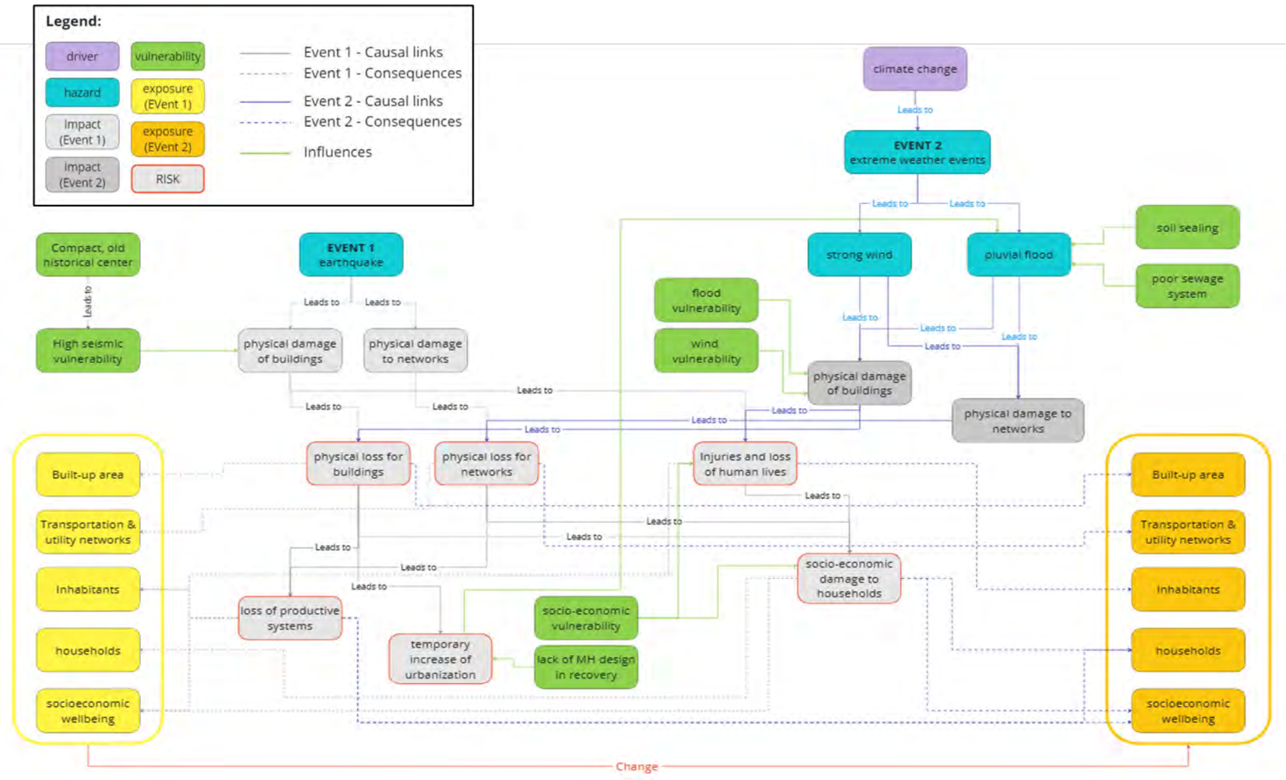


Figure 1 – Example of an impact chain.

References

March James G., Lee S. Sproull, Michal Tamuz (1991). Learning from samples of one or fewer. *Organization Science,* 2(1), 1–13.

Shepherd Theodore G., Emily Boyd, Raphael A. Calel, Sandra C. Chapman, Suraje Dessai, Ioana M. Dima-West, Hayley J. Fowler, et al. (2018). Storylines: an alternative approach to representing uncertainty in physical aspects of climate change.” *Climatic Change,* 151(3–4), 555–71.

Sillmann Jana, Theodore G. Shepherd, Bart Van Den Hurk, Wilco Hazeleger, Olivia Martius, Julia Slingo, and Jakob Zscheischler. (2021). Event-Based Storylines to Address Climate Risk. Earth’s Future, 9(2).

UNDRR-ISC 2020. Hazard Definition and Classification Review - Technical Report. 2021. “Hazard Information Profiles - Supplement to UNDRR-ISC Hazard Definition & Classification Review.” UNDRR-ISC.

Zebisch Marc, Stefano Terzi, Massimiliano Pittore, Kathrin Renner, and Stefan Schneiderbauer. (2022). Climate Impact Chains—A Conceptual Modelling Approach for Climate Risk Assessment in the Context of Adaptation Planning. In: Climate Adaptation Modelling, edited by Claus Kondrup, Paola Mercogliano, Francesco Bosello, Jaroslav Mysiak, Enrico Scoccimarro, Angela Rizzo, Rhian Ebrey, Marleen de Ruiter, Ad Jeuken, and Paul Watkiss, 217–24. Springer Climate. Cham: Springer International Publishing.

Derivation of surface aerosol concentration from satellite AOD over the city of Bologna

Giorgia Proietti Pelliccia[1], Tiziano Maestri[1], Erika Brattich[1], Federico Porcù[1], Silvana Di Sabatino[1], Francesco Barbano[1]

(1) Dept. of Physics and Astronomy, University of Bologna, giorgia.proietti6@unibo.it

Aerosol pollution in urban areas has been linked to short- and long-term health effects and diseases in many studies (Brunekreef and Holgate 2002). The main difficulty in monitoring urban aerosols is the sparsity of data: aerosol mass concentration near the surface is typically monitored through ground-based measurements of Particulate Matter mass concentration (PM) at fixed or mobile stations, that leave huge areas without measurements even within the same city. Satellites retrieval of columnar aerosol spectral properties, such as the Aerosol Optical Depth (AOD), can improve the spatial resolution and fill the gaps between ground-based stations, thanks to the large areas covered during each overpass. In the last decades, many studies attempted to derive PM concentrations near the ground using satellite AOD (Hoff and Christopher, 2009). This type of methodologies could be very useful to complement conventional monitoring methods in health-related studies and in the framework of multi-risk assessment and models such as the one developed in the PNRR-RETURN project.

The relationship between the two quantities can be approximated as linear in cases of well-mixed aerosols within the Boundary Layer, considering PM2.5 (mass concentration of particles with diameter less than 2.5 µm) and AOD at VIS wavelengths (Koelemeijer et al. 2006). The linear approximation holds relatively well when considering fine aerosol particles in urban areas and allows the determination of ground PM2.5 from satellite AOD. Coefficients can be calibrated through statistical linear regression and are dependent on location and time (of the order of a month or smaller timescale) (Di Nicolantonio et al. 2009). In this study, the linear approximation between satellite AOD and PM is investigated over the city of Bologna, using MAIAC AOD (550 nm) (Qin et al. 2021) and ground-based PM2.5 from local environmental agency (ARPAE) and from low-cost sensors. Data is analyzed considering the meteorological conditions (e.g., Relative Humidity, Air Temperature, Boundary Layer Height, …) and some assumptions on the chemical composition of local aerosols.

References

Brunekreef, Bert, and Stephen T. Holgate. 2002. 'Air Pollution and Health'. *The Lancet* 360 (9341): 1233–42.

Di Nicolantonio, W., Cacciari, A. and Tomasi, C. (2009) Particulate Matter at Surface: Northern Italy Monitoring Based on Satellite Remote Sensing, Meteorological Fields, and in-situ Samplings. IEEE *J. Sel. Top. Appl. Earth Obs. Remote Sens*., 2, 4, 284-292.

Hoff, R.M. and Christopher, S.A. (2009) Remote Sensing of Particulate Pollution from Space: Have We reached the Promised Land? *J. Air & Waste Manage. Assoc*., 59, 645-675.

Koelemeijer, R.B.A., Homan, C.D. and Matthijsen, J. (2006) Comparison of spatial and temporal variations of aerosol optical thickness and particulate matter over Europe. *Atmos. Environ*., 40, 5304-5315.

Qin, W., Fang, H., Wang, L., Wei, J., Zhang, M., Su, X., Bilal, M. and Liang, X. MODIS high-resolution MAIAC aerosol product: Global validation and analysis. *Atmos. Environ*. 2021, 264, 118684.

Towards a circular metabolism for urban and metropolitan settlements

Michelangelo Russo[1], Federica Vingelli[1], Libera Amenta[1], Rosaria Iodice[1]

(1) Dept. of Architecture, University of Naples Federico II, russomic@unina.it

Anthropic and natural risks, land pollution and abandonment processes, as well as social conflicts are closely connected in contemporary urban systems where man-made activities and the impacts of climate change can generate the emergence of new interrelated risks. This context marked by the increasing impacts on urban settlements has led current studies to frame risk related issued in an extensive framework of urban sustainability and resilience (Garzilli et al., 2022). Applying a metabolic and circular approach (Russo M., van Timmeren, 2022) to exposed urban settlements to different condition of risks means understanding and interpreting the complexity of risks interactions, in response to the spatial, environmental, and socioeconomic challenges of contemporaneity, towards a resilient and inclusive city, to imagine strategies for landscapes in transition (Russo, 2023) in line with European and global strategic agendas.

In this perspective, the ongoing research within the RETURN task *"T 5.4.4. - Towards a circular metabolism for urban and metropolitan settlements"* aims to study the potential of applying the principles of circular territorial metabolism in critical multi-risk urban contexts, to improve the habitability and quality of urban space while decreasing its vulnerability.

The Task is composed by two sub-Task: sub-Task 4.4.1 "Circularity principles for planning resilient cities" aims to understand how to apply possible circularity approaches at different levels/scales, e.g. considering soils, buildings, materials/resources, and material and immaterial interactions at different scales: landscape/landscape ecology, also through the analysis of best practices. Sub.Task 4.4.2 "Territorial metabolism and resilience guidelines applied to risk mitigation measures" intended to define guidelines for the planning of a circular territorial metabolism of the city and territory.

The main objective of Task 5.4.4 is to develop a model of circular territorial metabolism in critical multi-risk urban contexts in transition towards a resilient and inclusive city. The task will define guidelines for planning a circular territorial and urban metabolism that considers regenerative management strategies of territories (Amenta et al., 2022) resources and flows (materials/energy/soils/waste). The guidelines are aimed at supporting decision-making processes for strengthening the resilient capacities of urban communities and space and they will define actions, principles and directives focused on the mitigation risks through the evaluation and design of territorial transition and regeneration strategies. They can be a useful support for designing integrated circular metabolisms models for compromised urban contexts, that will then be tested in Urban Living Labs with the involvement of local communities and the main public and private actors. This will be line and in close connection with the objectives and method developed in "WP5 – Urban labs for dynamic multi-risk management" and in particular in the Task 5.5.2. "City-scale exercise for risk scenarios evaluation", for the development of the methodology of Urban Living Labs. Living labs are a method and an inclusive environment for studying urban contexts and co-designing and co-evaluating strategies and nature-based solutions capable of recycling context specific soils, flows and, more generally, of resources.

Research activities have identified, within the volcanic caldera of the "Campi Flegrei" in Naples, the former ILVA industrial area in the Bagnoli-Coroglio neighbourhood as a test case in which to experiment with innovative, nature-based reclamation processes in the regenerative model developed.

Since 1910 the area had hosted steel activity for many years and currently, abandoned for more than thirty years now, is configured as a vulnerable territory. The overlapping of anthropogenic, natural and environmental hazards on the area contributes to the delineation of a complex multi-hazard critical context. The conditions of disuse and abandonment suggest experimenting with transformations and rethinking it as an opportunity to manage the expected transition towards circularity and sustainability. From the analysis of the multiple critical issues that fall on the area, an interdisciplinary approach is needed to initiate the transition through urban regeneration practices in relation to risk mitigation. The area has been identified as a SIN (Site of National Interest) site due to the high degree of contamination. Industrial activity has polluted the subsoil, which has above-normal traces of heavy metals and hydrocarbons. Remediation, therefore, becomes a necessary condition for the future use of the area. The study of the Bagnoli-Coroglio site will produce a PoC (Proof of Concept) capable of demonstrating, within a transitional process, urban regeneration policies for risk mitigation in critical urban contexts. The models obtained will then be tested on an application case, also through interaction in multi-stakeholder and user-centred environments of Urban and Territorial Living Labs.

Figure 1 – Former industrial site of Bagnoli. Photo by Mario Ferrara.

References

Amenta L., Russo M., van Timmeren A. (2022). *Regenerative Territories. Dimensions of Circularity for Healthy Metabolisms.* Amenta L., Russo M., van Timmeren A. (Eds). Springer.

Garzilli F., Vingelli F., Vittiglio V. (2022). Shifting risk into productivity: inclusive and regenerative approaches within compromised contexts in peri-urban areas. In *Regenerative Territories: Dimensions of Circularity for Healthy Metabolisms,* 51-69. Cham: Springer International Publishing.

Russo M. (2023). Transitional Landscapes. In *Transitional Landscapes*, Macerata: Quodlibet, 19–27.

Russo M., van Timmeren A. (2022). Dimensions of circularity for healthy metabolisms and spaces. In: *Regenerative Territories. Dimensions of Circularity for Healthy Metabolisms.* Dimensions of Circularity for Healthy Metabolisms. Springer Cham, 1–27.

Development of software tools for seismic damage scenario assessment: a case study in Emilia-Romagna

Gianluca Salamida[1], Francesca Ferretti[1], Luca Pozza[1], Nicola Buratti[1]

(1) Dept. of Civil, Chemical, Environmental and Materials Engineering, University of Bologna, gianluca.salamida2@unibo.it

In the last decades, earthquakes in Italy had a major impact in terms of both human life and socio-economic losses. After the seismic events which struck Italy in recent years (2009 L'Aquila, 2012 Emilia and 2016 Central Italy earthquakes) several studies were conducted about the safety assessment of existing buildings in order to classify the main sources of vulnerability, with reference to different structural typologies (Penna et al. 2014, Savoia et al. 2017). In this perspective, various fragility models were developed for reinforced concrete buildings, masonry buildings and precast industrial buildings, both empirically and numerically (Verderame et al. 2014, Buratti et al. 2017, Ioannou et al. 2021, Ferretti et al. 2023). These studies, combined with prediction of the ground motion intensity allow to predict damage scenarios (Simoni et al. 2021).

Within this context, this work describes the development of a series of software tools that allow to analyze recorded accelerograms, create shake maps in terms of different ground motion intensity measures, and estimate damage scenarios. In particular, ground-motion recordings from the Italian National Accelerometric Network are processed to compute a number of ground motion Intensity Measures (IMs), while acceleration spectra are used to compare displacement demands for a series of equivalent single degree of freedom systems, derived from pushover analyses on a series of representative buildings, by using simplified methods (e.g. N2, CSM, IN2, etc.). These rely on the knowledge of specific features of the potentially affected area, both in terms of intrinsic characteristics (e.g. morphology, near surface geology, etc.) and elements at risk (e.g. building typologies, population distribution, etc.). The IMs calculated from the recordings at the various stations are used, together with attenuation and spatial correlation models, to obtain shake maps, using different criteria for quantifying site effects. These maps are used together with regional census data and various fragility models to estimate damage scenarios, using a Monte Carlo simulation approach.

Two software tools have been developed: the former can be used to analyze accelerometric recordings, calculating a series of ground motion intensity measures, and to assess the expected potential damage, based on recordings, on a set of residential and hospitality building types. The latter make possible to calculate shake-maps for the stricken territory, using different IMs, and derive a seismic damage scenario. An example of a damage scenario is shown in Figure 1, for the Emilia earthquake of 29th May 2012, for thirteen municipalities around the epicentre.

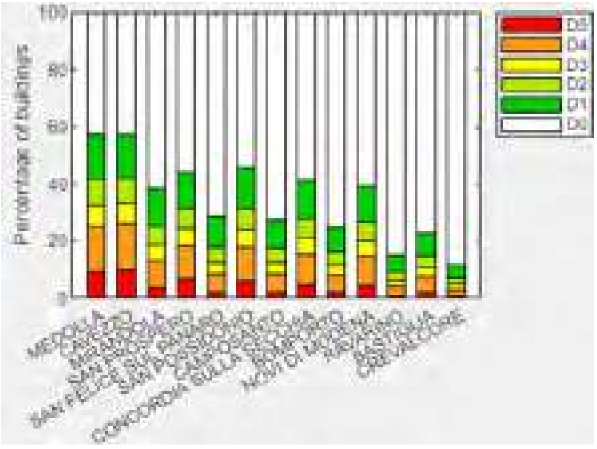


Figure 1 – Damage scenario for masonry buildings for the 29th May 2012 Emilia eaarthquake.

References

Buratti N., Minghini F., Ongaretto E., Savoia M., Tullini N. (2017). Empirical seismic fragility for the precast RC industrial buildings damaged by the 2012 Emilia (Italy) earthquakes, *Earthquake Engineering and Structural Dynamics*, 46(14), 2317–2335.

Ferretti F., Simoni E., Buratti N., Mazzotti C. (2023). Typological fragility analysis of masonry buildings in Emilia Romagna region (Italy), *Bulletin of Earthquake Engineering*, 21, 3321-3356.

Ioannou I., Bertelli S., Verrucci E., Arcidiacono V., Rossetto T. (2021). Empirical fragility assessment of residential buildings using data from the Emilia 2012 sequence of earthquakes, *Springer*, Netherlands.

Penna A., Morandi P., Rota M., Manzini C.F., Da Porto F., Magenes G. (2014). Performance of masonry buildings during the Emilia 2012 earthquake, *Bulletin of Earthquake Engineering*, 12 (5), 2255–2273.

Savoia M., Buratti N., Vincenzi L. (2017). Damage and collapses in industrial precast buildings after the 2012 Emilia earthquake, *Engineering Structures*, 137, 162–180.

Verderame GM., Ricci P., De Luca F., Del Gaudio C., De Risi MT. (2014). Damage scenarios for RC buildings during the 2012 Emilia (Italy) earthquake, *Soil Dynamics and Earthquake Engineering*, 66, 385–400.

Defining urban contexts towards multi-risk assessment: a clustering and hazard-based scoring approach for urban settlements based on open source data

Gabriella Tocchi[1]*, Maria Polese*[1]*, Carlo Del Gaudio*[1]*, Antonella Peresan*[2]*, Andrea Prota*[1]

(1) Department of Structures for Engineering and Architecture, University of Naples Federico II, gabriella.tocchi@unina.it
(2) National Institute of Oceanography and Applied Geophysics CRS-OGS

A comprehensive understanding of essential characteristics of urban settlements, including typo-morphological, demographic, social, economic and institutional features is essential for developing effective strategies to enhance the resilience of urban settlements to natural hazards. The complexity and concentrated infrastructure in urban settlements can exacerbate the vulnerability to natural hazards. The high population density in cities increases the potential for casualties and impacts during events like earthquakes, floods, and hurricanes. Indeed, rapid urbanization often occurs without adequate consideration of natural hazard risks, leading to poorly planned structures and insufficient resilience measures. The interconnectedness of urban systems, including transportation, utilities, and communication, heightens the susceptibility of cities to systemic failures during disasters. Informal settlements and marginalized communities within urban areas are often disproportionately affected, lacking the resources and infrastructure to withstand natural hazards. The reliance on centralized resources and critical facilities can exacerbate vulnerabilities, as disruptions to these systems have cascading effects on the entire urban population.

In this study, a national-scale characterization of urban settlements in Italy is proposed based on open-source data. Urban settlements range from small towns and cities to large metropolis, with local government or administrative boundaries often defining their limits. Publicly available data on the built environment and population in urban areas is typically provided with reference to the administrative level. Information derived from ISTAT (National Institute of Statistics in Italy) are used herein for a preliminary classification and clustering of Italian municipalities. Specifically, information related to degree of urbanization (that accounts for geographical contiguity and population density), urban centeredness degree (that quantifies the level of centrality of an area within an urban context), the number of inhabitants and the altimetric zone are considered.

Clustering urban settlements may help understand the most common types and features of urban settlements in a country. According to clustering criteria adopted, the 7953 Italian municipalities are grouped in 98 clusters. This means that in Italy there are 98 different urban settlement types. The cluster that encompasses the largest number of municipalities is the cluster representing low densely populated mountain rural areas (1630, the 20% of Italian municipalities). However, the representativeness of this cluster is much lower if we consider the residential population as evaluation parameter. The 17% of Italian population live in highly populated urban hubs cities (more than 250000 inhabitants) located in lowland areas. The cluster of towns/suburbs in lowland peri-urban areas with a population between 5000 and 50000 inhabitants (i.e., medium population class) is the most representative one both in terms of number of municipalities (521, the 7%) and in terms of population (11% of people live in these areas).

An urban context is characterized not only by its settlement conditions but also by the impeding hazards. According to EM-DAT (the international disaster database -https://www.emdat.be/), extreme temperature (i.e., heat waves), earthquakes, landslides and floods are the hazards that generated largest human and economic impacts in Italy during last century. Italian country is also exposed to Volcanic and Tsunami hazards;

such type of perils are very localized or very extreme events (i.e., rare events), and even if they did not cause relevant impacts in the last century, they could be responsible of devastating effects in case of occurrence.

Because of the diversity in geomorphological, climatic, and hydrological characteristics, the occurrence of various hazards across Italy differs, and so does their capacity to cause substantial impacts. A scoring method is proposed here to rank various hazards for each given urban setting. For each relevant peril in Italy (i.e., the ones listed above), the value of the corresponding intensity measure on the hazard map at a given return period (or a significant proxy for it) is used to define the corresponding score in a 0-1 scale; scores are normalized in the 0-1 scale based on the cumulative distribution function estimated for the entire Italian territory. The procedure is applied to urban contexts at the municipality scale. Using such scores, a ranking of all Italian municipalities with respect to a given hazardous event is carried out. Additionally, by overlaying land use maps with hazard maps, it becomes possible to assess residential, industrial, and rural zones within an urban context that could be exposed to each hazard. This process aids in defining specific scores associated with these areas.

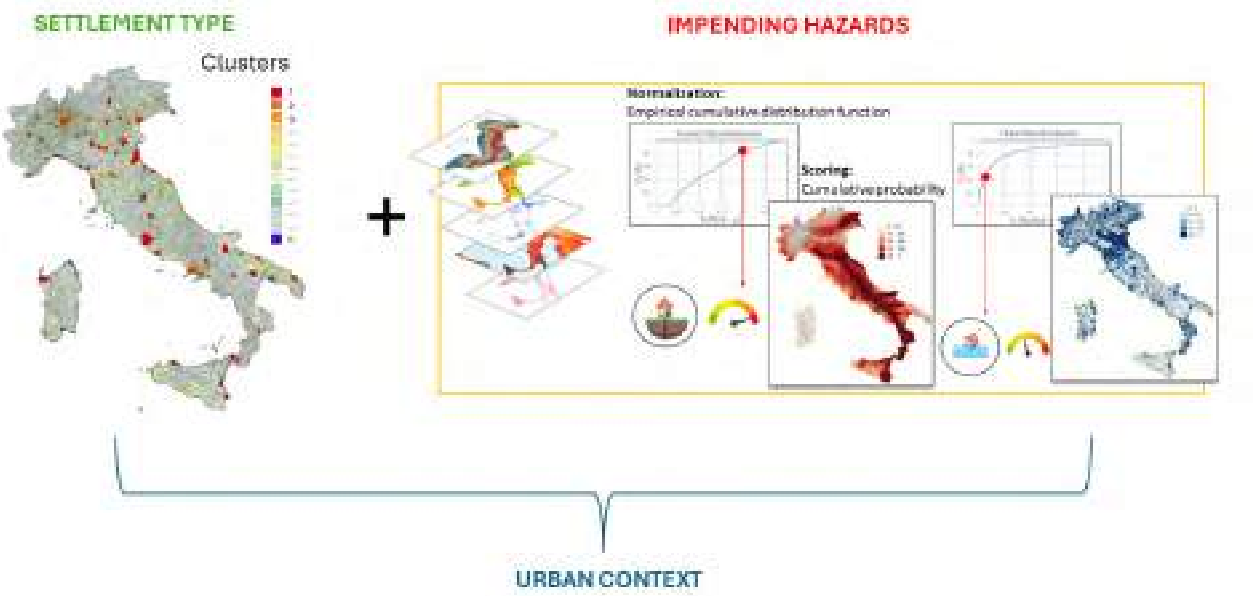


Figure 1 –Urban context is defined by the settlement type and the impending hazards. An example of score-based procedure for the identification of relevant hazards is reported, comparing seismic and flood hazards.

ADAPTIVE HOUSING: solutions for adaptive and resilient low-energy housing under climate change scenarios

Linda Toledo[1]

(1) Institute for Renewable Energy, Eurac Research, linda.toledo@eurac.edu

The issue addressed in this research project is **overheating in buildings**. The implications of overheating on human health may take different forms, which range from loss of concentration and reduction of productivity to more severe consequences, such as heatstroke. Importantly, these consequences can be suffered by a variety of individuals ranging from members of vulnerable groups to those affected by thermoregulation conditions and those living in urban areas or particularly humid environments (Dengel & Swainson, 2012).

Design, as a problem-solving activity, has attempted to cope with the governmental requirements of improved energy efficiency in buildings. However, even newly designed low-energy buildings have shown discrepancies between predicted and actual performances of buildings. For instance, in most EU geo-clusters, low-energy buildings are designed with a view of securing winter comfort (hence, they incorporate strategies for reducing the energy demand for heating); this means that often they end up aggravating the negative consequences of overheating in **highly insulated low-energy homes** (Porritt, 2012; Toledo, Cropper and Wright, 2017; Sharifi, Saman and Alemu, 2019)

Looking at the **risks of overheating**, some energy modelling studies have investigated the increase in demand of cooling in households as a consequence of climate change, based on the assumption that in the next years there will be a rapid increase in the need of **air conditioning** (Isaac and Van Vuuren, 2009)**.** Other studies, which are based on building simulation and use future climate scenarios, have shown that an increased risk of high indoor temperatures can occur if no other control measures are put in place (Attia and Gobin, 2020)**.** One common factor that has emerged from all the above-mentioned studies is that the combination of other (relatively traditional) measures such as external solar shading and air movement can help reduce high indoor temperatures (Porritt *et al.*, 2012).

Despite their significance, most of the current studies on performance of low-energy buildings are based on building simulation. However, unpredictable users' behaviour and context dynamics can produce discrepancies between predicted and actual building performance.

In addition, in recent years specific scientific attention has been paid to adaptive measures of comfort (Nicol, Rijal and Roaf, 2022). Think, for instance, about the studies concerning the introduction of ceiling fans, which have found a surplus of fifty percent in thermal acceptance (Bezaee et al, 2012). What makes the matter especially complex is the fact that comfort is a multidimensional system, which includes other sensorial perceptions as well as other factors affecting the thermal perception (Heschong, 1979).

The project ADAPTIVE HOUSING is investigating the role of adaptive behaviour in the process of securing comfort in low-energy homes in the context of a global increase in temperatures. Its main objectives consist of (a) assessing the potential impact of overheating in low-energy housing, and (b) developing guidelines for the design and operation of adaptive and resilient low-energy housing.

This project is purported to improve designers' ability to tackle requirements of energy efficiency while securing healthy and comfortable homes, both in the present climate and in future climate change.

As part of **(a) assessing the potential impact of overheating in low-energy housing**, a semi-systematic literature review will be conducted. Such review will cover the areas of climate change and thermal comfort and attempt to integrate these two disciplines. The main aim of this review is twofold:

- ➔ To provide a definition of risk, mitigation and adaptation measures to reduce overheating in low-energy homes. This task is contributing to the RETURN Project TS1 (WP3-T3.3 Definition of mitigation and adaptation measures).
- ➔ To distil a set of building adaptive and non-technological strategies/capacities that can be applied to low energy homes to reduce their sensitivity to increasing temperatures. This task is contributing to the RETURN Project TS1 (WP2-T2.4 Definition of mitigation and adaptation measures).

As part of **(b) to develop guidelines for the design and operation of adaptive and resilient low-energy housing**, ADAPTIVE HOUSING will contribute to the RETURN Project TS1 (WP4-T4.3: Guidelines for management of overheating risk in buildings).

References

Attia S., Gobin C. (2020). Climate Change Effects on Belgian Households: A Case Study of a Nearly Zero Energy Building. *Energies*, 13(20), 5357.

Heschong L. (1979). Thermal delight in architecture. *MIT press*.

Isaac M., Van Vuuren D.P. (2009). Modeling global residential sector energy demand for heating and air conditioning in the context of climate change. *Energy Policy*, 37(2), 507–521.

Nicol F., Rijal H.B., Roaf S. (2022) Routledge *Handbook of Resilient Thermal Comfort. 1st edn. London: Routledge*.

Porritt S.M. (2012). Adapting UK Dwellings for Heat Waves. *De Montfort University*.

Porritt S.M. et al. (2012). Ranking of interventions to reduce dwelling overheating during heat waves. E*nergy and Buildings*, 55, 16–27.

Sharifi S., Saman W., Alemu A. (2019). Identification of overheating in the top floors of energy-efficient multilevel dwellings. *Energy and Buildings*, 204, 109452.

Toledo L., Cropper P.C., Wright, A.J. (2017). Vulnerability and resilience in energy efficient homes: thermal response to heatwaves. in *DESIGN TO THRIVE*. PLEA, Edinburgh.

Dengel A., Swainson M. (2012). Overheating in new homes. A review of the evidence. NF46. *Milton Keynes: NHBC Foundation*.

Beizaee et al. (2012). Assessing the ability of PMV model in predicting thermal sensation in naturally ventilated buildings in UK. *7th Windsor Conference: The changing context of comfort in an unpredictable world*, (April), 12–15.

Spoke TS2: Multi-risk resilience of critical infrastructures

Impact of detention basins on flood frequency curves

Angelo Avino[1], Salvatore Manfreda[1]

(1) Department of Civil Architectural and Environmental Engineering, University of Naples Federico II, angelo.avino@unina.it

In recent decades, there has been a perceived global rise of flood hazards (Di Baldassare et al., 2010). Detention basin systems stand out as one of the most widely employed methods for flood attenuation. The flood mitigation caused by the presence of artificial reservoirs could modify the natural flow patterns, leading to several impacts on the downstream hydrological and geomorphological regime (Wang et al., 2017; Albertini et al., 2022).

The objective of this work is to investigate the effect of flood control and mitigation structures (detention dams) on downstream river basin dynamics, particularly on the flood frequency curve. However, the mitigation process is influenced by hydrologic and hydraulic factors. Therefore, it is needed to develop a mathematical framework to interpret the closed-form functional relationship between inflows and expected outflows. In Manfreda et al. (2021), a huge effort has been carried out to define a theoretically derived probability distribution of the peak outflows from in-line detention basins, by assuming the incoming flood peaks to be randomly distributed and characterized by rectangular hydrographs of fixed duration. The scheme of the detention dam has been assumed to have two openings (i.e., low-level opening at the basement and a crest spillway), since this schematization can be described in a closed form. When the volume below the spillway crest is totally filled, the crest spillway starts functioning. Therefore, the peak outflow, $Q_{p,out}$, assumes the following form:

$$Q_{p,out} = Q_c + (Q_{max} - Q_c)\left(1 - exp\left[-\frac{\left(t_p - \frac{W_{max}}{Q_{max} - Q_c}\right)}{k}\right]\right) \qquad [1]$$

where: Q_{max} is the peak discharge incoming in the detention basin, Q_c control value of discharge that is computed using the discharge equation of the submerged opening, t_p the event duration of the incoming flood hydrograph reaching the detention dam, W_{max} the volume of water accumulated in the dam at the crest level, k the delay constant of the conceptual linear reservoir.

The inverse function of equation [1] can be used to analytically compute the theoretically derived probability distribution of the peak outflow from an in-line detention dam when the water level is at the crest of the spillway. The expression of the theoretically derived probability distribution will be the following:

$$p(Q_{p,out}) = \left|\frac{dg^{-1}(Q_{p,out})}{dQ_{p,out}}\right| f_{Q_{p,out}}\left(g^{-1}(Q_{p,out})\right) \qquad [2]$$

The proposed methodology can be applicable to several case studies since it could be adapted to any probability distribution of incoming floods. Moreover, considering this, the framework can efficiently be implemented for the analysis and design of different detention basins.

Ongoing activities focus on the implementation of the mathematical framework to detention basins in Italy to assess the probability distribution of flood peak outflows by exploiting the findings of Evangelista et al. (2023). They tried to assess the attenuation potential of flood peaks in 265 large reservoirs all over Italy by enhancing the information of detailed infrastructure data, as well as several morphological features of the upstream basins.

To sum up, the main objective of the work is to test the developed procedure by applying it to several case studies where lamination effects have already been evaluated.

References

Albertini C., Miglino D., Iacobellis V., De Paola F., Manfreda S. (2022). Flood-prone areas delineation in coastal regions using the Geomorphic Flood Index. *Journal of Flood Risk Management*, 35(12), e12766.

Di Baldassarre G., Montanari A., Lins H., Koutsoyiannis D., Brandimarte L., Bloeschl G. (2010). Flood fatalities in Africa: from diagnosis to mitigation. *Geophysical Research Letters*, 37(22).

Evangelista G., Ganora D., Mazzoglio P., Pianigiani F., Claps P. (2023). Flood attenuation potential of Italian dams: sensitivity on geomorphic and climatological factors. *Water Resources Management*, 37, 6165-6181.

Manfreda S., Miglino D., Albertini C. (2021). Impact of detention dams on the probability distribution of floods. *Hydrology and Earth System Sciences*, 25, 4231-4424.

Wang W., Li H.Y., Leung L.R., Yigzaw W., Zhao J., Lu H., et al. (2017). Nonlinear filtering effects of reservoirs on flood frequency curves at the regional scale. *Water Resources Research*, 53, 8277-8292.

ALARP criterion for assessing the quantitative resilience indicators of critical infrastructures (road tunnels)

Davide Berardi[1], Marta Galuppi [2], Mara Lombardi[1]

(1) Dept. of Chemical Engineering, Materials & Environment, University of Rome Sapienza, davide.berardi@uniroma1.it
(2) Dept. of Civil, Constructional and Environmental Engineering, University of Rome Sapienza

In decision-making, the 'As Low As Reasonably Practicable' (ALARP) principle necessitates a balanced cost-risk analysis of safety design. This principle asserts that achieving minimal risk should maximize safety levels while ensuring fair profitability, and maximizing profits should maintain a minimal but sufficient safety level. Lord Asquith's definition of 'reasonably practicable' in the 1949 London court judgment 'Edwards v. National Coal Board' has become the legal basis for risk assessments, establishing the ALARP principle. Since then, this principle has been officially adopted, encouraging the implementation of safety measures by governments and businesses to mitigate and manage risks. For example, to assess the safety levels for a road tunnel's operation, the ALARP criterion as defined in the F-N Plan is adopted.

In Italy, indeed, it's imperative to consider multi-risk events due to a blend of factors, including high seismic activity, a multitude of road tunnels and significant traffic. Effectively managing information about risk factors and understanding their interconnectedness is essential (Lombardi et al., 2021). For instance, exploiting the latent information within data collected by seismic monitoring networks using geostatistical methods allows the extraction of vital quantitative seismic data. These data support decision-making systems, prioritizing seismic interventions in current infrastructures and informing the design of new ones (Guarascio et al., 2021).

Particular attention is given to integrating renewable energy sources and conserving energy in road tunnels, forming a key part of a wider strategy for resilience and sustainability. This approach aligns with the United Nations Sustainable Development Goals, notably SDG 9.1, focusing on development of resilient and sustainable infrastructures. Meeting these goals becomes a social responsibility, where knowledge turns theoretical propositions into tangible opportunities and initiatives (Kranz et al., 2022).

The research delves into several aspects of Critical Infrastructures: the integrated system's performance, energy efficiency, the use of renewable sources and safety measures. Decreasing energy consumption should not compromise safety levels or the energy supply for safety systems, especially lighting. Ensuring service continuity requires architectural designs that facilitate maintenance and address failures (Parise et al., 2022), demanding flexible infrastructure delivery.

A "sustainable road (or railway) tunnel" demands a multi-criteria approach that balances environmental, economic, and social aspects throughout the infrastructure lifecycle. Crafting strategies for the design and operation of Critical Infrastructures (CI), necessitates compliance with legal mandates, technical standards and established frameworks. While this approach is intricate, it requires a transformative change that addresses infrastructure sustainability by encompassing concerns related to renewable energies, climate change and CI resilience. Evaluating CI sustainability from energetic, social, resilient, and transitional standpoints underscores its comprehensive sustainability (Gijzel et al., 2022).

Mitigating risks linked to CI safety requires advanced risk management methodologies, ongoing operational performance monitoring and resilient green power systems. Advancing towards a comprehensive strategy involves integrating models and technologies like Real-Time Quantitative Risk Analysis (RTQRA) and Dynamic Performance Evaluation (DPE) for enhancing safety systems and technologies.

Quantitative Risk Analysis (QRA) offers a structured and quantitative assessment of risks, essential for devising effective risk mitigation strategies and ensuring operational safety. Risk analysis operates on preconditions and assumptions and does not replicate reality (Guarascio et al., 2007). This method relies on an in-depth comprehension of risk processes, transcending experience-based approaches and focusing on selected but representative scenarios. On the other hand, Dynamic Performance Evaluation (DPE) serves as a tool for real-time and predictive statistical computations of system performance based on current local conditions and system availability. The goal revolves around creating an integrated multi-risk model that encompassing safety protocols, structural maintenance and component reliability. Risk analysis operates across various time scales, including design, operation, emergency management and maintenance. Nevertheless, the integrated risk model can adapt to these distinct scales, furnishing insights to optimize processes. Figure 1 shows how such themes are investigated within the TS2 Spoke of the RETURN project.

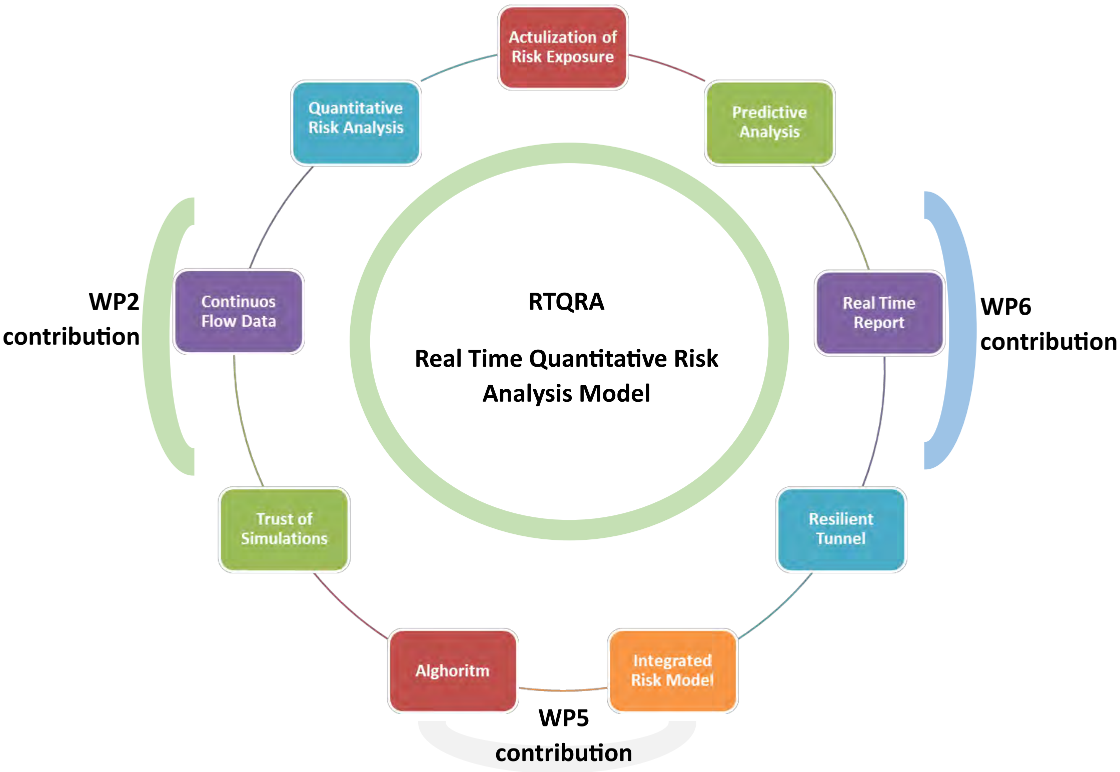


Figure 1 – Real Time Quantitative Risk Analysis model for CIs resilience.

The overarching goal is to provide comprehensive solutions ensuring the protection and resilience of road tunnels. Safety assessment spans diverse levels, encompassing individual assets (such as roads or railways and their critical points) up to the wider network, factoring in interconnections, alternative routes, interdependencies and domino effects. Emphasis is placed on multiple risks, encompassing both natural and accidental occurrences to be tackled through the development of an open knowledge-sharing tool. Specifically, a model based on the ALARP principle is tailored for Risk-Based Tunnel Design, particularly addressing fire incident scenarios. Italy has embraced ALARP Acceptability and Tolerability criteria, necessitating compliance verification to ensure a *minimum-sufficient level of safety*. The ALARP criterion, in this context, emerges as an effective approach for assessing and managing risks in critical infrastructures. Through a detailed and quantitative analysis, the significance of balancing risk reduction and the economic feasibility of mitigation measures is underscored, emphasizing the imperative for an integrated and sustainable approach to the resilience management within critical infrastructures.

References

Lombardi M., Libertà A.. Berardi D., Di Benedetto E., Guarascio M. (2021). Concepts and operational tools for multihazard risk analysis in road tunnels: the San Benedetto event, Italy. *Safety and Security Engineering IX*, 206.

Guarascio M., Libertà A., Berardi D., Di Benedetto E., Lombardi M., (2021). Seismic geostatistics application to the territorial infrastructure resilience and sustainability. *SAFE21*.

Kranz J., Schwichow M., Breitenmoser P., Niebert K. (2022). The (Un)political perspective on climate change in education - A systematic review. *Sustainability,* 14, 4194.

Parise G., Lombardi M. (2022). Ethics and eco-design for complex uses of energy: what we need for a sustainable future. *IEEE Industry Applications Magazine*, 28, 5, 74-79.

Gijzel D., Bosch-Rekveldt M., Schraven D., Hertogh M. (2020). Integrating sustainability into major infrastructure projects: four perspectives on sustainable tunnel development. *Sustainability*, 12, 6.

Guarascio M., Lombardi M., Rossi G., Sciarra G. (2007). Risk analysis and acceptability criteria. *WIT Transactions on the Built Environment, 94*, 131-138.

On site investigations and laboratory testing on full scale elements for the characterization of an existing RC bridge

Nicola Buratti[1], Gianluca Bottin[2], Luca Pozza[1], Diego Talledo[2], Luisa Berto[2], Anna Saetta[2], Marco Savoia[1]

(1) Dept. of Civil, Chemical, Environmental and Materials Engineering, University of Bologna, nicola.buratti@unibo.it
(2) Dept. DPC, University IUAV of Venezia

In recent years, the need to evaluate the residual capacity of existing infrastructure, which are approaching or exceeding their designed service life, has become a strategic issue worldwide. The definition of the mechanical characteristics and the degradation level of existing bridges has been widely investigated and nowadays there are different effective procedures for their assessment. In Italy, these aspects have been included within the general multi-hazard and multi-level framework for safety assessment of existing bridges recently proposed by the "Guidelines for classification and risk management, safety assessment, and structural health monitoring of existing bridges" (2020). These Guidelines represent a novel fundamental step in the regulatory framework of existing bridges (Cosenza and Losanno, 2021).

However, the degradation assessment is not fully sufficient to consolidate approaches to assess the residual capacity of existing structures. For this reason, several research works investigated the behaviour of structural elements extracted from bridges and viaducts scheduled for demolition, with hybrid numerical-experimental approaches (e.g. Savino et al. 2023, Pape and Melchers 2013, Tonelli et al. 2023, Jiang et al. 2023). Most of these studies deal with prestressed RC girders, given their intrinsic vulnerability and extensive presence across the national road infrastructure system. These experimental data can be crucial for a proper calibration of numerical models able to predict the life-cycle structural performance of RC elements.

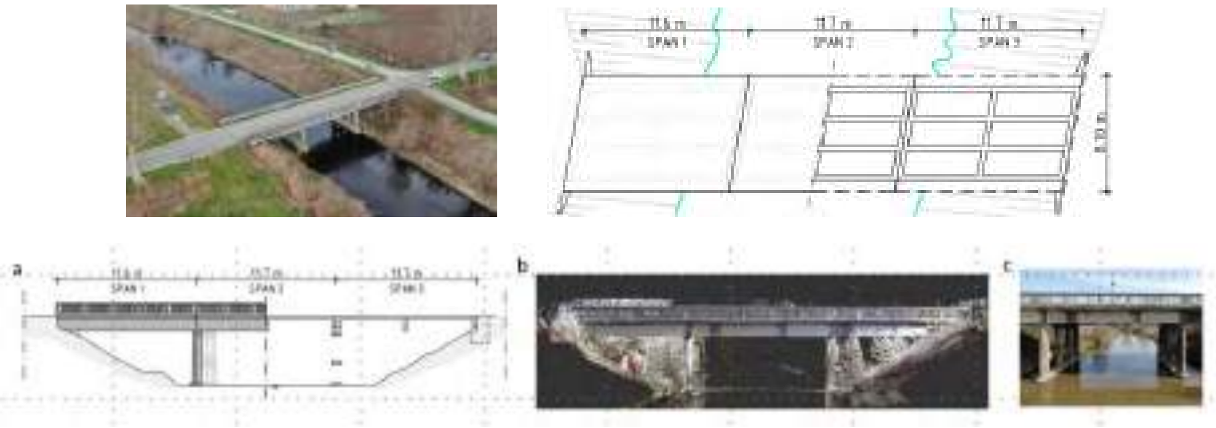


Figure 1 – Fratta bridge (Italy).

This work presents the first phases of an experimental and numerical research on an almost 80-years-old RC bridge in a rural area of Veneto region (Italy), scheduled for demolition. As part of the road system renewal project, it was scheduled the demolition of the existing three span Fratta river bridge (Figure 1) located in Valli Mocenighe, Piacenza d'Adige (PD) and the subsequent realization of a new single-span bridge in a mixed steel-concrete structure. In particular, in this paper preliminar numerical analyses are presented, in which simulations were conducted by assuming the mean values of all the material parameters in order to obtain the necessary information for the design of an experimental setup aimed at performing flexural tests on the bridge girders. Moreover, a Montecarlo analysis has been also carried out to assess the influence of the statistic variability of material parameters on the structural response.

References

Cosenza E., Losanno D. (2021) Assessment of existing reinforced-concrete bridges under road-traffic loads according to the new Italian guidelines, *Structural Concrete*, 22, 2868–2881.

Savino P., Tondolo F., Sabia D., Quattrone A., Biondini F., Rosati G., et al. (2023) Large-scale experimental static testing on 50-year-old prestressed concrete bridge girders. *Applied Science*, 13, 834.

Jiang H., Mo F., Chen Z., Wu J., Fang H., Fang Z., et al. (2023) Full-scale experimental study of shear and flexural behavior of 16-m retired reinforced concrete T-Beams. *Buildings,* 13, 2075.

Pape T.M., Melchers R.E. (2013). Performance of 45-year-old corroded prestressed concrete beams. Proceedings of the Institution of Civil Engineers, *Structures and Buildings*, 166(10), 547-559.

Tonelli D., Rossi F., Brighenti F., Verzobio A., Bonelli A., Zonta D. (2023). Prestressed concrete bridge tested to failure: the Alveo Vecchio viaduct case study. *Journal of Civil Structural Health Monitoring*, 13, 873–899.

Enhanced dashboard for prioritizing interventions to mitigate risks and improve resilience

Giuseppe Cammarata[1], *Davide Berardi*[2], *Mara Lombardi*[2]

(1) Technical Manager of the Industry & Security Technology, Research and Innovation Lab Digitech of Engineering Ingegneria Informatica S.p.A., giuseppe.cammarata@eng.it
(2) Dept. of Chemical Engineering, Materials & Environment, University of Rome Sapienza

This comprehensive research activity, focusing on spoke TS2 – Critical Infrastructures within the RETURN project's integrated technologies and solutions for holistic risk reduction (WP 6), combines extensive research efforts to advance analytics in data representation and extract valuable insights from diverse tasks. The primary research revolves around two distinct approaches: data analytics and visual analytics. The integration of these methodologies aims to streamline data analysis, facilitating the extraction of meaningful information and knowledge.

Data Visualization (Nica et al., 2023), or visual analytics (Afzal et al., 2023), involves identifying representative techniques applicable to various data types, ensuring effective analysis and representation. Conversely, Data Analytics encompasses a systematic process applied to datasets to identify trends and relationships, ultimately extracting valuable information (Pascariu et al., 2023).

The research activity addresses the vulnerability of geographical areas experiencing territorial imbalances due to climate change and intrinsic spatial vulnerabilities, casting doubt on their ability to achieve sustainable development. In response, the contribution involves the adoption and synthesis of digitally-enhanced disaster risk reduction techniques to support policymakers' actions. This approach emphasizes the importance of civic engagement and decision-making based on the integration and processing of available information.

The activity introduces the concept of "Territorial Digital Twins" (TDTs), emphasizing their potential benefits in networking distributed resources and integrating them into a decision-making dashboard. The paper underscores the importance of combining a technical approach with a social perspective in the development of TDTs to enhance community resilience. It highlights the practicality of using TDTs, incorporating techniques such as photogrammetry and GIS mapping, to facilitate their effective implementation at the local level (Chioni et al., 2023).

Throughout the project, the exploration of potential approaches to enhance analytics remains a key objective. The synergistic combination of diverse methods proves effective and efficient in mitigating risks and bolstering resilience. This is achieved by leveraging processed data, thoughtfully represented through dashboards (see Figure 1). The visualization process not only aims at representation but also engages in data exploration, enabling an in-depth study to identify anomalies, trends, and clusters.

Figure 1 – Example of dashboard for prioritizing interventions to mitigate risks.

Simultaneously, a dynamic model for resilience assessment seamlessly integrates with an informative dashboard within the Decision Support System (DSS), utilizing advanced computational algorithms (Nussbaumer et al., 2023). The safety of critical infrastructures is meticulously upheld through the implementation of Real-Time Quantitative Risk Analysis (RTQRA), enabling swift assessments. This capability provides decision-makers with sufficient time to make critical decisions during emergency scenarios.

The analysis employs a probabilistic model to identify precursors to critical conditions, incorporating real-time data and forecasts. Additionally, a thorough examination of safety requirements is conducted to establish comprehensive emergency management procedures for potential events such as seismic activities, fires, or landslides.

When faced with both natural and human-made disasters, the effective response from relevant authorities often relies on complex rescue operations involving numerous interdependent assignments. To navigate such complexity, decision support systems play a crucial role in decision-making and plan execution within rescue operations. Advances in data management solutions and artificial intelligence technologies have opened up enhanced opportunities for making decisions that are not only more efficient but also more effective, ultimately leading to improved search and rescue operations. This research aims to identify and integrate processes utilizing decision support systems, data management solutions, and artificial intelligence technologies, conducting a comprehensive analysis of existing solutions in terms of their research contributions to the investigated domain and exploring the potential for knowledge transfer between different application areas (Nasar et al., 2023).

The DSS is accurately designed as an early warning system, seamlessly integrating various subsystem services. It not only facilitates real-time risk evaluation but also conducts predictive analyses of system response, optimizing management practices for both operational and emergency conditions.

This integrated approach ensures a proactive stance against potential risks and enhances the overall resilience of critical infrastructure operations.

In conclusion, the research initiative achieved notable progress in analytics, particularly in data representation and insight extraction across diverse tasks. The integrated focus on data analytics and visual analytics aims to streamline data analysis and extract meaningful information.

Addressing the vulnerability of regions with territorial imbalances due to climate change and spatial vulnerabilities, the research emphasizes adopting digitally-enhanced disaster risk reduction techniques to support policymakers.

The introduction of TDTs and their potential benefits in networking distributed resources effectively demonstrates the research's innovative proposal.

The exploration of diverse approaches to enhance analytics remains a central objective. The synergistic combination of methods proves effective in mitigating risks and enhancing resilience. The integration of a dynamic resilience assessment model with an informative dashboard within the DSS showcases the utilization of advanced computational algorithms. The RTQRA ensures the meticulous maintenance of critical infrastructures' safety, facilitating swift assessments and providing decision-makers with sufficient time to navigate critical situations.

References

Afzal S., Ghani S., Hittawe M.M., Rashid S.F., Knio O.M., Hadwiger M., Hoteit I. (2023). Visualization and visual analytics approaches for image and video datasets: a survey. *ACM Transactions on Interactive Intelligent Systems*, 13(1), 1-41.

Chioni C., Pezzica C., Favargiotti S. (2023). Territorial Digital Twins: a key for increasing the community resilience of fragile mountain inner territories?. Sustainable Development.

Nasar W., Da Silva Torres R., Gundersen O.E., Karlsen A.T. (2023). The use of decision support in search and rescue: a systematic literature review. *ISPRS International Journal of Geo-Information*, 12(5), 182.

Nica E., Popescu G.H., Poliak M., Kliestik T., Sabie O.M. (2023). Digital twin simulation tools, spatial cognition algorithms, and multi-sensor fusion technology in Sustainable Urban Governance Networks. *Mathematics*, 11(9), 1981.

Nussbaumer A., Pope A., Neville K. (2023). A framework for applying ethics-by-design to decision support systems for emergency management. *Information Systems Journal*, 33(1), 34-55.

Pascariu G.C., Banica A., Nijkamp P. (2023). A meta-overview and bibliometric analysis of resilience in spatial planning–the relevance of place-based approaches. *Applied Spatial Analysis and Policy*, 16(3), 1097-1127.

Beyond NaTECH risk: safety and resilience in Hythane transport infrastructure

Elena Capasso[1], Andrea Di Domenico[1], Maria Portarapillo[1], Almerinda Di Benedetto[1], Micaela Demichela[2], Antonello Barresi[2], Morena Vitale[2], Chiara Vianello[3]

(1) Dept. of Chemical, Materials and Production Engineering, University of Naples Federico II, almerinda.dibenedetto@unina.it
(2) Dept. of Applied Science and Technology, Politecnico di Torino
(3) Dept. of Industrial Engineering, University of Padua

A technological accident initiated by a natural disaster is known as NaTech (Natural hazard triggering technological disasters). Today, such events are a topic of great interest and concern due to the increase in the intensity of weather-related phenomena, caused mainly by climate change and as a lack of management of the territories and their vulnerabilities. The RETURN (Multi-Risk sciEnce for resilienT commUnities undeR a changiNg climate) project funded under the PNRR is dedicated specifically to improving the entire disaster risk management cycle. As a POC, part of TS2 - Multi Risk Resilience of Critical Infrastructures, a NaTECH risk analysis of Hythane transport infrastructure was performed.

Hythane is a hydrogen-enriched methane mixture that is used as a potential bridge solution to reduce CO_2 emissions. The use of this mixture brings several immediate benefits in terms of emissions and the investment associated with the development of suitable infrastructure, which is significantly lower than for pure hydrogen. Therefore, the use of hydrogen in the form of Hythane could be the perfect solution for the near future. Nevertheless, the challenges associated with the use of Hythane must be kept in mind, namely the economic feasibility compared to the use of pure methane as well as safe storage and transport. The use of Hythane in transport and distribution networks, while tempting, must be properly weighed up by first conducting studies on the safety of the mixture and comparing it with the use of methane alone, but also on the compatibility of Hythane with current infrastructures.

To this end, a quantitative risk analysis (QRA) of Hythane pipelines was performed as the CH_4/H_2 ratio changes, using a specific framework for NaTech scenarios. Earthquakes, floods, and lightning strikes were assessed as natural events and loss of containment (LOC) triggers. Specific vulnerability models from the literature were used to assess the frequency of pipeline damage associated with natural events (Cozzani et al., 2014). These models were also used to determine the correct type of damage (catastrophic rupture or hole) and to understand the actual presence of an LOC. After assessing the frequency of occurrence of the LOC, the event tree analysis (ETA) was developed to assess the frequency of occurrence of the consequences. For the flooding event, the analysis showed no probability of failure associated with a mechanical fault, even under severe conditions, resulting in a zero value for the LOC frequency and thus concluding the analysis. In the case of a seismic event, the ETA results were atmospheric dispersion, vapour cloud explosion (VCE) and jet fire; however, in the case of a lightning strike, only jet fire, as a flammable material is released with a consistent probability of instantaneous ignition.

Once the frequency of occurrence of the possible consequences has been calculated, the associated consequences are analysed. To assess the consequences of jet fires, only empirical models were used to represent the radiant heat flux received at different distances from the point source for different CH_4/H_2 ratios. These models were applied to both seismic and lightning events and showed similar behaviour, i.e. as the mole fraction of hydrogen in the Hythane increases, the extent of the isorisk zone increases.

To modelling the release and dispersion of the Hythane mixture because of the LOC, computational fluid dynamics (CFD) simulations were carried out using a Reynolds Averaged Navier-Stokes (RANS) approach considering 1-minute release from a 5-cm diameter hole located at the top of the pipeline. CFD simulations considered factors such as wind speed, atmospheric stability, ground conditions and release height.

Preliminary results are shown in Figure 1, where the mole fraction of hythane (80%CH_4-20%H_2) on the left and the mole fraction of hythane within the flammability limits (right), both evaluated in the z-x plane passing through the hole, are reported. Figures show that the mass of flammable hythane relative to the total mass released at t=60s is extremely limited due to the limited flow rate and the high diffusivity of the mixture, which leads to rapid mixing of the hythane with the air. These results are also compared with those obtained using empirical modelling in steady state conditions.

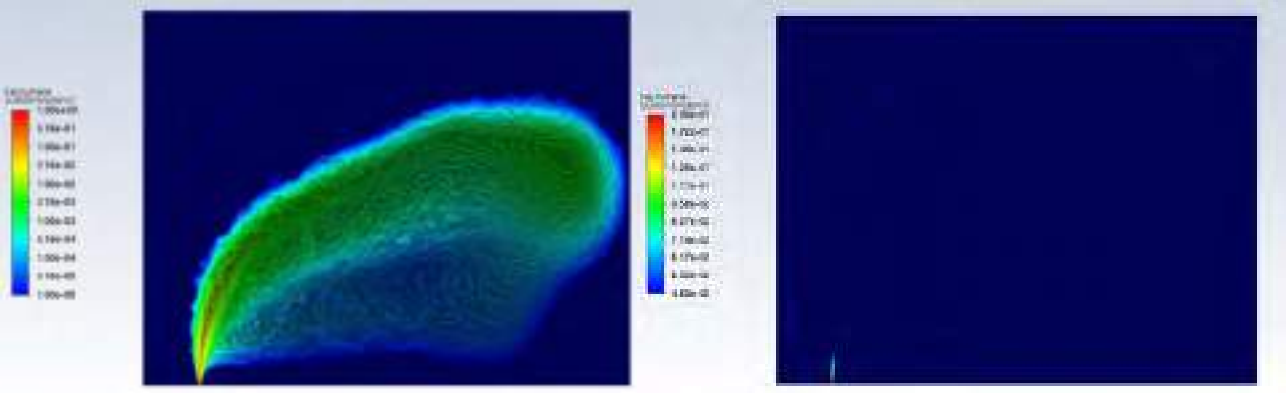


Figure 4 - Hythane dispersion in the case of H_2/CH_4= 0.25 in terms of molar fraction (left) and in terms of molar fraction included in the flammable limits (right)

To determine the optimum ratio, different CH_4/H_2 ratios that increase the hydrogen content of the mixture will also be evaluated both empirically and through CFD simulations. The results obtained will provide a solid basis for the development of proactive strategies and will contribute to improving the safety and resilience of pipelines in the face of unforeseen natural disasters. These results will be exploited in the Proof of Concept exercise related to the analysis of the distribution network and production units to support decarbonization in wide industrial area, characterized by several anthropic and natural hazards.

References

Cozzani V., Antonioni G., Landucci G. (2014). Quantitative assessment of domino and NaTech scenarios in complex industrial areas. *Journal of Loss Prevention in the Process Industries*, 28, 10-22.

Identification and localization of critical industrial assets in Italy

Pietro Carpanese[1], Luca Badin[1], Veronica Follador[1], Marco Ceresara[2], Elisa Saler[1], Marco Donà[1], Francesca da Porto[1]

(1) Dept. of Geosciences, University of Padova, pietro.carpanese@unipd.it

Catastrophic events have the power to impair a number of critical infrastructures, among which industrial sites play a significant role. This fact is acknowledged also by several codes, such as the CER (Critical entities' resilience) Directive 2022/2557, issued by the European Commission, which requires EU Member States to take specific measures to ensure essential services for the maintenance of economic activities. Especially when the factories utilize or produce substances that are considered dangerous for the people and the environment, the outcomes of possible accidents can be devastating.

This work aims to identify and map the main critical industrial sites in Italy, which require special attention when territorial scale risk assessments are to be carried out. Indeed, the retrieval of relevant exposure information on such a large scale is never a trivial activity, and open data are often inaccurate or incomplete. The sites that have been considered are those included in the Italian Legislative Decree of June 26, 2015, No. 105 “Direttiva Seveso III”. In accordance with this decree, the “Istituto Superiore per la Protezione e la Ricerca Ambientale” (ISPRA) built the inventory of facilities in Italy prone to major accidents, which currently counts 976 sites. These were deemed to be the most critical facilities with priority for analysis.

An algorithm for the automatic retrieval of exposure information on industrial sites was developed. The methodology has been applied to the Seveso inventory, but its application can be extended to collect similar information on other relevant industrial facilities. The algorithm first performs a Google Places search for each entry, searching for the plant by name and municipality to associate it with a set of coordinates. In this way, about 85% of the industrial facilities in question were correctly identified, while the remaining ones needed minor corrections or manual searching. Then, the algorithm retrieves ATECO information about the company that owns the plant by querying publicly available information via web scraping. Knowing the ATECO classification associated with the company operating the facility is useful to assume the industrial processes carried out within the plant. Furthermore, the algorithm collects hazard information for each industrial site. Specifically, for seismic hazard the MPS04 hazard map is used (Stucchi et al., 2011), and the study from Mori et al. (2020) was taken into account to associate each point to its specific soil class (A, B, C, D), according to the Italian regulation NTC 2018. Lastly, data about flood hazard in Italy were retrieved from the maps proposed by ISPRA. In this way, it was possible to map all the facilities susceptible to major hazards and to store the significant information within Geographic Information Systems (GIS). Figure 1 shows the map with the locations of all the Seveso industrial plants in Italy.

The Lombardy region contains the highest number of Seveso plants (249 plants, about 25% of the entire stock of 976), followed by Veneto, Emilia Romagna, Piedmont, and Campania. Most of the Seveso industries, nearly 59%, are located in Northern Italy (37% in the Northwest and 22% in the Northeast), while 41% of them are in the rest of Italy. Furthermore, it was possible to assess the distribution of the Seveso plants examined in terms of industrial sector: the most populated one in Italy is that dedicated to LPG (liquefied petroleum gas) storage, followed by chemical industries.

Figure 1 – Map of the locations of the Seveso industrial plants in Italy.

The algorithm is scalable, meaning it can be implemented for different territorial scales (national, regional, provincial, municipal and sub-municipal), based on the necessity of the study.

The application of the algorithm was tested for the Seveso list, however this is to be considered as a trial for further analyses. Indeed, the same procedure might be applied to other critical industrial activities for which a specific list has not been drafted yet. For example, specific industrial plants that deal with dangerous or polluting chemicals could be selected according to their ATECO code, and their location and business data could be retrieved automatically. In this way, it would be possible to create new databases for industries that, although below certain threshold levels, might still be considered critical and worth assessing.

References

Mori F., Mendicelli A., Moscatelli M., et al. (2020). A new Vs30 map for Italy based on the seismic microzonation dataset. *Engineering Geology*, 275, 105745.

Stucchi M., Meletti C., Montaldo V., et al. (2011). Seismic hazard assessment (2003-2009) for the Italian building code. *Bulletin of the Seismological Society of America*, 101, 1885–1911.

Transport infrastructure efficiency improvement: strategies to assess the landslide risk

Francesco Castelli[1], Tiziana Campisi[1], Valentina Lentini[1], Francesco Loiacono[1]

(1) Dept. of Engineering and Architecture, University of Enna "Kore", francesco.castelli@unikore.it

One of the most dangerous effects of climate change are heavy rainfalls, often responsible for the triggering of natural phenomena, such as floods, landslides (i.e. debris/earth flows) and/or rockfalls. The number of rainfall-induced landslides is expected to increase up to 400%, based on certain predictions of future weather. Frequently heavy rainfalls are the cause of fast-moving landslides, that occur in small areas, and are not predictable. These phenomena pose severe hazard to infrastructure and human lives and can cause extensive damage when interacting with the anthropized environment and the elements at risk. The identification of risk areas is therefore essential, and it is a preliminary step to design risk mitigation measures.

In medium/high-risk areas, where the transport infrastructure systems can be characterized by high levels of vulnerability, it is essential the improvement of knowledges in the field of hazard assessment and mitigation of damages. In this context, innovative methods for modeling fast moving events are required to reproduce a given debris/earth flow and/or a rockfall. On the other hand, risk assessment and the design of mitigation measures, can both be informed by back-analysis of previous events. There is a need to study the past events, to facilitate predictions of the behavior of extremely rapid landslides for hazard assessment.
With this aim, the research activity has been initially addressed to a better knowledge of the territory, also by developing widespread smart technologies (Castelli et al., 2017), which could facilitate managing and sharing complex information. In the authors opinion, cross-disciplinary collaboration between researchers, authorities, operators, and stakeholders could be a way of achieving the mutual learning and transfer of information, that would enable this knowledge to be transformed into practical strategies to strengthen the resilience of the built environment and, particularly, of the infrastructure systems.

Semi-quantitative methodologies to assess the risk of rainfall-induced landslides have been applied. Results derived from their application on large scale are handled to evaluate the susceptibility. The latter information is combined with weighted indexes, representative of the probability of the element at risk to be reached by the landslides, for the identification of risk area. These methodologies were applied to a lot of areas prone to landslides, often consisting in shallow movements induced by rainfall. Among these, the municipality of Gioiosa Marea (Sicily, South Italy), where the road network is frequently interested by traffic disruptions due to landslides (Figure 1), has been considered a target for the calibration of the models.

Starting from the study of the geological framework and the historical background, the research focused on the causes that triggered the landslides. In situ and laboratory tests, including geophysical investigations and triaxial tests in unsaturated conditions (Castelli et al., 2023), were carried out to investigate the factors affecting the dynamics of the events. These studies give us better knowledge of the mechanical and hydraulic properties that can be used to model these events, to assess the most appropriate strategies for the prevention and mitigation of related risk. It is discussed the capability of the prevision models to provide guidance on the useful life of structures, also in relation to the levels of functionality.


(a) (b)

Figure 1 - Landslides events occurred in the municipality of Gioiosa Marea (ME) in March 2016): a) a debris flow on SS113 km 87+060, and b) a rockfall on SS113 km 87+600.

Risk depends on the likelihood of triggered phenomena to provoke damages. The first condition to be verified is that triggered fast landslides should reach and interfere with elements at risk: this depends on runout distance and propagation mode. The caused damage thus differs according to the detached volume and the propagation velocity, as well as the element vulnerability.

These goals can be pursued via Quantitative Risk Analysis (QRA). The research focuses on procedures to perform quantitative analysis of the individual risk to life posed by instabilities affecting natural slopes, ranking urban areas based on the obtained QRA results. To these aims, the procedures have been tested in the studied areas with reference to the road network for which a comprehensive catalogue of events and information on exposed persons are available. Then, the risk to persons travelling on the road has been estimated by adopting a QRA procedure (Lentini et al., 2018). The proposed methodologies were first calibrated to predict the spatial and temporal occurrence of past surveyed phenomena. Susceptibility was then assessed in the whole municipality and validated by comparison with areas affected by slide movements according to the regional databases of historical landslides.

The study represents a procedure useful for the identification of intervention priority for infrastructures, and it provides a theoretical basis and a practical guide for the improvement of the efficiency of the transport infrastructures.

References

Castelli F., Lo Iacono F., Lentini V., Navarra G. (2017). Monitoraggio di infrastrutture civili mediante l’uso di sensori mems a basso costo: il caso studio del viadotto “Himera I”. *Atti XXVI Convegno Nazionale di Geotecnica “La Geotecnica nella Conservazione e Tutela del Patrimonio Costruito*”. Roma, 20-22 Giugno 2017, AGI Editore 2017, pp.897-905.

Castelli F., Lentini V., Di Venti A. (2023). Debris flow hazard assessment: laboratory experiences and numerical modelling. *Proc. 8th International Conference on Debris Flow Hazard Mitigation - DFHM8*, Torino, 26-29 June 2023.

Lentini V., Distefano G., Castelli F. (2018). Consequence analyses induced by landslides along transport infrastructures in the Enna area (South Italy). *Bulletin of Engineering Geology and the Environment*, 1-16, print ISSN 1435-9529, online ISSN 1435-9537.

Spatial vulnerability characterization between industrial infrastructure and territory using a multi-hazard, multi-scale approach

David Javier Castro Rodriguez[1], *Micaela Demichela*[1], *Antonello A. Barresi*[1], *Michele Torregrossa* [2], *Maria Castiglione* [2], *Santo Fabio Corsino* [2], *Giuseppe Beringheli*[2]

(1) Department of Applied Science and Technology, Politecnico di Torino, david.castro@polito.it
(2) Engineering Department, Università degli Studi di Palermo

Climate change trends could significantly increase annual damage to critical infrastructure in Europe by the end of the century, with industry being among the sectors with potential higher losses (Stoerk et al., 2018). In this regard, the European Commission has issued Directive 2022/2557 on the resilience of critical entities, by requiring Member States to identify and assess their risks, emphasizing to consider all relevant natural and man-made hazards that might result in incidents. Directive 2022/2557 stipulates that Member States must consider relevant risk assessments in compliance with sector-specific Union legislation, with explicit mention of Directive 2012/18/EU (Seveso III). Therefore, it demonstrates that at least a subset of macro-sectors belonging to the Major Hazards Industries (MHI) are considered critical entities.

In parallel, the MHI represents a source of threats to the territorial context where the plants are located, which coupled with other hazards, present unique risks to the communities and the environment. However, the current Land Use Planning (LUP) around MHI is only determined by the damage areas estimated in technological risk assessments, considering just the external vulnerable elements that could be impacted in case of an industrial accident. Conversely, the opposite direction where process plants are potential targets of the complex interaction of natural and territorial hazards, is often missed or overlooked, failing to address concomitant risks that could arise on the same territory in a bidirectional sense (Pilone et al., 2021). From this gap, a research question arises: can Major Hazard Industries (HIs) be characterized at different scales through a multi-hazard approach to detect vulnerability signals relevant to their surrounding territories? Then, the purpose of this research is to systematically characterize MHI from a multi-hazard approach to detect vulnerability signals. A downscaling was carried out in the Italian context being a representative study case as one of the countries with the largest number of Seveso plants. Space-dependent analyses were developed using open data and geographical information systems (GIS). Part of the methodology used in this work was generated under the activities of the Responsible Risk Resilience Center (R3C) of Polito.

First, from the available information obtained from national inventories (ISPRA, 2021), the Major Hazard Industries were clustered into the principal industrial macro-sectors defined in Ricci et al. (2021) and represented at a regional scale linking their distribution to meteorological data of interest. Second, at the regional scale selecting the Piedmont Region, the MHI were represented as punctual infrastructures, applying diverse threshold categories according to the LUP criteria in the national and regional legal framework. Subsequently, the population involved inside the different buffer zones in case of an accident was estimated in each province, considering the intersection between the so-called exclusion or observation areas, with the average population density (persons by hectare obtained from the National Institute of Statistics- ISTAT) (Castro Rodriguez et al., 2022). Third, at the municipal scale, a multi-hazard GIS-based tool was applied with a focus on the industrial context (a portion of territory inside and outside the plant boundaries), aiming to characterize vulnerability scenarios considering the bidirectional interaction between industry and territory (Castro Rodriguez et al., 2023). A hypothetical industrial plant was used as case study with elements from the real world to simulate scenarios.

Overall, this systematic and comprehensive approach delivers a spatial vulnerability profile between MHI and their surrounding territories. It aids in identifying signals that merit further correlation with insights gained from historical analyses on Natech impacting industrial infrastructure, across different natural hazards. Moreover, increase the awareness of stakeholders at different scales improving the decision-making process.

Water treatment plants are a recognized critical section within industrial plants, particularly the MHIs. They are vulnerable to intensive atmospheric phenomena, in particular heavy rains. From this the collaboration with the Università degli Studi di Palermo, to specifically address the issue of water treatment and to extend the developed approach to the civil water treatment plants (drinking and wastewater) at large. Heavy rains may cause geomorphological and hydraulic hazards that could affect the operation of drinking and wastewater TP. The PAI maps were used to assess these hazards. In addition, geolocalization of assets of interest, as punctual elements (DWTP and WWTP), was carried out using geographical information systems.

These topics are investigated within the RETURN project. Specifically, within the Spoke TS2-Multi Risk Resilience of Critical Infrastructures. WP 3 - Dynamic mapping of natural and climatic hazards over the infrastructure systems. T 3.2 – Robust hazard mapping over point critical infrastructures. Sub Task 3.2.2. Natural Hazards classification maps of point-like infrastructures of national relevance.
The synthesis of the principal results is represented in Figure 1.

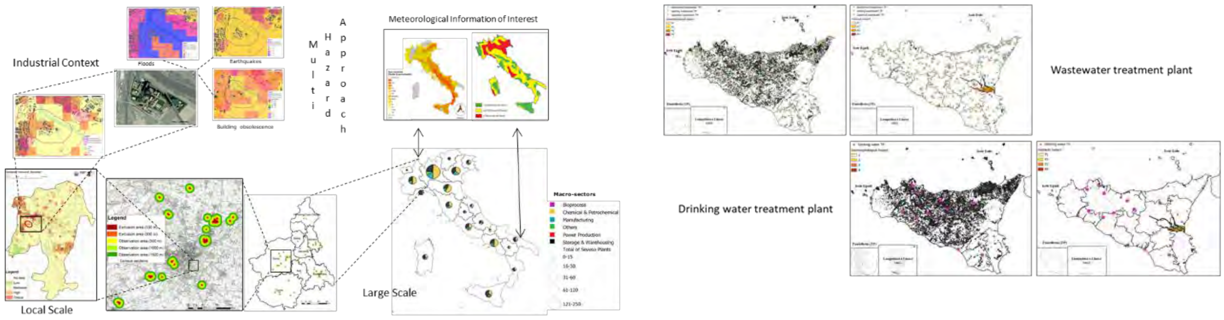


Figure 1 – Results from the multi-hazard, multi-scale approach depicting vulnerability between Industry and Territory.

References

Castro Rodriguez D.J., Demichela M., Beltramino S., Scalas M., Brunetta G., Barresi A. (2023). Vulnerability scenario characterization in an industrial context using a Natech indicator and a territorial multi-Risk approach. In: *Proceedings of 33rd European Safety and Reliability Conference* (ESREL 2023), Southampton, UK, 2181–2188.

Castro Rodriguez D.J., Beltramino S., Scalas M., Pilone E., Demichela M. (2022). Territorial representation of a vulnerability associated with the Seveso installations in a Nord Italian case study. In: *Proceedings of 32nd European Safety and Reliability Conference* (ESREL 2022), Research Publishing Services, 1463-1470.

ISPRA (2021). Inventario degli stabilimenti a rischio di incidenti rilevanti connessi con sostanze pericolose. Istituto Superiore per la Protezione e la Ricerca Ambiente. Sistema Nazionale per la Protezione dell’Ambiente.

Pilone E., Casson Moreno V., Cozzani V., Demichela M. (2021). Climate change and NaTech events: a step towards local-scale awareness and preparedness. *Safety Science,* 139, 105264.

Ricci F., Casson Moreno V., Cozzani V. (2021). A comprehensive analysis of the occurrence of Natech events in the process industry. *Process Safety and Environmental Protection,* 147, 703-713.

Storek T., Wagner G., Ward R.E.T. (2018). Policy Brief—Recommendations for Improving the Treatment of Risk and Uncertainty in Economic Estimates of Climate Impacts in the Sixth Intergovernmental Panel on Climate Change Assessment Report. *Review of Environmental Economics and Policy* 12, 371-376.

A case study of assessment of railway infrastructure vulnerability to debris flows

Chiara Cesali[1], Fabrizio Cabas[1], Alessandro Cappelli[1]

(1) ITALFERR SPA, Italian State Railways Group, Rome, Italy, e-mail: c.cesali@italferr.it

Increasing attention is today receiving the mobility of debris flows, in reason of their destroying effects, often related to the anthropization of piedmont areas. Particularly, it is necessary to identify the hazardous areas within which these granular flows may propagate.

To this purpose, a procedure to assess the railway infrastructure vulnerability to debris flows is developed and proposed. Specifically, the so-called "*basin-fan*" systems, potentially identifying "*critical*" areas, crossing an existing or a designed railway infrastructure are analyzed according to the following phases:

i) analysis of specifically produced geomorphological charts and/or available geomorphological risk maps provided by local governments, including the debris fans crossing the railway track;
ii) morphometric characterization of the selected debris fans and related drainage basins;
iii) evaluation of debris flow susceptibility of the examined “basin-debris fan” systems by means morphometric parameters, in situ observations, results of lab and in situ tests on materials composing basin slopes and information about historical events;
iv) estimation of magnitude of potential granular flows through empirical relationships or on the basis of thicknesses of debris covering basin slopes (for “basin - debris fan” systems susceptible to debris flows resulting from the previous phase *iii)*);
v) solid/debris and fluid/water volumes composing the potential granular flow, as well as the solid concentration value, through the “debris-graph” (D’Agostino et al., 2009) method, for specific hydrological inputs;
vi) geotechnical and rheological characterization of sliding materials;
vii) “hydraulic” analyses and/or numerical simulations of the propagation of the potential debris flows through a commercial software and definition of deposition (hazardous) areas.

The proposed procedure has been applied to the design phase of a new railway line. For confidentiality reasons, locations are not stated; codes and abbreviations are used for the examined “basin – debris fan” systems. The new railway infrastructure crosses some debris cones, potentially susceptible to debris flows phenomena.

The debris flow susceptibility of the crossed “basin-debris fan” systems is thus (preliminarily) evaluated through “morphometric” charts, derived from correlations between the parameters “area of the debris fan” (A_f) and “area of the basin” (A_b), “slope of the debris cone” (S_f) and “area of the basin” (A_b), available in technical literature (e.g. Bull, 1964):

$$A_f = c \cdot A_b^k$$

$$S_f = a \cdot A_b^m$$

The empirical coefficients *c, k, a, m* generally assume values ranged between 0.1 and 2.2, 0.7 and 1.1, 0.03 and 0.17, 0.35 and -0.15, respectively, according to in situ observations following “real” debris flows events (Harvey, 1997). To this purpose, for each “*basin – debris fan*” system (BFS), the morphometric properties (i.e. basin area, average basin slope, minimum and maximum elevations, area and slope of the debris cone, Melton Index, ….) have been thus evaluated and the “*basin – debris fan*” systems named BFS 1, BFS 4, BFS 5, BFS 6 have been identified as susceptible to debris flows phenomena (Figure 1 a, b, c).

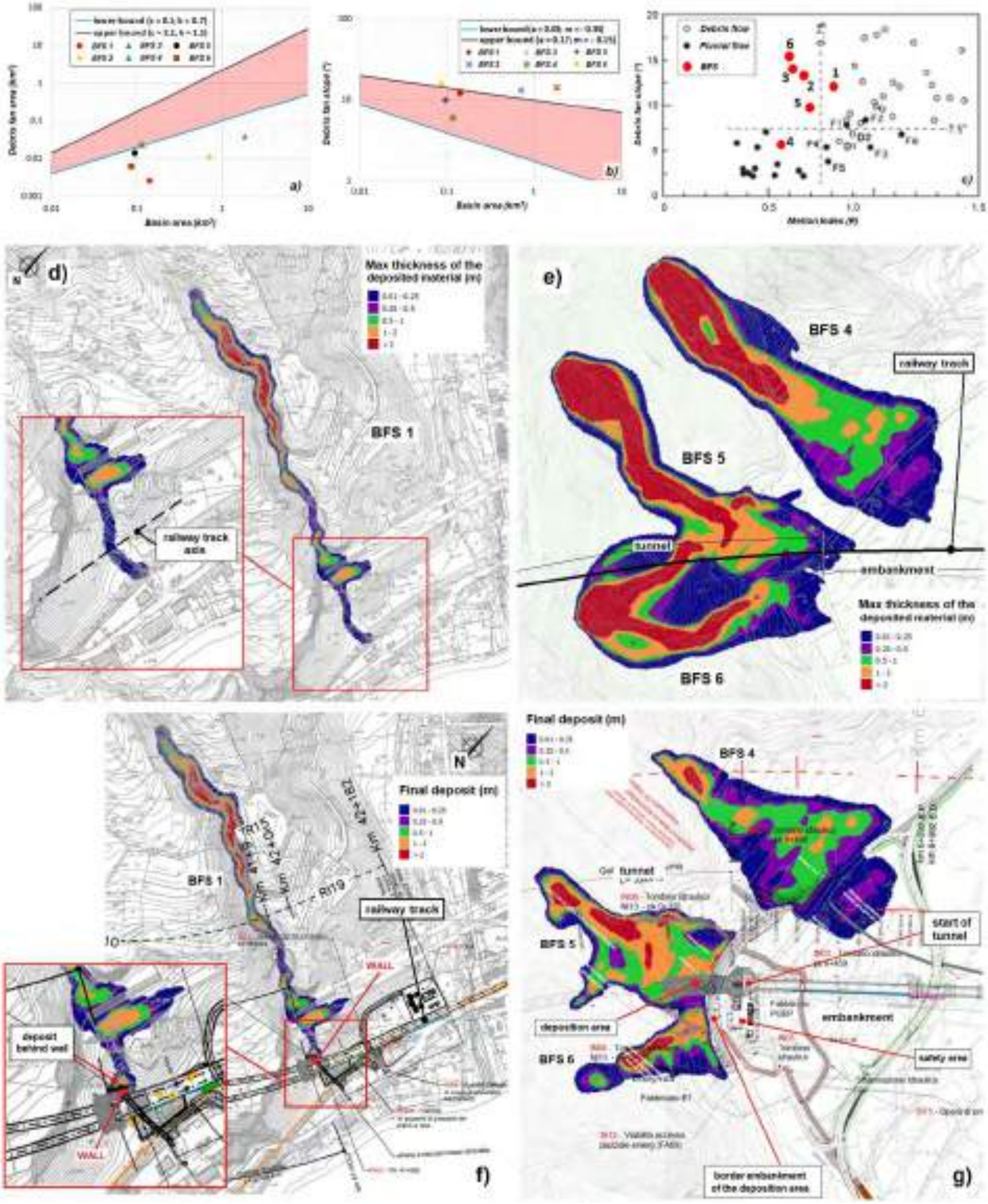


Figure 1 – a) Debris fan area vs Basin area; b) Debris fan slope vs Basin area; c) Debris fan slope vs Melton Index (by De Scally & Owens, 2004) for the examined "basin – debris fan" systems and results of numerical simulations under current conditions for d) BFS 1; e) BFS 4,5,6 and design conditions for f) BFS 1; g) BFS 4,5,6.

The volume of material involved in a debris flow potentially triggered within the examined "*basin – debris fan*" systems has been estimated by means assessments concerning the thickness of the debris blankets covering the basin slopes, supported by on-site investigations and analyses of their mechanical/geotechnical properties as well as through available empirical formulations (e.g. Ceriani et al. 2000).

The involved solid volume is therefore related to the liquid one, deriving from hydrological analyses (associated with a specific return period), through the "*debrisgraph*" method (D'Agostino et al. 2009), according to the maximum solid concentration of a debris flow (generally ranged between 0.5 and 0.65).

Once the magnitude of the potential debris flows within the examined "*basin – debris fan*" systems has been determined, numerical simulations of their propagation along the rivers/creeks, under the current/actual conditions, have been run through the numerical code *r.avaflow* (Mergili et al., 2012).

The obtained results show that the new railway track would cross the runout length of the simulated debris flows (Figure 1 d, e). Due to planimetric and altimetric constrains also related to the existing railway to which the new railway reconnects, the designed track could not be modified. Thus, to protect the new railway infrastructure, the following countermeasures have been defined:

- a wall along the creek of BFS 1, upstream the crossed railway line;
- a deposition area, delimited by an earthen embankment, at the end of the creeks of BFS 4, 5, 6, above the new designed railway tunnel.

The effectiveness of these countermeasures and their design parameters have been determined by repeating the previous numerical simulations under the "*post operam*" conditions (Figure 1 f, g).

References

Bull W.B. (1964). Geomorphology of segmented alluvial fans in western Fresno County, California. *U.S. Geological Survey Professional Paper*, 352, pp. 79-129.

Ceriani M., Crosta G., Frattini P., Quattrini S. (2000). Evaluation of hydrogeological hazard on alluvial fans. *Proceedings INTERPRAEVENT 2000*, *Villach*, 213-225.

D'Agostino V., et al. (2009). Field and laboratory investigations of runout distances of debris flows in the Dolomites (Eastern Italian Alps). *Geomorphology*, 115, 294–304.

De Scally A., Owens I.F. (2004). Morphometric controls and geomorphic responses on fans in the Southern Alps, New Zealand. *Earth Surface Processes and Landforms*, 29(3), 311-322.

Harvey A.M. (1997). The role of alluvial fans in arid zone fluvial system. *In Thomas, D.S.G. (ed.), Arid Zone Geomorphology: Process, Form and Change in Drylands, 2nd edn., Chichester: Wiley*, 231–259.

Mergili M., Fellin W., Moreiras S.M., Stötter J. (2012). Simulation of debris flows in the Central Andes based on Open Source GIS: Possibilities, limitations, and parameter sensitivity. *Natural Hazards*, 61(3), 1051-1081.

The Italian FlOod and Catchment Atlas (FOCA)

Pierluigi Claps[1], Giulia Evangelista[1], Daniele Ganora[1], Paola Mazzoglio[1], Irene Monforte[1]

(1) Department of Environment, Land and Infrastructure Engineering, Politecnico di Torino, pierluigi.claps@polito.it

In recent years, various national databases of geomorphoclimatic watershed attributes have been released. Notable examples include the CAMELS datasets, developed for countries like the United States, the United Kingdom, Australia, Chile, Brazil, Switzerland, France, and Germany (now integrated into Caravan), as well as LamaH-CE (related to the areas of the upper Danube up to the Austrian-Slovakian borders and some nearby catchments).

In Italy, as of today, only partial-coverage datasets (both in terms of spatial extent and number of variables) are available. One of the reasons behind this lack is the dismantlement of the National Hydrographic Service named “Servizio Mareografico e Idrografico Nazionale” (SIMN), that has led to a federated management of the national monitoring network by 21 different administrative agencies.

This work introduces FOCA (Italian FlOod and Catchment Atlas), a comprehensive national-scale compilation featuring 631 Italian river basins. These basins have been thoroughly characterized, offering a wealth of information comprising over 100 attributes related to geomorphology, soil, land cover, NDVI, climate, and precipitation extremes. Basin boundaries are provided as a key information of the dataset, empowering users to incorporate additional descriptors using their models or datasets.

The catchment selection criterion adopted in this work stems from the purpose to improve a national-scale inventory named "Catalogo delle Piene dei Corsi d'acqua Italiani" (Claps et al., 2020a, 2020b, 2020c), a result of a data rescue initiative that merged recent digital data with historical information available in printed documents. The 631 chosen catchments are those for which peak or daily discharges are available, and therefore all included in Claps et al. (2020a, 2020b, 2020c). The spatial distribution of the basin is visible in Figure 1.

The inclusion of descriptors in FOCA adheres to three key criteria:

a. national spatial coverage;
b. absence of regional or local distortions;
c. adequate spatial resolution.

Preference was accorded to local sources, with global data utilized only as last option. Even if the use of global datasets facilitates the comparison of the results obtained in large-scale hydrology works, local datasets are, without doubts, characterized by higher-quality information.

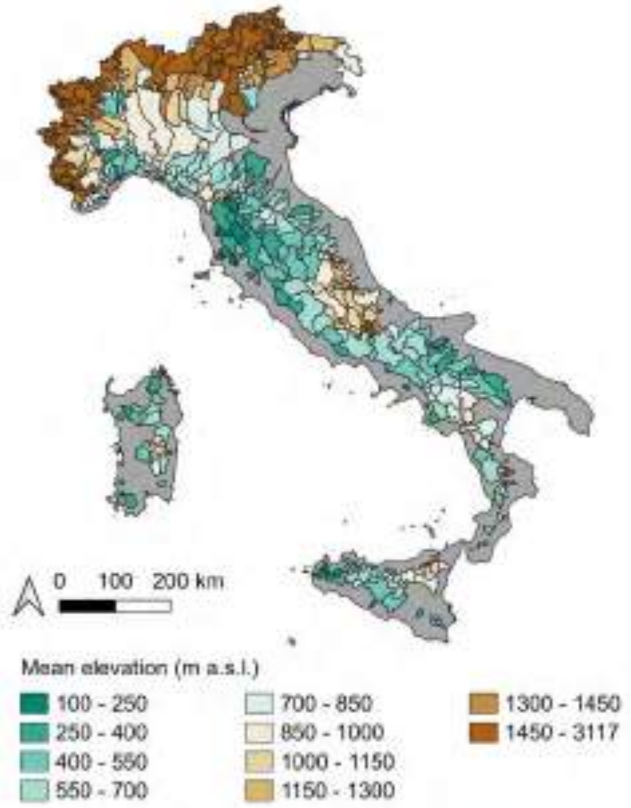


Figure 1 – Mean elevation of the 631 river basins included in FOCA.

FOCA distinguishes itself from other national datasets through its robust collection of geomorphological descriptors, computed using the r.basin algorithm of GRASS GIS and subjected to meticulous quality controls. Another distinctive feature is the inclusion of extreme rainfall characteristics, calculated using station data rather than reanalysis data (the latter is the approach used in the development of CAMELS datasets). For this purpose, the Improved Italian - Rainfall Extreme Dataset (I^2-RED; Mazzoglio et al., 2020) has been used. I^2-RED is a national collection of rainfall extremes measured by over 5000 rain gauges from 1916 to the present.

This nationwide data collection opens the door to a myriad of environmental applications, particularly in the field of flood studies.

References

Claps P., Ganora D., Apostolo A., Brignolo I., Monforte I. (2020a). Catalogo delle Piene dei Corsi d'acqua Italiani. Vol. 1. Ed. CINID. 499 pagg.

Claps P., Ganora D., Apostolo A., Brignolo I., Monforte I. (2020b). Catalogo delle Piene dei Corsi d'acqua Italiani. Vol. 2. Ed. CINID. 537 pagg.

Claps P., Ganora D., Apostolo A., Brignolo I., Monforte I. (2020c). Catalogo delle Piene dei Corsi d'acqua Italiani. Vol. 3. Ed. CINID. 401 pagg.

Mazzoglio P., Butera I., Claps P. (2020). I^2-RED: a massive update and quality control of the Italian annual extreme rainfall dataset. *Water*, 12, 3308.

Merging road network functionality analysis with a probabilistic approach for flood impacts definition

Bruno Colavitto[1], Tatiana Ghizzoni[1], Eva Trasforini[1]

(1) CIMA Research Foundation, Via Armando Magliotto 2, 17100, Savona, Italy, bruno.colavitto@cimafoundation.org

Both the Sendai Framework and the Sustainable Development Goals highlight the importance of building safe and sustainable transportation systems. Therefore, studying the vulnerability of transport networks not only from a structural (i.e., its physical components), but from a functional (the travel time) and topological (the network arrangement) perspectives, is essential to understand the direct and indirect effects associated to a given hazard (Dong et al., 2022). Vulnerability is closely related to the potential connectivity loss and to the concept of accessibility, as a measure of the ability of the road network to provide users access to an area, a given service or facility. This idea is in the core of many regional-scale studies dealing with the problem of defining areas (e.g., small towns) that can remain potentially isolated because of natural events (Taylor and Susilawati, 2012; Alasia et al., 2017). Many of these works simulate single events or random flood scenarios and use their results to perform the classic percolation method over the network and analyze the functional consequences of flooding (e.g., Papilloud and Keiler, 2021; Koks et al., 2023). However, the problem of isolation has not yet been addressed from a probabilistic point of view.

CIMA Research Foundation has already developed a computational probabilistic approach to simulate a set of scenarios affecting a region. This method is based on the aggregation at a given areal unit (the Minimum Units of Loss; MULs) of the impacts caused by the different (flood) hazard scenarios at different return periods. The main strengths of this approach are 1) the capability of the scenarios modelling of preserving the statistical properties of what has been observed (the event's definition), and 2) simulating events that never occurred but may occur in the future (the probabilistic events generation). The output of the scenario generation process is an event catalogue covering thousands of years, that is merged with the hazard maps/susceptibility maps to generate scenario maps. Those scenario maps combined with exposure and vulnerability information can be used to evaluate the impact of each scenario on the road network functionality.

In the context of the RETURN project (TS2: Multi Risk Resilience of Critical Infrastructures - WP3: Dynamic mapping of natural and climatic hazards over the infrastructure systems – Subtask 3.1.1 Hazard mapping on Critical Infrastructure - Water related), we aim to integrate a road network analysis approach in the framework of a flood probabilistic risk assessment. However, as the effects of floods on the road network are not limited to the area actually hit by the event, we seek to adapt the classical approach to solve the following question: how can we associate direct damages to specific road segments with such indirect impacts (e.g., the isolation of certain areas)? Though the question *per se* might be trivial, the computational effort linked to the characterization of each of the thousands (*n*-) flood scenarios impacting the road network may not.

Our methodology aims to be applied in Italy at national/regional level. However, given the current availability of data, a case-study is considered at national level for Cambodia. For this country, a long series of flood event scenarios, for which to analyze the direct impacts, were already computed. Typical risk metrics (Annual Average Loss - AAL and Probable Maximum Loss Curve – PML curve) relevant for the transportation system, e.g. km of roads affected and direct economic loss to the road network were also obtained. Having the (probabilistic) footprint of hazards, we seek to propagate the direct impacts to functional ones (Fig. 1). Hence, a road network analysis is performed, using free and open data from OpenStreet Maps within a Python environment. We calculated the betweenness connectivity index for each segment and vertex of the network, and we defined Origin-Destination pairs (locations of interest – service centers). The network with the connectivity values and the O-D pairs represents the exposure layer for the probabilistic risk assessment (Fig. 1B). After running the model, we obtain, on one hand, a regional map with the areas expected to get the most of network losses in terms of connectivity (Fig. 1C). It can be seen that the roads close to the capital city (Phnom Penh) and those to the east are the most vulnerable, since a direct damage in those roads segments could imply a larger loss of connectivity to the overall network. On the other hand, we obtain the probability of disruption of each Origin-Destination path, to be used as input for the percolation method to calculate the isolation potential of each location of interest.

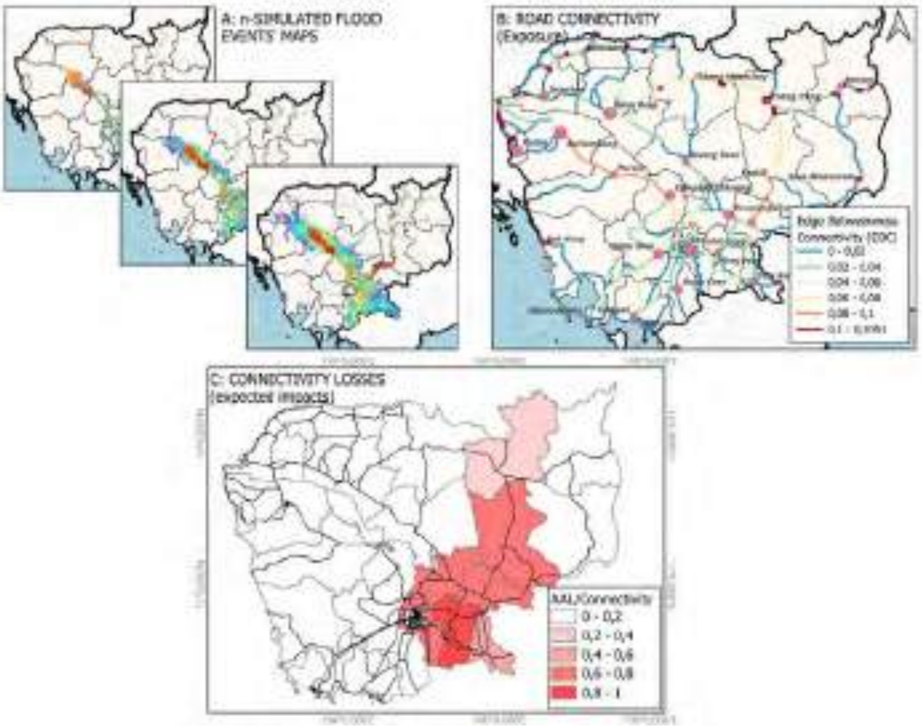


Figure 1 – Connectivity losses with a probabilistic approach. A) n-simulated flood events' maps; B) Road network classified by the edges' connectivity values, and potential origin (red dots)-destination (pink dots, service centers, main cities) pairs; C) Preliminary results showing administrative units classified by the ratio of AAL/total connectivity of road segments in each.

References

Alasia, A., Bédard, F., Bélanger, J., Guimond, E., Penney, C. (2017). Measuring Remoteness and Accessibility-a Set of Indices for Canadian Communities. *Statistics Canada: Reports on Special Business Projects*, 18-001-X.

Dong, S., Gao, X., Mostafavi, A., Gao, J. (2022) Modest flooding can trigger catastrophic road network collapse due to compound failure. *Communications Earth & Environment*, 3, 38.

Koks, E., Rozenberg, J., Tariverdi, M., Dickens, B., Fox, C., van Ginkel, K., Hallegatte, S. (2023) A global assessment of national road network vulnerability. *Environmental Research: Infrastructure and Sustainability*, 3, 025008.

Papilloud, T., Keiler, M. (2021) Vulnerability patterns of road network to extreme floods based on accessibility measures. *Transportation Research Part D: Transport and Environment*, 100, 103045.

Taylor, M., Susilawati (2012) Remoteness and accessibility in the vulnerability analysis of regional road networks. *Transportation Research Part A: Policy and Practice*, 46(5), 761-771.

Key elements for a homogeneous flood hazard assessment on Large Dams in Italy

Giulia Evangelista[1], Daniele Ganora[1], Paola Mazzoglio[1], Francesca Pianigiani[2], Pierluigi Claps[1]

(1) Department of Environment, Land and Infrastructure Engineering, Politecnico di Torino, giulia.evangelista@polito.it
(2) General Department of Dams and Hydro-Electrical Infrastructures, Ministry of Infrastructure and Transport

Within the context of flood risk assessment and management, recent scientific contributions have extensively explored how the hydrological response of a watershed can undergo substantial changes in the presence of artificial reservoirs. However, as of today, the methodological framework for evaluating the intrinsic attenuation capacity of individual reservoirs based on their geometric features and the average peak flow generated by the upstream watershed cannot be considered clearly defined.

This study aims to systematically outline the key aspects of the problem to allow for preliminary, yet as objective as possible, assessments of the effectiveness of peak flow attenuation in Large Italian Dams. The research seeks to avoid limiting solutions to a specific reference basin and instead aims for broader applicability on a national scale.

In a large-scale context, such as the national level, standardizing hydrological forcings and adopted hydraulic conditions is essential to ensure consistency and comparability of results. In this direction, the “natural” flood attenuation potential of 265 large reservoirs all over Italy is devised, in terms of the development of a Mitigation Efficiency Ranking. The resulting classification can be used to prioritise the implementation of Dam Emergency Plans in Italy and to support similar initiatives worldwide.

To maintain homogeneity in such a wide area, standardized hydrograph shapes are used and index-flood from the rational method is adopted as the incoming peak value, enhancing the results of a recent analysis of all Italian rainfall extremes (Mazzoglio et al., 2020). The attenuation index is computed by solving the differential equation of lakes. Twenty-four different design floods were derived adopting only two hydrograph shapes and minimal parameter options, i.e., the basin runoff coefficient, the time of concentration and the parameters of the Intensity-Duration-Frequency (IDF) curve. The study covers 265 reservoirs across Italy, selected on the basis of preliminary criteria of relevance, and their respective watersheds.

The results of the classification for the 265 dammed watersheds in all the tested configurations demonstrate to be strongly sensitive to the assumptions on the time of concentration and to some rainfall features, while, for instance, the hydrograph shape seems to exert much less influence on the ranking outcome.

References

Mazzoglio P., Butera I., Claps P. (2020). I^2-RED: a massive update and quality control of the Italian annual extreme rainfall dataset. *Water*, 12, 3308.

A comprehensive analysis of actions taken for resilience assessment of critical infrastructures

Marta Galuppi[1], Davide Berardi[2], Mara Lombardi[2]

(1) Dept. of Civil, Constructional and Environmental Engineering, University of Rome Sapienza, marta.galuppi@uniroma1.it
(2) Dept. of Chemical Engineering, Materials & Environment, University of Rome Sapienza

Nowadays, as underlined with the European Directive 2022/2557 the protection of the critical infrastructure induced the interest of the scientific community and involves spoke TS2 – Critical Infrastructures of the RETURN project. The principal aim of this research is to assess resilience quantitatively and establish a connection between risk assessment and the lifecycle of the infrastructure. Resilience, as discussed by Kosovac and Logan (2021), is not an absolute concept, necessitating the establishment of criteria to define what is considered sufficiently resilient. Consequently, a risk-based design approach forms the foundational framework for evaluating risk assessments of essential infrastructures (i.e. energy, transport) and reinforcing changes induced by Climate Change.

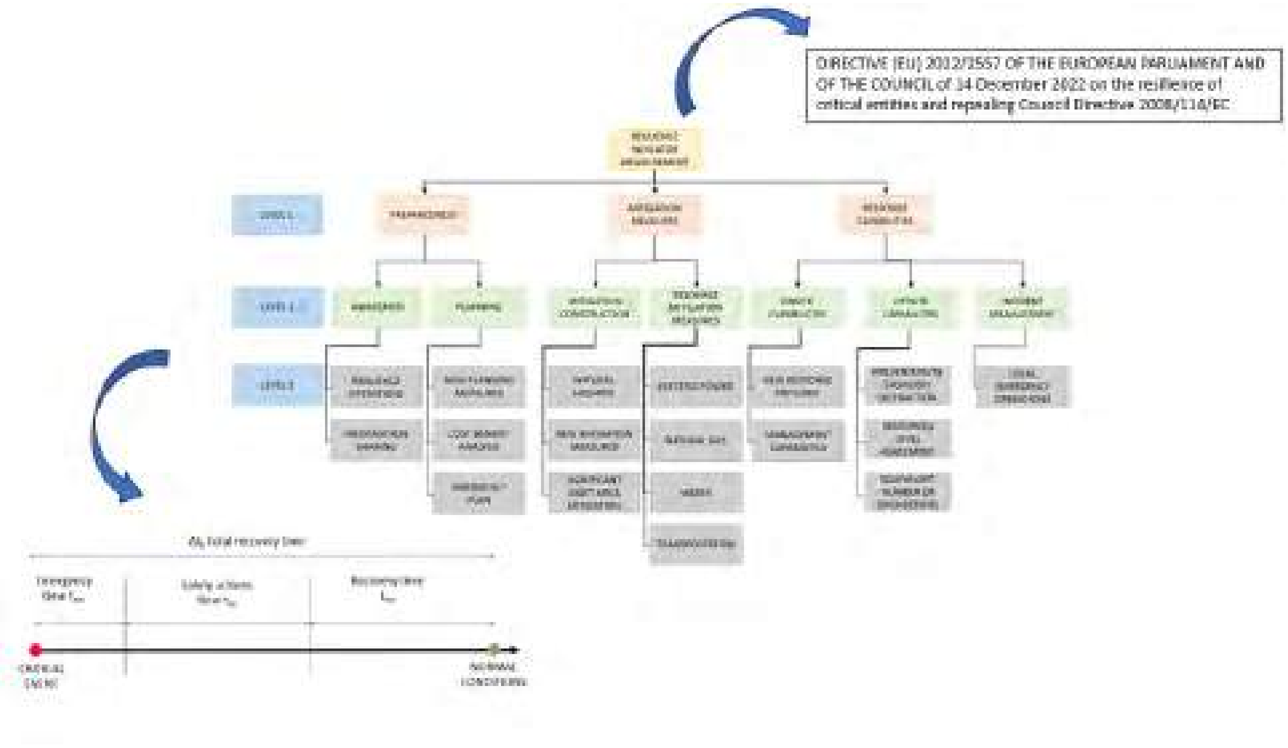


Figure 1 – Resilience flow chart of critical infrastructures.

In Figure 1, the resilience flow chart is presented. There are three level corresponding three different phases: preparedness, mitigation measures and response capabilities. As mentioned earlier, the infrastructure can either be discrete points or a combination of various discrete and non-discrete components that converge, along with individual assessments, into the resilience indicator. This indicator, as defined in Figure 1, has additive properties, allowing for the evaluation of individual assets (components) and their sum into the overall resilience indicator. The evaluation involves different assets, the residual risk indicator associated with the components, and the design criteria, utilizing a quantitative probabilistic method for analyzing multi-hazard resilience (Kong et al., 2019). Notably, this method considers scenarios where hazards of different types or magnitudes occur simultaneously or successively with damaging force.

The evaluation process involves the following steps:

1. Assessment of Different Assets: Each individual asset within the infrastructure is assessed for its resilience. This evaluation considers various factors such as robustness, redundancy, and adaptability to disruptions.

2. Residual Risk Indicator: For each component, a residual risk indicator is calculated. This indicator quantifies the level of risk that remains even after implementing resilience measures.

3. Design Criteria: The design criteria outline the standards and requirements that the infrastructure should meet to achieve a certain level of resilience. These criteria serve as benchmarks for evaluating the infrastructure's performance.

4. Integration into Resilience Indicator: The assessments of individual assets, residual risk indicators, and design criteria are integrated into the overall resilience indicator. This composite indicator provides a comprehensive measure of the infrastructure's resilience.

By combining these components, the evaluation process ensures a holistic and comprehensive understanding of the infrastructure's ability to withstand and recover from various disturbances and adverse events.

The model's result is represented by quantitative risk indicators that, to comply with the acceptability in case of risk to human life, will be estimated based on the Expected Value of damage, which defines the Individual Risk, and the Social Risk. Specifically, the Individual Risk Indicator is evaluated by knowing the level of exposure of the area of interest as a normalization factor to be applied.

The resilience concept is strongly time dependent as shown in Figure 1. The total restoration time is the result of the sum of the following times:

- Emergency time t_{em}: the time elapsed between the onset of a critical event and the activation of mitigation actions.
- Safety actions time t_{sa}: the time taken for safety measures to counteract the emergency and initiate the recovery process.
- Recovery time t_{rec}: the time it takes for the infrastructure to recover and return to normal operating conditions.

The sum of the three different time represents the total recovery time Δt_{tr} required when a critical event occurs, and the infrastructure needs to restore its capabilities to overcome the critical conditions and return to normal operation.

Regarding the concept of resilience is essential to take account of the multiple hazards which can affect a critical infrastructure. The resilience for example can be evaluated for seismic design (Chen et al., 2023) or fire hazards (Zhu et al., 2023). According to what has been illustrated, it can be easily inferred that the topic of risk assessment is extensively discussed in literature (Ranasinghe et al. 2023), especially when it comes to highly significant systems for society, such as critical infrastructure. However, despite the growing interest in this subject, there is often a tendency to focus solely on a single hazard, which, although achievable, does not fully represent reality. As emphasized earlier, the literature on risk assessment related to critical infrastructure commonly focuses on the effects of a single hazard, thus neglecting the potentially derived effects from multiple interacting hazards.

The question becomes link the resilience indicator to continuous monitoring. This research highlights the importance of emergency management in terms of response time and the activation of appropriate measures and security procedures to avoid rendering an infrastructure unavailable after a critical event. All of this relates to the concepts of residual risk and acceptability, as risk-based design aims to achieve a higher level of infrastructure availability and safety for both the infrastructure itself and its users.

References

Kosovac A., Logan T.M. (2021). Resilience: lessons to be learned from safety and acceptable risk. *Journal of Safety Science and Resilience*, 2, 4, 253-257.

Kong J., Simonovic S.P., Zhang C. (2019). Sequential hazards resilience of interdependent infrastructure system: a case study of greater Toronto area energy infrastructure system. *Risk Analysis*, 39, 1141-1168.

Chen X., Shen J., Bao X., Wu X., Tang W., Cui H. (2023). A review of seismic resilience of shield tunnels. *Tunnelling and Underground Space Technology*, 136, 2023, 105075.

Zhu Z., Carlton A., Quiel S.E., Naito C.J. (2023). Objective-level resilience assessment of circular roadway tunnels with reinforced concrete liners for vehicle fire hazards. *Resilient Cities and Structures*, 2, 3, 1-18.

Ranasinghe U., Jefferies M., Davis P., Pillay M. (2020). Resilience engineering indicators and safety management: a systematic review. *Safety and Health at Work*, 11, 2, 127-135.

Methodologies for soil characterization and field monitoring of river embankments

Guido Gottardi[1], Ilaria Bertolini[1], Michela Marchi[1]

(1) DICAM Department, University of Bologna, guido.gottardi2@unibo.it

Assessing a realistic probability of failure in current river embankments under changing boundary conditions results an increasingly challenging task for researchers and practitioners, mostly due to the variability in soil moisture and pore water pressure distribution and to the complexity of soil behavior in partially saturated conditions. Taking into account such complexities requires a comprehensive approach in the analysis, modelling and design of these critical linear infrastructures, which enables to account for soil suction fluctuations and water content variations and aims at employing suitable soil models for the actual estimation of their stability (frames “a” and “b” in Figure 1). The implementation of purposely designed monitoring systems emerges as a practical strategy to facilitate model calibration, refine predictive analyses and ensure reliability. However, obtaining on-site measurements of critical variables at significant depths results often practically difficult. Moreover, accurate laboratory soil characterization in partially saturated conditions is still typically achieved for research purposes, rather than for practical applications.

An extensive full-scale monitoring system has been thus designed and installed in a flood defense section of the River Secchia, north of Modena (northern Italy). This system encompasses an array of field measurements, rather innovative in this field, specific laboratory tests and numerical analyses. The final aim is to establish a methodological framework to be used for a reliable evaluation of the changeable stability conditions of river embankments under transient flow and, also, to shed a light on potential limitations inherent to the commonly adopted methods of analysis.

Depending on the nature of the river embankment failure mechanism involved, the attention can be also focused on the investigation of the hydraulic and mechanical behaviour of the soil units located underneath the ground level, typically in saturated conditions. Due to the water flow produced by relevant hydraulic gradients during high water events, significant internal erosion processes can take place and develop in these layers, such as Backward Erosion Piping (BEP). BEP Is especially recurrent in large low-land rivers located all over the world and, in Italy, along the Po River in particular. BEP mainly affects the sandy soil (aquifer) possibly underlying a water-retaining structure and, during a sufficiently high and persistent hydrometric peak, it can locally trigger an erosion process caused by the removal and transport of sand particles through a discontinuity (exit pipe) in the cohesive top confining layer (blanket) (frame “c” in Figure 1). During BEP progression, it is possible to recognize the ongoing phenomenon because at the exit point of the water flow (where the discontinuity is located) a sand volcano (“sand boil”) is formed (frame “d” in Figure 1).

From a recent survey, a total of 130 sand boils have been catalogued along the Po River and it was noticed that, during severe high-water events, a large part of these historical sand boils reactivate simultaneously (frame “e” in Figure 1). An embankment section along the Po River, close to Guarda Ferrarese (FE) and affected in the past by many episodes of sand boil reactivations, has been selected as a representative case-study, with the aim of devising a robust methodology for the identification of the governing parameters, including again laboratory tests, field investigations and monitoring, numerical modelling in two and three dimensions.

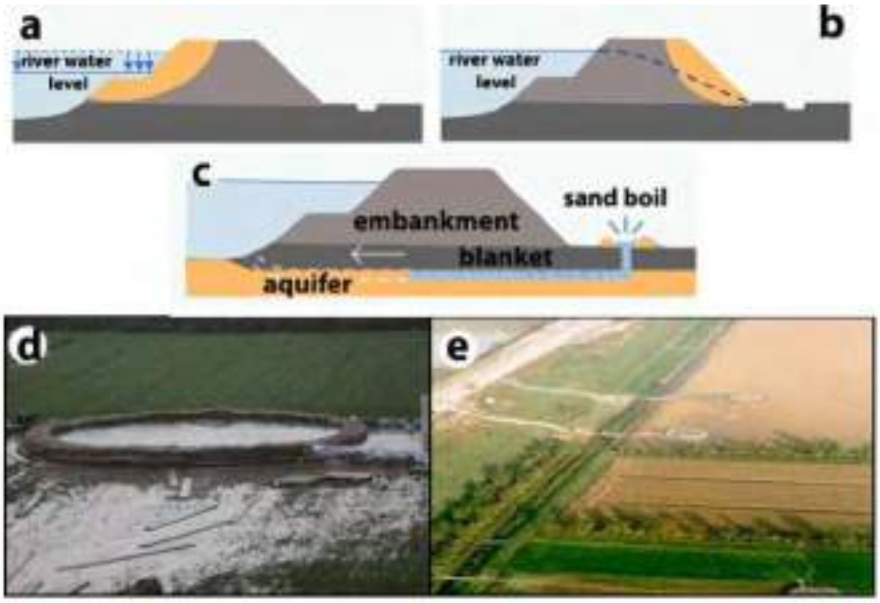


Figure 1 – Formation of a slip surface in the inner slope (a) and in the outer slope (b) due to the propagation of the saturation profile in the bank body during high water events (failure for soil saturation). In frame (c) mechanism of formation of erosion pipes at the interface between the sandy aquifer and the cohesive topsoil due to BEP phenomena. Photos of the sand boil reactivation in Boretto (d) and Colorno sul Po (e) during the high-water events registered in 2014 and 2000, respectively.

Co-creation process for requirement identification to strengthen disaster risk management

Luisa Lavalle[1], *Sonia Giovinazzi*[1], *Maria Luisa Villani*[1], *Alberto Tofani*[1], *Tatiana Patriarca*[1], *Nicola Bazzurro*[2],

(1) Critical Infrastructures Analysis and Protection Laboratory, ENEA, luisa.lavalle@enea.it
(2) IREN SpA

The traditional reliability analysis approaches and tools are insufficient to support critical infrastructure operators to effectively cope with the new challenges posed by the natural events. In fact, operators are used to manage a number of simultaneous faults which is common for the infrastructure (typically single or double faults), and the infrastructures are designed to handle these conditions. Unfortunately, extreme natural events have the potential to disrupt several key assets (and several key infrastructures) at the same time with subsequent effects difficult to predict. Also, impacts of extreme weather and climate change on infrastructures differ across the country, being the extent and probability of suffering a certain impact both location-dependent and asset-dependent. Experts on hazard and vulnerability assessment should therefore be involved in any analysis targeting the estimation of possible risks and impacts on the exposed assets.

Identifying, modelling and analysing the relevant critical infrastructures within the national territory as well as eliciting their intra- and inter- dependencies which may contribute to service interruptions is key for paving the way to foresight and risk management at a systemic level and is one of the activities to be carried out in the TS2 spoke of the RETURN project.

To achieve the mentioned goals, the identified approach started from a co-creation process with stakeholders, asset managers and domain experts for the identification of the requirements of the analysis and will further develop with the characterization (for both physical and functional features) of a critical infrastructure as a stand-alone system at component level and the system characterization at system-of-system level.

The co-creation process includes 4 interconnected and interactive phases represented in Figure 1 and briefly outlined in the following, namely: i) gather expertise; ii) build a shared understanding; iii) needs prioritization and iv) needs assessment. Feedback among the 4 different steps is expected, for example whenever the assessment leads to a better and new understanding of the information or methods needed to cope with extreme events; feedback is represented as dotted arrows in Figure 1.

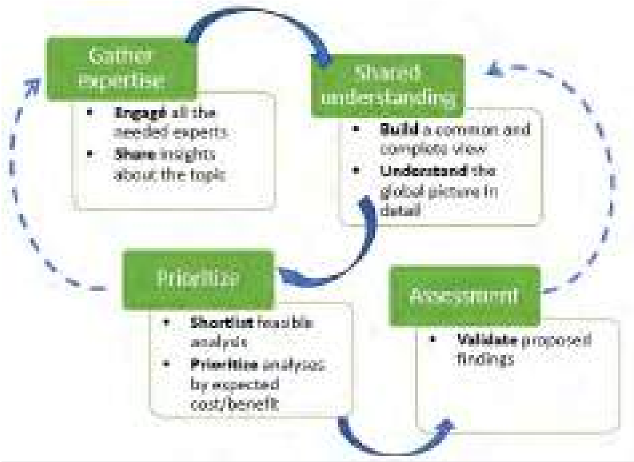


Figure 1 - Overview of the requirement identification co-creation process originally proposed and adopted within the RETURN project.

Gather expertise. This step aims to elicit knowledge from both domain experts, including among others infrastructure operators, asset manager, engineers (structural, geotechnical, electrical etc.) and the scientific community of the project encompassing hazard and vulnerably modelling experts. The aim is to elicit from CIs' asset managers and operators inputs on: open issues, perceived priorities, bottlenecks when managing their infrastructures under the threats created by changing climates; the availability and accuracy of data to characterize their managed CI system from a physical and functional point of view; the level of understanding, the feasibility, cost/benefit and sustainability of different approaches and strategies for adaptation, mitigation and resilience enhancement. On the other hand, the scientific experts can have the opportunity to raise awareness among the asset manager and operators about future possible scenarios, expected issues as well as the state of the art and the expected research advancements.

Build a shared understanding. This step aims to shift from a simple knowledge elicitation to a co-creation process where all the engaged experts and stakeholders can collaborate to create a shared understanding and alignment, leveraging their diverse insights. With this step everyone should get a more holistic view of the problem and a mutual knowledge growth in line with the RETURN vision to enforce the key competences in disaster risk management. Expected results include identification of viable solutions and strategies by combining the scientific knowledge with asset managers skills expertise and know-how on what is going to work, and what not, in their domain of expertise.

Prioritize needs. This step aims to shortlist and prioritize the analyses to be carried out in a certain timeframe depending on the interest, feasibility and state-of-the-art knowledge. Inputs include knowledge and data availability, operators' perception of their needs, areas with consolidated and adequate solutions where support is not needed, available time/money/person resources, expected impact and cost/benefit analysis.

Assessment. Once the target of the analysis is clearly identified, it is necessary to define, as part of the co-creative process, meaningful KPIs (Key Performance Indicators) to inform and support the different decision-making processes in which operators and asset managers can be engaged in the different phases of climate adaptation and disaster risk management processes. The results of the analysis need to be validated by the operators with respect to plausibility, relevance and further analysis needs.

It is envisaged that the four-step process would need to be repeated for two subsequent phases namely:

- Phase 1) when the focus is on the system as a stand-alone system, as described above;

- Phase 2) when the focus is on the system-of-system functioning and interdependencies. In this case, stakeholders of the different domains need to be gathered and suggested brainstorming input is the shortlist of the most critical scenarios for the single infrastructures.

Results achieved in RETURN – described in an internal confidential deliverable – show that improved territorial hazards maps at local scale with different climatic scenarios are needed.

References

https://www.undrr.org/quick/50922

2030 Agenda for Sustainable Development, UN General Assembly, transforming our world. Available online: https://www.refworld.org/docid/57b6e3e44.html.

UNISDR Sendai Framework for Disaster Risk Reduction 2015-2030. A/CONF.224/L.2. Available online: https://digitallibrary.un.org/record/793460?ln=en.

FEMA. HAZUS-MH Platform. Available online: https://www.fema.gov/flood-maps/products-tools/hazus.

Evaluation of dam siltation in different Italian geological context through sediment transport model

Laura Longoni[1], Monica Corti[1], Domenico Calcaterra[2], Pantaleone De Vita[2], Monica Papini[1]

(1) Dipartimento di Ingegneria Civile e Ambientale, Politecnico di Milano, laura.longoni@polimi.it
(2) Dipartimento di Scienze della Terra, dell'Ambiente e delle Risorse, Università degli Studi di Napoli Federico II

Dams represent a historically significant infrastructure system for energy production, which is becoming even more crucial today due to the energy crisis and climate change associated with fossil fuel consumption. In addition to this, artificial reservoirs play a crucial role in water storage and river flow regulation, contributing to the mitigation of flood risks for downstream inhabited areas. It is evident that any alteration to the "dam system" can have significant repercussions.

An essential factor in dam management is siltation, the gradual accumulation of sediments within the reservoir, resulting in a reduction of its total capacity and limiting its functionality, especially in terms of hydroelectric energy production. The purpose of the presented work is to evaluate the response of an erosion and sediment transport model applied to the siltation issue in different geological contexts, which can influence water erosion and circulation.

The physically based model considered is called SMART-SED (Sustainable MAnagement of sediment transpoRT in responSE to climate change conDitions), developed in recent years by the Politecnico di Milano (Gatti et al., 2023). SMART-SED can simulate hydrological, erosion, and sediment transport processes at a watershed scale, starting from geographical and meteorological input data, often available for free from regional/national geoportals or global databases. The final raster-type outputs relate to various simulated processes, such as water velocity, water and sediment height, infiltration, erosion, evapotranspiration, and liquid and solid flow values for each calculation time step at user-defined control points.

From a conceptual standpoint, the innovation of this model lies in the dynamic and automatic identification of the drainage network, as opposed to the a priori and static definition of flow cells in most similar models found in literature. Additionally, using global terrain databases, SMART-SED can derive the grain size composition at a desired resolution through statistical downscaling (Gatti et al., 2021).

The selected case studies cover areas ranging from 5 to 48 km2 and were chosen in different geological contexts within Italy, providing historical data on siltation, such as bathymetry and sediment volumes removed over the years. In the Alpine region, the watersheds of the Tartano stream (SO) and the Caldone stream (LC) were considered. Simulations were also conducted in the Cilento region, in the southern Apennines, near the Carmine and Nocellito dams along the Alento River (SA). All analyzed sites involve artificial basins with a dam, except for the Caldone stream, which was considered as a "pilot case study" for model development and due to the availability of bathymetric measurements in a sedimentation basin along the stream.

Following a detailed sensitivity analysis of input parameters and their calibration, accounting for land use and local geological context, SMART-SED was applied to the four cases over one-year time intervals, simulating different years to assess sediment production under varying rainfall regimes. The obtained results were then validated based on available siltation data. It was observed that the SMART-SED model, initially designed for assessing flood hazard and sediment transport in mountainous areas, is also suitable for estimating dam siltation. The model provided a precise approximation of the order of magnitude of the cumulative volume of sediments produced within the analyzed watersheds and transported into the reservoirs. In the context of a complex issue concerning "low-emission" energy production in a changing world, SMART-SED could become a useful tool for dam management.

References

Gatti F., Bonaventura L., Menafoglio A., Papini M., Longoni L. (2023). A fully coupled superficial runoff and soil erosion basin scale model with efficient time stepping. *Computers & Geosciences*, 177, 105362.

Gatti F., Menafoglio A., Togni N., Bonaventura L., Brambilla D., Papini M., et al. (2021). A novel downscaling procedure for compositional data in the Aitchison geometry with application to soil texture data. *Stoch. Environ. Res. Risk Assess.*, 35(6), 1223-1241.

Towards flood-related hazard assessment guidelines for land transport infrastructures

Benedetta Moccia[1], Elena Ridolfi[1], Francesco Napolitano[1]

(1) Department of Civil, Constructional and Environmental Engineering (DICEA), Sapienza University of Rome, benedetta.moccia@uniroma1.it

Italy exhibits a considerable susceptibility to hydrogeological risk due to unfavorable geological and geomorphological terrain characteristics and human interventions. The study of flood hazard over land transportation networks is crucial due to its profound implications on public safety, infrastructure resilience, and socioeconomic well-being (Ochsner et al., 2023; Zhu et al., 2022). These factors emphasize the need for comprehensive risk assessments of infrastructure to proactively mitigate potential sources of damages. Moreover, in recent years, the frequency and intensity of extreme weather events, including heavy rainfall and flooding, have increased globally, posing significant threats to transportation infrastructure (Bubeck et al., 2019; Rebally et al., 2021). Flooding has the potential to cause damage to land transport infrastructures (LTIs) through both direct impacts resulting from physical contact with flood waters and indirect impacts occurring outside the floodplain area, not necessarily involving direct physical contact, often referred to as cascade impacts (Arrighi et al., 2021). According to Van Ginkel et al. (2021) transportation assets damages during flood events can be further divided in direct/indirect and tangible/intangible. For these reasons, identifying LTI segments vulnerable to flooding enables a precise risk-based targeting of actions, contributing to the development of an efficient asset management plan (Cheetham et al., 2016). Accurate flood hazard assessments can indeed inform strategic planning, infrastructure design, and emergency preparedness measures, contributing to the development of sustainable and resilient transportation systems (Argyroudis et al., 2020). Moreover, in the face of climate change and its associated challenges, comprehensive studies on flood hazards are essential for ensuring the safety and functionality of transportation networks, safeguarding lives, and minimizing the economic impact of extreme weather events.

In this study we aim at developing a guideline to classify flood-related hazards for LTIs. Specifically, based on the infrastructure cross-section construction type (e.g., embankment, trench, tunnel, and bridges), we aim at classifying all the possible flood-related hazards that can affect the efficiency of the network, such as potential damages due to embankment overtopping, erosion, and washout, as well as collisions involving trains or vehicles with river flow, deposits, or debris. Then, thanks to the national Flood Risk Management Plans (PGRA; Trigila et al., (2021)) which provide most of the flood-prone areas in Italy for different hazard scenarios, it is possible to examine and classify all the possible water-infrastructure interactions. In the PGRA, some mapped areas are also associated to the source of the flood (e.g., fluvial, pluvial, sea, groundwater, etc.) and its characteristics. Such information will help us in defining the level of criticality to which the infrastructure segment is exposed. For small basins not always mapped in the PGRA, hydraulic simulations should be performed (Samela et al., 2023). Finally, the classification of flood-related hazard will be distinguished based on the nature of the crossed watersheds (e.g. natural or urbanized). Both regulations and morphological/hydraulic features, including concentration time, area, land use, land type, river slope, etc., vary between these settings. Additionally, the interaction between the river network and drainage systems in urbanized areas plays a crucial role.

We posit that this ongoing study, currently in its preliminary phase, holds the potential to enhance our understanding of the high-risk components within the LTIs. Through this exploration, we anticipate the ability to pinpoint specific elements at heightened risk. This understanding will, in turn, provide a valuable foundation for crafting a comprehensive and efficient plan focused on the maintenance and implementation of effective mitigation measures.

References

Argyroudis S.A., Mitoulis S.A., Hofer L., Zanini M.A., Tubaldi E., Frangopol D.M. (2020). Resilience assessment framework for critical infrastructure in a multi-hazard environment: Case study on transport assets. *Science of the Total Environment*, 714, 136854.

Arrighi C., Pregnolato M., Castelli F. (2021). Indirect flood impacts and cascade risk across interdependent linear infrastructures. *Natural Hazards and Earth System Sciences*, 21, 1955–1969.

Bubeck P., Dillenardt L., Alfieri L., Feyen L., Thieken A.H., Kellermann P. (2019). Global warming to increase flood risk on European railways. *Climatic Change*, 155, 19–36.

Cheetham M., Chirouze F., Bredier L. (2016). RISK VIP: Evaluation of flood risk on the French Railway Network using an innovative GIS approach. *E3S Web of Conferences*, 7.

Ochsner M., Palmqvist C., Olsson N.O.E., Winslott L. (2023). The effects of flooding on railway infrastructure : a literature review. *Transportation Research Procedia*, 72, 1786-1791.

Rebally A., Valeo C., He J., Saidi S. (2021). Flood impact assessments on transportation networks: a review of methods and associated temporal and spatial scales. *Frontiers in Sustainable Cities*, 3.

Samela C., Carisi F., Domeneghetti A., Petruccelli N., Castellarin A., Iacobini F., Rinaldi A., Zammuto A., Brath A. (2023). A methodological framework for flood hazard assessment for land transport infrastructures. *International Journal of Disaster Risk Reduction*, 85, 103491.

Trigila A., Iadanza C., Lastoria B., Bussettini M., Barbano A. (2021). Dissesto Idrogeologico in Italia: pericolosità e indicatori di rischio, in: Edizione 2021. ISPRA, Rapporti 356/2021. pp. 183.

Van Ginkel K.C.H., Dottori F., Alfieri L., Feyen L., Koks E.E. (2021). Flood risk assessment of the European road network. *Natural Hazards and Earth System Sciences*, 21, 1011–1027.

Zhu W., Liu K., Wang M., Ward P.J., Koks E.E. (2022). System vulnerability to flood events and risk assessment of railway systems based on national and river basin scales in China. *Natural Hazards and Earth System Sciences*, 22, 1519–1540.

Planning and management of reservoirs for agricultural use: assessment of water resource availability through rainfall-runoff modelling in ungauged catchments

Mattia Neri[1]*, Alberto Montanari*[1]*, Elena Toth*[1]

(1) Department of Civil, Chemical, Environmental, and Materials Engineering, University of Bologna, mattia.neri5@unibo.it

The design and assessment of measures for adapting water infrastructures to climate change require an estimate of the water availability over historical and future periods, with the aim of ensuring the diversification of supply sources and their sustainable use.

Surface waters play a fundamental role in agriculture in many parts of the country and are, in comparison to groundwater, more immediately susceptible to extreme events, such as droughts. To increase their availability along the entire year, and in particular during the irrigation season, it may be necessary to plan additional storage volumes. For this purpose, medium-sized irrigation reservoirs (exploitable by more than one single farm) represent a valuable opportunity that many irrigation consortia in Emilia-Romagna are deploying or considering.

When planning the location and size of such reservoirs, in addition to information on the quantity and timing of the demand, the main design variables depend on the amount of streamflow that may be withdrawn from the river, once that the constraints on the environmental flows are satisfied. Unfortunately, long time series of streamflow observations, especially in smaller catchments, are rarely available and it is therefore necessary to implement a procedure for estimating the historical time-series of river flow in the sections where the reservoirs are planned, on the basis of some kind of regionalization.

Given the importance of information on the timing of the flows in the ungauged sections, a process-based approach is here adopted, based on rainfall-runoff modelling, which might also be used, if forced by climate future scenarios rather than by historical meteorological series, to evaluate possible changes in the basin response expected for the future decades.

Rainfall-runoff modelling in ungauged basins involves the regionalisation of the model parameters (e.g. He et al., 2011) which are transferred from one or more gauged basins, assumed to be hydrologically similar to the target (ungauged) catchments.

The case study here chosen as a proof-of-concept refers to three ungauged small catchments in the Emilia-Romagna Apennine, where the location of the closure section has been deemed suitable for reservoir construction according to preliminary technical feasibility studies. The procedure involved a preliminary step in which we identified gauged basins in the region assumed to be hydrologically similar to the target ones (see Figure 1), and we collected and validated the available daily streamflow data. Historical meteorological forcing time series for all the basins are estimated using E-OBS dataset (Cornes et al., 2018, which provides gridded climatic variables from 1950 to present at daily scale), also in order to assure the replicability of the procedure in any other European area. Successively, a daily and continuously simulating rainfall-runoff model is calibrated and validated for all the gauged basins. Finally, a consolidated parameter regionalisation approach (e.g. Neri et al., 2020; Oudin et al., 2008) was tested in leave-one-out cross-validation on the gauged catchments of with satisfactory performances. The regionalization procedure was thus applied to simulate flow time series at the ungauged river sections of interest during the historical period (1950-2022).

The flow simulations produced from the described approach, after subtracting the required environmental flows, allow to estimate the available water volumes that may be withdrawn from the ungauged rivers, and thus stored in the planned reservoirs, during the rainy months (October to April) preceding the start of the irrigation season. Once the capacity of the potential reservoir has been set, such seasonal volumes are used to compute the probability of failure, that is the number of years when the reservoir does not fill by the end of April, in relation to the total number of years in the observation period, from 1951 to 2022. Such probability of failure and the corresponding deficit ("missing" water volume in each year) is fundamental for assessing the potential damages to the crops or for planning and designing potential alternative water sources to integrate the deficits.

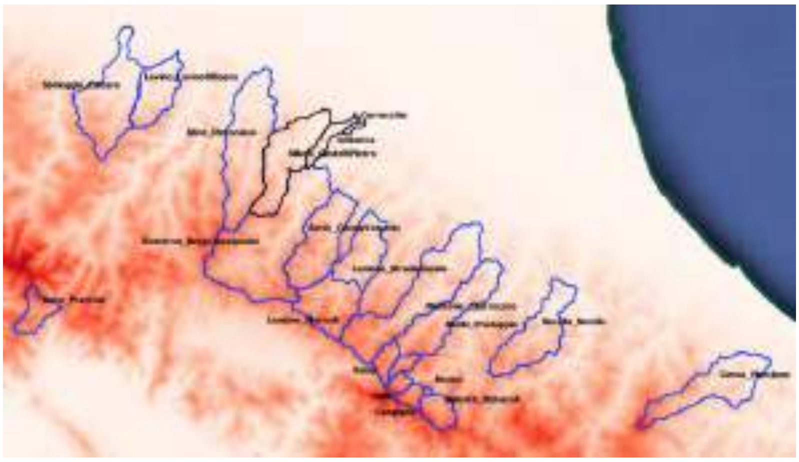


Figure 1 – In black the three target (ungauged) basins; in blue the set of hydrologically similar gauged basins in which the donors are sought.

References

Cornes R. C., van der Schrier G., van den Besselaar E. J., Jones P. D. (2018). An ensemble version of the E-OBS temperature and precipitation data sets. *Journal of Geophysical Research: Atmospheres*, 123(17), 9391-9409.

He Y., Bárdossy A., Zehe E. (2011). A review of regionalisation for continuous streamflow simulation. *Hydrol. Earth Syst. Sci.* 15, 3539–3553.

Neri M., Parajka J., Toth E. (2020). Importance of the informative content in the study area when regionalising rainfall-runoff model parameters: the role of nested catchments and gauging station density. *Hydrol. Earth Syst. Sci.* 24, 5149–5171.

Oudin L., Andréassian V., Perrin C., Michel C., Le Moine N. (2008). Spatial proximity, physical similarity, regression and ungaged catchments: A comparison of regionalization approaches based on 913 French catchments. *Water Resour. Res.* 44, 48–54.

Advanced approaches for the assessment of coastal structures/infrastructures resilience: tsunami fragility

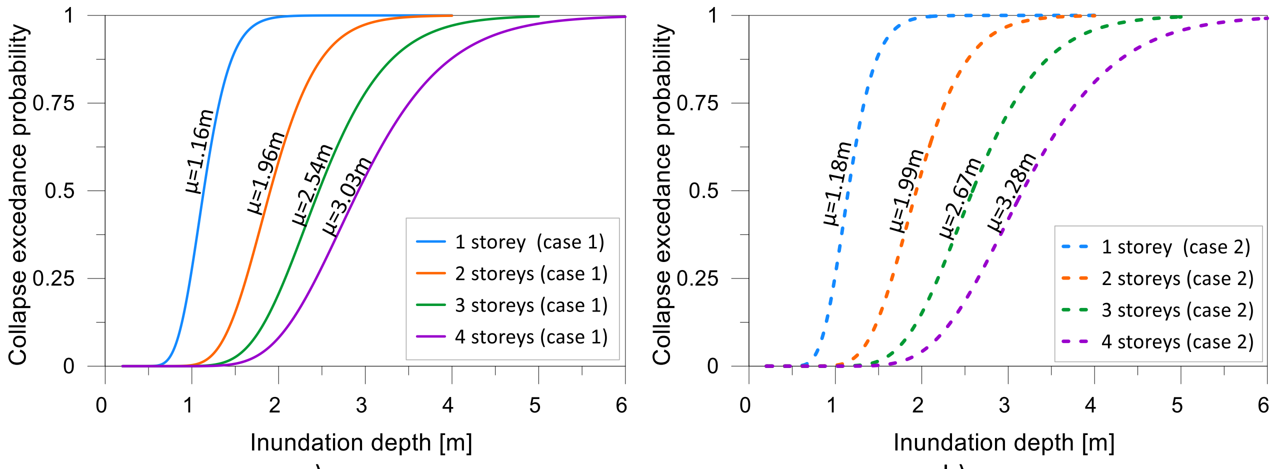
Maria Concetta Oddo[1], Liborio Cavaleri[1]

(1) Dept. of Engineering, University of Palermo, mariaconcetta.oddo01@unipa.it

The assessment of coastal regions' vulnerability to tsunami events is of paramount importance for mitigating the potential impact of this natural action. In recent years, numerous studies, (Einser, 2005; Imuara et al., 2019; Rafliana et al., 2022), have focused on evaluating tsunami hazards and risks to seaport structures driven by the critical need to mitigate these dangers. This need is emphasized by the growing populations and economic activities along coastal regions (Jelínek and Krausmann, 2008). Established strategies for minimizing tsunami impact often include the implementation of early warning systems, spatial planning and the development of resilient infrastructures. In this context, tsunami fragility curves play a crucial role in shaping and enhancing the effectiveness of these strategies.

In this study, a novel approach is proposed for the construction of fragility curves for structures exposed to tsunami events. This methodology is based on Monte Carlo simulation and it is implemented using the Python programming language. The procedure includes the generation of random variables, including structural geometry, material mechanical characteristics, tsunami horizontal loads, vertical external forces due to weight and service loads, and internal forces resulting from the random combination of structural geometry and external forces. Through Monte Carlo simulations, uncertainties associated with these random variables are synthesized into a unique uncertainty parameter, without the need to resort to ambiguous regression analyses and rules of combination of the uncertainties of demand and capacity. This method not only enhances the precision of vulnerability assessments compared to the available approaches (Ferrotto and Cavaleri, 2021; Medina et al., 2019), but also facilitates a more dynamic and adaptable analysis, benefitting from the capabilities of Python in executing complex simulations.

The results here provided (some of them are included in Fig. 1) refer to the tsunami vulnerability of masonry buildings typical of the Mediterranean area and allows the recognition of the effectiveness of the proposed methodology, providing a straightforward and well-suitable tool to obtain valuable insights into vulnerability patterns across various types of structures and infrastructures. This enables the development of more targeted and effective mitigation strategies.



a) b)

Figure 1 – Analytical collapse exceedance probability. Comparison between buildings with different number of storeys in the case of: a) lower masonry strength; b) higher masonry strength.

The approach discussed has been recognized as extensible to the vulnerability assessment of infrastructures, particularly bridges. This perspective outlines the potential for a unified procedure that can comprehensively address enhancing resilience against natural disasters as Tsunamis.

Further developments aim to extend the proposed methodology to the potential adoption of a multi-risk approach in vulnerability assessments, considering both earthquake and tsunami effects simultaneously. By integrating these risk factors, the research aims to provide a more holistic understanding of the overall vulnerability of infrastructures in coastal areas.

References

Eisner R.K. (2005). Planning for tsunami: reducing future losses through mitigation. *Natural Hazards*, 35(1), 155-162.

Ferrotto M.F., Cavaleri L. (2021). Masonry structures: a proposal of analytical generation of fragility functions for tsunami impact – Application to the Mediterranean coasts. *Engineering Structures*, 242, 112463.

Imamura F., Boret S.P., Suppasri A., Muhari A. (2019). Recent occurrences of serious tsunami damage and the future challenges of tsunami disaster risk reduction. *Progress in Disaster Science*, 1, 100009.

Jelínek R., Krausmann E. (2008). Approaches to tsunami risk assessment. *JRC Scientific and Technical Reports*, 48713, 9-38.

Medina S., Lizarazo-Marriaga J., Estrada M., Koshimura S., Mas E., Adriano B. (2019). Tsunami analytical fragility curves for the Colombian Pacific coast: a reinforced concrete building example. *Engineering Structures*, 196, 109309.

Rafliana I., Jalayer F., Cerase A., Cugliari L., Baiguera M., Salmanidou D., et al. (2022). Tsunami risk communication and management: contemporary gaps and challenges. *International Journal of Disaster Risk Reduction*, 70, 102771.

Application of a stochastic model for water demand assessment under water scarcity and intermittent networks

Stefania Piazza[1], Maria Concetta Sambito[1], Gabriele Freni[1]

(1) Dept. of Engineering and Architecture, University of Enna “Kore”, stefanina.piazza@unikore.it

Climate change is affecting water resources and other aspects of life in many countries, generating more frequent extreme events (Sivakumar 2011). Especially droughts and the consequent urban water scarcity events make water supply management critical (Mo, et al. 2024). Cities are particularly sensitive to this issue as they face increased demand to meet human needs due to the increase in urban populations worldwide and, at the same time, ageing infrastructures losing their efficiency in delivering water resources to users (Salimi and Al-Ghamdi 2019). Frequently, non-forecasted water scarcity conditions are managed by implementing intermittent water supply to reduce pipe leakages and compress water consumption by rationing water resources among users (De Marchis, et al. 2011). The impact of such practices on asset ageing and increased maintenance needs are well documented in the literature (Ciliberti, et al. 2021).

Users react to intermittent supply by implementing local private tanks to collect as much water resources as possible to cope with water distribution suspension periods. Such tanks are commonly overdesigned following the common perception that water resources are essential for human activities and the general need of users to safeguard their water supplies.

This study evaluated the impact of water scarcity and users' self-adaptation strategies on water demand under intermittent flow conditions by implementing an experimental campaign in a real network. This was analyzed starting from consumption data, monitored at the inlet and outlet of private tanks for a residential area in the metropolitan area of Palermo (Figure1). Different pressure conditions and levels of overdesign were considered to better characterize demand patterns in intermittent supply. The analysis was conducted using a short-term water demand forecast model that reproduces periodic patterns observed at an annual, weekly and daily level, in order to evaluate the adaptation response of users concerning the scarcity of water resources, through the comparison between the real pattern of the network and the pattern of local tanks.

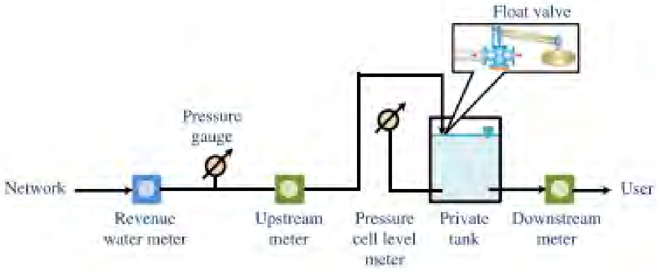


Figure 1 – A schematic of the monitoring installation.

References

Ciliberti F.G., Berardi L., Laucelli D.B., Giustolisi O. (2021). Digital Transformation Paradigm for Asset Management in Water Distribution Networks.” In: *10th International Conference on ENERGY and ENVIRONMENT (CIEM)*, Bucharest, Romania, 1-5.

De Marchis M., Fontanazza C.M., Freni G., La Loggia G., Napoli E., Notaro V. (2011). Analysis of the impact of intermittent distribution by modelling the network-filling process. *Journal of Hydroinformatics*, 2011, 358-373.

Mo L., Lou S., Wang Y., Liu Z., Ren P. (2024). Studying the evolutions, differences, and water security impacts of water demands under shared socioeconomic pathways: a SEMs-bootstrap-ANN approach applied to Sichuan Province. *Journal of Environmental Management*, 349.

Salimi M., Al-Ghamdi S.G. (2019). Climate change impacts on critical urban infrastructure and urban resiliency strategies for the Middle East. *Sustainable Cities and Society*, 54, 1-45.

Sivakumar B. (2011). Global climate change and its impacts on water resources planning and management: assessment and challenges. *Stochastic Environmental Research and Risk Assessment*, 25, 583-600.

Dynamic identification of bridges: from field tests based on standard equipment to laboratory validation of advanced solutions

Giuseppe Quaranta[1], Biagio Carboni[1], Walter Lacarbonara[1]

(1) Department of Structural and Geotechnical Engineering, Sapienza University of Rome, giuseppe.quaranta@uniroma1.it

Bridges are critical infrastructure components of high financial and societal relevance. For ensuring the safety and efficient operation of these systems, a regular procedure for inspection and maintenance is mandated by current codes and standards, relying primarily on use of visual inspections for NDE. Vibration-based monitoring is a more efficient way to characterize the actual behavior of bridges as well as to monitor their health. Its effectiveness basically depends on seamless developments in sensing, data acquisition and transmission systems, as well as processing and analysis protocols to assess the structural conditions for the purposes of characterization, design verification, operation and maintenance decision-support, and post-event management (Karakostas et al., 2023). Within the framework of the WP 6.4 of the RETURN project, the present contribution aims at illustrating the obtained results and ongoing efforts directed towards the development of new methodologies and the implementation of sophisticated technologies for the dynamic identification of bridges (Figure 1).

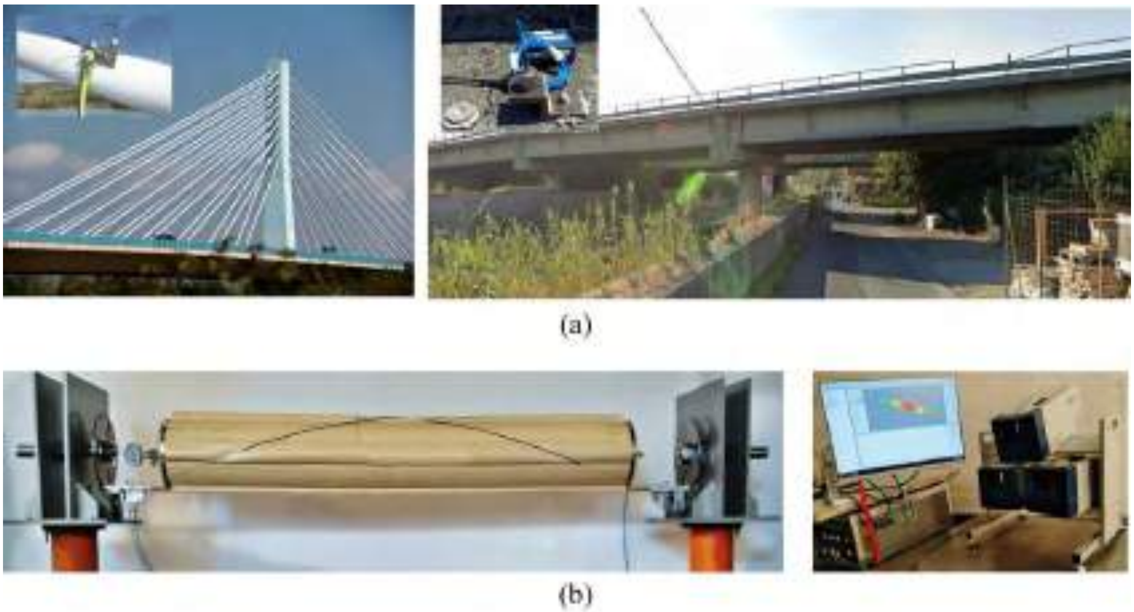


Figure 1 – Dynamic identification of bridges: acquisition of the free response using standard accelerometers on real bridges (a) and laboratory tests on a new concept of tensairity by means of advanced 3D laser vibrometry (b).

Initially, novel strategies for the automatic modal identification of bridges based on their free vibrations recorded through standard accelerometers will be illustrated. The proposed approach relies on advanced signal decomposition techniques, namely the Variational Mode Decomposition and the Empirical Fourier Decomposition (Mazzeo et al., 2023, 2024). Modal damping ratios are estimated by means of a robust area-based approach to mitigate the noise-induced disturbances whereas a time-domain method based on the phase shift of the free vibration response peaks is employed to identify the mode shapes. Applications to simply supported and stay-cabled roadway bridges as well as to railway bridges will be presented. Finally, the feasibility of advanced 3D laser vibrometry for dynamic monitoring of bridges will be discussed by examining preliminary experimental results obtained from challenging laboratory tests performed on a new concept of a tensairity beam (Lacarbonara and Carboni 2015) envisioned as the key component of temporary, post-hazard bridge installments.

References

Karakostas C., Quaranta G., Chatzi E., Zülfikar A.C., Çetindemir O., De Roeck G., et al. (2023). Seismic assessment of bridges through structural health monitoring – A state-of-the-art review. *Bullettin of Earthquake Engineering*, in press.

Mazzeo M., De Domenico D., Quaranta G., Santoro R. (2023). Automatic modal identification of bridges based on free vibrations and advanced signal decomposition techniques. *64th International Conference on Vibroengineering*, 21-22 September 2023, Trieste, Italy.

Mazzeo M., De Domenico D., Quaranta G., Santoro R. (2024). An efficient automatic modal identification method based on free vibration response and enhanced Empirical Fourier Decomposition technique. *Engineering Structures*, 298, 117046.

Lacarbonara W., Carboni B. (2015). Tensairity structure with shape memory strands, Sapienza University of Rome, IT Patent No. 102015000055410, EU Patent EP3353360A1, US Patent US10407939B2.

Definition of offshore boundary conditions for earthquakes tsunami inundation numerical simulations through probabilistic databases

Gioele Ruffini[1], Carolina Codato[1], Myrta Castellino[1], Paolo De Girolamo[1]

(1) Department of Civil, Constructional and Environmental Engineering, Sapienza University of Rome, gioele.ruffini@uniroma1.it

Tsunamis are powerful transient waves, triggered primarily by submarine seismic activities such as earthquakes, volcanic eruptions, or underwater and subaerial landslides (Goda et al., 2014). These waves are usually characterized by long wave periods T and high energy levels. Tsunamis can travel for great distances with minimal energy dissipation, and their impact with the coast is often the cause of devastating effects. Understanding the complex dynamics of tsunamis is critical for coastal risk assessment. Ongoing research aims to improve our ability to further develop methodologies to mitigate their impact (Grezio et al., 2012). In recent years, between all the different possible approaches for coastal risk assessment, the probabilistic one, referred to as Probabilistic Tsunami Hazard Assessment (PTHA) (Grezio et al., 2017), has gained widespread popularity with the European project TSUMAPS-NEAM (Basili et al., 2018) being a recent example of PTHA based on seismic sources. PTHAs usually provide to the end user synthetic hazard parameters, e.g., Maximum Inundation Height *MIH*, used in the TSUMAPS-NEAM project. These parameters are usually defined at a prescribed distance from the coast or water depth, to assess the probabilistic hazard of a certain coastal area. However, this type of methodologies propagates the hazard inshore with very simplified approaches which do not take into account the real influence of the seabed and coastal morphology variations on the propagation of tsunami waves. These simplified approaches can be accepted as a first approximation, but must be verified with more realistic numerical methods especially when evaluating the impact of tsunami waves on critical infrastructures.

This work is developed as part of the NRRP RETURN extended partnership project within WP3/DV 3.2.c "Hazard mapping due to Tsunamis caused by earthquakes." The aim is to define a universally applicable methodology, by using the results of a PTHA as an initial step, to define the inputs for high-resolution flood simulations in critical areas. As an illustrative case, this study uses the seismic-PTHA NEAMTHM18 hazard curves, resulting from TSUMAPS-NEAM project, calculated for the *MIH* as the basis for the developed methodology. These hazard curves are defined for selected Points Of Interest (POIs) distributed along the entire coastline of the Northeast Atlantic, Mediterranean Sea, and Connected Sea Basin (NEAM), with an interdistance of about 20 km at a depth of h = 50 m.

To better describe the methodology, a flow chart is presented in Figure 1 and also briefly summarized in the following.

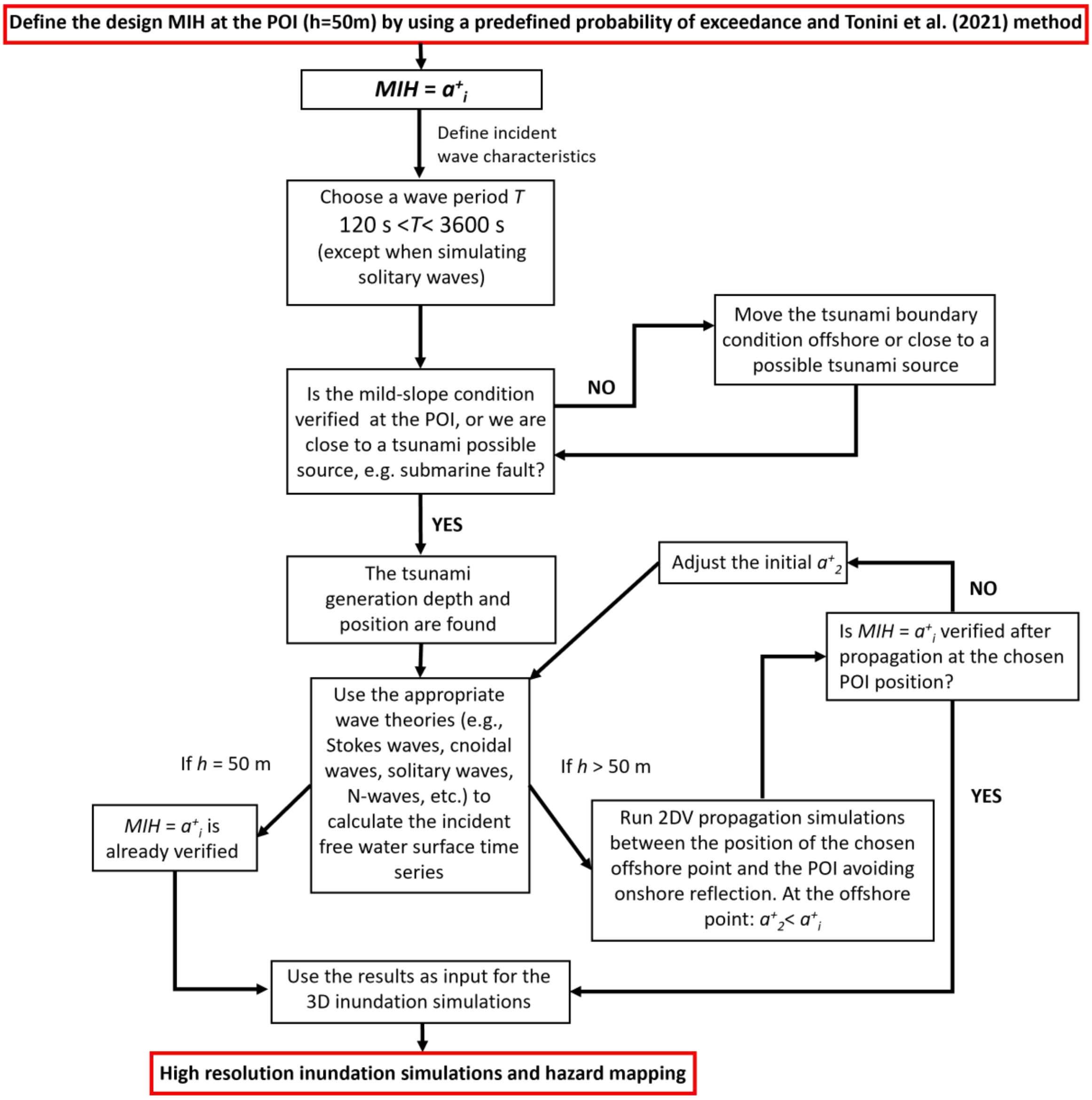


Figure 1 – Flow chart of the developed methodology.

First, the probability of exceedance of a certain area or infrastructure is chosen following e.g., design codes such as the NTC2018 for Italy. After, the design *MIH* is chosen as the maximum value among all POIs within a 40 km radius centred in the specific area of interest following Tonini et al. (2021). At the chosen POI the equivalence $MIH = a^+_i$, *where* a^+_i *is the incident tsunami positive amplitude, is considered true*. The next step involves defining the characteristics of the incident wave starting from *T* using a range of 120s to 3600s, considered scientifically reasonable intervals by Basili et al. (2018). It is crucial to initially verify the mild-slope condition at the POI. If this does not occur, the simulations must start further offshore at depths and locations where the mild-slope condition is met or close to a potential tsunami source. At this depth and position, for each chosen *T,* the relevant wave theories (e.g, Stokes waves, cnoidal waves, solitary waves, N-waves etc.) are found and used to calculate the input free water surface time series for the inundation simulations. Two different conditions can be found at the chosen position: $h = 50$ m, i.e., at the location of the POI, for which $MIH = a^+_i$ is already verified. Otherwise, if $h > 50$ m, 2DV propagation simulations need to be conducted from the selected offshore point where $a^+_2 < a^+_i$ (a^+_2 is the amplitude of the input tsunami offshore) to the POI location, varying a^+_2 until $MIH = a^+_i$ is verified at the end of propagation. This procedure is carried out for each fixed value of *T* and/or wave theory, in order to propagate different incident tsunami time series, and additionally avoiding onshore reflection. The resulting incident tsunami time series, from both conditions, are then used as the input signal for 3D inundation simulations aimed at mapping coastal hazard from tsunami waves.

References

Basili R., Brizuela B., Herrero A. et al. (2021). The Making of the NEAM Tsunami Hazard Model 2018 (NEAMTHM18). *Frontiers in Earth Science*, 9, 628061.

Goda K., Mai P.M., Yasuda T. et al (2014). Sensitivity of tsunami wave profiles and inundation simulations to earthquake slip and fault geometry for the 2011 Tohoku earthquake. *Earth, Planets and Space*, 66, 1-20.

Grezio A., Gasparini P., Marzocchi W. et al. (2012). Tsunami risk assessments in Messina, Sicily–Italy. *Natural Hazards and Earth System Sciences*, 12(1), 151-163.

Grezio A., Babeyko A., Baptista M.A. et al. (2017). Probabilistic tsunami hazard analysis: multiple sources and global applications. *Reviews of Geophysics*, 55(4), 1158-1198.

Tonini R., Di Manna P., Lorito et al. (2021). Testing tsunami inundation maps for evacuation planning in Italy. *Frontiers in Earth Science*, 9, 82.

Flood risk mapping through advanced machine learning techniques and geomorphic data integration

Jorge Saavedra Navarro[1]*, Ruodan Zhuang*[1]*, Cinzia Albertini*[2]*, Salvatore Manfreda*[1]

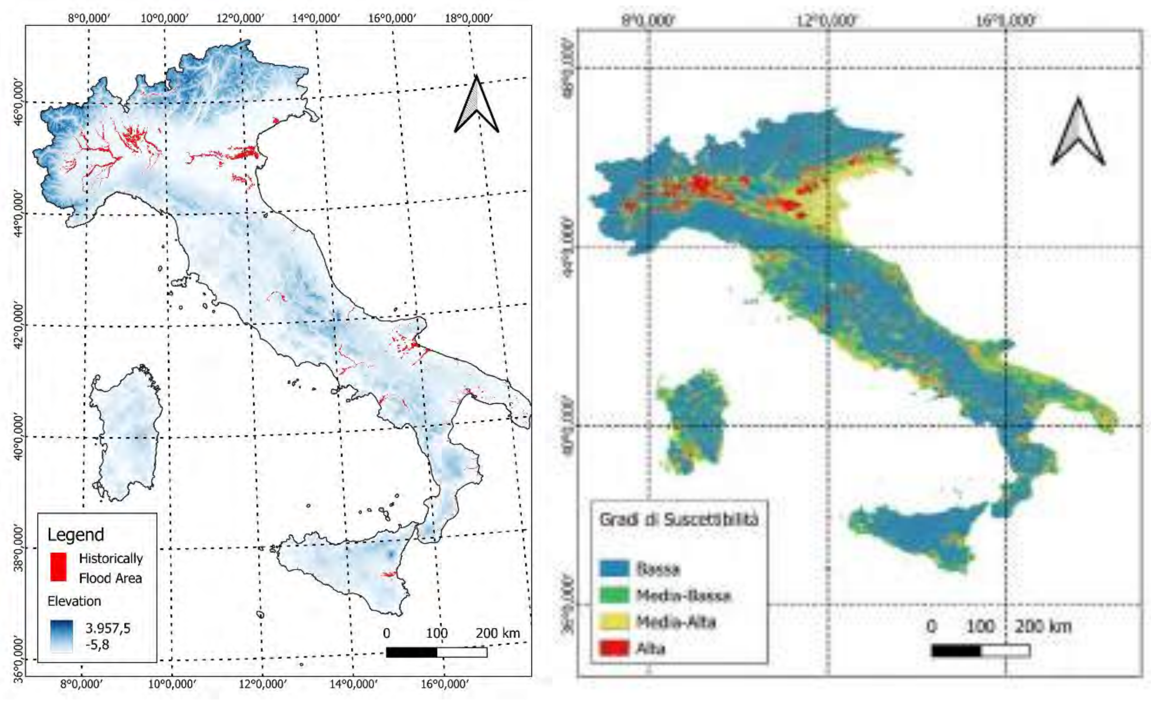
1. *Dipartimento di Ingegneria Civile, Edile e Ambientale, Università degli Studi di Napoli Federico II,* *jorgeandres.saavedranavarro@unina.it*
2. *Dipartimento di Scienze del Suolo, della Pianta e degli Alimenti, Università degli Studi di Bari Aldo Moro*

Flood events rank among the most destructive natural hazards, necessitating comprehensive risk management strategies to mitigate their impact on human health, the environment, cultural heritage, and economic activities. In this context, various approaches have been developed for identifying flood-prone areas (Manfreda et al. 2015; Samela et al. 2017; D'Angelo et al. 2022), but there is still a need to enhance their capabilities due to dynamic changes in landscape and infrastructure.

In recent years, there has been a proliferation of remote sensing observations that can support dynamic and continuous mapping of flood-prone areas by integrating the most updated information (Albertini et al., 2022). This study explores the potential of machine learning (ML) techniques, including Random Forest, Support Vector Machine, and Navies Bayer model, utilizing geomorphic information such as slope, elevation, precipitation, land use/land cover, elevation difference to the nearest river, and others as predictor variables (Kaya and Derin, 2023). The best model and set of variables were explored by adopting approximately 30 variables spanning types, hydrologic, topographic, and categorical categories. Careful consideration was given to avoiding high correlations between variables in test subsets, ensuring relevance, and avoiding redundancy. Calibration and validation of the model employ Copernicus Emergency Management Service maps from Sentinel-2 satellites coupled with regional maps of past flood events.

Results highlight that the best ML technique is represented by the Random Forest, adopting a range of 5 to 8 variables for effective delineation of flood-prone areas. Among the selected variables, the most relevant ones include Rainfall, Geomorphic Flood index - GFI, Lithology, and others. The study demonstrates that a minimal amount of information (between 0.1% and 10%) suffices for optimal model performance (AUC greater than 0.8).

The study covered the entire territory of Italy, resulting in a flood-prone map at a 90m resolution, validated with flood maps provided by national agencies and obtained through traditional hydraulic models (Lastoria et al. 2021).



(a) (b)

Figure 1 - (a) Flood reference maps. (b) Preliminary results.

References

Albertini C., Gioia A., Iacobellis V., Manfreda S. (2022). Detection of surface water and floods with multispectral satellites. *Remote Sensing*, 14, 6005.

Cagla Melisa Kaya, Leyla Derin (2023). Parameters and methods used in flood susceptibility mapping: a review. *Journal of Water and Climate Change*, 14(6), 1935–1960.

D'Angelo C., Passalacqua P., Fiori A., Volpi E. (2022). Identification of flood-prone areas with GeoFlood: lessons learned from the Tiber River case study. *Journal of Flood Risk Management*, 15(2), e12795.

Lastoria B., Bussettini M., Mariani S., Piva F., Braca G. (2021). Rapporto sulle condizioni di pericolosità da alluvione in Italia e indicatori di rischio associati. Istituto Superiore per la Protezione e la Ricerca Ambientale, Rapporti 353/21, Roma.

Manfreda S., Samela C., Gioia A., Consoli G., Iacobellis V., Giuzio L., Cantisani A., Sole A. (2015). Flood-prone areas assessment using linear binary classifiers based on flood maps obtained from 1D and 2D hydraulic models. *Natural Hazards,* 79(2), 735-754.

Samela C., Troy T.J., Manfreda S. (2017). Geomorphic classifiers for flood-prone areas delineation for data-scarce environments. *Advances in Water Resources*, 102, 13-28.

AI and Deep Learning systems for intelligent unsupervised surveys: tunnel and cavities applications

Alessandra Spadaro[1], Marco Piras[1], Marcello Chiaberge[2], Pierluigi Claps[1], Marco Ambrosio[2], Gianluca Dara[2]

(1) Dept. of Environment, Land and Infrastructure Engineering (DIATI), Politecnico di Torino, alessandra.spadaro@polito
(2) Interdepartmental Centre for Service Robotics (PIC4SeR), Politecnico di Torino

In recent years, GeoAI (Geospatial Artificial Intelligence), which refers to the intersection of Geographic Information Systems (GIS), Artificial Intelligence (AI) and Machine Learning (ML), is playing a crucial role in different aspects, e.g. in the analysis and interpretation of geospatial data, leading to better understanding, decision-making and automation of various geospatial-related activities.

Surveys and inspections can be challenging in the field of application concerning tunnels and galleries for several reasons (Sjölander et al., 2023), such as i) limited access, confined spaces, and poor lighting; ii) geometric repetitiveness with very similar patterns and textures; iii) absence of GPS signal and the need to use alternative technologies for positioning; iv) operational and safety risks for operators in case of instability. According to this, the application of AI has the potential to improve and solve these problems, as well as improve efficiency, safety, and cost-effectiveness (Liu et al., 2024).

These topics are investigated within Spoke WP 6.4 of the RETURN project, precisely Task 6.4.2 “AI and Deep Learning systems for intelligent unsupervised surveys” due to the collaboration between the Department of Environment, Land and Infrastructure Engineering (DIATI) and the Interdepartmental Centre for Service Robotics (PIC4SeR) of the Politecnico di Torino.

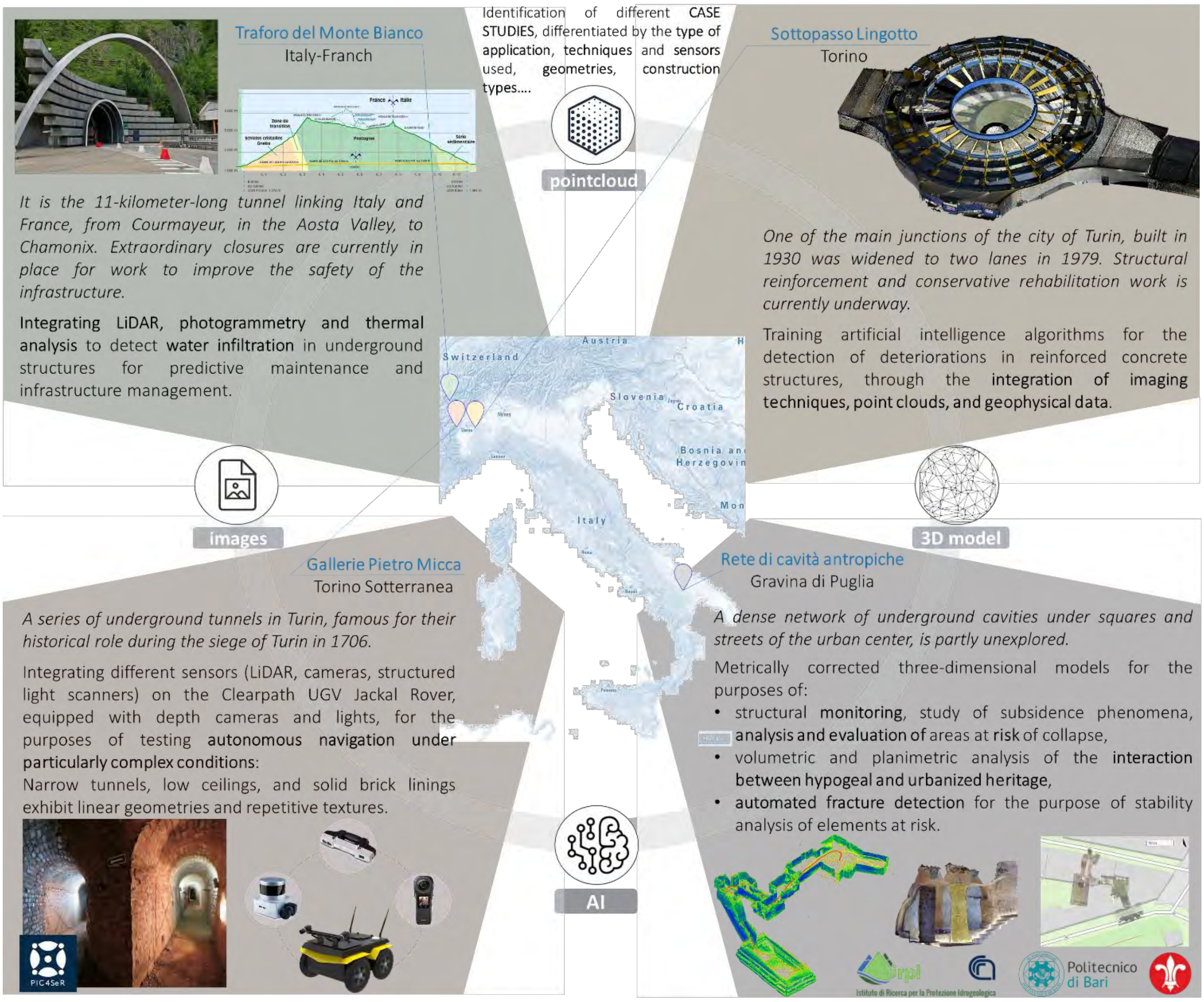
The task will investigate the application of AI/DL to data collected with several sensors to perform autonomous surveys and infrastructure inspections within the context of tunnels, cavities, and underpasses.

The methodology followed starts from the acquisition phase; data collection, using both conventional and unmanned systems (rovers and drones), aims to test the technologies necessary for autonomous navigation, particularly in complex conditions. The goal is to map environments that are challenging for humans to access. The calibration, data fusion, and data processing of images, point cloud, and 3D models are supported by AI; crucial, the data post-processing uses AI and ML, combining innovative solutions for classification, segmentation, and damage detection and recognition. The final step is digital information management using GIS and BIM platforms to realize digital twins for intelligent infrastructure management.

The case studies identified are differentiated by the type of application, sensors and technologies used, geometries, and construction types:

- *Gallerie Pietro Micca* in Turin (Piedmont): integration of different sensors (LiDAR, depth and 360 cameras, structured laser scanners, etc.) on the Clearpath UGV Jackal rover for testing the autonomous navigation under complex conditions: narrow tunnels, low ceilings, and solid brick linings exhibit linear geometries and repetitive textures;
- *Network of anthropic cavities* in Gravina di Puglia (Apulia): evaluation of different geomatic techniques for generating metrically corrected three-dimensional models for structural monitoring, study of subsidence phenomena, analysis and evaluation of areas at risk of collapse, automated fracture detection for stability analysis of elements at risk.
- *Sottopasso Lingotto* in Turin (Piedmont): training artificial intelligence algorithms for the detection of deteriorations in reinforced concrete structures through the integration of imaging techniques, lasers, and geophysical data.

- *Traforo del Monte Bianco* (Aosta Valley): integration of LiDAR, photogrammetry, and thermal analysis to detect water infiltration in underground structures for predictive maintenance and infrastructure management.



Identification of different CASE STUDIES, differentiated by the type of application, techniques and sensors used, geometries, construction types....

Traforo del Monte Bianco
Italy-Franch

It is the 11-kilometer-long tunnel linking Italy and France, from Courmayeur, in the Aosta Valley, to Chamonix. Extraordinary closures are currently in place for work to improve the safety of the infrastructure.

Integrating LiDAR, photogrammetry and **thermal analysis** to detect **water infiltration** in underground structures for predictive maintenance and infrastructure management.

Sottopasso Lingotto
Torino

One of the main junctions of the city of Turin, built in 1930 was widened to two lanes in 1979. Structural reinforcement and conservative rehabilitation work is currently underway.

Training artificial intelligence algorithms for the detection of deteriorations in reinforced concrete structures, through the **integration of imaging techniques, point clouds, and geophysical data**.

Gallerie Pietro Micca
Torino Sotterranea

A series of underground tunnels in Turin, famous for their historical role during the siege of Turin in 1706.

Integrating different sensors (LiDAR, cameras, structured light scanners) on the Clearpath UGV Jackal Rover, equipped with depth cameras and lights, for the purposes of testing **autonomous navigation** under **particularly complex conditions**:
Narrow tunnels, low ceilings, and solid brick linings exhibit linear geometries and repetitive textures.

Rete di cavità antropiche
Gravina di Puglia

A dense network of underground cavities under squares and streets of the urban center, is partly unexplored.

Metrically corrected three-dimensional models for the purposes of:

- structural **monitoring**, study of subsidence phenomena, **analysis and evaluation of** areas at **risk** of collapse,
- volumetric and planimetric analysis of the **interaction between hypogeal and urbanized heritage**,
- **automated fracture detection** for the purpose of stability analysis of elements at risk.

Figure 1 – Integration of point cloud, images and 3D model with AI for different case studies and applications.

References

Sjölander A., Belloni V., Ansell A.,Nordström E. (2023) Towards Automated Inspections of Tunnels: A Review of Optical Inspections and Autonomous Assessment of Concrete Tunnel Linings. *Sensors*, 23(6), 3189;

Liu L., Song, Z., Li X. (2024) Artificial intelligence in tunnel construction: A comprehensive review of hotspots and frontier topics. *KeAI*, Geohazard Mechanics.

A new perspective for national landslide susceptibility assessment

Giacomo Titti[1], Matteo Antelmi[2], Francesco Fusco[2], Laura Longoni[2], Monica Papini[2], Lisa Borgatti[1]

(1) Department of Civil, Chemical, Environmental and Materials Engineering, Alma Mater Studiorum University of Bologna, giacomo.titti@unibo.it
(2) Department of Civil and Environmental Engineering (DICA), Politecnico di Milano

Landslides represent a severe geohazard in many countries. The availability of inventories depicting the spatial and temporal distribution of landslides is crucial for assessing landslide susceptibility and risk for territorial planning or investigating landscape evolution. For the Italian territory, several landslide hazard and risk maps, from regional to national scale, were produced. This was possible thanks to the availability of the IFFI dataset, a unique long-time landslide inventory collected and maintained by ISPRA institute. However, the real usefulness of this inventory is rather limited due to their common spatial inhomogeneity or use of different mapping methods and classification criteria.

Despite the evolution in the last years of the techniques used to assess the natural hazard susceptibility at national scale such as statistical models, AI based models (i.e. Convolutional Neural Networks) and others, was impressive, the results are still limited by the quality of the data used, in particular, of the landslide inventory used. Actually, other geodatabases from local to regional scale are available such those of the “Hydrological Districts”, a public authority in charge of regulating territorial planning, under the safeguard against landslides and floods. They cannot cover the entire Italian territory, nevertheless, locally, they could represent an improvement in precision and accuracy with respect to the national dataset available, mainly due to the higher scale of resolution then the IFFI one.

In this work, we present an innovative approach to assess landslide susceptibility, from local to municipal scale, based on regional landslide inventories. Using a data-driven machine learning technique, we propose to train a single model on a landslide inventory consisting of a composition of regional inventories. The entire analysis has been done using the SRT tool for Google Earth Engine and the SZ-plugin for QGIS. The data used and processed are freely available and downloadable.

The approach proposed has been tested in the framework of RETURN project considering two areas: the first one comprises a sector of the railway that connects Napoli to Bari (southern Italy); and the second one in areas affected by the Marche region 2022 flooding events (central Italy).

Digital Twin, Virtual Reality and Metaverse: what technologies to support the asset management workforce?

Francesca Maria Ugliotti[1], Anna Osello[1]

(1) Dept. of Structural, Geotechnical and Building Engineering, Politecnico di Torino, francesca.ugliotti@polito.it

The challenging paradigm of the Digital Twin of construction combined with the new possibilities offered by information and visualization technologies provide innovative ways to approach, study, and investigate the risk and vulnerability of an area. The Digital Twin is proposed as a digital copy of an artefact, city or territory overcoming the use of Geographic information system (GIS) and Building Information Models (BIM) as capable of establishing a bi-directional data transfer between the physical object and the model (Khallaf et al., 2022). On the other hand, three-dimensional dealing with infrastructure has opened up new horizons related to communication and the fruition of the assets, expanding the pool of users that can be reached. If the *digital model* is the computer representation of the work containing all the information for its life cycle, the *virtual model* is an interactive simulation of it.

The Spoke TS2 of the RETURN project also reflects how these methodological and technological advances can be leveraged to enhance the asset management workforce and forecasting capacity. In particular, situational awareness applications are considered for the staff's re-skilling and up-skilling. In this context, WebGIS platforms, Virtual Reality experiences, and the new frontier of the Metaverse can play a role.

Geospatial technologies promote spatial thinking skills and enhance content knowledge necessary to examine linear infrastructure, which requires a multi-scalar approach concerning their specific connotation. Possible integration with BIM, which examines the scale of the point artefact, enhances the system capability by allowing it to move from particular to broader context. As understanding the context is necessary for comprehending the problems, the WebGIS framework enables integration, simulation, analysis, and visualization of the GIS technology result in an online environment. The distribution of spatial geographic information is, at this point, interfaced with big data from the sensor network, empowering stakeholders' decisions based on real-time changing situations. Through Decision Support Systems, they can have valuable information for planning and management without so much effort and time. According to the literature, incorporating traditional knowledge into modern technology is suitable for disaster risk reduction education. In recent years, web hazard maps have received attention not only from experts but also from students (Song et al., 2022), and flood resilience information systems for raising awareness among citizens (Albano et al., 2015).

On the other hand, the navigability of the model achievable through Virtual Reality (Ghobadi et al., 2020) technologies overturn the condition of the observer on both an experiential and conceptual level. Starting from digital models, it is possible to promote engaging and stimulating cognitive experiences to illustrate even to a non-technical or non-expert audience how complex constructions work so that political and economic choices can be made with greater awareness. The immediacy and hypermedia nature of the graphical representation makes the virtual model a powerful tool that enables more effective dialogue in, for example, local authorities planning conferences and service meetings. At the same time, it makes it possible to create innovative training solutions for the training of actors who operate in different roles on infrastructures: improving knowledge of sites, even those that are difficult to reach; transferring skills for maintenance; simulating or reproducing critical situations (Tender et al., 2023), such as emergencies or failures, which when they occur require a rapid response. Let us imagine the potential and stakeholder interest in simulating an accident interconnected perhaps to a natural event on a railroad tunnel section. Examining the situation in a realistic and safe environment without needing to be in the field allows for the best assessment of safety procedures and operation management efficiency while also reducing costs.

As the final frontier, the Metaverse (Ritterbusch et al., 2023) emerges as the further evolution of these immersive and multimedia environments by enabling their interconnection and decentralization based on open platform. Unlike the traditional virtual world, the concept of community emerges strongly, emphasizing much more realistic interaction between people and with their surroundings.

As we glimpse the possibilities are remarkable. Are we ready for change?

References

Khallaf R., Khallaf L., Anumba C.J., Madubuike O.C. (2022). Review of Digital Twins for Constructed Facilities. Buildings, 12, 2029.

Song J., Yamauchi H., Oguchi T., Ogura T. (2022). Application of web hazard maps to high school education for disaster risk reduction. International Journal of Disaster Risk Reduction, 72, 102866.

Albano R., Sole A., Adamowski J. (2015). READY: a web-based geographical information system for enhanced flood resilience through raising awareness in citizens. *Natural Hazards and Earth System Sciences*, 15, 1645-1658.

Ghobadi M., Sepasgozar, S. (2020). An Investigation of Virtual Reality Technology Adoption in the Construction Industry. In: *Smart Cities and Construction Technologies*.

Tender M., Fuller P., Vaughan A., Demian P., Chow V., Silva F., Couto J., Santos R. (2023). Lessons learned from the use of virtual reality for occupational safety and health training in Thames tideway tunnel. In: *CIBW099W123 - Digital Transformation of Health and Safety in Construction: Proceedings Book*, pp. 461-470.

Ritterbusch G., Teichmann M. (2023). Defining the Metaverse: A Systematic Literature Review. *IEEE Access*.

Hydrogen leak detection: monitoring and control methodologies

Morena Vitale[1], Micaela Demichela[1], Antonello Barresi[1]

(1) Department of Applied Science and Technology, Politecnico di Torino, morena.vitale@polito.it

A promising gas for reducing environmental pollution and the use of fossil fuels is hydrogen. Compared to hydrocarbons, hydrogen offers the advantage of generating only water as combustion product. Hydrogen has a low density (0.0899 kg/m^3), making it extremely light. Furthermore, it has a wide flammability range, between 4% and 75%, and a relatively low minimum ignition energy of 0.017 mJ. Consequently, in the event of a leak, there is a risk that the hydrogen forms flammable mixtures with air, which can easily trigger jet fires (Elaoud et al., 2009).

Furthermore, due to the extremely small size of hydrogen molecules, this gas can penetrate materials, compromising their microscopic and macroscopic tensile strength, fatigue strength and fracture toughness (Dwivedi and Vishwakarma, 2018). This phenomenon is known as hydrogen embrittlement (HE), a complex phenomenon involving several mechanisms including the physical and chemical absorption and hydrogen dissolution.

Numerous studies have focused on the analysis of hydrogen losses to outline a concentration distribution model in time and space, necessary to calculate a safety distance. The aforementioned parameter plays a fundamental role in ensuring safety in the vicinity of hydrogen infrastructure. This takes on relevance in the context of the design of plants and distribution networks intended for a more widespread use of the gas, underlining the importance of adopting rigorous safety criteria to protect both people and surrounding structures.

Additional research, performed at laboratory level with different methodologies, was performed to simulate the behavior of hydrogen to develop descriptive equations, especially in situations of leakage from tanks or pipes. Monitoring hydrogen leaks is important to ensure safety in the process industry, considering the ageing of infrastructure and natural events that can increase the frequency of these leaks. Nowadays, however, there is a lack of research that specifically addresses the detection of hydrogen leaks on a plant scale.

This monitoring can be carried out using different platforms capable of acquiring data, such as photographs and/or videos, from different altitudes, thus providing a diversified spatio-temporal resolution (Pillosu, 2020). Drones, also known as unmanned aerial vehicles (UAVs), emerge as the most versatile and flexible platforms, as they are controlled by an operator on the ground, who can pre-set the flight plan or change direction, altitude, and speed during the flight itself. These platforms cover smaller areas, which results in data of greater precision and resolution. The use of drones for monitoring requires the installation of a specific device, known as sensor, designed to detect released gases or small fires that are difficult to detect. The specified tool allows to capture photos and/or videos at safe distances. This methodology is particularly suitable in the presence of flammable or corrosive substances, which could compromise or cause malfunctions in the equipment. Druart et al. (2021) used a drone-mounted infrared camera to detect methane leaks from a storage tank. The test was conducted at three different flight heights: 80 m, 40 m and 20 m, with gas losses of 200 g/s, 10 g/s and 1 g/s respectively. The study showed that even at an altitude of 80 m also the smallest methane leak can be clearly detected. This form of monitoring has advantages in terms of the speed of real-time data acquisition and the ability to locate gas leaks in a totally safe way.

The use of drones equipped with cameras represents an effective solution to address the problem of hydrogen leaks. The most widespread technologies on the market for identifying the presence of combustibles in the air include infrared sensors and catalytic bed sensors. However, hydrogen is not capable of absorbing infrared radiation like hydrocarbons. On the other hand, catalytic bed sensors do not allow detection at safe distances. Two methods are proposed to address the proposed problem:

- The Schlieren method for gas detection is an optical technique that exploits density variations in a transparent medium, offering the possibility of visualizing and recording gas flows. Density variations within the gas cause light rays to bend, creating patterns known as Schlieren lines or density shadows. By using a sensing system, such as a high-sensitivity camera that can be placed on the drone, changes in light intensity in density shadows can be captured. The resulting images allow to highlight variations in gas density, making visible leaks or flows allowing real-time monitoring (Hargather and Settles, 2012)
- Hydrogen, thanks to its low minimum ignition energy value and high heat of combustion, is capable of easily generating jet fire once released, producing a significant amount of heat. These can be easily detected using a thermal camera installed on a drone, allowing real-time monitoring of hydrogen leaks.

Therefore, the primary objective of this research is to formulate advanced methodologies to implement an effective monitoring and control system to detect any hydrogen leaks within industrial process plants. The study contributes to the POC Multi-risk analysis of energy and process infrastructures.

References

Druart G., Foucher P.Y., Doz S., Watremez X., Jourdan S., Vanneau E., et a. (2021). Test of SIMAGAZ: a LWIR cryogenic multispectral infrared camera for methane gas leak detection and quantification. *Algorithms, Technologies, and Applications for Multispectral and Hyperspectral Imaging XXVII*, 11727, 53-59.

Dwivedi S.K., Vishwakarma M. (2018). Hydrogen embrittlement in different materials: a review. *International Journal of Hydrogen Energy*, 43(46), 21603-21616.

Elaoud S., Hadj-Taïeb L., Hadj-Taïeb E. (2010). Leak detection of hydrogen–natural gas mixtures in pipes using the characteristics method of specified time intervals. *Journal of Loss Prevention in the Process Industries*, 23(5), 637-645.

Hargather, M. J., Settles, G.S. (2012). A comparison of three quantitative schlieren techniques. *Optics and Lasers in Engineering*, 50(1), 8-17.

Pillosu M. (2020). Very Deep Super Resolution (VDSR): Applicazione su dati acquisita da UAV e da satellite in ambito agricoltura di precisione. *Doctoral dissertation*, Politecnico di Torino.

Proof of concept of an exceptional transport corridor exposed to multi-risk conditions: definition and preliminary analyses

Giulio Zani[1], Alessia Abbozzo[1], Matteo Antelmi[1], Marco Belloli[2], Gabriele Cazzulani[2], Francesco Fusco[1], Pier Francesco Giordano[3], Maria Giuseppina Limongelli[3], Laura Longoni[1], Martina Vitali[2], Marco di Prisco[1]

(1) Dept. of Civil and Environmental Engineering, Politecnico di Milano, giulio.zani@polimi.it
(2) Dept. of Mechanical Engineering, Politecnico di Milano
(3) Dept. of Architecture, Built Environment and Construction Engineering, Politecnico di Milano

In the northeastern region of Italy, there are an estimated 27,000 to 54,000 exceptional transports annually, primarily serving the steel industry. This area, integral to industrial production, requires safeguarding due to its robust economy. However, ensuring the secure transportation of exceptional loads is a significant concern, given the constraints imposed by the existing road infrastructure, which often requires maintenance.

To facilitate the movement of exceptional vehicles, mandatory special permits must be obtained from road authorities before embarking on the intended journey. Restrictions on exceptional transports may involve timing constraints (sometimes only permitted during nighttime hours) and specific routes to follow. New guidelines on bridge maintenance introduced in 2022 pose a severe risk to the issuance of traffic permits, potentially halting exceptional transportation.

The Proof of Concept (POC) documented in this work aims to assess the safety and resilience of a freight transport corridor and its possible alternative road segments, at present employed for the transit of exceptional loads. Stretching approximately 350 km (Figure 1), this corridor connects the metropolitan area of Milan to the port of Marghera, intersecting various road infrastructures and orographic and hydraulic discontinuities. The route, identified by stakeholders specialized in the transportation of exceptional cargo, includes infrastructures managed by local administrations and large road management companies. A preliminary survey based on AINOP cartography and an initial inspection revealed around 100 bridges, each with distinct materials, static schemes, states of preservation, and intersecting interferences.

The ultimate goal of the POC is to propose a methodology for evaluating the road segment, considering the impacts of both human activities (ordinary traffic and exceptional loads) and natural factors (hydrological, geological, seismic, and climate change) on the safety and resilience of the system. The research includes compiling a list of priority infrastructure and designing traditional and innovative monitoring systems to assess structural behavior, detect structural responses during exceptional transits, and enable real-time communication with exceptional transport vehicles through geolocation systems.

Alternative road segments are also explored to establish backup connections in the event of catastrophic incidents such as floods, landslides, or earthquakes that may disrupt the primary route. To comprehensively incorporate multiple natural hazards, an additional route is also included, extending from Milan to the Italy-Switzerland border at Campocologno; this last runs along the eastern shore of Lake Como and intersects areas characterized by active landslides and significant hydrogeological risks during extreme meteorological events.

Figure 1 – Selected freight transport corridor connecting Milan to the port of Marghera.

Spoke TS3: Communities’ resilience to risk: social, economic, legal and cultural dimensions

Structuring co-design approaches for built environment and widespread heritage in fragile contexts: a first analysis of existing successful practices

Emilia Corradi [1], Francesca Vigotti[2], Camillo Frattari[3], Francesco Airoldi[4]

(1) Dept. of Architecture and Urban Studies, Politecnico di Milano, emilia.corradi@polimi.it

The paper sets some reflections in compliance with the objectives of the RETURN project Spoke TS3, Work Package 4 "*Community-Based (CB) approaches, codesign and policies*", Task 7.4.4 "*New approach in integrated planning based on co-design processes for DRR e CCA policies*", with a specific focus on the role of architectural design and conservation participatory strategies for Disaster Risk Reduction and Management (DRR, DRM) and Climate Change Adaptation (CCA) in fragile territories. Therefore, the contribution aims to investigate existing co-design approaches for the built environment and widespread heritage (e.g. landscapes, settlements, traditional knowledge, and construction techniques) in vulnerable contexts, concerning the increasing exposure to risk and uncertainty accelerated by climate change and environmental crisis. To achieve conditions of anti-fragility of communities and places – an urgency related to changing scenarios in increasingly contracted temporalities – a critical reading of the state of the art is proposed by looking at the role of community-based processes in the effectiveness of past experiences, examining reference protocols and some outputs of past research.

Cultural heritage has been included in DRR, DRM and CCA policies, and protocols relatively recently: a growing interest that is reflected in literature over the last two decades, with a significant increase after the publication and adoption in 2015 of *The Sendai Framework for Disaster Risk Reduction (2015-2030)*. Besides referring to the significance of comprehending, evaluating, and sharing the impacts of disasters on cultural heritage and supporting its protection on national and local levels, the document confirms the significance of local knowledge, as already stated in the *Hyogo Framework for Action (2005-2015)*. In fact, *The Sendai Framework for Disaster Risk Reduction* states the importance of integrating scientific knowledge with traditional knowledge and techniques and ensuring site-specific policies and actions (UNDRR 2015). On the international level, the UNESCO World Heritage Centre together with other supranational Bodies and Agencies like ICCROM, have recognized the crucial part represented by heritage when dealing with natural and man-induced catastrophic events and hazards (UNESCO, 2010). Furthermore, the role and mobilization of communities with their traditional knowledge have been set as pivotal in enhancing mitigation and management strategies related to the risks posed by disasters. These considerations on a progressively more inclusive and participative approach have resulted in different outcomes, ranging from handbooks and training specifically dedicated to heritage professionals, architects, and planners, to toolkits, manuals, and educational activities targeting technicians, local authorities, and inhabitants. Such actions are often structured relying on and including local knowledge and traditional building techniques, considered as resilient practices.

An example of co-design based also on traditional knowledge and practices, and architectural implications in DRR and CCA within fragile context can be seen in the work of Pakistan architect Yasmeen Lari. In the 1980 she cofounded the Heritage foundation of Pakistan, a not-for-profit organization engaged in research, publication, and conservation of cultural heritage. After the 2005 Kashmir earthquake Lari engaged population by a self-help approach and contributed to the rehabilitation of communities by designing emergency architecture and teaching skills to indigenous people to rebuild their home. Inspired by circular economy and zero carbon construction policy, the "DRR–Compliant Sustainable Construction, 'Build back safer with vernacular methodologies' Technical Support Program" (Lari, 2012) is a manual that provides technical solutions to improve traditional building techniques, and to engage and train artisans for rehabilitation and reconstruction of settlements. Since education and training are relevant parts of risk prevention, another tool developed by Lari is the “Disaster Preparedness Manual” and “Disaster Preparedness and Management” DVD (Lari et al., 2013), written both in English and Urdu for a widespread comprehension (Corradi, 2021). The manual contains illustrations and photographs that describe actions to be taken “before, during and after” the disaster that could be easily understood and communicated by population.

Given this background, the contribution reflects on the possibilities of design to trigger or catalyze dynamics of change in these fragile contexts, proposing a design-driven research methodology based on topics of spatial education. Architectural design and intervention for built heritage is thus understood as a space of collective engagement, identifying participation as the key in the process of territorial regeneration. Furthermore, a comprehensive understanding of the local context in different realms should be included as an important part of the knowledge process when dealing with built environment and widespread heritage facing risks and hazards: it allows to identify not only contemporary peculiarities and relevant actors, but to acknowledge also past catastrophic events, their consequences on a specific site, and the measures adopted in time to recover from disasters and manage risk and vulnerability.

The role of designers, heritage professionals, and planners might be crucial in developing successful participatory strategies for Disaster Risk Reduction based on a cross-sectoral and broad understanding of a specific context, its communities, and peculiarities: architects and planners should operate in co-design with local stakeholders to effectively integrate their knowledge with traditional ones, developing site-specific resilient intervention strategies. In this context, Yasmeen Lari work could represent a virtuous case of an approach that might serve as a model for research activities and the development of co-design practices and policies within the Task 7.4.4 “*New approach in integrated planning based on co-design processes for DRR e CCA policies*” of RETURN Spoke TS3.

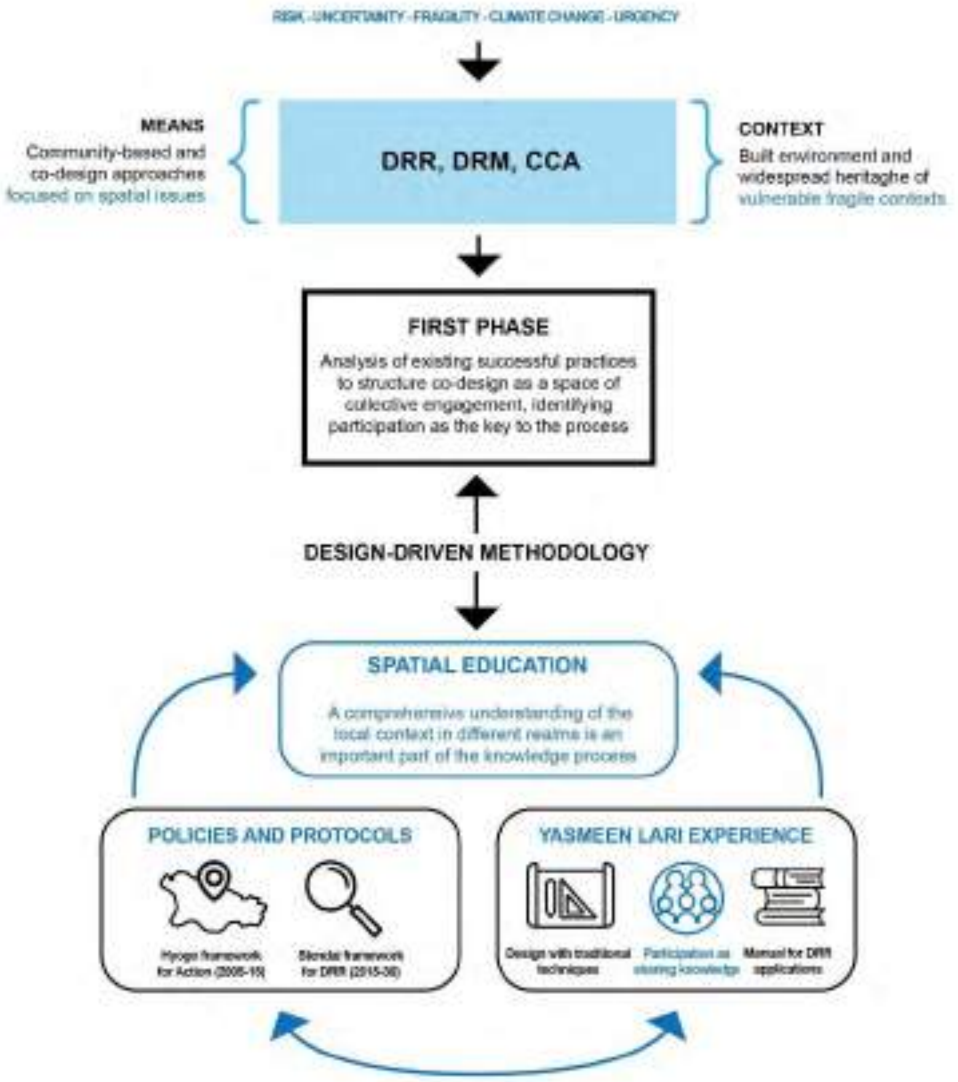


Figure 1 – Conceptual diagram of the first analysis of existing co-design successful practices.

References

Corradi E. (2021). The future underpinned the past, in: Berlingieri F., Corradi E., Cozza C., Forino I. (2021). *Yasmeen Lari: An Architect*, Pearson, Milano.

Lari Y. (2012). *DRR–Compliant Sustainable Construction Build Back Safer with Vernacular Methodologies: Technical Support Programm*e. Heritage Foundation of Pakistan, Karachi-Pk, 1.10.

Lari Y. (2013). *Disaster Preparedness Manual*, Heritage Foundation of Pakistan, Karachi-Pk.

UNDRR (2015). Sendai Framework 2015–2030. Sendai, Japan, 32 p.

UNESCO (2010). Managing disaster risks for World Heritage. Paris, France, 66 p.

Assessing the exposure of cultural heritage to multiple risks, with a focus on cities of art and intangible social, aesthetic and spiritual values

Chiara Franciosi[1], Filippo Fraschini[1], Marta Giambelli[1], Antonio Gioia[1], Marina Morando[1]

(1) CIMA Foundation, chiara.franciosi@cimafoundation.org

Cultural heritage is one of the key elements characterising the resilience of a community to natural events, due to both its tangible attributes (such as, for example, the source of income generated by touristic activities connected to a particular monument) and the intangible ones (the social cohesion generated by places or monuments significant for the history of a given community). Because of this multifaceted framework, it is important to carefully define and analyse the cultural heritage dimension in order to produce policies and actions to effectively mitigate the potential damage resulting from disaster events, increasing the resilience of the related community.

In this context, some critical elements emerge with respect to the characterization of cultural heritage, in particular: i) CH is a complex dimension, difficult to frame on a conceptual and terminological level, with a significant intangible component; ii) cultural heritage has a subjective component, therefore the community itself participates in the definition and attribution of meaning to its own cultural heritage.

It therefore becomes necessary to define a holistic approach that allows for a medium-long term critical reflection on the practices implemented by communities in the management and care of their living space in order to understand not only the historical and environmental elements characterising a community but what are the "protection" actions that are most suited with the social context and achievable within it.

To analyse the cultural heritage of a given territory, understanding its identity function, traditional "top-down" context analyses are therefore insufficient, but it is considered essential to involve the communities (be they public institutions, local stakeholders or the citizens themselves) in identifying the elements to characterise the cultural heritage of a specific territory.

In this way, it becomes possible to understand this intangible component and to integrate this dimension into the risk analysis, focusing on the cultural heritage as an element of the ability of a territory and a population to react to disastrous events.

Starting from the results and deliverables of the task 4.1 (literature review on community-based approaches in DRR and CCA and the related guidelines for community-based approaches), our activity will be structured over four main activities:

i) The analysis of the European and Italian normative framework related to cultural heritage in order to identify cultural heritage definitions and related recurring tangible and intangible dimensions.

ii) An in-depth literature review on methods and tools to engage local communities in identifying and valuing cultural heritage exposed elements.

iii) The definition of guidelines and procedures for the participatory assessment of the exposed cultural heritage of a target community.

iv) A test of the proposed guidelines in a proof of concept.

References

«Report sulla valutazione della funzione identitaria e culturale di una comunità». Analisi del processo messo in atto per realizzare un investimento di flood proofing in luoghi ritenuti prioritari per il mantenimento della funzione identitaria e culturale della comunità (come ad es. luoghi di culto, luoghi di aggregazione, edifici pubblici, elementi del patrimonio culturale). Progetto PROTERINA-3Évolution (Interreg ITA-FRA Marittimo 2014-2020).

Munerol F., Altamura M. (2021). La fragilità del centro storico: l'Aquila ed Albenga, in una lettura di protezione civile. La legislazione per i centri storici. Atti del Seminario organizzato nei giorni 27 ottobre, 3 e 10 novembre 2021, Genova.

Citizen participation in civil protection planning (CPP) considering different demographic and socio-cultural contexts

Chiara Franciosi[1], Filippo Fraschini[1], Marta Giambelli[1], Antonio Gioia[1], Marina Morando[1]

(1) CIMA Foundation, chiara.franciosi@cimafoundation.org

The Italian Civil Protection System is considered one of the Italian excellences. It succeeds in putting/holding together the prevention phase, the preparedness phase and the response phase for protecting assets such as life, physical integrity, property, settlements, animals and the environment from damage or the danger of damage resulting from calamitous events. Moreover, the Italian Civil Protection is based on an articulated network of relationships between citizens, public and private entities, together contributing to the effectiveness of the System. This particular framework allows the community to be placed at the centre of civil protection choices.

In recent years, in order to strengthen this network, efforts have been made to identify and define a new model of action that allows covering the so-called "last mile" of the Civil Protection System, identifying this model in the participatory civil protection processes.

After some local testing, the participatory process of civil protection measures and procedures has emerged as a planning procedure better tailored on the territory and contextually more effective, becoming an instrument of cooperation and consultation between the community and the public administration. Participatory processes have proven capable of creating a more manageable and "shared" territory, in which planning choices become the “heritage” of both the decision-maker and the community, increasing local resilience.

In addition, through participatory processes it is possible to collect and systematise socio-economic territorial data and knowledge, which could hardly emerge from a remote analysis, and to build civil protection solutions that are more shared and consequently more accepted by the citizens themselves, who have the opportunity to play the role of active citizens.

The participatory processes also allow for the creation of greater awareness of risk and simultaneously that enhancement of local knowledge that fosters local empowerment and community resilience, which in the civil protection context takes on the declination of a community's ability to cope with calamitous events, overcome them and emerge strengthened or even transformed.

Moreover, Community Based Approaches (CBA) have been recognised as a powerful approach to design and implement effective disaster risk reduction (DRR) and climate change adaptation (CCA) policies. The recognition of the importance of community participation in DRR emerged in the 1980s when it was acknowledged that communities possess resources and capacities that can be utilised to reduce disaster risks, addressing local concerns and needs. The Sendai Framework for Disaster Risk Reduction stressed the importance of empowering local authorities and communities through inclusive, accessible, and non-discriminatory participation (UNDRR, 2015). While the United Nations Framework Convention on Climate Change (UNFCCC) recognised the importance of community involvement and participation in addressing climate change impacts as early as 1992, the concept of Community-Based Adaptation took longer to gain traction within adaptation policies. However, the Paris Agreement (2015) clearly states that “Parties acknowledge that adaptation action should follow a […] participatory and fully transparent approach, taking into consideration vulnerable groups, communities and ecosystems and should be based on and guided by […] traditional knowledge, knowledge of indigenous peoples and local knowledge systems”.

CIMA Foundation has supported public administrations in designing and developing CBA aimed at the participatory identification of civil protection policies and procedures. According to these experiences, CBA emerged as an effective tool: i) to increase the trust relationships between the public administration and the corresponding community; ii) to empower the resilience and adaptive capacity of the community, increasing their knowledge and ownership on risk mitigation procedures and behaviours and finally iii) to integrate the modelled climate and meteorological predictions with local knowledge on past natural events reducing the inherent uncertainty of modelled forecasts.

Moreover, significant needs emerged to design and conduct an effective and equitable CBA processes: i) to dedicate adequate economic and human resources to the participatory process; ii) to engage facilitators as an essential support to the whole process; iii) to engage the local community over the whole duration of CB project, sharing and discussing the participatory process objectives, methods and locations for the CB meetings, the most relevant stakeholders to engage and clearly presenting to the community the outcomes of the process.

Starting from these experiences and from the insights coming from the literature review conducted in the task 4.1 ("Common set of methods and guidelines for CB activities") this task will test the CBA methodology developed in the task 4.1 in three proof of concepts: i) Bagnara Calabra; ii) 5 Terre; iii) Savona. Process or methodology gaps will be identified and analysed and filled. The lessons learned from the proof of concepts and the theoretical analysis will feed in the task 4.1 guidelines.

References

Shaw R., Chan E., Lian F., Lu L., Shi P., Yang S., Chan G., Wong J. (2017). Co-designing DRR Solutions: Towards participatory action and communication in science, technology and academia, ASTAAG, IRDR and CCOUC, Hong Kong, China.

King, S. (2014). Community-Based Adaptation in practice: CARE Global Overview. CARE Climate Change. https://careclimatechange.org/community-based-adaptation-in-practice/

International Institute for Environment and Development (2009). 60 Participatory learning and action – Community-based adaptation to climate change, Nottingham, UK

Stakeholders' identification and engagement in the RETURN project

Isabel Gomes[1], Federica Romagnoli[2], Francesca Munerol[1]

(1) Planning and Procedures Department, CIMA Research Foundation, isabel.gomes@cimafoundation.org
(2) Centre for Global Mountain Safeguard Research (GLOMOS), EURAC Research

Studies on stakeholder engagement define "project's stakeholders" as actors with a specific interest and/or influence over or by, the activities and results of a project (Bobbio, 2004; Magrath & Whitty, 2017). The type and category of stakeholders determine their influence and role in decision-making, ultimately impacting project success. Mayfield (2013) highlights that despite the popularity of project management methodologies, mismanagement of stakeholder relations remains a common cause of project failures.

Recognising the national-level relevance and potential social and institutional impacts of the RETURN project, a dedicated Working Group was established to support stakeholder mapping, identification, and involvement. This group operates at a pivotal level within Spoke TS3 however the methodology developed is open to any partner willing to follow the process which has so far been articulated in nine main steps (currently on step 4): i) context analysis and design of the methodological approach; ii) initial stakeholder identification exercise (project level); iii) sharing the methodological approach with partners and creation of a formal Working Group; iv) detailed stakeholder identification exercise (WP and Task level); v) setting a strategy map for each task and stakeholder; vi) conducting six participatory annual stakeholders' meetings (April/November each year); vii) monitoring and evaluation of the process (success rate, new needs, gaps, opportunities); viii) feedback on the support received and impacts observed on RETURN's products and outcomes; ix) public dissemination of the process and of the observed impacts on project's outcomes.

Proceedings regarding the undergoing process will be monitored and shared with the RETURN community through the dedicated Working Group and the Stakeholders Annual Meetings.

References

Bobbio L. (a cura di) (2004). A più voci. Amministrazioni pubbliche, imprese, associazioni e nei processi decisionali http://www.cantieripa.it/allegati/A_più_voci.pdf inclusivi, Napoli, ESI.

Mayfield P. (2013). "Practical People Engagement: Leading Change through the Power of Relationships", *Elbereth Publishing*, 2013

Mcgrath S.K., Whitty S.J. (2017). Stakeholder defined. *International Journal of Managing Project in Business*, 10(4).

Guidelines for systematic multi-risk mapping for cultural heritage, from site to urban to regional and national scales

Emanuele Intrieri[1], Silvia Bianchini[1], Alessio Gatto[1], Samuele Segon[1], Chiara Arrighi[2], Antonino Maria Marra[3], Mario Di Bacco[2], Gianfranco Stipo[3], Vieri Cardinali[3], Marco Tanganell[3], Mario De Stefano[3], Fabio Castelli[2]

(1) Dept. of Earth Science, University of Florence, emanuele.intrieri@unifi.it
(2) Dept. of Civil and Environmental Engineering, University of Florence
(3) Dept. of Architecture, University of Florence

This study presents a comprehensive framework for the establishment of guidelines aimed at creating multiscale and multi-risk maps, addressing landslide, flood, and earthquake risks.

Any risk mitigation strategy requires previous knowledge of the areas where interventions are a priority; this can be achieved with several methods, the most common of which is through a risk mapping that features the location where the expected loss for a particular type of event is higher. Such maps are generally focused on a single hazard or on a single scale. Moreover, even when present, these risk maps usually do not have a special aim at cultural heritage elements, which in turn are crucial and prevalent on the Italian territory. Therefore, the rationale for this study stems from the needs of decision makers operating with cultural heritage, who would benefit from a strategical tool detailing how to develop holistic maps encompassing different scales and types of risk.

The proposed guidelines are structured according to the components of the risk equation and then detail the different approaches required for diverse scales and types of risk. The methodology adopted by the guidelines is to describe a standardized method explaining how to take advantage of existing official spatial data, sewing them together in a comprehensive framework.

The multiscale approach is realized in two different ways. On one hand, the different scales require different methods for defining the losses of the elements at risk. At the local (e.g. single building) scale, the losses can be determined with interdisciplinary approaches accounting for tangible (i.e., economic) and intangible (i.e., social, aesthetic, and spiritual significance) losses of the cultural heritage. At the urban, regional, and national scales the sheer number of elements with potential cultural value is so high that a less refined methodology is necessary. In this case, the value of cultural heritage can be derived by databases such as the General Catalogue of Cultural Heritage, curated by the Italian Ministry of Culture, after an appropriate data elaboration consisting in transforming the Ministry's classification into a numerical value and weighting it to assign an aggregate value to a larger resolution cell which might include other elements at risk. The passage from the national to the urban scale permits to explode one cell size into its single cultural heritage elements, and from the urban scale to the local scale to assess its value with a site-specific analysis.

On the other hand, the adoption of multiple scales also influences the accuracy in the description of the elements at risk. For example, at the national or regional scale, a building exposed to flood risk is represented as a vector point whose location can be compared with the hazard map to assess the hazard level of that specific cultural heritage, whereas at the local scale a 3D knowledge of the building revealing the location and height of its openings permits a detailed modeling enabling, for example, the possibility to quantify the water levels within different areas of the building.

A particular type of element at risk is also addressed, namely the reserves of biosphere. In this case, next to the aforementioned multi-scale and multi-risk concepts, a specific approach is applied. In fact, a reserve of biosphere is first disassembled into its elementary components and intrinsic values (such as its relevant landscape, zoological and economic elements), then each one is evaluated separately with respect to every different type of threat, and finally a comprehensive value is obtained for the reserve of biosphere as a whole.

In conclusion, by addressing also specific issues such as data and scale homogenization, the guidelines constitute a robust framework for developing maps useful for informed decision-making, resilient planning, and data-informed resource distribution to minimize the potential impact of hazards on culturally significant sites and artifacts. The prosecution of this study will be to demonstrate its applicability through proofs of concepts, showcasing its efficacy at different scales.

Why aggregate ratio judgements to improve epistemic, ethical, and legal aspects of decisions about natural risk?

Pavel Janda[1]

(1) Dept. of Architecture and Urban Studies, Politecnico di Milano, pavel.janda@polimi.it

Aggregating experts' judgements about various relevant criteria or alternatives into a helpful decision-aiding tool is commonplace in many decision processes. Thus, searching for an optimal judgement aggregation procedure is one of the pivotal tasks in multi-criteria decision theory and opinion pooling, decision-aid tools that – among others – are intensively used in risk management and analysis of natural disasters. For example, the Analytic Hierarchy Process (AHP) is one of the main multi-criteria decision methods used in risk management of natural disasters (Sen et al., 2023). One of the main theoretical discussions about AHP concerns the optimal aggregating function and its resistance to outcome manipulations, see (Aires et al., 2018, pp. 335-338).

This communication takes a general axiomatic approach to argue that one should aggregate ratio judgements (either value judgements, e.g., those used in AHP, or belief judgements, e.g., odds) instead of absolute judgements (e.g., probabilities) for the following two reasons.

1. **The mathematical structure underlying ratio judgements (and their aggregation) allows one to satisfy many desirable axioms that – for absolute judgements – lead to undesirable or straight impossibility results.** For example, aggregation of ratio judgements is sensitive to individual judgements (Aczél, 1984, p. 288). It avoids decisions dictated purely by a single judgement, i.e., dictatorial choices, which is epistemically and ethically desirable. For another example, assume ratio judgements to express relative comparisons of alternatives, e.g., *a* and *b*. A requirement following measurement theory (Roberts, 2009, pp. 64-74) is that the result of aggregation should not be affected by a different framing (e.g., an order) of the comparison to avoid possible manipulations. For example, if *a* is judged *k* times better or more likely than *b*, then *b* should be 1/k times better or more likely than *a*. Every ratio judgement must have its multiplicative inverse to satisfy this requirement. Since 0 has no multiplicative inverse, comparative judgements cannot take that value (Aczél, 1984, p. 291). The simple step of excluding 0 from possible values blocks an impossibility result, e.g., see (Mcconway, 1981, pp. 411-412), which shows that an aggregating function cannot be locally sensitive and satisfy unanimity, both desirable properties. Unanimity says that if every individual judgement equals *x*, the aggregated judgement should also be *x*. Local sensitivity says that one can weigh each opinion of an expert differently according to that expert's expertise.
2. **Aggregation of ratio judgements is better suited to control and mitigate possible manipulations such as rank reversal than aggregation of absolute judgements, which can improve legal and ethical aspects of decisions.**
    (a) Normalisation always exposes one to the possibility of a rank reversal (Barzilai et al., 1994, p. 59), i.e., one can always find judgements for which normalisation changes the final ranking of alternatives. One can limit this risk by restricting what values judgements can take, so the values needed to perform a rank reversal are not always available. But ratio judgements can avoid normalisation altogether. For example, odds need not be normalised, but probabilities do. One may argue that odds are less informative than probabilities, but converting odds to probabilities (absolute judgements) requires normalising and thus re-introducing avoided impossibility results and risk of rank reversal, so the trade-off seems reasonable. Normalisation in multi-criteria

decision methods such as AHP requires deeper discussion, but one may avoid it even there, see (Barzilai et al., 1994). Another consequence of the no-need-for-normalisation of ratio judgements is that the independence axiom – an aggregated judgement about alternative *a* depends on individual judgements only about that *a* – is satisfied. However, avoiding normalisation does not mean that scaling is not applicable. It still holds that if the individual ratio judgements are scaled by $s > 0$, then the result of their aggregation is also scaled by *s* (Aczél, 1984, p. 289).

(b) (Aczél, 1984) proved that the weighted geometric mean (WGM) is the aggregating method that uniquely satisfies many desired axioms for ratio judgements. The WGM has already received a lot of favourable attention, and some authors (Aires et al., 2018, pp. 337-338) even argue that it is not susceptible to the rank reversal problem, i.e., roughly speaking, a deletion or introduction of alternatives does not change the final ranking. I will argue that the WGM can only entirely avoid the risk of rank reversal if a strong condition similar to state-wise dominance is satisfied. Still, I will show that the WGM manages the rank reversal problem better than the weighted linear average (a common rival to the WGM), which can improve legality and ethical aspects of, e.g., shortlisting. Finally, given the context of ratio judgements as pair-wise comparative judgements, I will discuss if and when a rank reversal could be legitimate, assuming the independence axiom holds, which can be easily controlled by principle sub-matrices (Barzilai et al., 1994, p. 60).

References

Aczél J. (1984). On weighted synthesis of judgements. *Aequationes Mathematicae*, 27, 288-307.

Aires R.F.d.F., Ferreira L. (2018). The rank reversal problem in multi-criteria decision making: a literature review. *Pesquisa Operacional*, 38(2), 331–362.

Barzilai J., Golany B. (1994). AHP Rank Reversal, Normalization and Aggregation Rules. *INFOR: Information Systems and Operational Research*, 32(2), 57-64.

Mcconway, K. J. (1981). Marginalization and Linear Opinion Pools. *Journal of the American Statistical Association*, 76(374), 410-114.

Roberts F.S. (2009). *Measurement Theory*. CUP.

Sen G., Sari B. (2023). Multi-criteria decision analysis models for emergency and disaster management: a systematic review. In: Gul, M., Yucesan, M., and Erdogan, M., editors, *Multi-Criteria Decision Analysis Case Studies in Disaster Management*, 17–29. CRC.

Analyzing effective risk communication: evidence from a literature review

Alessandra Massa[1]*, Francesca Comunello*[1]

(1) Dept. of Communication and Social Research, Sapienza University of Rome, alessandra.massa@uniroma1.it

Risk communication (hereafter RC) is complex, demanding a profound grasp of involved risks. Effective RC necessitates audience consideration and suitable communication methods. This presentation explores international literature on RC, aiming to systematize cases (campaigns, tools, and experiences) to identify success factors and obstacles, addressing the following research questions:

RQ1: What are the characteristics of the literature that has addressed RC?
RQ2: What are the elements of effectiveness noted in the literature for proper RC?
RQ3: What are the elements pointed out in the literature that inhibit or limit the effectiveness of RC?

A scoping review addressed these questions, pinpointing areas of high research attention and potential gaps. The scoping review serves as a launchpad for further research, stakeholder consultation, state-of-the-art assessment, and action planning. The search string focused on three knowledge areas: environmental risks, RC as a research field, and specific elements of RC, referencing key works like Covello et al. (1986) and McGuire's persuasive message framework (2013).

The study explored five databases, yielding 2217 papers. After deduplication, 1387 articles underwent screening based on inclusion and exclusion criteria to address the research questions. Identification of relevant papers followed the communication *intentionality* principle, in line with mass communication research themes (Katz & Lazarsfeld, 1954) and classic definitions of public communication campaigns (Atkin, 1981; Paisley, 1989). See Figure 1 for a summary of the abstract screening and paper retrieval process.

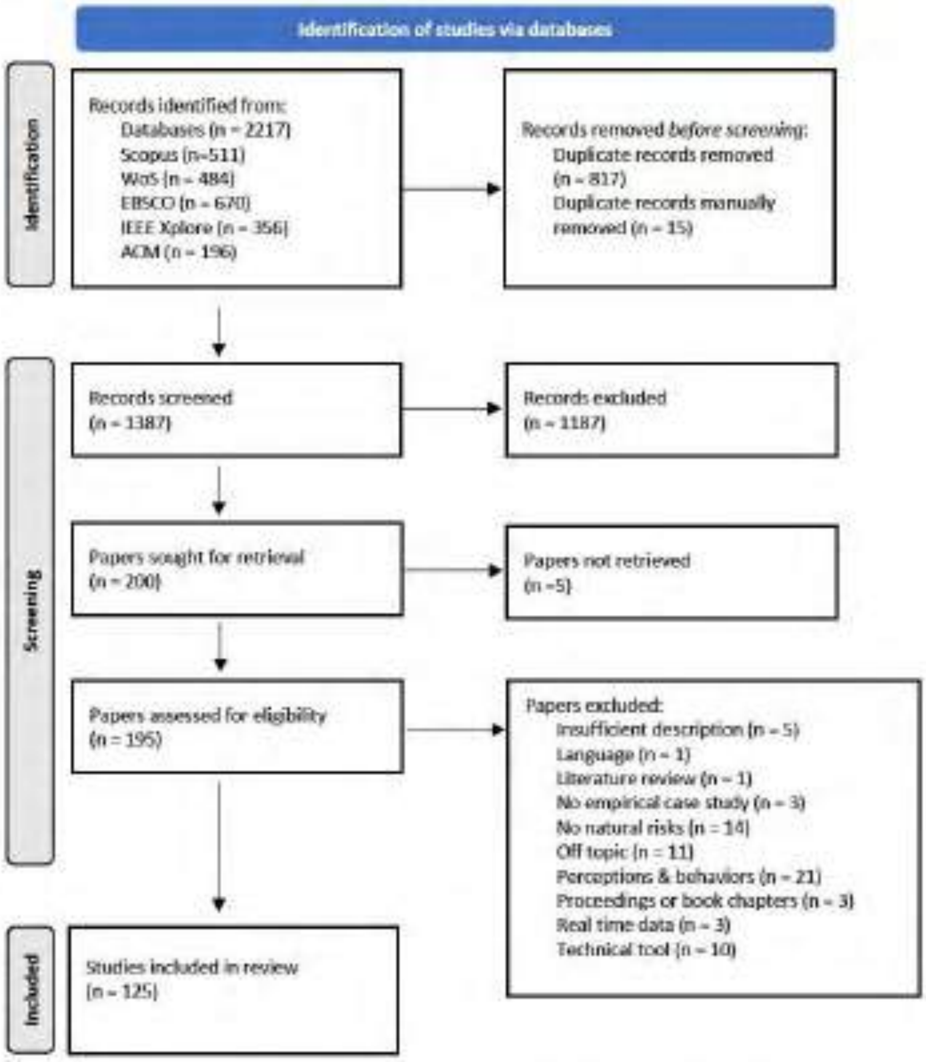


Figure 1 - PRISMA Flowchart.

The papers were analyzed using a grid to isolate essential information. Authors, publication year, journal, title, and abstract were organized in a matrix for cross-reading. Moreover, the analysis grid explored theoretical frameworks, instrument features, methods, main results, good practices, success factors, and inhibitors.

Regarding literature characteristics (RQ1), selected papers (2006-2023) spanned 66 journals. Predominant topics included flooding, hydrogeological risk, storms, typhoons, hurricanes, and tornadoes. Most papers focused on pre-risk communication, analyzing national experiences. America had the highest representation. Few papers provided clear RC definitions. Theoretical frameworks varied from risk society to social movement theories. Tools were addressed in 73 papers, case studies in 45 papers, and seven articles summarized communication campaigns. Most papers employed qualitative research.

RC campaigns, led by institutions and government agencies, use a tailored media mix directed at general audiences. Campaign success emphasizes participation, trustworthiness, and risk narratives. Case studies highlight diverse activities by agencies and operators, requiring organizational coordination, tailored strategies, and trustworthiness. Findings aren't generalizable, depending on specific risks and community traits. Various tools, including visual aids and digital platforms, are designed to present risk information effectively. Social media is a valuable platform for warnings. Adapting methods to local sociocultural diversity is crucial for resonating with the target audience.

Success (RQ2) and inhibiting factors (RQ3) in RC involve organizational aspects, emphasizing flexible staff, internal communication, inter-organizational cooperation, and involving experts. Hindrances include staff/budget shortages, cooperation gaps, weak identity, and a lack of communication culture. Case-specific valuable elements can be found. Personalization, visual cues, and targeted tools are helpful, but unfamiliar elements or conflicts with risk representation can hinder success. Audience characteristics define success, requiring targeted communication. Neglecting demographics and cultural awareness can lead to communication failures.

The media environment incentivizes successful risk communication through mixed media approaches. However, concerns in various papers include misinformation, lack of media policies, misrepresentation of risks in popular culture, and messages not tailored to media characteristics.

Establishing trustworthiness and source credibility is vital for effective RC. Successful RC tools depend on scientists to convey objective information, produce concise content, and provide visual aids. The literature recommends using data and emotional cues for attention. Issues arise when communicators use inappropriate formats, rely solely on worst-case scenarios, or lack awareness of data and technical information. Successful risk communication should utilize quiet periods for risk socialization, initiate post-event conversations, and avoid long gaps between occurrences. Timely actions and avoiding a false sense of security in awareness campaigns are crucial.

Narrative devices and organized content aid in delivering factual information that resonates with local audiences. Personal stories are compelling, keeping messages short, clear, and coherent, avoiding complex statistics and technical details to prevent information overload.

Citizen participation is positive for organizations promoting risk preparedness. Sharing risk memories fosters public debates. Hindrances include language barriers, cultural resistance, excessive agency involvement, and sporadic campaigns with limited impact, especially in politicized communities.

Further investigation is needed for risk communication targeting specific groups, including multicultural communities, non-residents, and diverse genders and ages. Understanding internal organizational processes and the political dimension and enhancing expert involvement are crucial. Finally, while participation benefits the early stages of RC, its contribution in emergency phases is still being defined.

References

Atkin C.K. (1981). Mass Media Information Effectiveness. In: R.E. Rice & W.J. Paisley (Eds.), *Public Communication Campaigns*. Beverly Hills: Sage.

Covello V., von Winterfeldt D., Slovic P. (1986). Risk communication: a review of the literature. *Risk Abstracts*, 3, 171-182.

Katz E., Lazarsfeld P.F. (1955). *Personal Influence. The Part Played by People in the Flow of Mass Communication*. New York: Free Press.

McGuire W.J. (2013). McGuire's Classic Input-Output Framework for Constructing Persuasive Messages. In: R.R. Rice & C.H. Aktin (Eds.), *Public Communication Campaigns*. London-New York: Sage.

Paisley W. (1989). Public Communication Campaigns: The American Experience. In: R.E. Rice & C.K. Atkin. *Public Communication Campaigns*. Newbury Park: Sage.

The Audit for the forecasting, monitoring and communication Institutions of Civil Protection: with RETURN to improve the "risk weighting" phase

Francesca Munerol[1], Marco Altamura[1], Marta Giambelli[1], Antonio Gioia[1], Luca Molini[1], Marina Morando[1]

(1) CIMA Research Foundation, francesca.munerol@cimafoundation.org

The purpose of the auditing of the Institutions responsible for regional and national alert functions is to verify compliance with the regulatory framework and the existence, quality as well as observance of the procedures and operational practices adopted by the Institution itself. Auditing has the aim of examining in depth the topic of legal responsibilities of operators who, at different levels, carry out the functions of forecasting, monitoring/surveillance and communication of critical issues triggered by natural and anthropogenic risks, in the context of the alert system. In the context of close collaboration between the audited Institution and the auditing researchers, the activity starts (1) from the contextual analysis of national and regional legislation, internal organizational regulations/deeds and the documentation of the quality management system, as well as "guarantee figures"; then continues with the (2) mapping of the areas at risk or of any critical issues to which the organization is exposed in carrying out forecasting activities, which could lead to "system errors in the field of Civil Protection"; the Audit then hesitates with the (3) risk weighting and (4) mitigation actions. The risk exposure quantification or weighting phase is the heart of the Audit procedure and is made up of (3.1) weighting of the risk aspects, areas and areas and (3.2) the identification of possible improvement actions. The weighting phase is conducted by applying consolidated and replicable methodologies, but adapted to the specificity of the Institution being examined. The Researchers' effort is to objectively strengthen this phase, through a consolidation of the indicators compared to what is available in literature and in practice, and of risk weighting techniques.

Empowering communities: the key to effective disaster risk reduction strategies

Benedetta Oberti[1], *Elisa Ravazzoli*[1,2]

(1) Center for Climate Change and Transformation, Eurac Research, benedetta.oberti@eurac.edu
(2) Institute for Regional Development, Eurac Research

In 2022, a total of 387 natural disasters occurred worldwide, resulting in a death toll of 30,704 (including missing persons). Beyond the human impact, the economic consequences, while less tragic, are also significant. In 2022, climate-related extremes led to economic losses estimated at EUR 52.3 billion. In the future, these events are anticipated to increase in both frequency and intensity, driven by a projected 1.8°C rise in global temperatures by 2100 (IPCC, 2021). This projection is based on the IPCC scenario, where global CO2 emissions are significantly reduced but not at an accelerated pace, reaching net-zero after 2050. This trajectory is expected to result in heightened economic burdens and, more significantly, an increase in human losses.

The potential loss of life and damage to assets caused by a natural disaster (i.e., disaster risk) can be reduced by designing, implementing, and evaluating measures that improve disaster preparedness, prevention, response, and recovery practices (i.e., disaster risk management). Traditional top-down measures alone, initiated at higher levels of governance and imposed upon local communities, fail in considering the specific needs and perspectives of those directly affected by disasters, and do not address the context-specific nature of disaster risks at the community level (Adger, 2003; Ayers et al., 2009). This can be solved by combining top-down measures with bottom-up ones that actively involve communities in disaster risk management (i.e., community-based approaches, CBAs).

While CBAs to disaster risk reduction (DRR) have been widely researched (Cradock-Henry et al., 2021; Fazey et al., 2021; Campos et al., 2021) there remains a lack of clarity regarding the fundamental aspects that characterized a CBA and the critical elements necessary to categorize an approach as such. Additionally, there is a limited understanding of the most effective tools for incorporating a community into the policy cycle of DRR measures.

This study aims to examine the key elements that define and contribute to the success of a CBA, along with the relationships among them. The objective is to derive a conceptual framework that describes such an approach. Furthermore, it aims to explore the optimal tools for engaging with a community in the design, implementation, and monitoring of DRR measures.

A literature review was conducted by employing Web of Science and Scopus as research engines. The search was centered around keywords related to participation, community-based approaches, co-design, bottom-up strategies, and disaster risk. Initial screening involved reviewing the abstracts of the identified papers to select those pertinent to the research questions. The chosen articles underwent an additional assessment based on inclusion and exclusion criteria through a detailed reading process. Ultimately, 74 papers were deemed relevant and underwent in-depth analysis, forming the basis for this study. A deductive content analysis was employed, utilizing pre-defined categories to examine the content of the papers.

The literature analysis uncovered numerous ways in which a community can participate in the DRR strategy policy process. However, the analysis also identified certain elements that are consistently present in every CB approach. While the specific form of these elements may vary across different approaches, the analysis revealed that they collectively form the defining features of each CBA. By extracting the constitutive and essential features of these recurring elements, it has been possible to regroup them into 4 dimensions:

Drivers, Local Context, Community agency, and Participatory process, each composed of sub-dimensions. The study delves into these dimensions in detail, providing an understanding of the key features that characterize CBAs.

As regards the most effective tools for incorporating a community into the policy cycle of DRR measures, the literature review unveiled a wide array of tools that can be used. Among the most commonly used are Scenario Adaptation Pathways, Transect Walks, Seasonal Calendars, Questionnaires, and Focus Groups. Each approach utilizes distinct tools depending on factors such as the number of community members involved, the desired degree of community participation and form of communication, and the purpose of the participatory activity (e.g., vulnerability assessment, risk mapping, etc.). From the literature analysis, no single tool or group of tools has emerged as more effective than others; on the contrary, the choice of the most suitable tool depends on the context.

In the realm of DRR, this study elucidates the constitutive elements that characterize a CB approach. By categorizing these elements into four main dimensions and discerning the relationships among them, the study introduces a novel conceptual framework, serving as an archetype for each real-world CBAs. Additionally, it offers an overview of the most commonly utilized and effective tools for engaging with a community in the policy cycle of DRR measures. Through these insights, the study aids policymakers, researchers, and practitioners in the implementation of CB approaches in risk management. These stakeholders now possess a clear understanding of the essential dimensions to consider when planning community engagement and have insights into the tools at their disposal.

References

Adger W.N. (2003). Social Capital, Collective Action, and Adaptation to Climate Change. *Economic Geography*, 79(4), 387–404.

Ayers J., Forsyth T. (2009). Community-Based Adaptation to Climate Change. *Environment: Science and Policy for Sustainable Development*, 51(4), 22–31.

Campos I., Vizinho A., Coelho C., Alves F., Truninger M., Pereira C., et al. (2016). Participation, scenarios and pathways in long-term planning for climate change adaptation. *Planning Theory & Practice*, 17(4), 537–556.

Cradock-Henry N.A., Blackett P., Connolly J., Frame B., Teixeira E., Johnstone P., et al. (2021). Principles and process for developing participatory adaptation pathways in the primary industries. *Elementa: Science of the Anthropocene*, 9(1), 00175.

Intergovernmental Panel on Climate Change (IPCC) (2023). Climate Change 2021 – The Physical Science Basis: Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.

Fazey I., Carmen E., Ross H., Rao-Williams J., Hodgson A., Searle B.A., et al. (2021). Social dynamics of community resilience building in the face of climate change: The case of three Scottish communities. *Sustainability Science,* 16(5), 1731–1747.

Task 7.2.1: on the use of Multi Criteria Analysis to evaluate risk reduction effectiveness in a multi-hazard environment

Daria Ottonelli[1], Alessandro Rubino[2], Anna Rita Balingit[3], Camillo Frattari[4], Cassandra Cozza[4], Daniela Mele[5], Daniela Molinari[6], Diana Caporale[2], Emilia Corradi[4], Fabio Castelli[7], Federica Romagnoli[8], Filippo Fraschini[1], Francesca Vigotti[4], Francesco Airoldi[4], Giacomo Scandolo[9], Gloria Padovan[3], Luca Cetara[10], Marco Bindi[3], Massimo Moretti[5], Panagiotis Asaridis[6], Paola Fontanella Pisa[8,11,12], Pasquale La Malva[10], Simona Muratori[13], Tommaso Bastiani[10]

(1) CIMA Research Foundation, daria.ottonelli@cimafoundation.org
(2) Ionian Department of Law, Economics and Environment, Università degli studi di Bari Aldo Moro
(3) Department of Agriculture, Food, Environment and Forestry, Università degli Studì di Firenze
(4) Department of Architecture and Urban Studies, Politecnico di Milano
(5) Department of Earth and Geoenvironmental Sciences, Università degli studi di Bari Aldo Moro
(6) Department of Civil and Environmental Engineering, Politecnico di Milano
(7) Department of Civil and Environmental Engineering, Università degli Studì di Firenze
(8) Center for Global Mountain Safeguard Research (GLOMOS), Eurac Research
(9) Department of Economics, Università degli Studì di Firenze
(10) Representing Office Roma, Eurac Research
(11) Global Mountain Safeguard Research Program (GLOMOS), United Nations University Institute for Environment and Human Security (UNU-EHS)
(12) Graduate School of Environmental Studies, Tohoku University
(13) Poliedra, Politecnico di Milano

Literature review (Gamper et al., 2006) leads to Multi Criteria Analysis (MCA) as the most promising tool to support decision making in natural risks management, especially in multi-hazard contexts. Nevertheless, its implementation is limited in practice for the lack of both standards/guidelines and of benchmark studies. The objective of WP 7.2 is to overcome these limitations.

The first step was the framing of a flowchart representing the process leading to the selection of alternatives by means of MCA, identifying the operative steps required for its implementation.

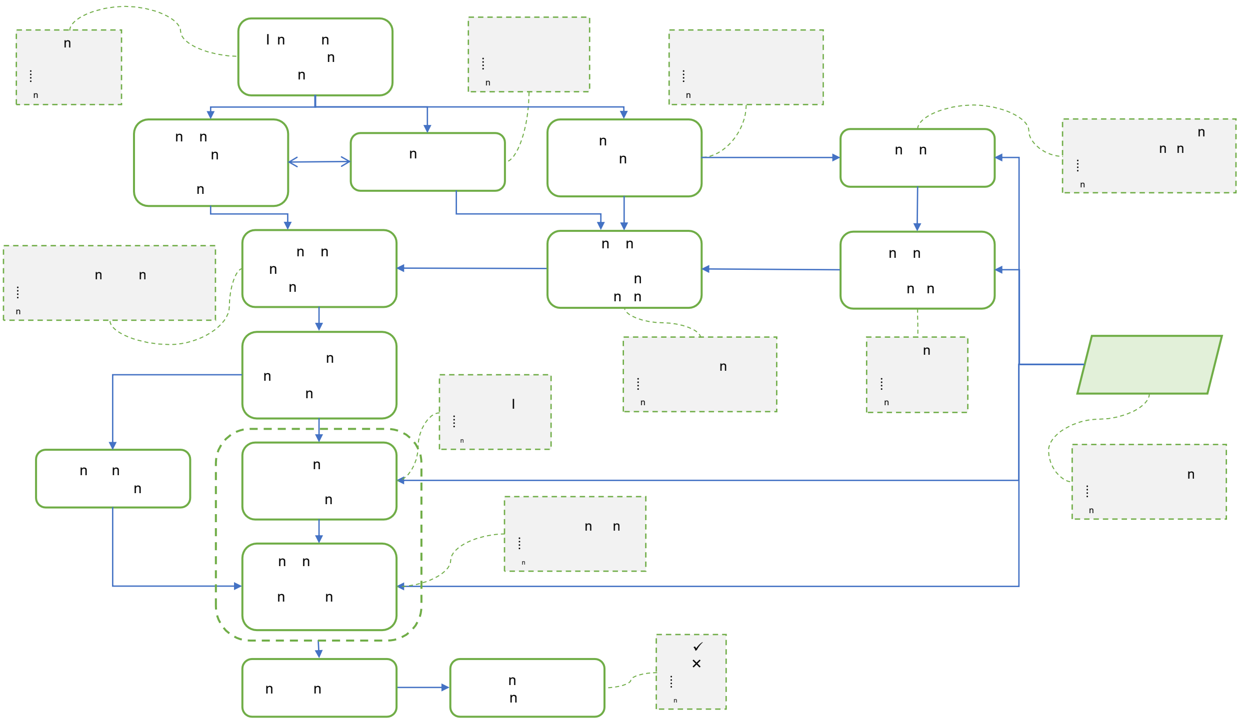


Figure 1 – MCA flowchart.

The process starts with the identification of the risk reduction alternatives. The literature highlights that they could refer to both structural and non-structural measures and could work on different hazards/risks and/or on their components, in the different phases of the risk chain, implying a high level of heterogeneity that increases the complexity of the decision-making problem. In fact, two scenarios may occur. The one in which the various alternatives have been identified by decision makers/stakeholders, and the one in which alternatives must be identified during the process. In the flowchart the first scenario is considered, as the most common one occurring in natural risk management.

Each alternative is then characterized in terms of: (i) temporal and spatial scale of effectiveness, (ii) potential risk reduction, and (iii) other impacts on the interested communities (e.g., on environmental quality, labor market, cultural identity). In multi-hazard contexts, evaluating whether a measure that was designed to reduce a certain risk may affect also other risks is important, especially when an increase is possible. The whole evaluation can then benefit from the existence of an abacus of alternatives which identifies the most promising measures that can be implemented and characterizes them in terms of potential risk reduction or increase (with respect to different hazards), and temporal and spatial scale of effectiveness. The evaluation of secondary impacts (beyond risk reduction) is instead more context/problem-dependent and requires a proper definition of “interested communities”.

The characterization of the alternatives, as well as the recognition of stakeholders’ needs and expectations, are at the base of the following step that is the definition of objectives (also called “criteria” in MCA problems). In fact, depending on the investigated context, it is likely that other objectives exist beyond risk reduction, like improving environmental quality, increasing cultural identity, promoting sustainable development (Curt et al., 2022). This phase is crucial for the following definition of attributes and indicators, according to which alternatives are evaluated.

Attributes and indicators must enable modelers and decision makers to evaluate the capability of the different alternatives of meeting the problem’s objectives. Especially, attributes must consider the impacts of the alternative measures in terms of both risk reduction (or increase) and secondary effects. Such an analysis requires an in-depth, generalized investigation of the types of elements that are exposed to different natural hazards, as well as of the potential direct and indirect damage to them in case of an event. On the other hand, the identification of indicators is strongly related to the spatial and temporal scales of the analysis, as the same attribute can be differently evaluated at different scales. In this regard, the literature highlights present challenges in considering climate change drivers and effects, as well as the dynamic nature of exposure and vulnerability (Golfam et al., 2019).

Once the value of each indicator has been evaluated (for all the alternatives of intervention), it is possible to identify which MCA tool is more appropriate for the investigated problem and to define the related parameters (e.g., utility functions, weights). Stakeholders' involvement is crucial in these phases; it is then required to identify stakeholders for different community types and reduction measures, along with the most effective tools for their involvement. At last, the various alternatives are evaluated and ranked, according to the defined methodology. Particular attention must be given to the uncertainty characterizing the entire decision-making process to enhance the robustness of decisions. Uncertainty can arise from both the choice of the MCA tool and the definition of parameters (Chitsaz and Banihabib, 2015). Therefore, a sensitivity analysis must be conducted to analyze how the adopted modeling choices influence the evaluation of the alternatives. The literature highlights the need for further knowledge advancements in this regard (de Brito and Evers, 2016).

According to the flowchart, the main phases of the ongoing task 7.2.2 are devoted to: (i) the definition of communities of interest; (ii) the development of the abacus of risk reduction strategies; (iii) the full investigation of hazards and related impact; (iv) the full characterization of indicators.

At the same time, the literature highlights the importance of tuning MCA approaches to real application; task 7.2.4, that started in parallel to task 7.2.2, is focused on the identification of pilot case.

References

Chitsaz N., Banihabib M.E. (2015). Comparison of Different Multi Criteria Decision-Making Models in Prioritizing Flood Management Alternatives. *Water Resour. Manage*., 29, 2503–2525.

Curt C., Di Maiolo P., Schleyer-Lindenmann A, Tricot A., Arnaud A., Curt T., et al. (2022). Assessing the environmental and social co-benefits and disbenefits of natural risk management measures. *Heliyon,* 8, 12.

de Brito M.M., Evers M. (2016). Multi-criteria decision-making for flood risk management: a survey of the current state of the art. *Nat. Hazards Earth Syst. Sci.*, 16, 1019–1033.

Gamper C. D., Thöni M., Weck-Hannemann H. (2006). A conceptual approach to the use of Cost Benefit and Multi Criteria Analysis in natural hazard management. *Nat. Hazards Earth Syst. Sci.*, 6, 293–302.

Golfam P., Ashofteh P.S., Loáiciga H.A. (2019). Evaluation of the VIKOR and FOWA Multi-Criteria Decision Making Methods for Climate-Change Adaptation of Agricultural Water Supply. *Water Resour. Manage.*, 33, 2867–2884.

Deep *vs* shallow magmatic systems controlling pure Plinian *vs* caldera-forming eruptions: natural and experimental evidence

Danilo Mauro Palladino[1], Cristina Perinelli[1], Giovanni Luca Cardello[2], Aida Maria Conte[3], Lorenzo Monaco[4], Gianluca Sottili[1], Mario Gaeta[1]

(1) Department of Earth Sciences, University of Rome Sapienza, danilo.palladino@uniroma1.it
(2) Department of Chemical, Physical, Mathematical and Natural Sciences, University of Sassari
(3) Istituto Di Geologia Ambientale E Geoingegneria (IGAG), Consiglio Nazionale delle Ricerche
(4) Istituto di Scienze Marine (ISMAR), Consiglio Nazionale delle Ricerche

The activity history of Ventotene volcano (Pontian Islands, Tyrrhenian Sea) shows shifts from repeated, pure Plinian events (Cala Battaglia eruptions; UBC hereafter) to a caldera-forming eruption (Parata Grande eruption; PGT hereafter). Here, we show how the depth of the magma reservoir is a relevant factor controlling the observed change in the eruptive style. Textural and chemical features of juvenile (pumice and scoria) clasts put constraints on deep *vs* shallow pre-eruptive magmatic systems at Ventotene, feeding pure Plinian and decompression caldera-forming events, respectively. The UCB pumice clasts show low phenocryst content (<3 vol%), including primary analcime microlites, embedded in a volatile-rich phonolitic glass, reflected in the correspondence between interstitial glass composition and bulk rock composition. This suggests an efficient separation of the crystalline charge from the parental magma at high depth (P_{H2O}>200 MPa), as constrained by the analcime microlites. Conversely, pumice clasts from the initial Plinian fall and pyroclastic current deposits of PGT contain abundant phenocrysts and antecrysts (10-25 vol%), along with feldspar microlites, which leads to a marked difference between the phono-trachytic composition of the interstitial glasses and the shoshonitic, tephri-phonolitic to latitic bulk juvenile compositions. Such difference in the crystalline cargo and the lack of primary analcime in the PGT pumice clasts with respect to UCB points to pre-eruptive magma storage in a relatively shallow (P_{H2O}<200 MPa), sill-like, magma chamber (low roof depth/width aspect ratio), prone to caldera collapse. The latter was triggered by the decompression induced by magma withdrawal during the Plinian phase, as typical of an underpressure caldera scenario. Homogeneous phono-trachytic glasses, with variable phenocryst assemblages, through the PGT eruptive succession point out a crystal-zoned magma chamber, consistent with a shift from central conduit to ring faults during an underpressure caldera-forming event. In this picture, the high amounts of olivine+clinopyroxene antecrysts in the PGT welded spatter indicate the isothermal depressurization of the peripheral, degassed, mafic portion of the magma chamber at the onset of caldera collapse. The Ventotene case study highlights the causes of a relatively common time sequence from Plinian events without accompanying caldera collapse, which usually characterize the early activity history of Quaternary central Italy volcanoes, toward caldera-forming events that take place later in the activity history. Moreover, Ventotene volcano is a small-scale analogous of Campi Flegrei due to the similar: i) magma compositions; ii) deposit architecture of the caldera-forming eruption and iii) temporal shift from pure Plinian to caldera-forming eruptive style. Ongoing experimental study aims at exploring the hypothesis of polybaric differentiation (leading to pure Plinian) vs. isobaric differentiation in a sill-like magma chamber (leading to caldera-forming) by a set of stepwise fractional crystallization experiments at variable pressures (200–800 MPa) on compositions spanning from hydrous shoshonite (3 wt.% of H_2O) to oversatured phonolites.

The matrix “Hazards-Impacts” as foundation for implementing MCA in natural risk management

Alessandro Rubino[1], Diana Caporale[1], Anna Rita Balingit[2], Camillo Frattari[3], Cassandra Cozza[3], Daniela Mele[4], Daniela Molinari[5], Daria Ottonelli[6], Emilia Corradi[3], Fabio Castelli[7], Federica Romagnoli[8], Filippo Fraschini[6], Francesca Vigotti[3], Francesco Airoldi[3], Giacomo Scandolo[9], Gloria Padovan[2], Luca Cetara[10], Marco Bindi[2], Massimo Moretti[4], Panagiotis Asaridis[5], Paola Fontanella Pisa[8,11,12], Pasquale La Malva[10], Simona Muratori[13], Tommaso Bastiani[10]

(1) Ionian Department of Law, Economics and Environment, Università degli studi di Bari Aldo Moro, alessandro.rubino@uniba.it
(2) Department of Agriculture, Food, Environment and Forestry, Università degli Studì di Firenze
(3) Department of Architecture and Urban Studies, Politecnico di Milano
(4) Department of Earth and Geoenvironmental Sciences, Università degli studi di Bari Aldo Moro
(5) Department of Civil and Environmental Engineering, Politecnico di Milano
(6) CIMA Research Foundation
(7) Department of Civil and Environmental Engineering, Università degli Studì di Firenze
(8) Center for Global Mountain Safeguard Research (GLOMOS), Eurac Research
(9) Department of Economics, Università degli Studì di Firenze
(10) Representing Office Roma, Eurac Research
(11) Global Mountain Safeguard Research Program (GLOMOS), United Nations University Institute for Environment and Human Security (UNU-EHS)
(12) Graduate School of Environmental Studies, Tohoku University
(13) Poliedra, Politecnico di Milano

The definition of standards/guidelines on how to implement Multi Criteria Analysis in natural risks management requires, as a fundamental step, an in-depth, generalized investigation of the types of elements that are exposed to different natural hazards, as well as of the potential direct and indirect damages to them in case of an event (referred to as “hazards-impacts matrix” in the following) (Hochrainer-Stigler et al., 2023). This phase is crucial for the definition of attributes and indicators according to which alternatives for risk reduction are evaluated. The process that led to the definition of the hazards-impacts matrix included the following steps:

(i) the classification of the exposed elements;
(ii) the identification of potential direct and indirect damages to them in an individual hazard perspective;
(iii) the merge of the “individual” matrices into a multi-hazard framework.

Exposed elements have been divided into seven categories according to evidence in the literature, highlighting a sort of homogeneity in related impacts in case of an event, especially in terms of indirect impacts, tools for their evaluation, and related stakeholders (Table 1).

Table 1 – Classification of elements exposed to natural hazards.

Categories	Description of related impacts	Example of related impacts
People and population	Everything that has a direct and indirect impact on people health, including the effects on social vulnerability and impacts aggravating the condition of vulnerable people	Injuries, death, psychological unease, spread of pathologies, well-being decrease, poverty increase, incidence of respiratory diseases, usage conflict
Built environment	Every physical direct impact on built environment, from residential, production and cultural use, to infrastructure building	Physical damages, damage to residential buildings, damage to productive buildings, damage to cultural buildings, damage to public buildings, temporal or permanent damage to infrastructures, physical reduced capacity
Public services	Every impact on public services availability (local authorities, municipal offices, hospital, institutional and planning, infrastructure) that does not have a pure physical component, including territorial governance and institutional and regulatory crowding out	Reduction of services availability and efficiency (e.g., less hospital places, and service for general and specific purposes, less employees able to reach the offices), transports availability, water and energy supply, energy production, energy cost, interruption of telecommunications, school closures, administrative service reduction/slow down General effect of crowding out with respect to business as usual activities
Environmental systems	Every direct and indirect impact on ecosystem and natural biodiversity, and on his relationship with people, including reduction of biodiversity	Disruption of the value of green and natural areas (including protected natural areas and green infrastructure), pollution, biodiversity, quantity and quality of vegetation, ground quality (effects on fires, floods, landslides, avalanches), usability of ecosystem services, reduced access/availability and usability for the general public
Identity and cultural Heritage	Every impact on the capacity of the population to identify as part of a community (e.g., on how communities see themselves and the continuity of their local community/town)	Social identity, place identity, traditional activities, cultural landscape (international, national, local)
Business activities	Every direct and indirect impact of production factors, including industrial, agricultural, cultural and touristic activities	Agriculture production, consistency of farms, supply chain interruption; functionality of the food supply chain, production disruption, tourist operator costs, farmers/breeders and industrial costs (energy costs will not be considered here)
Financial system	Impacts on the companies' credit worthiness, and/or reputation, commercial and touristic image that might impact on the credit worthiness of a company, region, household or any other economic agent	Access to credit and to market, stock market expectations and return, cash and public fund transfers insurance and credit cost. Examples include credit rating (Standard & Poor's, Moody's, Spread), stock quotation and pre booking cancellation of touristic activities

The identification of potential direct and indirect damages related to individual hazards was based on an extensive literature review. The analysis focused on five hazards (floods, landslides, drought, earthquakes, and volcanoes) as the most representative and widespread natural hazards in the Italian context. Still, the exercise will allow for generalizing results to other hazards presently not included in the analysis, such as wildfires. Environmental degradation is not here considered as a hazard but as a consequence (negative impact) in case of an event occurrence of the aforementioned natural hazards. Identified damages represent (some of) the attributes according to which alternative risk reduction measures are evaluated in the MCA process, especially with respect to their capability of reducing (or increasing) a certain risk. For this reason, the analysis of damages was also devoted to the identification of possible indicators for their evaluation. In this phase, a generalized approach was adopted, looking for international literature and without focusing on the relevance of the damage or the usability of the indicator in the Italian context, with the main objective of avoiding the risk of missing relevant knowledge. Still, the problem arises on how to define a spatial and temporal boundary to the analysis when indirect damages are considered.

The merge of the individual matrices into a multi-hazard framework had the objective of identifying "common patterns" in expected damages to support the standardization of the MCA process (i.e., the identification of relevant attributes to be considered into the evaluation of alternatives of intervention when multiple hazards affect the context under investigation) (Kappes et al. 2012; Zschau, 2017). In doing so, trade-offs and synergies between disaster risk reduction measures will be also identified (de Ruiter et al., 2021). On the other hand, the analysis allowed to highlight specificities of individual hazards. In this phase, a selection has been made on relevant damages for the Italian context, considering factors such as prevalence and contextual appropriateness. Moreover, damages have been assembled into homogeneous classes. This grouping strategy aims to streamline the evaluation process by limiting the number of attributes to be included and weighted by stakeholders. The ongoing final stage of the process is dedicated to the identification and characterization of indicators suitable for the Italian context. This phase is a collaborative effort involving all RETURN spokes and considers the availability of data for the evaluation of these indicators. The collaboration ensures a comprehensive and contextually relevant set of indicators for the subsequent stages of the MCA process.

The extensive literature supporting the classification of exposed elements and the identification of attributes/indicators will be included in the final deliverable of task 7.2.2

References

de Ruiter M.C., de Bruijn J.A., Englhardt J., Daniell J.E., de Moel H., Ward P.J. (2021). The asynergies of structural disaster risk reduction measures: Comparing floods and earthquakes. *Earth's Future*, 9, e2020EF001531.

Hochrainer-Stigler S., Šakić Trogrlić R., Reiter K., Ward P. J., de Ruiter M.C., Duncan M.J., et al. (2023). Toward a framework for systemic multi-hazard and multi-risk assessment and management. *iScience*, 26, 5, 106736.

Kappes M.S., Keiler M., von Elverfeldt K., Glade T. (2012). Challenges of analyzing multi-hazard risk: a review. *Nat. Hazards*, 64, 1925–1958.

Zschau J. (2017). Where are we with multihazards, multirisks assessment capacities? Science for disaster risk management 2017: knowing better and losing less, edited by: Poljansek K., Marin Ferrer M., De Groeve T., Clark I., *European Union*, Brussels, Belgium.

Natural hazard education with XR technologies: a scoping review

Stefano Scippo[1], Damiana Luzzi[1], Stefano Cuomo[1], Maria Ranieri[1]

(1) Dept. of Education, Languages, Interculture, Literatures and Psychology (FORLILPSI), University of Florence, stefano.scippo@unifi.it

Background: Faced with the rise in natural disasters (, 3), correlated with climate change (I , 8) , numerous studies on Disaster Risk Reduction Education (DRRE) have emerged since the '90s, predominantly employing a didactic transmission-based approach (Nakano & Yamori, 2021). For DRRE to be effective, it should align with an "interactive, experiential and participatory" educational model (Kagawa & Selby, 2012, p. 207), which could be costly and risky. A potential solution might lie in an educational approach utilizing simulations facilitated by eXtended Reality (XR).

Research Question: This study aims to conduct a scoping review to explore educational methodologies employing eXtended Reality for enhancing knowledge among teachers, students, and citizens about environmental risks, natural disasters (including climate-related ones), and their management.

Search String Definition: A search string composed of 66 keywords was formulated, spanning three domains: 1) education and target audience, 2) environment and natural hazards, 3) technologies. The keyword selection process resulted from a collaborative approach characterized by brainstorming among the research team members of WP6. This process also considered keywords identified by other WPs within the TS3 Spoke, focusing on the environmental and natural hazards domain.

Data Collection: On June 21st, 2023, the search string was executed across five databases: EBSCOhost, IEEE Xplore, PubMed, Scopus, and Web of Science. Results (2719) were imported as .ris files into Rayyan — a web and mobile-accessible platform leveraging Machine Learning. After deduplicating and removing abstract-less papers, 2,152 abstracts (published between 2013 and 2023) were analyzed.

Selection Criteria: Abstract analysis excluded 2,062 papers, followed by further exclusion of 56 papers after full-text scrutiny. Exclusions encompassed studies focusing solely on unrelated technological topics (e.g., Artificial Intelligence, IoT, wearable devices), usability tests, risk management-specific training, papers not addressing environmental risks or natural disasters, non-forest fires, evacuation simulations, studies lacking teaching and learning outcome information, studies outside educational realms, and inaccessible full-texts.

Main Results: The 34 included papers were examined regarding paper context, type of risk addressed, research methodology and constraints, learning objectives, XR technology's educational use, identified outcomes, and educational affordances of XR.

Regarding the context and types of risk addressed, since 2016, there has been an increase in scientific production primarily focusing on seismic events (12 studies) and floods (9). Asia, contributing significantly with 18 publications, notably led by Japan (7 studies), remains the primary source.

Methodologically, the 34 studies were categorized as empirical (26 studies) and non-empirical (8 studies). Empirical studies involve users or experts in XR tool validation, while non-empirical ones include a systematic review and theoretical proposals lacking experimental validation. Empirical studies were further classified into predominantly quantitative, qualitative, or mixed-method approaches. Six qualitative studies involved small user or expert groups, while 20 quantitative or mixed-method studies employed seven different research designs. Most studies (17) used a quasi-experimental design, mainly the one-group post-test design, mainly focusing on the evaluation of XR technology usability rather than its educational effectiveness. Methodological limitations in non-experimental studies render results hypothetical, necessitating further empirical verification.

From an educational standpoint, learning objectives mainly focus on knowledge and skills required for survival in natural disaster emergencies. All studies advocate using XR technologies for simulations or serious games, yet none develop a comprehensive educational framework around these XR tools.

Concerning the study results, XR-based tools demonstrate potential superiority over traditional approaches in teaching risk and emergency management skills and knowledge. However, the validity of these conclusions is higher for studies based on experimental research design. In other cases, conclusions remain hypothetical without empirical evidence. Regarding the educational affordances of XR for DRRE, studies primarily confirm those commonly recognized in the literature, particularly emphasizing engagement.

Authors' Conclusions: Analyzed literature generally lacks specific educational frameworks for employing XR technologies in DRRE, primarily focusing on knowledge and skills necessary for survival. Hence, there's a need to broaden educational approaches toward uncertainty education, aiming for the development of complex competencies that involve educational work not only looking at knowledge and skills but also at attitudes such as risk perception.

References

CRED (2023). 2022 Disasters in numbers. Brussels: Centre for Research on the Epidemiology of Disasters (CRED). https://cred.be/sites/default/files/2022_EMDAT_report.pdf

IPCC (2018). Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.

Kagawa F., Selby D. (2012). Ready for the storm: education for disaster risk reduction and climate change adaptation and mitigation. *Journal of Education for Sustainable Development*, 6(2), 207-217.

Nakano G., Yamori K. (2021). Disaster risk reduction education that enhances the proactive attitudes of learners: A bridge between knowledge and behavior. *International Journal of Disaster Risk Reduction*, 66, 102620.

Community resilience to flooding risks under climate change: case of cultural cities

Alemayehu Shanko[1], Fabio Castelli[2]

(1) Department of Civil and Environmental Engineering, UniFI, alemayehu.shanko@unifi.it
(2) Department of Civil and Environmental Engineering, UniFI

Disasters of various kinds with increased sphere of influence and frequency are on the rise all over the world.(UNDRR, 2019). Moreover, with the rapid urbanization, urban areas are increasingly exposed to natural hazards like flooding (Paliaga et al., 2020). This research focuses on creating a resilient community and analyze its dynamic response to shocks and disasters related to climate change. The study involves the application of a resilience model in a culturally significant city like that of the city of Florence and aims for the protection of its world renown cultural assets from damages and total destructions. The intended results would aim to present a quantitative and dynamic evaluation of resilience through the use of System Dynamics Modelling (SDM) in the setting of a significantly historical city at the risk of flooding.

For the research, twenty indicators of resilience were identified and categorized under four groups of resilience namely economic, social, organizational and infrastructural dimensions. Social aspects of resilience considers inherent bonds and connections, including cultural heritage that could form the core of the community capital to cope up when disaster happens (Cimellaro et al., 2016). The economic dimension refers to the capacity of the economic system to respond to disasters and reduce losses (Ye et al., 2022). The organizational component deals with the capability of local or regional authorities to rescue citizens and make resource available when a shock happens (Cimellaro et al., 2016). On the other hand, the infrastructural component looks at the robustness of existing road, electricity, drainage and housing infrastructures to absorb shocks. System dynamic (SD) approach, capable of simulating the complex interaction of various components with their the temporal variations, was adopted for modelling and analysis. This modelling technique allows for mathematical equation to be used in modeling temporal evolution (Datola et al., 2022).

Data for each of the identified indicators was collected from various sources but mainly from the commune of Florence open data platform. Even if the scope of the study is the city of Florence, some indicators like health care required data of regional communes, while others have spatial resolution of the region. The different sets of data collected have different scales and ranges which makes it illogical to use them in their raw values. Thus, data normalization was adopted. The effect of each indicator on the overall resilience of the city would not be the same. To account for this, weights were assigned to each indicator accordingly. The weight assignment used an objective weight assignment, to remove any kind of bias that could be introduced by subjective weight assignment techniques.

Preliminary test runs of the model produced various results indicative of resilience in economic, social, organizational and infrastructural dimensions. The economic resilience was modelled using factors like health care funding, tourism funding, status of poverty, employment condition and status of flood insurance. For the test run that covered the years between 2000 and 2022, the Economic resilience showed a decrease of about 20% given that economic condition of families has significantly deteriorated in the period mentioned. On the other hand, Infrastructural resilience increased by significant amount owing to huge investments and focus given to maintaining cultural assets. As for social and organizational resilience, they didn’t show that much of a significant pattern, except for organizational resilience to show an upward leap in around the year 2020, as a result of more focus given to disasters following the pandemic.

Given that the results are preliminary and more has to be done to improve the findings, it is worth to mention some limitations. One limitation involves the rationale used in weight assignment. As of now, the weighting method doesn't account inherent dynamicity. It is more of a static approach, which fails to count for changes in importance of the various indicators in times of normalcy and disaster. Another major limitation would involve determining the level of causal loops that could exist within the system.

References

Cimellaro G.P., Renschler C., Reinhorn A.M., Arendt, L. (2016). PEOPLES: a framework for evaluating Resilience. *Journal of Structural Engineering*, 142(10).

Datola G., Bottero M., De Angelis E., Romagnoli F. (2022). Operationalizing resilience: a methodological framework for assessing urban resilience through System Dynamics Model. In Ecological Modelling (Vol. 465). Elsevier.

Paliaga G., Luino F., Turconi L., Marincioni F., Faccini F. (2020). Exposure to geo-hydrological hazards of the metropolitan area of Genoa, Italy: a multi-temporal analysis of the Bisagno stream. *Sustainability*, 12(3).

UNDRR. (2019). Global Assessment Report on Disaster Risk Reduction 2019. United Nations.

Ye C., Hu M., Lu L., Dong Q., Gu M. (2022). Spatio-temporal evolution and factor explanatory power analysis of urban resilience in the Yangtze River Economic Belt. *Geography and Sustainability*, 3(4), 299–311.

A meta-analysis on the antecedents of risk perception of various natural hazards

Annalisa Theodorou[1], Alessandro Milani[2], Federica Dessi[3], Mei Xie[4], Marino Bonaiuto[5]

(1) Department of Social and Developmental Psychology, Sapienza University of Rome, annalisa.theodorou@uniroma1.it

Over the past century, the number of deaths attributable to natural hazards has experienced a significant decline thanks to improved early prediction, better preparedness for both people and infrastructure, and a more coordinated response (Ritchie et al., 2022). Involving people is crucial to ensure better preparedness and response to natural hazards. To this aim, it is important to study risk perception to motivate individuals to engage in protective behaviours, both before and after a natural hazard (van Valkengoed and Steg, 2019). Different aspects define risk perception: the perceived likelihood of the event to occur, the expected negative consequences, and the perceived vulnerability. How is risk perception determined? To answer this question, quantitative summaries (i.e., meta-analysis) of the research findings in the literature are essential but not available yet. Therefore, this contribution aims to: 1) meta-analytically estimate effect sizes of different potential antecedents of risk perception; and 2) investigate the effect of possible moderators of such relationships.

A query string was used on Scopus, Web of Science, and PsycINFO, and a final number of 121 records (127 studies) was included based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2021). The natural hazards considered were: 1) geological or geophysical hazards originating from internal earth processes (e.g., earthquakes, volcanic activity, landslides; UNDRR, 2015); 2) hydro-meteorological hazards of atmospheric, hydrological, or oceanographic origin (e.g., cyclones, floods; UNDRR, 2015); 3) natural hazards considered as effects of climate change (e.g., sea level rise, loss of biodiversity; United Nations, 2023). Studies measuring risk perception using a general measure and the expected consequences of the natural hazard were retained.

Results for the first aim show that, among thirty-two predictors identified, twenty report significant effect sizes (see Figure 1). They can be organized into three clusters (following Bonaiuto and Ariccio, 2020): 1) factors related to the relationship individual-risk (i.e., Objective Risk, Prior Experience, Prior Experience Severity, Preparedness, Knowledge, Vulnerability, Expected Response Efficacy, Event Perceived Likelihood, Negative Emotions, Climate Change Awareness); 2) factors related to the relationship individual-community (Media Use, Trust in Authorities, Social Norms); and 3) individual factors i.e., sociodemographic factors (namely Conservative, Household Size, Woman) and dispositional factors (namely, Egoistic Values, Altruistic Values, Biospheric Values, Pro-Environmental Orientation). The first cluster shows the highest number of variables with strong effects (≥ 30). Overall, an effect of publication bias and study heterogeneity is observed and it highlights the need for caution in interpreting certain results.

Regarding the second aim, namely identifying moderators of the relationships between each antecedent and risk perception, the type of natural hazard considered and the level of risk area of the sample proved to be relevant in some cases. Of note are the non-significant effects of the moderators Case study (y/n), Rural/urban sample, Age, and Gender, which strengthen the generalisability of the observed relationship. It has to be stressed that existing research is scanty regarding some natural hazards (e.g., landslides, drought); thus, future studies may consider studying risk perception antecedents in relation to these understudied natural hazards. Policymakers should consider the three clusters of antecedents. For instance, regarding the first cluster, knowledge may be favoured through media and education. Moreover, personal prior experience may be prompted through simulations that may show participants the possible risk through direct training. Regarding the second cluster, community interventions may consider the power of descriptive and injunctive norms in sustaining risk perception, that is, the pressure exerted by means of both suggested (injunctive norms) and adopted (descriptive norms) consensual behaviours by significant others. Moreover, trust in authorities may be favoured through direct dialogue with institutions and leaders more attentive to the needs of the population. Lastly, regarding the third cluster, both socio-demographic and dispositional factors resulted from the meta-analyses may be taken into consideration when designing educational, informational, and community interventions, to tailor specific actions for different individuals. On the whole, this represents a novel attempt to quantitatively summarize the available literature about the determinants of risk perception, considering interdisciplinary studies, including grey literature, and without limits in terms of publication date.

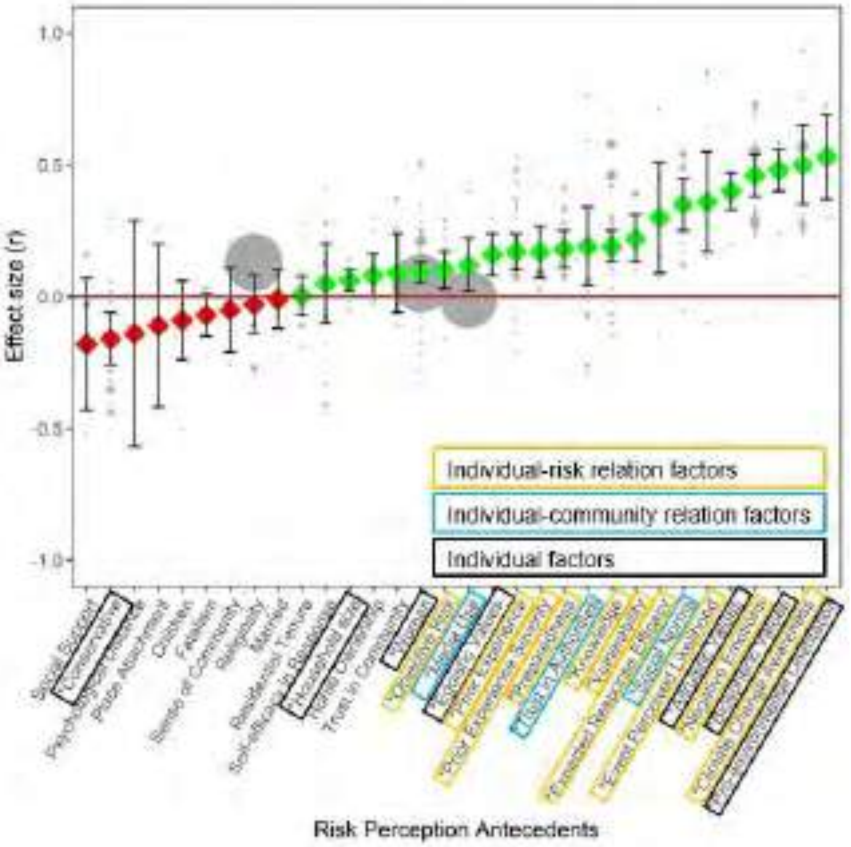


Figure 1 – Graphical representation of mean estimated effects for the antecedents of risk perception. Red diamonds indicate negative meta-analytical effect sizes. Green diamonds indicate positive meta-analytical effect sizes. Error bars represent 95% confidence intervals. The red line indicates the zero. Confidence intervals that include the zero (error bars that cross the red line) indicate non-significant effect sizes (i.e., Social Support, Psychological Distance, Place Attachment, Children, Fatalism, Sense of Community, Religiosity, Married, Residential Tenure, Self-efficacy in Response, Home Ownership, and Trust in Community). Variables names marked with an asterisk indicate significant effect sizes for that antecedent. Each grey circle represents the single effect size observed in each individual study included in each meta-analysis, while the size of each circle represents the sample size of the respective study.

References

Bonaiuto M., Ariccio S. (2020). La resilienza comunitaria. Cornice concettuale e strumenti di misura. In: L. Caravaggi (a cura di), Progetto SISMI-DTC Lazio. *Conoscenze e innovazioni per la ricostruzione e il miglioramento sismico dei centri storici del Lazio*. Macerata, Quodlibet, pp. 78-84.

Page M. J., Moher D., Bossuyt P.M., Boutron I., Hoffmann T.C., Mulrow C.D., et al. (2021). PRISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews. *BMJ*, n° 160.

Ritchie H., Rosado P., Roser M. (2022). Natural Disasters. https://ourworldindata.org/natural-disasters

UNDRR (2015). Sendai Framework for Disaster Risk Reduction 2015-2030. https://www.unisdr.org/we/inform/publications/43291

United Nations (2023). Causes and Effects of Climate Change. https://www.un.org/en/climatechange/science/causes-effects-climate-change

van Valkengoed A.M., Steg L. (2019). Meta-analyses of factors motivating climate change adaptation behaviour. *Nature Climate Change*, 9(2), 158–163.

Spoke DS: Science underpinning climate services for risk mitigation and adaptation

An impact oriented application of dynamically downscaled CMIP6 scenarios

Alessandro Anav[1], Marta Antonelli[1], Sandro Calmanti[1], Adriana Carillo[1], Franco Catalano[1], Alessandro Dell'Aquila[1], Roberto Iacono[1], Salvatore Marullo[1], Ernesto Napolitano[1], Massimiliano Palma[1], Giovanna Pisacane[1], Gianmaria Sannino[1], Maria Vittoria Struglia[1]

(1) Italian National Agency for New Technologies, Energy and the Environment (ENEA), mariavittoria.struglia@enea.it

Although global climate models (GCMs) and Earth system models (ESMs) represent an important source of climate information for the regional scale, regional climate models (RCMs) allow to better represent the complex phenomena that emerge at higher resolutions, especially over regions of complex orography or with heterogeneous surface characteristics, such as the Mediterranean basin (Doblas-Reyes et al. 2021). As a matter of fact, the last IPCC (Intergovernmental Panel on Climate Change) Assessment Report (AR) acknowledged that regional climate information for impacts and risk assessment is increasingly robust and mature to feed climate services and impacts studies with the higher resolution they need (Ranasinghe et al. 2021). On the other hand, local information on climate change impacts produced by global models should be considered with some caution (Gualdi et al. 2013).

The Mediterranean basin is a well-known hot-spot region for climate change (Giorgi 2006) and it is particularly vulnerable to both hydrogeological risks (heavy rainfall, landslides, flooding) and coastal risks (sea level rise, marine heat waves) with effects on the health and economies of communities.

In this work, basing on the already available results of the dynamical downscaling of CMIP6 scenarios performed with a Regional Earth System Model (Anav et al. 2023), we present the projected changes in some relevant atmospheric Essential Climate Variables (ECVs) and Essential Ocean Variables (EOVs), with a special focus on the projections of Sea Level Rise (SLR) and the representation of Marine Heat Waves (MHW).

The simulations performed in Anav et al. (2023) and used in this work have been developed in the framework of the coordinated regional modeling initiative Med-CORDEX (Coordinated Regional Climate Downscaling Experiment). They were based on an updated version of the regional Earth System Model ENEA-REG designed to downscale, over the Mediterranean basin, the models used in the Coupled Model Intercomparison Project (CMIP6). The regional ESM includes coupled atmosphere (WRF), ocean (MITgcm), land (Noah-MP, embedded within WRF), and river (HD) components with spatial resolution of 12 km for the atmosphere, 1/12° for the ocean and 0.5° for the river rooting model.

In the framework of the RETURN project and objectives, devoted to multi-risk assessment, this work represents an example of how climate projected fields can be used in the calculation of relevant indicators both under current and future climate. The RETURN DS (spoke 8) activities include both the production of high-resolution atmospheric climate projections and the estimation of the climate indicators relevant for different impact sectors. So, the results presented in this contribution are relevant under both aspects, as a possible benchmark for new projections and as an example of an impact-oriented application

Figure 1 shows the temporal evolution of annual near-surface air temperature and sea surface temperature averaged over the entire Mediterranean basin (sea only) as simulated by ENEA-REG, along with corresponding global driver simulations and observational datasets for reference.

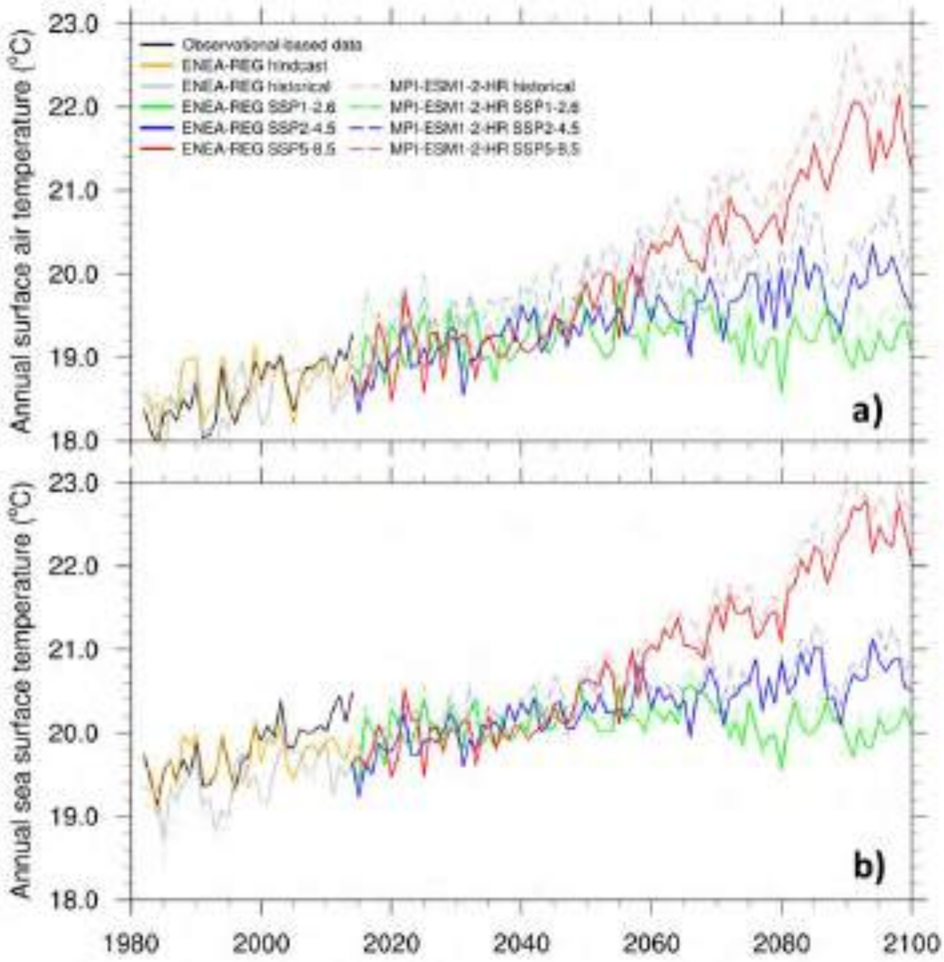


Figure 1 – Annual time series of near-surface air temperature (a) and Sea Surface temperature (b) (°C) from the ENEA-REG scenario simulations averaged over the entire Mediterranean basin.

References

Anav A., Antonelli M., Calmanti S., Carillo A., Catalano F., Dell'Aquila A., et al. (2023) Dynamical downscaling of cmip6 scenarios with enea-reg: an impact-oriented application for the med-cordex region**.** Accepted in Climate Dynamics.

Doblas-Reyes F., Sorensson A., Almazroui M., Dosio A., Gutowski W., Haarsma R., et al. (2021). Linking global to regional climate change. Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

Gualdi S., Somot S., Li L., Artale V., Adani M., Bellucci A., et al. (2013) The CIRCE simulations: regional climate change projections with realistic representation of the Mediterranean Sea. *Bulletin of the American Meteorological Society*, 94(1), 65-81.

Ranasinghe R., Ruane A.C., Vautard R., Arnell N., Coppola E., Cruz F.A., et al. (2021). Climate change information for regional impact and for risk assessment. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group 1 to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, 1767-1926.

Double-nested domain to downscale global CMIP6 data from a regional European domain to a fine spatial scale domain centered over Italy

Alessandro Anav[1], Marta Antonelli[1], Irene Cionni[1], Alessandro Dell'Aquila[1], Gianmaria Sannino[1], Maria Vittoria Struglia[1]

(1) Italian National Agency for New Technologies, Energy and the Environment (ENEA), mariavittoria.struglia@enea.it

Reliable climate information at regional scale is of primary importance for users and decision makers. Global Models are the unavoidable tool for understanding how climate may change in the future under specific hypothesis of the increasing rate of greenhouse gases (scenarios), as they include all the relevant large scale forcings and simulate the large-scale circulation dynamics. To compare the results of the projections coming from different models, since 1995 the World Climate Research Programme (WCRP) launched the Coupled Model Intercomparison Project (CMIP) which is now in its sixth phase (CMIP6).

Regional Climate Models (RCMs) allow to represent at higher resolutions the phenomena that emerge over regions of complex orography or with heterogeneous surface characteristics (Doblas-Reyes et al. 2021), such as the Mediterranean basin and our national territory. RCMs are dynamical models like GCMs, but they are defined on a limited area with a horizontal resolution much higher than GCMs and are implemented as a boundary condition problem, with boundary information provided by the GCMs, that act as drivers of the regional models. The COordinated Regional climate Downscaling Experiment (CORDEX) (Giorgi et al., 2009) provides multi-model ensemble of historical and future projections for various regions in the world. Typical resolutions for the CORDEX experiments range from 50 to 10 km.

The physics processes that cannot be explicitly resolved at the resolution scale of the model's grid are treated by means of parameterizations. A relatively recent thread in regional climate modelling consists in pushing model resolution to scales where deep convection can be solved explicitly rather than parameterized (<4 km).

An extended review on regional convection-permitting climate modelling can be found in Prein et al (2015) and in Lucas-Picher (2021).

The CORDEX initiative highlighted that ensemble means appear more reliable than single model realizations, due to the wide ensemble spread. Moreover, the kilometer-scale climate projections show important differences from the coarser resolution simulations. Results seem encouraging towards the use of convection-permitting model ensembles to produce assessments of the local impacts of future climate change.

In this framework, we use a double-nested domain to downscale the coarse global CMIP6 forcing data from a regional domain, covering the whole Europe, to a fine spatial scale domain centered over Italy. The first domain (D01) is projected on a Lambert conformal with a horizontal spatial resolution of 15 km, while the nested domain (D02) has a resolution of 5 km. The output from the nested domain D02 could be used for further downscaling at resolutions of the order of 1-2km using Convection-Permitting Models.

We produce a coherent set of high-resolution multi-scenario climate simulations based on the Weather Research and Forecasting model (WRF version 4.2.2, Skamarock et al. 2008).

To validate the system a hindcast simulation initialized and forced through ERA5 (Hersbach et al. 2020) has been produced to reproduce present climate over the Euro-Mediterranean region for period 1980-2014 for domains D01 and D02.

For future impact assessment, a historical and three CMIP6 global scenario simulations (SSP1-2.6, SSP2-4.5, SSP5-8.5) will be downscaled. The present-climate experiments cover the period 1st August 1980-31st December 2014, while future climate simulations will span the period 2015-2100.

We present preliminary results of the planned simulations, on both D01 and D02 domains, showing some variables belonging to the category of Essential Climate Variables (ECVs), as defined by The Global Climate Observing System (GCOS – https://gcos.wmo.int/en/home).

As an example, Figure 1 shows the temporal evolution of the near surface temperature, downscaled over the D01 domain, and averaged over different subdomains, for the hindcast and 3 scenarios driven by ERA5 reanalyses and the MPI-CMIP6 scenarios, respectively. Such subdomains are known as Prudence domains and are used as standard regions for the evaluation of Euro-CORDEX climate simulations: BI-British Islands, IP-Iberian Peninsula, FR-France, ME-Middle Europe, SC-Scandinavia, AL-Alps, MD-Mediterranean, EA-Eastern Europe. The hindcast simulation closely follows the interannual variability of the driver for all the subdomains. Some slight biases, within 0.5°C can be seen in the IP, MD and SC domains, within the standard deviation of the interannual variability of the period.

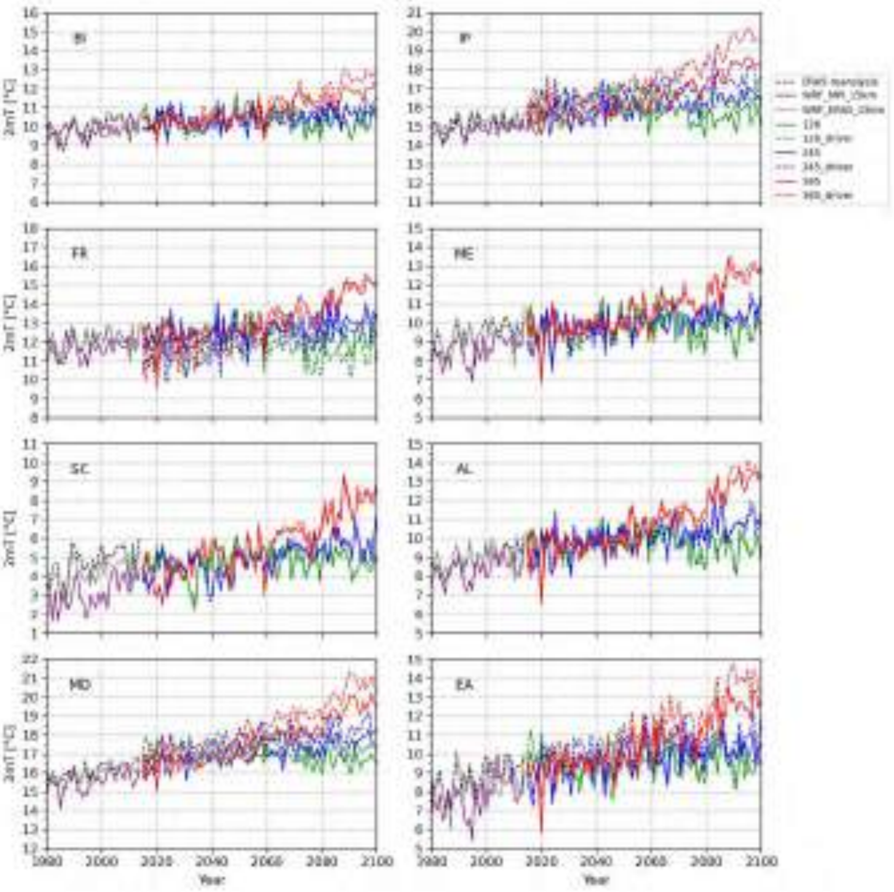


Figure 1 – Interannual variability of the T2m on the Prudence subdomains: for hindcast and 3 scenario simulations on D01-15Km. Dashed lines: drivers, solid lines dynamically downscaled field.

Preliminary results for the seasonal mean of the near surface temperature and precipitation, computed from the hindcast simulation performed on domain D02 at the finest resolution of 5km, highlight both the effects of the first dynamical downscaling and of the high-resolution on D02, which are particularly apparent in the alpine zone where the details of orography can be captured.

To summarize, a numerical modelling chain to produce multi-scenario simulations at different resolutions has been realized. A protocol simulation has been defined and its effectiveness has been proven using the ERA5 dataset as global driver. Finally, preliminary results of some scenario simulations will be shown.

References

Doblas-Reyes F., Sorensson A., Almazroui M., Dosio A., Gutowski W., Haarsma R., et al. (2021). Linking global to regional climate change. Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

Giorgi F., Jones C., Asrar G.R. (2009). Addressing climate information needs at the regional level: the CORDEX framework. *WMO Bulletin*, 58(3), 175-183.

Hersbach H., Bell B., Berrisford P., Hirahara S., Horányi A., Muñoz-Sabater J., et al. (2020). The ERA5 global reanalysis. *Quarterly Journal of the Royal Meteorological Society*, 146(730), 1999-2049.

Lucas-Picher P., Argüeso D., Brisson E., Tramblay Y., Berg P., Lemonsu A., et al. (2021). Convection-permitting modeling with regional climate models: Latest developments and next steps. *Wiley Interdiscip. Rev. Clim. Chang.*, 12, 1–59.

Prein A.F. et al. (2015). A review on regional convection-permitting climate modeling: demonstrations, prospects, and challenges. *Reviews of Geophysics*, 53(2), 323–361.

Skamarock W.C., Klemp J.B. (2008). A time-split nonhydrostatic atmospheric model for weather research and forecasting applications. *Journal of computational physics*, 227(7), 3465-3485.

A matter of scale: thermodynamic and large-scale constraints in extreme rainfall under a changing climate

Santa Andria[1], Marco Borga[2], Marco Marani[1]

(1) Department of Civil, Environmental, and Architectural Engineering, University of Padova, santatriniainaomenafinaritra.andriamanantena@phd.unipd.it
(2) Department of Land, Environment, Agriculture and Forestry, University of Padova

Changes in the hydrological cycle and, in particular, in rainfall extreme events induced by global warming are expected to pose significantly increased hazards in the coming decades. However, changes in the probability of occurrence of intense precipitation remain poorly understood even in observations. Here we investigate the thermodynamic and large-scale constraints to the generation of extreme rainfall at both hourly and daily scales. To this aim, we address some of the ambiguities intrinsic to the traditional definition of the dependence of extreme rainfall on temperature as mediated by the Clausius-Clapeyron (CC) relation. For this purpose, we use a non-asymptotic extreme value distribution (Marani and Ignaccolo, 2015) as a basis for our analysis. In this framework, the distribution of extremes emerges from the distribution of the ordinary events, here allowed to vary under climate change. The distribution of annual maxima is expressed as a function of the probability distribution of all events (that may be inferred using most of the available data, rather than just on yearly maxima) and of the number of event occurrences per year. The rationale here is that a warming of the atmosphere will affect the distribution of all rainfall events, i.e. the shape of the ordinary event distribution, rather than just rainfall extremes as in traditional CC arguments. Based on this approach, we then analyze the relation between the parameters of the probability distribution of ordinary precipitation events and temperature at the daily and hourly scales, using observational data in Padova, Italy (where almost 300 years of observations are available) and multiple stations in the continental US.

While local temperature is widely considered to be a major driver of change in rainfall regimes, changes in large-scale circulation are also expected to play a significant role in shaping future rainfall regimes. In order to represent the effects of large-scale circulation, and analyze changes that remain unexplained by local temperature, we compute here the Vertically Integrated Moisture Convergence, derived from the ECMWF Reanalysis v5 (ERA5) dataset.

Our results indicate that hourly precipitation is mainly controlled by thermodynamics, with the scale parameter of the probability distribution of hourly precipitation intensity showing a CC dependence. Conversely, at the daily scale, we show that precipitation variability is not explained by temperature changes but is rather driven by other factors such as large-scale circulation. These results support the need for an integrated approach, which quantitatively accounts for both local thermodynamics and large-scale circulation to estimate future changes in daily precipitation extremes under a climate change.

References

Marani M., Ignaccolo M. (2015). A metastatistical approach to rainfall extremes. *Advances in Water Resources*, *79*, 121-126.

Improving the ecological knowledge needed for sustainable management and climate change adaptation in marine-coastal ecosystems: fisheries in the northern Adriatic Sea and the Venice Lagoon

Alberto Barausse[1], Alex Faccin[2], Giovanna Guadagnin[3], Filippo Piccardi[1], Carlo Zampieri[1,2], Carlotta Mazzoldi[1]

(1) Dept. of Biology, University of Padova, alberto.barausse@unipd.it
(2) Dept. of Civil, Environmental and Architectural Engineering, University of Padova
(3) Dept. of Earth and Marine Sciences, University of Palermo

Coastal and marine ecosystems host a rich biodiversity which supports the provision of key benefits to societies. However, the joint action of climate change and multiple other human pressures, such as fisheries, pollution, eutrophication and habitat loss, is threatening these ecosystems and the services they provide to humans. To plan sustainable management and conservation actions and adapt to the ongoing climate change, decision makers need effective ecological modelling tools capable of predicting the response of coastal-marine biodiversity and ecosystem services to the cumulative action of natural factors and human pressures. This work aims to support the development of a mechanistic understanding of how coastal-marine ecosystems function, which is a precondition to develop quantitative decision support tools and risk analyses, by focusing on the fisheries of two socio-economically important and biodiversity-rich coastal ecosystems, the northern Adriatic Sea and the Venice Lagoon. The northern Adriatic Sea is one of the most exploited marine ecosystems in the world, where fisheries are of great socio-economic importance, while artisanal fisheries in the Venice Lagoon represent not only a locally important socio-economic activity but also a living cultural heritage. Here, we combine statistical analysis of long-term fishery records and environmental datasets, fishers' local ecological knowledge, and field studies, to improve our ecological understanding of the impact exerted by multiple natural and anthropogenic pressures on the local fisheries of the northern Adriatic Sea and the Venice Lagoon. The selected pressures include different facets of climate change (*i.e.*, not just increasing average temperatures, but also higher frequency and stronger intensity of heat waves), as well as other sources of risk for coastal ecosystems such as blooms of gelatinous plankton (in particular jellyfish and the invasive ctenophore *Mnemiopsis leidyi*) and anoxic episodes. The role of productive coastal habitats such as salt marshes in protecting coastal biodiversity and fishery resources from heat waves is also investigated through the combination of spatio-temporal data analysis with field sampling. The results of this ongoing work represent a valuable addition to the knowledge needed to construct predictive ecological modelling tools to support decision making in coastal and marine ecosystems in times of global change.

Exploratory investigations for the development of a novel Mediterranean Sea reanalysis

Federica Borile[1], Pietro Miraglio[2], Giulia Vecchioni[1], Ali Aydogdu[2], Emanuela Clementi[2], Paolo Oddo[1], Nadia Pinardi[1]

(1) Dept. of Physics and Astronomy, Bologna University, federica.borile2@unibo.it
(2) Euro Mediterranean Centre on Climate Change

Over the last three decades, there has been an expansion in real-time ocean observations through satellite and in situ platforms, enhancing our understanding of the ocean's condition and changes. In the Mediterranean Sea, the Copernicus Marine Service has generated two reanalyses over the past decade, varying in horizontal resolution. These reanalyses were released by Adani et al. (2011) and Escudier et al. (2021), contributing to an evolving comprehension of the circulation patterns, overturning circulation, and water mass formation rates in different regions of the Mediterranean basin. The extensive time series of reanalysis data aids in crafting ocean climate indicators which is a major goal of RETURN.

Ocean reanalyses hinge on data assimilation schemes to bridge the gap between model simulations and real-world observations. These schemes seamlessly integrate observational data into the numerical model, refining the model's representation of the ocean's intricate dynamics. The goal of this work is to enhance the existing reanalysis components for the Mediterranean Sea to improve the quality of a new product.

The data assimilation scheme that will be used is an advanced variational assimilation scheme proposed by Storto et al. (2018), which considers temperature and salinity profiles and satellite data. In the framework of the PNRR project an improved assimilation scheme specifically tailored to harness the valuable satellite Sea Level Anomaly (SLA) data is developed for the Mediterranean Sea. This innovative scheme promises to enhance the accuracy and utility of ocean reanalyses, propelling our understanding of the Mediterranean Sea changes and trends.

The assimilation of in situ and satellite observations will be integrated into the modeling component of the reanalysis, as depicted in Figure 1. This component is the Nucleus for European Modelling of the Ocean (NEMO) ocean general circulation model. The simulated period spans from 1980 to the present, and the domain is defined with an eddy-resolving resolution of 1/24 degree. The modeled Mediterranean basin is then expanded with a portion of the Atlantic Ocean to enhance the resolution of salinity and heat exchanges through the Gibraltar Strait. To establish the modeling framework, multiple boundary conditions are set, including dynamic atmospheric fields at the sea surface, river discharge along the coast, and ocean transport at the lateral open boundaries of the domain. The model is initialized at rest, using temperature and salinity initial conditions from the 1975-84 SeaDataNet climatology for the Mediterranean Sea and the World Ocean Atlas 18 climatology for the Atlantic domain. Lateral Open Boundary Conditions (LOBC) are applied in the Atlantic and at the Dardanelles Strait. Atlantic LOBC is interpolated from a global ocean reanalysis spanning the meteorological satellite era at eddy-permitting resolution. At the same time, Dardanelles LOBC is derived from a two-layer hydraulic model of the Turkish Straits System.

This work presents a series of planned sensitivity experiments that are aimed at identifying the optimal model configuration, enhancing the Mediterranean Sea dynamics representation, and improving the consistency between observed and simulated ocean. Various advection, diffusivity, and viscosity schemes will be tested and compared with results from previous reanalyses. Regarding the ocean momentum, a new lateral viscosity scheme will be tested, using a variable spatial distribution of the viscosity coefficients based on the scheme proposed by Smagorinsky (1963). For the vertical diffusion of tracers, a turbulent kinetic energy closure scheme (Gaspar et al., 1990) will be investigated. The improvements will be validated by comparing the results with in-situ observations as well as with the two previous reanalyses.

Finally, this study aims to enhance the representation of water mass exchange, salinity and heat transport through the Gibraltar Strait. Given the crucial role the strait plays in accurately simulating ocean dynamics across the entire basin, a regional refinement of the model grid will be implemented in both the vertical and horizontal directions.

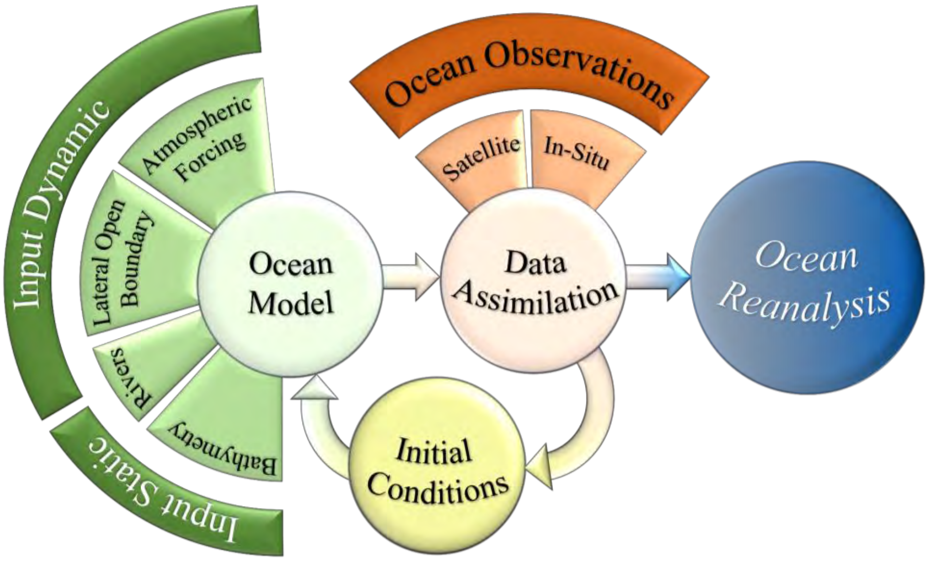


Figure 1 – Components of the ocean reanalysis of the Mediterranean Sea.

References

Adani M., Dobricic S., Pinardi N. (2011). Quality assessment of a 1985–2007 Mediterranean Sea reanalysis. *Journal of Atmospheric and Oceanic Technology*, 28, 569–589.

Escudier R., Clementi E., Cipollone A., Pistoia J., Drudi M., Grandi A., et al. (2021). High resolution reanalysis for the Mediterranean Sea. *Frontiers in Earth Science,* 9:702285.

Gaspar, P., Grégoris Y., LefevreJ. M. (1990). A simple eddy kinetic energy model for simulations of the oceanic vertical mixing: tests at station papa and long-term upper ocean study site. *Journal of Geophysical Research*, 95 (C9), 16 179.

Smagorinsky J. (1963). General circulation experiments with the primitive equations: I. the basic experiment. *Monthly Weather Review*, 91 (3), 99–164.

Storto A., Oddo P., Cipollone A., Mirouze I., Lemieux-Dudon B. (2018). Extending an oceanographic variational scheme to allow for affordable hybrid and four-dimensional data assimilation. *Ocean Modelling*, 128, pp. 67 - 86.

Unrevealing political, socioeconomic, and institutional barriers in climate mitigation and adaptation strategies—A comprehensive analytical framework for a systematic literature review

Giliberto Capano[1], Alexandra D'Angelo[1], Stefania Profeti[1], Melania Michetti[2]

(1) Dipartimento di Scienze Politiche e Sociali, Università di Bologna, giliberto.capano@unibo.it
(2) ENEA-SSPT-MET, Bologna Research Centre, Division Models and Technologies for Risks Reduction

A substantial and well-established body of scientific research on the determinants of climate change offers empirical evidence regarding effective means and strategies to mitigate and adapt to climate change. However, as widely acknowledged, there is significant diversity, in a comparative perspective, regarding the complete or adequately effective implementation of policy solutions following scientific evidence. This diversity depends, above all, on specific social, organizational, institutional, process, and procedural dimensions that can represent either barriers or enablers to the transferability of existing scientific knowledge within decision-making processes, organizations, and (national and local) communities in order to reduce risks or manage crises should they occur. There is considerable research on these critical dimensions to foster effective mitigation and adaptation policies, but due to prevailing disciplinary specialization, there is no systematic analysis of the results of these research streams in social science.

We have started a systematic review of current research on socioeconomic, political and institutional barriers and enablers. The systematic review will cover all publications registered in Scopus for the period 2000-2023 in the following subjects: Social Sciences (14 sub-subjects); Multidisciplinary; Decision Sciences; Business, Management and Accounting; Economics, Econometrics and Finance; Psychology and 3 sub-subjects in Physical Sciences (General Environmental Science, Environmental Science (miscellaneous); Management, Monitoring, Policy and Law).

We have extracted around 8,000 publications on the DROUGHT, HEATWEAVE and FLOOD climate hazards, and categorized them according to their risk reduction or crisis management focus.

Here we present and discuss the analytical framework (and its components) for coding and evaluating the extracted articles (see the table below).

We have made a distinction between BARRIERS and ENABLERS, and categorized them as either INTERNAL or EXTERNAL with respect to political and institutional processes.

We have conceptualized four external dimensions and four internal dimensions, each comprising a number of specific sub-dimensions, as summarized in the following table.

The presentation will explain the conceptual choices made to capture all relevant characteristics of political, socioeconomic and institutional factors.

Types of Barriers/Enablers	Categories (and sub-categories)
EXTERNAL (to the political-institutional process)	a. *Geographical/Enviromental factors* - Lack of natural resource access - Natural resources scarcity - Exposed geographical location - Geographical isolation - Others b. *Socio-economic factors* - Socioeconomic (inequality) ▪ gender, age, household structure, education levels, race, life expectar investment opportunities, occupati - Disparities in technology access and technology capacity - Others c. *Cognitive/experiential factors* - Lack of awareness - Perceptions of risk, risk attitude - Others d. *Cultural and Behavioural factors* - Social Capital - Social cohesion - Cultural norms - Community participation and engagement - Other
INTERNAL (to the political-institutional process)	a. *Policy capacity* - Analytical capacity - Organizational capacity - Political Capacity - Financial capacity b. *Governance arrangements*: - Inter-institutional relations - Public-private relations - Involvement of stakeholders and citizens - Relations with experts/scientists - Institutional design of the sector - Other c. *Power/interests* - diffuse vs. concentrated interests - material vs. immaterial interests d. *Ideas/Beliefs* (on policy instruments to be adopted)

Drought and human mobility in Africa

Serena Ceola[1], Johanna Mård[2], Giuliano Di Baldassarre[2]

(1) Department of Civil, Chemical, Environmental, and Materials Engineering, Alma Mater Studiorum Università di Bologna, serena.ceola@unibo.it

(2) Centre of Natural Hazards and Disaster Science (CNDS), and Department of Earth Sciences, Air, Water and Landscape Science, Uppsala University

Human displacements due to climate and weather extremes are dramatically increasing worldwide, mainly across areas where extreme events interact with high vulnerability and low adaptive capacity, such that they are now recognized as a primary humanitarian challenge of the 21st century (Caretta et al., 2022). Human mobility from droughts is multifaceted and depends on environmental, political, social, demographic and economic factors. A controversial discussion is currently taking place in the scientific literature: a lot of empirical studies exist, but with different levels of contribution (i.e., drought influences/does not influence human mobility) and with different spatial and temporal levels of analysis. However, an extensive literature review (see Hoffmann et al., 2020) clearly reports that environmental factors are considered to be a key driver of human migration and mobility in the majority of the examined studies. Although droughts cannot be considered as the single trigger, they significantly influence people's decision to move (Xu & Famiglietti, 2023). Yet, the ways in which droughts influence patterns of human settlements have remained poorly understood.

Here we explore the relationships between drought occurrences and changes in the spatial distribution of human settlements across 50 African countries for the period 1992–2013. Since long-term yearly data on human displacements are not consistently available for the entire African continent, we employ both country-based and spatially explicit data sets as reliable proxies. We base our continental study on urban population data and nighttime lights, as a proxy for the spatial and temporal distribution of human settlements. For each country, we evaluate annual relative urban population (%) and human distance to rivers [km] (Ceola et al., 2015). To identify drought years, we extract annual drought occurrences from two indicators, the international disaster database EM-DAT and the standardized precipitation evapotranspiration index (SPEI-12) records. We then compute human displacements as variations in human distribution between adjacent years, which are then associated with drought (or non-drought) years. We finally examine the consistency between drought occurrences and changes in human settlement patterns to identify macroscopic trends at the continental scale.

Our results show that drought occurrences across Africa are often associated with (other things being equal) human mobility toward rivers or cities. In particular, we found that human settlements tend to get closer to water bodies or urban areas during drought conditions, as compared to non-drought periods, in 70%–81% of African countries (Figure 1 and Table 1).

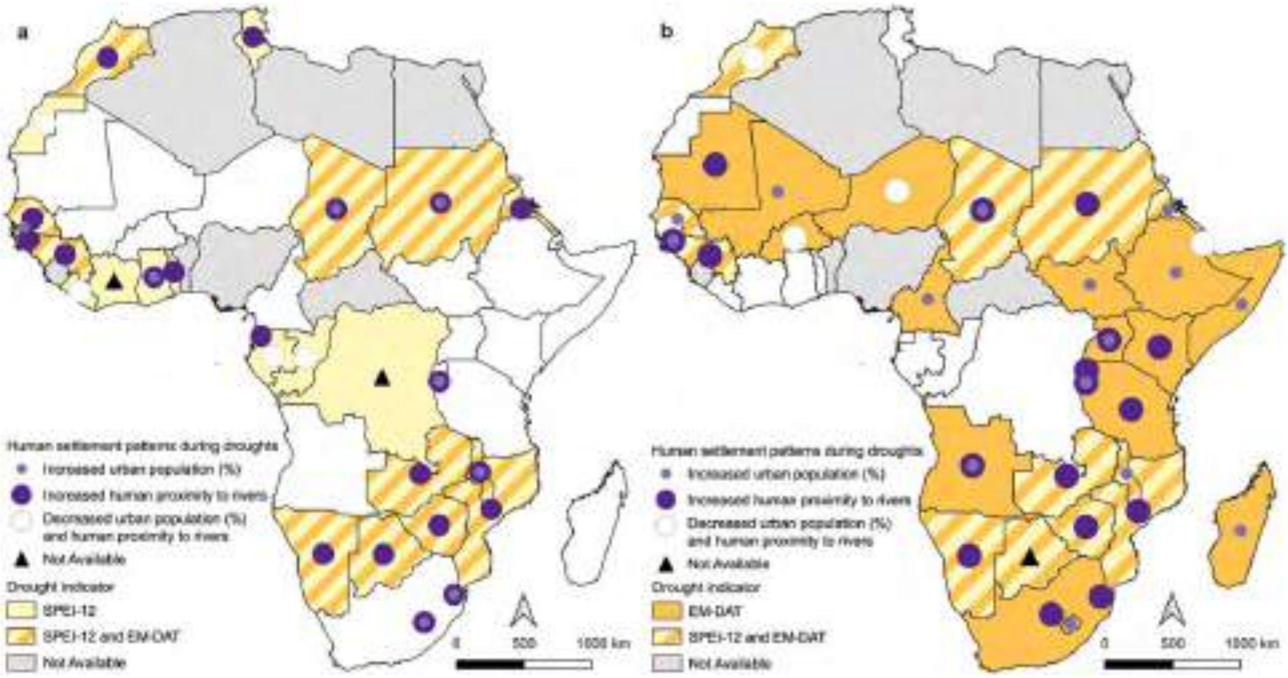


Figure 5 - Drought-induced variations in human settlement patterns across Africa. (a) Country-based patterns of increased human displacement toward rivers (purple circles) and urban centers (light purple circles) between adjacent years (drought year and antecedent year), derived by comparing median values during drought and non-drought years, according to SPEI-12 drought records (light yellow). (b) Same as in a, but according to EM-DAT drought records (orange). Countries that experienced droughts according to both indicators are shown with a striped light yellow and orange pattern.

Table 1- Relative occurrence (%) of drought-induced variations in human settlement patterns across Africa. Statistics are grouped according to the availability of drought records (EM-DAT and SPEI-12 records), whether the antecedent or subsequent year is considered and whether drought years are opposed to non-drought years or the whole study period (values in parenthesis).

	EM-DAT drought records		**SPEI-12 drought records**	
	Antecedent year	Subsequent year	Antecedent year	Subsequent year
Increased human displacements during droughts towards:				
Rivers	36% (30%)	27% (21%)	44% (44%)	33% (33%)
Urban Areas	30% (9%)	27% (9%)	4% (7%)	19% (19%)
Rivers and Urban Areas	15% (30%)	27% (33%)	30% (22%)	19% (15%)
Not Available	3% (3%)	- (-)	7% (7%)	- (-)

This large-scale trend clearly highlights that the occurrence of drought events, although not being the single driving factor, significantly influences human mobility. Human mobility and migration represent increasingly important strategies for climate change adaptation and disaster risk reduction. Focusing on Africa, future socio-economic and climatic scenarios will likely enhance impacts of droughts on society. There are concerns that a >2°C global warming will significantly increase the frequency of precipitation deficits and double drought duration from 2 to 4 months over Northern Africa, western Sahel and Southern Africa. Urban extent in drylands is projected to increase by ~300%-700% in Africa by 2030 when compared to 2000, without considering climate change (Güneralp et al., 2015). Furthermore, by interpreting this outcome from a broader perspective, which includes consecutive drought-to-flood events, adverse consequences might occur. An increased human presence in urban areas and close to rivers may result into an increased human exposure to floods, and thus leading to a potentially increased flood risk. Therefore, further investigations are foreseen and encouraged to better understand the interplay between human mobility and climate change in order to increase the resilience of vulnerable areas and population to hydrological extreme events and support the development of sustainable and effective planning strategies for the near future.

References

Caretta, M. A., Mukherji, A., Arfanuzzaman, M., Betts, R. A., Gelfan, A., Hirabayashi, Y., et al. (2022). Water. In H.-O. Pörtner, D. C. Roberts, M. Tignor, E. S. Poloczanska, K. Mintenbeck, A. Alegría, et al. (Eds.), *Climate change 2022: Impacts, adaptation and vulnerability. Contribution of working group II to the sixth assessment report of the intergovernmental panel on climate change* (pp. 551–712). Cambridge University Press.

Ceola, S., Laio, F., Montanari, A. (2015). Human-impacted waters: New perspectives from global high-resolution monitoring. *Water Resources Research*, 51(9), 7064–7079.

Hoffmann, R., Dimitrova, A., Muttarak, R., Crespo Cuaresma, J., Peisker, J. (2020). A meta-analysis of country-level studies on environmental change and migration. *Nature Climate Change*, 10, 904–912.

Xu, L., Famiglietti, J. S. (2023). Global patterns of water-driven human migration. *WIREs Water*, 10(4), e1647.

Güneralp, B., Güneralp, I., Liu, Y. (2015). Changing global patterns of urban exposure to flood and drought hazards. *Global Environmental Change*, 31, 217–225.

A methodology for railway infrastructure vulnerability assessment with respect to rain-induced hydrogeological instability under different climate change scenarios. Case study: flood induced risk assessment along Fabriano - Jesi railway

Massimo Comedini[1], Elena Conigliaro[1], Federico Draetta[1], Sara Padulosi [1], Stefania Vagnozzi [1], Federica Bardi[1], Flavio Conato[1], Chiara Cesali[1], Michele Ciarniello[1], Luisa Alfieri[1], Ivan Agostino[2], Zammuto Alessandra[2], Andrea Mastrangelo[3], Andrea Scuri[3], Marta Dinoi[3], Cinzia Limatola[3], Marco Maglionico[4], Annalisa Di Bernardino[5], Serena Falasca[5]

(1) Italferr Spa, e.conigliaro@italferr.it
(2) RFI
(3) Enser Srl
(4) Dipartimento di Ingegneria Civile Chimica Ambientale e dei Materiali, Università di Bologna
(5) Dipartimento di Fisica, Sapienza Università di Roma

Climate change, according to the definition provided by the United Nations, is *"the totality of long-term changes in weather patterns and temperatures"*. Although this is a natural process it appears to be greatly accelerated by anthropogenic activities. Compared to the pre-industrial era, the global average temperature has increased by about 2°C, leading to the intensification of extreme weather events such as floods, flash floods, heat waves and prolonged periods of drought. In such a climate context, it's important to evaluate strategic infrastructures resilience to changing external natural forcing and to propose strategies to increase it. Such a priority can be clearly found also within the *Paris Agreement* (2015) and the *EU Regulation 2020/852* (2020).

Since 2022, FS Group starts developing a methodology for the analysis of railway infrastructure vulnerability to rain-induced hydrogeological instability under different climate change scenarios. The aim is to propose a tool for decision making support in order to orient investment plan.

The proposed methodology provides a physical-mathematical relationship of the type of ***Hazard-Asset*** (expected impact on the infrastructure, in terms of possible damage scenarios, under different weather-climate frameworks).

Hazard represents the physical characteristics of the meteorological forcing (intensity, duration, frequency, etc.) combined with local morphological and hydrogeological characteristics; ***Asset*** represents the set of geometric and structural characteristics of the infrastructure, which determines the way in which it may be damaged. The proposed methodology is applied to a case study related to flood induced risk assessment along Fabriano - Jesi railway.

The study is conducted with respect to reference climate condition and for two future projections (2050 and 2100). The latter are simulated for two different climate change scenarios (*RCP 4.5* and *RCP 8.5*, according to *IPCC*).

The climate data, used as inputs for hydrogeological modelling, are obtained through running of numerical atmospheric circulation model ***WRF: Weather Research and Forecasting*** (*NCAR; NOAA; AFWA*).

Simulations are conducted using two-way nesting technique. Tree nested domains are set with increasing spatial resolution, from 27-km resolution of mother domain, to 3-km resolution of child domain. The innermost domain is centered on central Italy.

Specific Risk is defined as a combination of the two components: ***Hazard*** and ***Asset***.

A combination of two factors is proposed for flood ***Hazard*** computation: *Water Depth [m]* and *Specific Flow Rate [*$m^2 \cdot s^{-1}$*]*. In order to estimate such hydraulic variables, rainfall simulated by *WRF Model* are turned into flow rates through hydrogeological modelling. Then HEC RAS 1D hydraulic modelling is performed for the case study to map flood propagation. The result value of flood ***Hazard*** is subdivided into four classes: from *Very High* to *Low*.

For the case study, ***Asset*** is related to infrastructure elevation with respect to water depth. Fabriano - Jesi railway is classified as follow:

- Elevated components (Embankments; Bridges). In this case, vulnerability is linked to damage scenarios (seepage, piping, overflow) triggered by hydraulic gradient.
- Not Elevated. In this case vulnerability is set as maximum value as soon as infrastructure runs inside a flood area.

The result value of ***Asset*** vulnerability is subdivided into four classes: from *Very High* to *Low*.

For the case study ***Hazard*** and ***Asset*** maps are finally overlapped. The aim is to identify the infrastructure components with the highest hydrogeological ***Specific Risk*** under current climate conditions and for different climate projections. (*Fig. 1*).

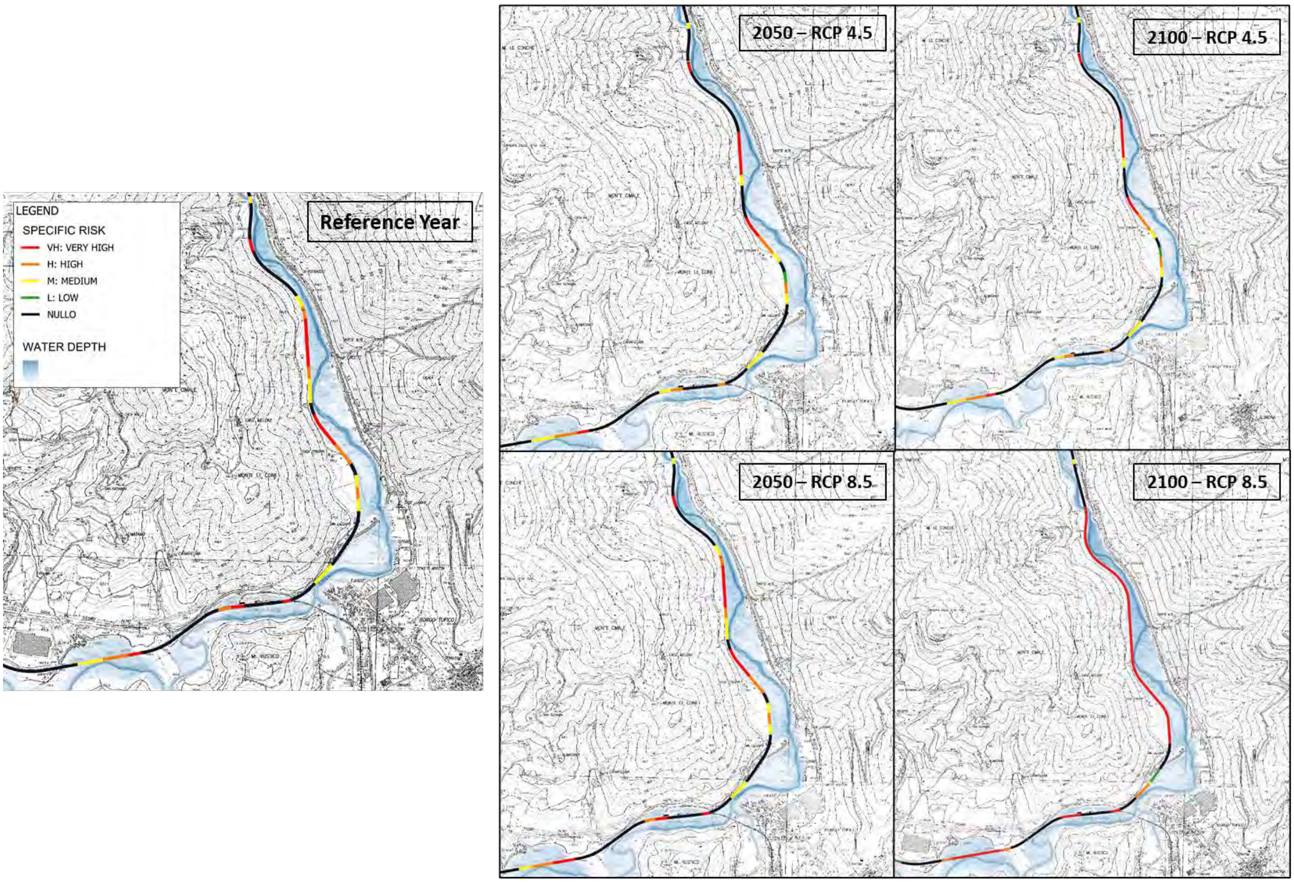


Figure 1 – Specific Risk Map for reference climate condition and for future projections: 2050 – RCP 4.5; 2050 – RCP 8.5; 2100 – RCP 4.5 and 2100 – RCP 8.5

The proposed methodology can be easily applied to other cases as a support tool in the management of the infrastructure, to guide the allocation of resources and investments, with the goal of suggesting which are the most critical components of the system in current conditions and under ongoing climate change scenarios.

References

Lionello P., Scarascia L. (2018). The relation between climate change in the Mediterranean region and global warming. *Regional Environmental Change*, 18, 1481-1493.

Skamarock W. C., Klemp J. B., Dudhia J., Gill D. O., Liu Z., Berner J., Huang X. (2021). A Description of the Advanced Research WRF Model Version 4.3 (No. NCAR/TN- 56+STR).

Solomon B. D. (2023). Intergovernmental panel on climate change (IPCC). *Edward Elgar Publishing In Dictionary of Ecological Economics* (pp. 302-302).

Collegio nazionale degli ingegneri ferroviari italiani (1916). *Rivista tecnica delle ferrovie italiane*.

Rinaldi A, Guerrucci L. (2017). Linee guida per la definizione della graduatoria di priorità dei tratti di infrastruttura ferroviaria interessati da fenomeni potenziali di dissesto idrogeologico, in base al valore di rischio ferroviario.

Scanning Electron Microscope protocol for exogenous particles and pollutants detection in human tissues

Francesco Decataldo[1], Francesca Borghi[1], Francesca Graziosi[1], Eva Vanna Lorenza Negri[1], Francesco Saverio Violante[1]

(1) Dept. of Medical and Surgical Sciences, University of Bologna, francesco.decataldo2@unibo.it

Climate change directly or indirectly impacts on the environmental quality (e.g., on air and water quality), for example introducing pollutants, particles, or contaminants throughout the increase of extreme weather events (Bolan et al., 2024). Thus, human interactions with exogenous agents that might impact their health are likely to become more frequent over years. In order to understand how diverse particles/fibers/pollutants may affect human health, we need validated procedures to reliably and quantitatively detect them, both in the environment as well as in human tissues in which they may accumulate.

Owing to the high resolution and contrast that Scanning Electron Microscope (SEM) can provide, this instrument could be used for semi-quantitative analysis of inorganic compounds in biological samples, following ad hoc preparation procedure (e.g., digestion of the organic tissue).

Besides environmental sampling studies for air quality evaluation, we introduced a step-by-step protocol for mapping, evaluating (in terms of number), and chemically characterizing inorganic material present in human tissues. In particular, the biological material obtained from biopsies is extracted from the matrix, then digested soaking them in sodium hypochlorite solution (7% active chloride), which is left in the oven (60°C): depending on the sample mass, 2 to 10 days are needed for a complete digestion of the biological material. The solution (containing the sample) is then filtered on a polycarbonate membrane, as reported by Visonà and collaborators for inorganic fibers (Visonà et al., 2021), which is finally placed inside a Petri dish and dried in an oven (50°C).

Samples are observed using secondary (or backscattered electrons detector to highlight contrast differences between biological residuals and inorganic particles) at a magnification of 2000x. Observations were conducted on 500 fields (equal to 1,5% of the filtering area). Inorganic particles/agents are quantified and then analyzed using Energy Dispersive X-Ray (EDX) Analysis to provide (and eventually map) their chemical composition. This procedure allows to quantify the number of fibers in function of the dry mass of the biological tissue. Lungs, ovary, bladder, ureter, lymph node, bone marrow, and prostate have been analyzed proving the versatility and reliability of the proposed methods. Similarly, asbestos, titanium, and praseodymium fibers, as well as silicon and aluminum aggregates have been found/observed in the reported tissues. Figure 1 reports two examples of inorganic fiber and aggregate detection investigated using the chemical micro-analysis.

We plan to compare a SEM-EDX automatic procedure versus a manual one, for saving sampling and analysis time, while maintaining a quantitative reliable evaluation.

Finally, to broaden the agents that could be selectively and quantitatively monitored, our future activities will be directed towards the translation of this protocol for microparticles contamination detection in human tissues, using Raman Spectroscopy-based Imaging.

This work is performed in Spoke DS8 of the Return Project.

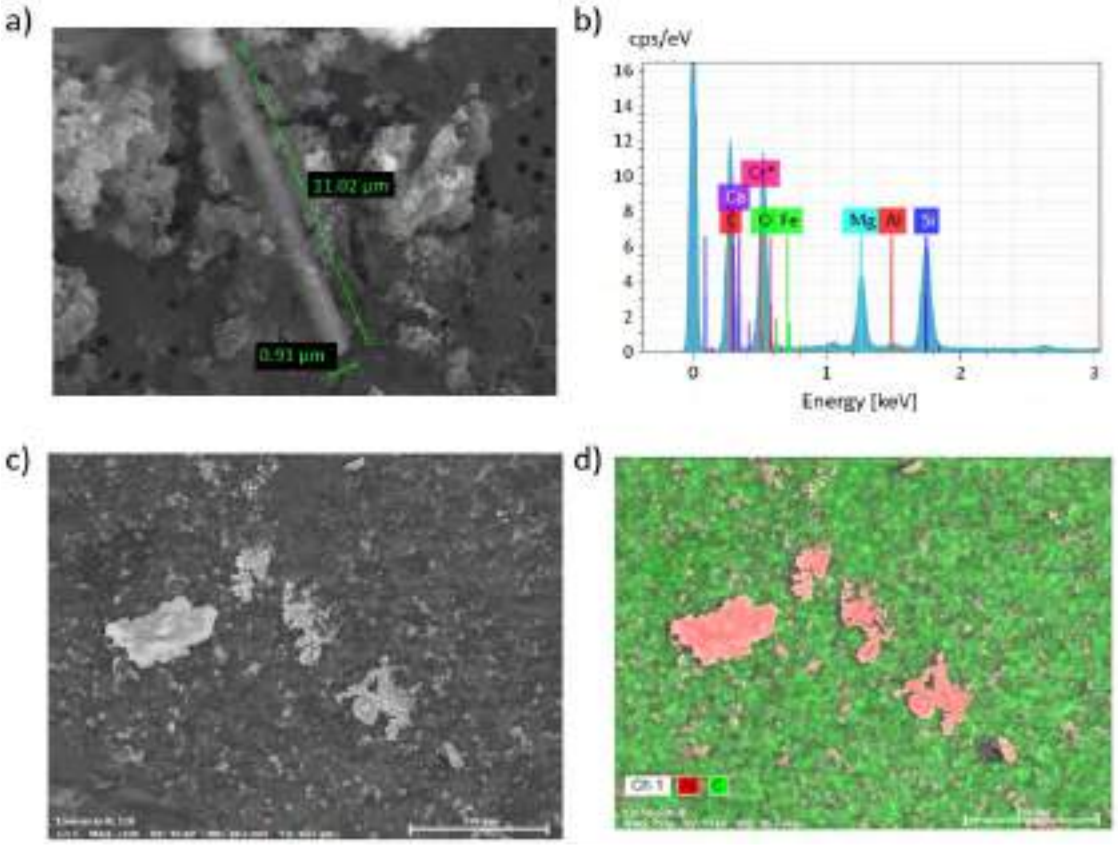


Figure 1 – a) Abstestos fibre acquired using secondary electron detector at SEM, observed in a digested lung biopsy filtered on a polycarbonate membrane. b) EDX spectrum of the asbetesos fibre in (a). c) Aluminum aggregates observed in a digested lymph node biopsy filtered on a polycarbonate membrane. d) EDX mapping highlighting the aluminum (red) and carbon (green) rich areas.

References

Bolan S., Padhye L.P., Jasemizad T., Govarthanan M., Karmegam N., Wijesekara H., et al. (2024). Impacts of climate change on the fate of contaminants through extreme weather events. *Science of The Total Environment*, 909, 168388.

Visonà S.D., Capella S., Bodini S., Borrelli P., Villani S., Crespi E., et al. (2021). Inorganic fiber lung burden in subjects with occupational and/or anthropogenic environmental asbestos exposure in Broni (Pavia, Northern Italy): an SEM-EDS study on autoptic samples. *International Journal of Environmental Research and Public Health*, 18, 4, 2053.

A new perspective for multirisk assessment under multiuncertainty

The RETURN Uncertainty Task Force, including (in alphabetical order):

Piero Dellino[1], Carlo Esposito[2], Gabriele Freni[3], Ebrahim Ghaderpour[2], Paolo Lazzari[4], Marco Marani[5], Alberto Montanari[6], Warner Marzocchi[7], Malvina Ongaro[8], Marco Reale[4], Maria Vittoria Struglia[9]

(1) Dipartimento Di Scienze Della Terra e Geoambientali, Università di Bari, pierfrancesco.dellino@uniba.it
(2) Department of Earth Sciences & CERI Research Center, Sapienza University of Rome
(3) Department of Engineering and Architetcture - University of Enna "Kore"
(4) Section of Oceanography, National Institute of Oceanography and Applied Geophysics – OGS
(5) Department of Civil, Environmental, and Architectural Engineering, University of Padova
(6) Department of Civil, Chemical, Environmental and Material Engineering, University of Bologna
(7) Department of Earth, Environmental, and Resources Sciences, University of Naples Federico II
(8) Department of Civil and Environmental Engineering, Politecnico di Milano
(9) Italian National Agency for New Technologies, Energy and the Environment (ENEA)

Assessment and management of the uncertainties in the context of natural hazards have recently received an increasing attention in the disciplinary literature. Several approaches have been proposed for single proofs of concept in the past few decades. In fact, in real-world applications, a problem is usually confronted with multiple types of uncertainties that may have different nature. Recent events occurred in different parts of the globe have indeed pointed out the complexity of the problem when communities are exposed and vulnerable to multiple risks, that are typically estimated with different approaches. Diversity of interpretations, typical of the different disciplines involved, may hinder uncertainty evaluation and communication.

The RETURN task force on uncertainty is working on the definition of a framework to support uncertainty assessment and communication in the framework of Civil protection under multiple risks. A first essential requirement for such framework has been identified by recognizing the need for a quantitative (numerical) assessment of uncertainty (or reliability of evaluation/prediction). The quantification of uncertainty is desirable for two reasons. First, it allows the aggregation of uncertainty assessments coming from multiple sources of risk into an overall representation of uncertainty for a multi-risk context. Second, it simplifies the connection between scientific modelling and decision-making, providing reference values on which warning systems and alert levels can then be based. In that respect, the use of probabilities is one possible solution – even though not the only one – that the task force will explore.

In a multi-risk context, the problem is then shifted from uncertainty estimation to finding an efficient solution to model testing. A usual procedure in disciplinary studies is to hindcast past event, with the awareness that model reliability in a changing environment may vary when shifting from hindcast to projection/prediction. It is therefore essential to focus on the application – say the estimation of climate impact indicators defined within RETURN – and to identify solutions for comparing projections/predictions with actual realization of data, patterns and/or statistics. Proper assumptions need to be introduced to make sure that reliability of predictions obtained in a testing environment is representative of future reliability.

The RETURN task force is working on the identification of candidate methodologies (see Marzocchi et al., 2024, this book of abstracts) to validate model predictions by defining and testing their probability distribution. An interesting opportunity is offered by data-driven approaches which allow us to reproduce the probability of predictions through machine learning and ensemble-based data assimilation. An interesting example is offered by nearest-neighbour techniques (see Figure 1 for a specific example of river flow prediction; see also Yates et etl, 2003; Yazd et al., 2019; Koutsoyiannis and Montanari, 2022; Ghaderpour et al., 2023a, 2023b). Innovative nearest-neighbour solutions are being currently considered.

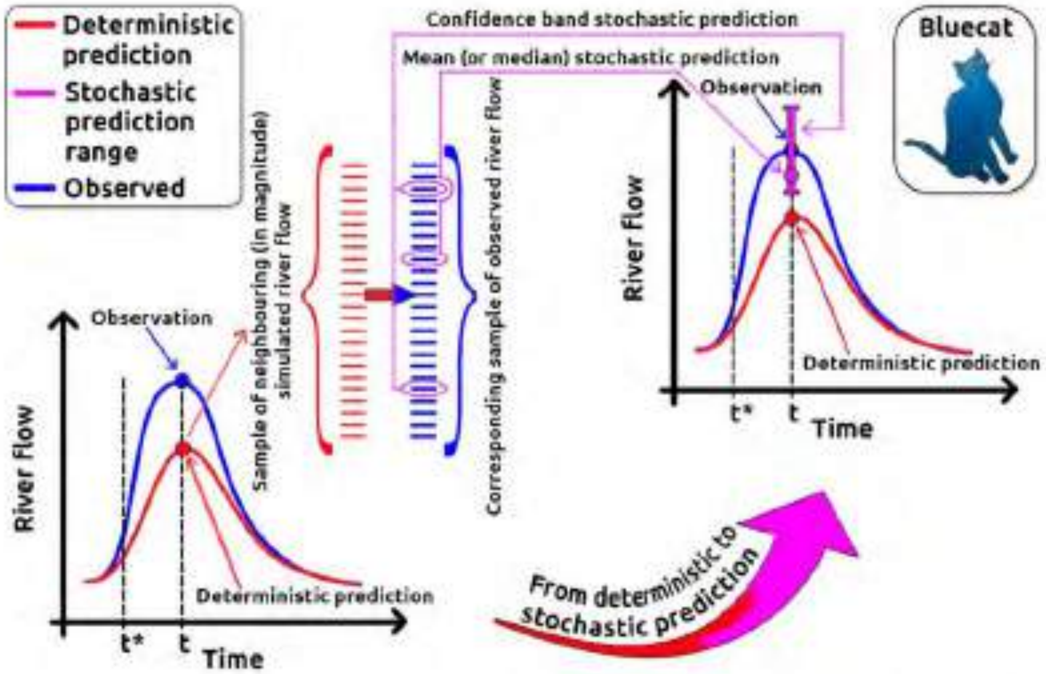


Figure 1. Schematic representation of the Bluecat concept underlying the transformation of the deterministic model (D-model) to a stochastic model (S-model). The painting in the upper right corner is cropped from the picture available at https://www.flickr.com/photos/cizauskas/36142084534/ of the Andy Warhol exhibition at the High Museum, Atlanta, Georgia, USA (CC BY-NC-ND 4.0).

Figure 1 – From Koutsoyiannis and Montanari (2023).

References

Koutsoyiannis D., Montanari A. (2022). Bluecat: a local uncertainty estimator for deterministic simulations and predictions. *Water Resources Research*, 58(1), e2021WR031215.

Yates D., Gangopadhyay S., Rajagopalan B., Strzepek K. (2003). A technique for generating regional climate scenarios using a nearest-neighbor algorithm. *Water resources research*, 39(7).

Yazd H.R.G.H., Salehnia N., Kolsoumi S., Hoogenboom G. (2019). Prediction of climate variables by comparing the k-nearest neighbor method and MIROC5 outputs in an arid environment. *Climate Research*, 77(2), 99-114.

Ghaderpour E., Zaghloul M.S., Dastour H., Gupta A., Achari G., Hassan, Q.K. (2023a). Least-Squares Triple Cross-Wavelet and Multivariate Regression Analyses of Climate and River Flow in Athabasca River Basin. *Journal of Hydrometeorology*. 2023a, 24, 1883–1900.

Ghaderpour E., Mazzanti P., Scarascia Mugnozza G., Bozzano F. (2023b). Coherency and phase delay analyses between land cover and climate across Italy via the least-squares wavelet software. *International Journal of Applied Earth Observations and Geoinformation*, 118, 103241.

A regionalized framework for the Metastatistical Extreme Value Distribution applied to sub-daily rainfall

Pietro Devò[1], Maria Francesca Caruso[1], Marco Borga[2,3],Marco Marani[1,3]

(1) Department of Civil, Architectural, and Environmental Engineering, University of Padova, pietro.devo@studenti.unipd.it
(2) Department of Land, Environment, Agriculture and Forestry, University of Padova
(3) Research Center on Climate Change Impacts, University of Padova

The estimation of extreme rainfall based on short records is of considerable interest, above all in the context of rapidly changing rainfall regimes. Regionalization techniques, by trading space for time, allow to partially overcome the lack of long observational records. The recently-introduced Metastatistical Extreme Value (MEV) distribution, which infers the probability distribution of annual maxima from all observed rainfall events, also contributed towards improving our ability to estimate large quantiles based on short observational time series. Here we combine established regionalization techniques, aggregating data from multiple adjacent stations complying with set homogeneity criteria, with MEVD-based methodologies to explore how their joint use may further reduce the uncertainty with which large extremes may be estimated. In the present work we focus on observations from the Veneto Region Environmental Protection Agency (Italy), which includes a round 200 stations, with an average distance of 15 km and deployed in a wide range of elevations and in different rainfall regimes, providing time series with a time resolution of 5 minutes. To evaluate possible improvements with respect to regionalization techniques based on traditional extreme value theory, such as the Generalized Extreme Value (GEV) distribution, we comparatively apply the proposed MEVD-based regionalization approaches and GEV-based methods. The results show the benefits arising from the regionalization technique, which enhances the robustness of the models by increasing the consistency of the observed data population, particularly in lowlands, where homogeneous regions can be trivially identified. The proposed regionalization approach based on the metastatistic distribution brings to a significant reduction of the estimation uncertainty for very high ratios between the forecasting return period value and the length of the calibration sample when compared to traditional methods.

References

Marani M., Ignaccolo M. (2015). A metastatistical approach to rainfall extremes. *Advances in Water Resources*, 79, 121–126.

Historical rainfall data in northern Italy predict larger meteorological drought hazard than climate projections

Rui Guo[1] and Alberto Montanari[1]

(1) Department of Civil, Chemical, Environmental and Materials Engineering (DICAM), University of Bologna, rui.guo2@unibo.it

Simulations of daily rainfall for the region of Bologna produced by 13 climate models for the period 1850–2100 are compared with the historical series of daily rainfall observed in Bologna for the period 1850–2014 and analysed to assess meteorological drought changes up to 2100. In particular, we focus on monthly and annual rainfall data, seasonality, and drought events to derive information on the future development of critical events for water resource availability. The results show that historical data analysis under the assumption of stationarity provides more precautionary predictions for long-term meteorological droughts with respect to climate model simulations, thereby outlining that information integration is key to obtaining technical indications.

Nine centuries streamflow reconstruction for the Po River

Rui Guo[1], Hung T. T. Nguyen[2], Stefano Galelli[2,3], Serena Ceola[1], Alberto Montanari[1]

(1) Department of Civil, Chemical, Environmental and Materials Engineering (DICAM), University of Bologna, rui.guo2@unibo.it
(2) Tree Ring Laboratory, Lamont-Doherty Earth Observatory, Columbia University
(3) Pillar of Engineering Systems and Design, Singapore University of Technology and Design

The Po River, the longest watercourse in Italy, suffered the worst drought of the past 70 years in 2022. Extreme events such as this severe drought, which caused great economic losses, are projected to occur more frequently under climate change. Relative short instrumental streamflow records limit our understanding of the long-term streamflow variability, while considering past climatic data could effectively improve future water resources management. Tree rings provide key information to this aim. Using information derived from tree rings, we reconstruct the annual streamflow of the Po river over the past nine centuries under a climate-informed framework. To quantify the uncertainty arising from the tree rings' information, our results are compared with the observation series through different measures of performance. We show that both megadroughts and megafloods have occurred along the Po River in the past centuries. Our findings help gain a deeper understanding of multicentennial streamflow variability of the Po river, thus providing essential technical indications for designing adaptation strategies under climate change.

Mountain permafrost in the Eastern Italian Alps: assessment of the current and future state of a crucial hazard indicator

Costanza Morino[1], Luca Carturan[1], Mirko Pavoni[2], Jacopo Boaga[2], Roberto Seppi[3], Matteo Zumiani[4]

(1) Department of Land, Environment, Agriculture and Forestry (TESAF), University of Padova, costanza.morino@gmail.com
(2) Department of Geosciences, University of Padova
(3) Department of Earth and Environmental Sciences, University of Pavia
(4) Geological Service, Autonomous Province of Trento

Permafrost in mountain areas worldwide is increasingly impacted by the present climate change, a phenomenon with striking consequences on landscapes and associated with frequent hazards affecting local communities, infrastructures, and the environment. Rock glaciers are geomorphological "sentinels" of changes in the temperature state, extension, and distribution of permafrost in mountain environments. In this respect, in the Eastern Italian Alps the interest on natural-hazard assessment and mitigation and management of water resources in terrains affected by mountain permafrost is growing. The identification, analysis, and modelling of the current and future changes of geomorphological processes and landform evolution related to degrading permafrost in this region is paramount.

Our research group is working on the current and projected impacts of climate change on the alpine cryosphere of the Eastern Italian Alps in the framework of the Spoke DS8 of the project RETURN (Extended Partnership funded from the European Union Next-GenerationEU – National Recovery and Resilience Plan – NRRP, Mission 4, Component 2, Investment 1.3 – D.D. 1243 2/8/2022, PE0000005). Here, we present the study approach and preliminary results focussing on the permafrost conditions of mountain slopes in the Province of Trento. Our objectives are: i) to understand the current local and regional permafrost state and distribution, ii) to model the distribution and state of permafrost in future warming scenarios, and iii) to determine whether the ongoing permafrost degradation is causing an increase of slope instability in terms of frequency and magnitude. We use a multidisciplinary approach that comprises a) photogrammetric analyses aimed at reconstructing interannual variations and possible acceleration of rock glacier kinematics, b) geophysics aimed at estimating the volume of permafrost in active and pseudo-relict rock glaciers, c) ground-surface temperature monitoring aimed at modelling the conditions of permafrost at local and regional scale, and d) geomorphological analyses on areas affected by landslides related to permafrost degradation.

We expect that the results of our activities focusing on the analyses of alpine cryosphere components – and in particular mountain permafrost – in the Eastern Italian Alps will contribute to improve our understanding of current geomorphological processes and related hazards in this region and in other mountain areas of the world affected by thawing permafrost.

Inventory and assessment of impact-oriented hazard indicators

Sonia Silvestri[1], Marco Marani[2], Alberto Montanari[3], Claudia Agnini[4], Gabriele Antolini[5], Chiara Arrighi[6], Alberto Barausse[7], Giacomo Bertoldi[8], Giovanni Besio[9], Luis Germano Biolchi[5], Marco Borga[10], Elena Bresci[6], Enrica Caporali[6], Luca Carturan[10], Emilia Corradi[11], Gianpiero Cossarini[12], Federica Costantini[1], Alice Crespi[8], Marta Della Seta[13], Chiara Favaretto[2], Gabriele Freni[14], Beatrice Maria Sole Giambastiani[1], Paolo Lazzari[12], Fabrizio Lirer[13], Andrea Lira Loarca[9], Melania Michetti[15], Daniela Molinari[11], Costanza Morino[10], Laura Pezzolesi[1], Daniela Piacentini[13], Luigi Piemontese[6], Nadia Pinardi[16], Massimiliano Pittore[8], Marco Reale[12], Claudia Romagnoli[1], Piero Ruol[2], Stefano Salon[12], Maria Sambito[14], Cosimo Solidoro[12], Maria Vittoria Struglia[15], Silvia Unguendoli[5], Andrea Valentini[5], Giulia Villani[5]

(1) Dipartimento BiGeA, Università di Bologna, sonia.silvestri5@unibo.it
(2) Dipartimento ICEA, Università di Padova
(3) Dipartimento DICAM, Università di Bologna
(4) Dipartimento di Geoscienze, Università di Padova
(5) Agenzia Regionale Prevenzione Ambiente Energia Emilia-Romagna
(6) Università di Firenze
(7) Dipartimento DiBio, Università di Padova
(8) EURAC Bolzano
(9) Dipartimento DICCA, Università di Genova
(10) Dipartimento TESAF, Università di Padova
(11) Politecnico di Milano
(12) OGS Trieste
(13) Università la Sapienza Roma
(14) Libera Università di Enna Kore
(15) ENEA
(16) Dipartimento DIFA, Università di Bologna

We present the definition, listing, and generation of RETURN-wide climate-related hazard indicators. The work is based on a thorough examination of the recent literature on climate indicators. Internationally, a significant approach is represented by the UN Global Set of Climate Indicators (UN, 2022), which was adopted by the UN Statistical Commission in 2022. In particular, some of the indicators adopted here were drawn from the "Impact" section of the UN GSCI, according to the goals of Task 8.2.1. A hierarchical structure was adopted here, inspired by the UN approach, to qualify indicators. At the national level, an important source of information is the National System for Environmental Protection (Sistema Nazionale per la Protezione dell'Ambiente, SNPA, 2021) (SNPA, 2021). SNPA is constituted by the 21 Regional Environmental Protection Agencies (Regional and Provincial ARPA) and Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA). SNPA has a formal advising role to the Italian Government in matters related to the environment. Hence, it was deemed important to align the present effort to identify climate change indicators to a system that has a binding value for laws to be formulated by Italian governments on the environment, including Climate. The structure adopted for climate-related hazard indicators within the RETURN Project, described below, was thus devised to be consistent with the above two frameworks, which are a reference at an international and national level. To the original 13 impact sectors proposed by SNPA (SNPA, 2021), 2 additional sectors were added, giving a total of 15 impact sectors considered in the RETURN project.

Once the structure of the indicator set was defined, extensive interactions, initially within DS8, and subsequently across the whole partnership, were carried out. In particular the following meetings were organised: 1) DS8 WP leaders; 2) VS1 WP leaders; 3) Ambassadors from all Spokes. Subsequently, each Ambassador from all spokes circulated the list devised by TS8.2.1 Leaders, which contained more than 200 indicators, to stimulate suggestions, integrations, and revisions in general. Furthermore, researchers from all Spokes were invited to take ownership of indicators of interest to their work and spoke. This process ensured a large participation by the entire RETURN partnership and will be continued to allow the inclusion of further indicators as activities proceed.

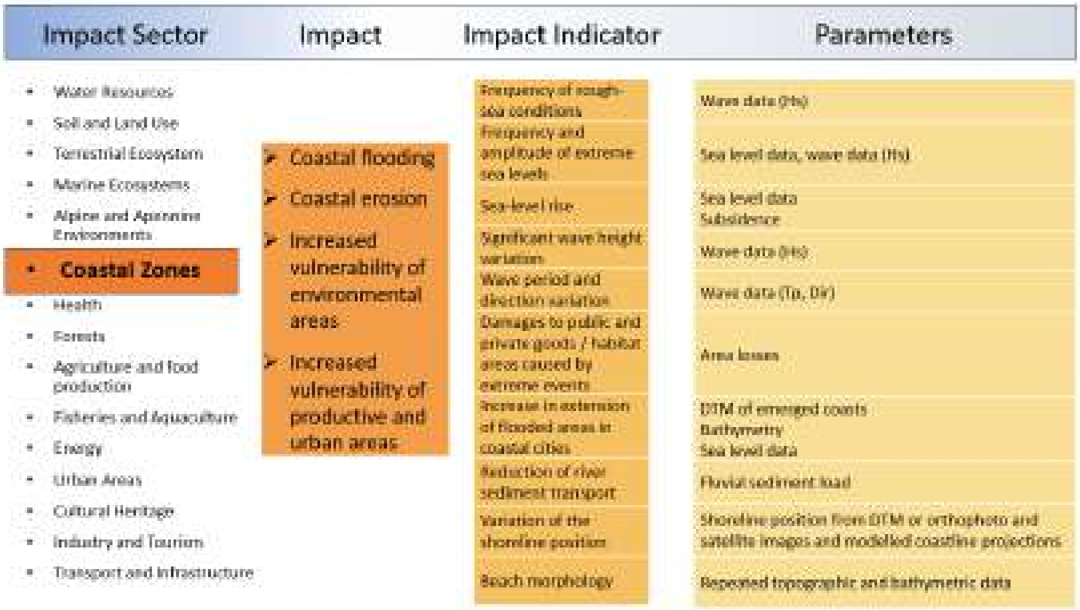
In accordance with the SNPA approach (ISPRA, 2023) we adopt the following definition of an impact-oriented hazard climate-related indicator: a tool aimed at facilitating the observation and understanding of medium to long-term trends in environmental, social, and economic phenomena that, based on scientific literature results, quantitatively represent cause-effect relations within earth-system change processes. Some indicators do not represent an exclusive cause-effect relation with climate change, but result from the combination of multiple factors, including climatic change.

As mentioned, the RETURN project identifies 15 *Impact Sectors, i.e.* the geographical, socio-economic, or environmental sectors that include relevant climate-related hazard indicators. The 15 *Impact Sectors* are: Water Resources, Soil and Land Use, Terrestrial Ecosystem, Marine Ecosystems, Alpine and Apennine Environment, Coastal Zones, Health, Forests, Agriculture and food production, Fisheries and Aquaculture, Energy, Urban Areas, Cultural Heritage, Industry and Tourism, Transport and Infrastructure.

Within each Impact Sector, the hierarchical structure includes the following fields:

- *Impact:* description of the impact to which the indicator is related;
- *Impact Indicator:* a quantitative definition of the indicator;
- *Parameters:* physical parameters required for the Impact Indicator calculation, along with sources where such data may be retrieved;
- *Proof of Concept:* Proof of Concept location, where the indicator will be computed;
- *GIS database:* existing databases where indicator or data for its calculation can be found;
- *Spoke information:* eight columns are provided where researchers from different Spokes self-identified as responsible for computing the indicator on specific PoC and on specific datasets (observations, proxies, projections). This information identifies indicators that are certain to be produced during the course of the project by the indicated researchers. Indicators lacking a specific responsible person will be produced/calculated as the project progresses and as RETURN researchers take ownership of more indicators.

The impact-oriented hazard indicator set developed provides a comprehensive and modular framework for RETURN activities. It identifies meaningful indicators that can be computed based on observations, projections, and, often, on paleo-reconstructions. The set of indicators was built to provide a sound basis for RETURN activities, including RETURN researchers responsible for their calculations. Yet, it is a modular set of indicators that will evolve as RETURN activities progress. Finally, the structured list of impact-oriented hazard indicators will define the framework for the design and construction of the RETURN data portal.



Impact Indicator	Parameters
Frequency of rough-sea conditions	Wave data (Hs)
Frequency and amplitude of extreme sea levels	Sea level data, wave data (Hs)
Sea-level rise	Sea level data Subsidence
Significant wave height variation	Wave data (Hs)
Wave period and direction variation	Wave data (Tp, Dir)
Damages to public and private goods / habitat areas caused by extreme events	Area losses
Increase in extension of flooded areas in coastal cities	DTM of emerged coasts Bathymetry Sea level data
Reduction of river sediment transport	Fluvial sediment load
Variation of the shoreline position	Shoreline position from DTM or orthophoto and satellite images and modelled coastline projections
Beach morphology	Repeated topographic and bathymetric data

Figure 1 – Structure of impact-oriented indicators descriptors adopted in the RETURN project with focus on the coastal zone as an example.

References

ISPRA (2023). Indicatori di impatto dei cambiamenti climatici – Piattaforma Nazionale Adattamento ai Cambiamenti Climatici (https://climadat.isprambiente.it/dati-e-indicatori/indicatori-di-impatto-dei-cambiamenti-climatici/)

SNPA (2021). Rapporto sugli indicatori di impatto dei cambiamenti climatici – Edizione 2021. Report SNPA 21/2021 – ISBN: 978-88-448-1058-0

United Nation (2022). Global Set of Climate Change Statistics and Indicators (https://unstats.un.org/unsd/envstats/climatechange.cshtml#:~:text=The%20Global%20Set%20was%20adopted,according%20to%20their%20individual%20concerns%2C)

Paleo and historical climate records: fluvial terraces and floodplains along the northern Apennines (Italy)

Francesco Troiani[1], Michele Delchiaro[1], Marta Della Seta[1], Giulia Iacobucci[1], Valeria Ruscitto[1], Marta Zocchi[1], Daniela Piacentini[1]

(1) Dept. of Earth Sciences, Sapienza University of Rome, francesco.troiani@uniroma1.it

Fluvial landforms and deposits provide one of the most readily studied Quaternary continental records, and the fluvial terraces, together with the present floodplains, represent important landscape components of different morphoclimatic contexts worldwide. During the late Quaternary, in the temperate zone of the northern hemisphere, the cyclical alternation of erosional and depositional processes was the dominant response of the fluvial systems to climate change. At the longer timescale (i.e., 10^4-10^5 years), fluvial processes interchanged as a function of orbital, eccentricity-driven climate cycles to generate, favored by regional tectonic uplift in mountainous and hilly regions, typical staircases of staked fill terraces (Vandenberghe, 2003; Bridgland and Westaway, 2008). At the millennial and secular timescales, deciphering the cause of alternating stages of fluvial erosion and deposition is rather complex. In fact, some other climatic forcing such as vegetation distribution, extreme events (i.e., augmented frequency in flooding episodes), variations of channel-hillslope connectivity, other than anthropic activities and land use become predominant to influence fluvial processes. This is a peculiarity of fluvial dynamics during the Holocene time and at present days. Therefore, the use of fluvial terraces and recent floodplains as indicators of the effects of climate changes at different space-time scales suggests that some methodological problems must be considered. For example, particular attention should be targeted to the selection of the different elements composing a fluvial terrace or a floodplain to be used for intra- and extra-valley morpho-stratigraphic correlations (i.e., alluvial deposits/bedrock boundary or terrace top-surface) (Zondervan et al., 2022). In addition, consideration should be devoted to a realistic estimation of the space-time resolution provided by internal sediment facies changes that can indicate the occurrence of occasional flooding events at the river reach scale and/or systematic fluvial pattern variations at a broader river basin scale. Finally, the use of the fluvial indicators as paleo or historical climate records must be supported by a profound knowledge of the history of fluvial dynamics that it would be better to be well constrained from a geochronological point of view.

In the frame of Spoke 8, WP2 project activities, this contribution deals with two case studies from the peri-Adriatic sector of the northern Apennines of Italy, where different geomorphological techniques have been tested to reconstruct the genesis and development of fluvial terrace staircases and the geomorphology of the present floodplains. Automatic extraction of terrace top-surface and land-surface quantitative (LSQ) analyses have been performed respectively along the Tesino River valley sides and the Misa River valley floor, complemented by absolute dating of terrace deposits using Optically Stimulated Luminescence (OSL) and geomorphological field surveys.

Results from the Tesino River valley, reported in Delchiaro et al. (2023), allowed the mapping of the Pleistocene fluvial terrace surfaces, distinguished and classified into three different levels. Furthermore, three new OSL dating allowed to confirm and integrate the terrace chronology for the most recent fluvial terrace level and to provide, for the first time, geochronological constraints to the ancient terrace levels. The latter provides a correlation of fluvial deposition stage with main Pleistocene cold stages (Figure 1).

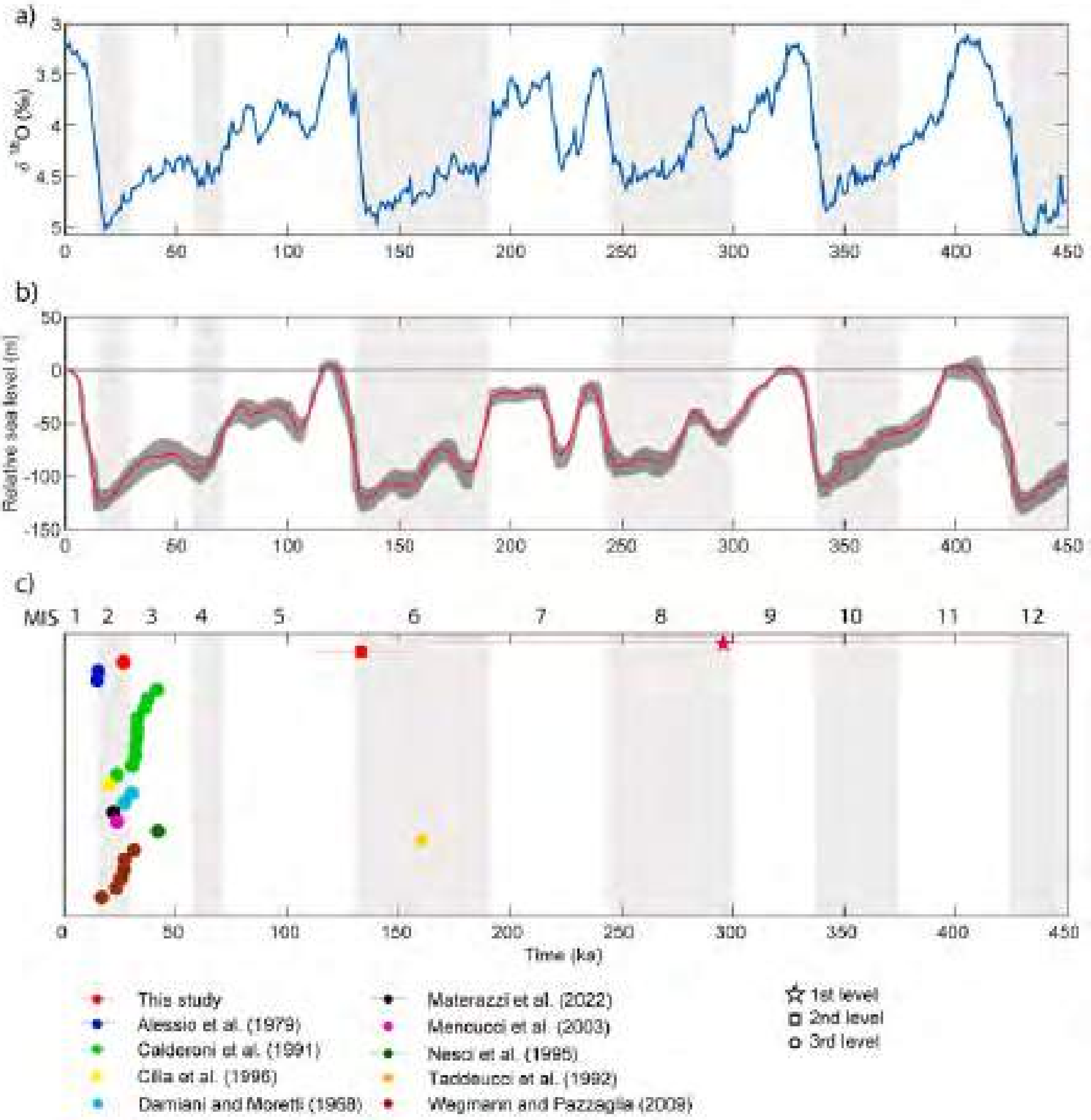


Figure 1 – a) Oxygen isotope curve of globally distributed benthic records. b) The global eustatic curve updated for the last 500 ka. c) The age distribution of available data for the peri-Adriatic sector of the northern Apennines of Italy, including the present study ages (from: Delchiaro et al., 2023; references for the adopted eustatic and Oxygen isotope curves are there included).

Along the Misa River valley, Iacobucci et al. (2022) demonstrated that the adopted approach allowed for distinguishing and mapping in detail the main fill terrace level characterized by well-developed and continuous terrace surface, and a discontinuous and remodeled, ca. 3 m-high, terrace scarp that separates the terrace top–surface from the lower and younger terrace levels. These latter are of strath typology and formed during the Holocene. The main terrace was formed during the late Pleistocene under full-glacial, cold conditions, whereas the younger ones were formed at periods of channel stationarity during the general post-glacial downcutting phase.

From a methodological point of view, the field surveys revealed in both case studies to be precious for differentiating the terrace typologies and verifying the results from the automatic extraction of terrace levels.

These latter outcomes helped distinguish the different terrace levels and assess their along-valley distribution, as well as objectively identifying and mapping the top–surface of the main terrace levels. This contribution confirms the value of fluvial terraces and floodplains as paleo and historical climate records and the effectiveness of the study of past changes in fluvial dynamics for hazard-oriented interpretations of processes trajectories within fluvial systems under changing climate.

References

Bridgland D.R., Westaway R. (2008). Climatically controlled river terrace staircases: a worldwide Quaternary phenomenon. *Geomorphology*, 98(3-4), 285-315.

Delchiaro M., Iacobucci G., Della Seta M., Gribenski N., Piacentini D., Ruscitto V., et al. (2023). A fluvial record of late Quaternary climate changes and tectonic uplift along the Marche Piedmont Zone of the Apennines: New insights from the Tesino River (Italy). *Geomorphology*, 445.

Iacobucci G., Piacentini D., Troiani F. (2022). Enhancing the identification and mapping of fluvial terraces combining geomorphological field survey with land-surface quantitative analysis. *Geosciences,* 12 (11), 425.

Vandenberghe J. (2003). Climate forcing of fluvial system development: an evolution of ideas. *Quaternary Science Reviews*, 22(20), 2053-2060.

Zondervan J.R., Stokes M., Telfer M.W., Boulton S.J., Mather A.E., Buylaert J.P., et al. (2022). Constraining a model of punctuated river incision for Quaternary strath terrace formation. *Geomorphology,* 414, 108396.

UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

Politecnico di Torino

SAPIENZA UNIVERSITÀ DI ROMA

POLITECNICO MILANO 1863

UNIVERSITÀ DEGLI STUDI FIRENZE

UNIVERSITÀ DEGLI STUDI DI ENNA "KORE"

UNIVERSITÀ DEGLI STUDI DI PADOVA

UNIVERSITÀ DEGLI STUDI DI BARI ALDO MORO

Università Ca'Foscari Venezia

UNIVERSITÀ DEGLI STUDI DI PALERMO

ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA

UNIVERSITÀ DEGLI STUDI DI GENOVA

Università degli Studi di Cagliari

OGS

cima RESEARCH FOUNDATION

ENEA Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile

GENERALI

FERROVIE DELLO STATO ITALIANE

iren

PROTEZIONE CIVILE

AlmavivA

EURAC research

arpae

eni rewind

ENGINEERING

Return