multi-Risk sciEnce for resilienT commUnities undeR a changiNgclimate

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1. Technical references

Project Acronym	RETURN
Project Title	multi-Risk sciEnce for resilienT commUnities undeR a changiNg climate
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Deliverable No.	DV2.2.2
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PP = Restricted to other programme participants (including the Commission Services)

RE = Restricted to a group specified by the consortium (including the Commission Services)

CO = Confidential, only for members of the consortium (including the Commission Services)

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Version	Date	Lead contributor	Description
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0.5	31.07.23	RF; WP coordinators and TK leaders	Final version and editing

2. ABSTRACT

This report summarized the scientific research activities carried out in the period January – July 2023 by the Task 2.2.1 "Identification of areas at different scales affected or predisposed to ground instabilities, either in the subaerial (a) and submerged (b) environment by existing inventories and archives –implemented and updated by EO services – and permanent and temporary geophysical observatories (dynamic mapping)" (hereinafter referred to as TK1) of the Work Package 2.2 "State of the art and knowledge base to define impact-oriented hazard indicators" (hereinafter referred to as WP2) inside the vertical spoke VS2 "Ground Instabilities" of the Extended Partnership RETURN.

It should be noted that VS2 structured WP2, WP3 and WP4 by identifying the following areas of interest for each of them:

- WP2 focuses on the detection and analysis of PREDISPOSING factors to ground instabilities.
- WP3 targets PREPARATORY factors to ground instabilities.
- WP4 is centered on TRIGGERING and multiple geohazards cascading scenarios (MULTIHAZARD).

In accordance with the definitions given within the VS2, the distinction between predisposing, preparatory and triggering factors/processes is made on a temporal basis: in fact, it means that the predisposing factors are considered invariable on the observation scale, while the preparatory factors show changes or cyclical trends during the same period. As consequence, a trigger is considered as a process that acts in a very short and well-defined time.

The activities of WP2 were directed in the reference period to the examination of the factors predisposing the ground instabilities, starting from a series of case studies (defined Learning Examples, LEs) which represent experiences that each partner has carried out in recent times, and which include cutting-edge analyzes in the theme of characterization of predisposing factors and in the spatial and temporal quantification of susceptibility.

The partner involved in the WP2 are ENEA, OGS, POLITO, UNIBA, UNIBO, UNIFI, UNIGE, UNINA, UNIPA, UNIPD and UNIROMA1. WP2 leaders are Riccardo Fanti (UNIFI) e Mario Parise (UNIBA), TK1 leader is Francesco Maria Chiocci (UNIROMA1), TK2 leader is Mario Parise (UNIBA), TK3 leader is Matteo Berti (UNIBO). 72 researchers participate in the activities of WP2/TK1 (i.e. TK 2.2.1): 5 from ENEA, 3 from OGS, 6 from POLITO, 5 from UNIBA, 6 from UNIBO, 7 from UNIFI, 7 from UNIGE, 8 from UNINA, 13 from UNIPA, 8 from UNIPD and 4 from UNIROMA1.

The goal of TK1 (Identification of areas at different scales affected or predisposed to ground instabilities, either in the subaerial (a) and submerged (b) environment by existing inventories and archives –implemented and updated by EO services – and permanent and temporary geophysical observatories (dynamic mapping)) and the issue of DV 2.2.2 (Detection and classification of potentially threatening ground instabilities) have been interpreted in the framework of the LEs collection.

According with the main idea of the Project and of VS2, the learning phase had the objective of building a Rationale for preparatory processes to be used as input to the Proof of Concept (PoC). This phase has been articulated in three stages:

i) Inventory of Learning Examples (LE).
ii) Individuation of the preparatory processes analyzed in each LE.
iii) Definition of a Rationale for each process based on the available LEs.

Within this framework, DV 2.2.2 is regarded as the conversion of a representative dataset extracted from all Learning Examples (LEs) into a comprehensive collection of information focused on identifying various contributing factors. This process, referred to as the "inversion of the information matrix" in the project's context, aims to establish a valuable framework for implementing the envisioned Proof of Concept (PoC). Indeed, the successful execution of the PoC necessitates a firm foundation anchored in the framework of

predisposing factors and processes. The overarching applicability of this framework strengthens its value as it enables a detached discussion beyond the confines of any specific context.

3. Table of contents

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4. First Section

4.1 Learning Examples (LEs) vs Predisposing Factors

After the first phase of the project, during which the LEs more suitable to describe the Predisposing Factors/Process for various instability phenomena were identified, each Partner was asked to translate the chosen Examples in a more specific way providing more detailed information on the phenomenon and on the factors characterizing it. In the following months (**May – June 2023**), for each LE the WP2 leaders and TK leaders collected from all the institutions a single form whose attributes, described in the previous phase in a synthetic way with a checkbox, were filled in with in-depth descriptions (as shown in Table 1**Errore. L'origine riferimento non è stata trovata.**) to be shared among all partners in a collective online repository. In particular, these forms summarize the research work following a shared attribute scheme which includes:

- The Partner proposing the LE;
- The Localization of the LE (site name and/or geographical location or area of interest);
- The Environment (subaerial/submerged);
- The Context (mountain/hill/plain/coast/near-shore);
- The Scale (local/intermediate/regional);
- The Effect (landslide/subsidence/sinkhole/liquefaction);
- The Type of data and time horizon of the analysis (base data used for the analysis and the temporal interval of the case);
- The Considered Predisposing Factors (the environmental variables that have been considered in the learning example as predisposing factors);

- The Analysis methods and models used (on site monitoring/remote, monitoring/deterministic analysis/statistical, analysis/machine learning);

- Note (any additional annotations that do not fit into the previous fields).

The LEs forms have been checked by WP2 leaders and TK leaders with the aim of verify the suitable assignment of each LE to the analyzed factors/processes of each WP (predisposing processes – WP2; preparatory processes: WP3; trigger: WP4).

Then, during this control phase, WP2 leaders and TK leaders with continuous exchanges and interactions with the proposing institutions grouped the proposed predisposing factors by macro-area of afference (Macro-Factors) with the aim of starting a homogenization of the factors in order to be able to compare them between different LEs.

The Macro-Factors selected for all four ground instabilities considered (Effects) were: Geological, Geomorphological, Structural, Tectonics, Vegetation, Pedological, Geotechnical, Hydrogeological, Climate, Erosion, Anthropic factors.

At the end of this stage, the “matrix inversion” was performed. The focus of the analysis was turned to the Factors/Processes (instead of the single LEs) quantified through the outputs of the related LEs. All the collected forms, once checked, have been combined in a single synoptic shared table to allow for an overall view of the LEs and Factors/Processes. An extract of four significant cases from the LEs inventory is shown in Table *2*.

Integrating the information of all the LEs inventory, a preliminary overview of the LE coverage of the different Macro-Predisposing Factors/Processes is reported in Table 1.

Table 1. Example of a Learning Example form filled in by one of the institutions, with explanation of the expected content.

<table>
<tr><th>RETURN Project | VS2 – Ground Instabilities | WP2 “Predisposing Factors”</th></tr>
<tr><th>LEARNING EXAMPLES SUMMARY FORM</th></tr>
</table>

Partner
(Specify University or Organization)
UNINA

Localization of the Learning Example
(enter the name of the area, according to the scale of analysis: es. Appennino Meridionale, Ciociaria, Bacino del Fiume Esino, Monte Baldo (TN), ecc.)
Campania

Environment
(Leave the category already indicated in the spoke census)
Subaerial

Context
(Leave the category already indicated in the spoke census)
Mountain and hill

Scale
(Leave the category already indicated in the spoke census spoke, but with the possibility of further specification: eg. Physiographic unit – Basin of n km^2; Local – Coastal cliff; etc.)
Regional

Effect
(Describe the instability phenomena subject to analysis in the learning example, also specifying the types of individual phenomena or groups of them (maximum a few lines)

eg. Slow landslides – Debris flows – Rock collapses – Sinkholes in urban areas of anthropic cavities – Sea-land retrogressive coastal landslides – Submarine landslides on canyon head – Open-slope landslides, etc..)
Landslides of Campania Region

Type of data used and time horizon of the analysis
(Synthesize the base data used for the analysis – e.g. existing inventories, previous studies, ad hoc topographic surveys, seismic profiles, multi-beam echometric surveys, historical data, etc. – and the temporal extension of the case – e.g. single event, seasonal, multi-year, etc.)
Inventory map of the Southern Apennines Basin District Authority, topographic maps, aerial photos, direct surveys, interferometric data (PS data). Scientific publications.

Considered Predisposing Factors
(Synthesize - also in the form of a list - the environmental variables that have been considered in the learning example as predisposing factors, declining this concept in a free form, although adhering to the experience of the learning example)
Geo-lithological, geomorphological, structural and mechanical factors

Analysis methods and models used
(Synthesize the analytical methods and models that have been considered in the learning example, defining each approach in a free form, adhering to the learning example experience)
Inventory of landslides in the Campania Region and creation of a database (e.g. identification of the type of movement, style, distribution and activity status of the landslides)

Note
(Use the field for any additional annotations that do not fit into the previous fields)

Table 2. Extract of four cases from the inventory of LEs and the Predisposing Factors/Process for WP2. The green fields represent the Macro-Predisposing Factors/Processes summarized by those Considered.

LE ID	Partner	LEs location	Scale	Effect	Type of data used and time interval of the analysis	Considered Predisposing Factors/Process	Macro-Predisposing Factors/Process
8	UNIBO	Appennino Emiliano-Romagnolo	Regional	Slow landslides: • Earth flows. • Complex slide-flow landslides. Rapid to extremely rapid landslides: • Translational landslides in rock.	• Cartography of the instability (from aerial photographic analysis and field surveys). • Geological map at 1:10,000 scale. • Digital terrain model with 10 m cell and derived levels. • Historical inventory of landslides. • PS satellite interferometry data. • Double-pass satellite interferometry data. • Satellite data of soil surface moisture. The historical landslide inventory has been complete since about the 1950s, but detailed comparison analyzes with interferomeric data are possible starting in 2018.	• Geology. • Topography (and derived parameters). • Land use. • Precipitation. • Soil moisture. • Activity status (meant as the time since the last reactivation).	• Geological. • Geomorphological. • Pedological. • Climate. • Hydrological.
33	UNIPD	Delta Po	Delta – about 600 km2. Local – protective works (embankments, barriers).	Subsidence in anthropic and sparsely urbanized areas.	Previous studies on the evolution of the subsidence phenomenon. Medium and high resolution SAR images. GNSS data from permanent and non-permanent stations. Time horizon: multi-year.	• Tectonics • Sea level changes • Geotechnical characteristics of recent unconsolidated deposits • Filtration conditions	• Tectonics. • Climate. • Geotechnical.
7	UNIBA	Regione Puglia	Regional - Local (municipal scale, or specific sites)	Sinkholes: sinkhole phenomena of different genesis (as per the classification of Gutierrez et al., 2014), connected to cavities of natural (karst) and/or artificial origin.	• Previous inventories. • Bibliographic studies. • Historical data. • Shapefiles. • Topographic measurement. • Aerial photos. • Digital elevation model. • Geophysical surveys. • Data deriving from speleological surveys. Multi-year time extension, both on a regional and local scale.	• Depth from the ground level of the vault of the underground cavity. • Geometry and extension of the cavity. • Lithotype and stratigraphic details. • State of fracture of the rock mass. • Proximity of the cavity to the sea and to the groundwater, or water inside. • Processes of degradation and erosion due to exogenous agents. In specific relation to natural contexts, the following should be considered as additional predisposing factors: • Presence of acid fluids.	• Geomorphological. • Geological. • Hydrological. • Erosion. • Anthropic factors.

						• Degree of activity of the karst system during flood events	
37	UNIROMA	Regione Lazio	Regional	Earthquake-induced liquefaction of soils	DTM (and derived morphometric products). "Geothematic" maps (lithological map, hydrogeological map, vegetation map). INGV grid for basic seismic hazard. Maps of the Vs30 (Mori et alii). MS1 studies. Time extension: multi-year	• Land morphology. • Outcropping lithology. • Groundwater subsidence. • Expected PGA values (both seismic bedrock and "real" soil) for different return times	• Geomorphological. • Geological. • Hydrological. • Tectonics.

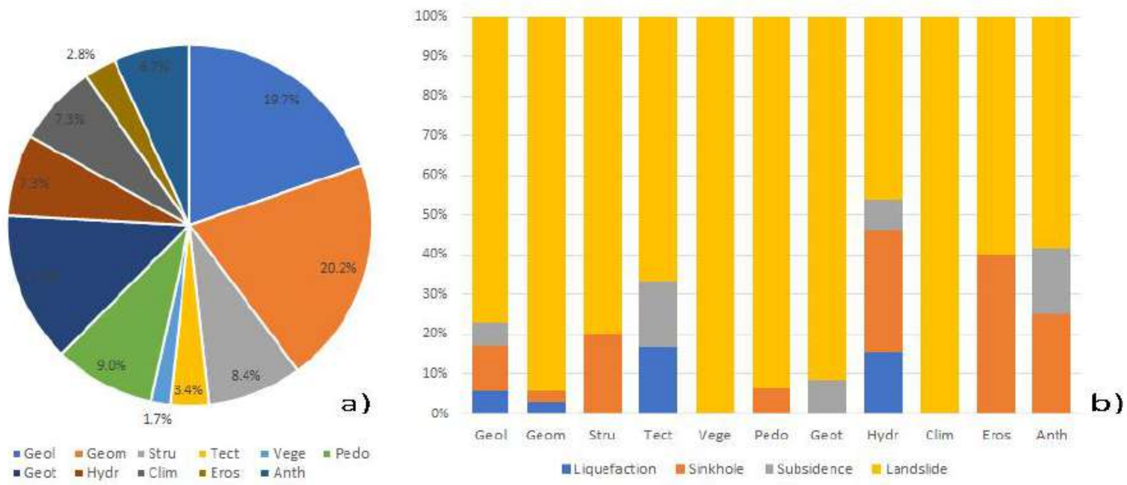

Figure 1. (a) Distribution of Macro-Predisposing Factors within the LEs; (b) Percentage of the Effects within the Macro-Predisposing Factors described in the Les forms. Geol - Geological; Geom - Geomorphological; Stru - Structural; Tect – Tectonics; Vege – Vegetation; Pedo – Pedological; Geot – Geotechnical; Hydr – Hydrogeological; Clim – Climate; Eros - Erosion; Anth - Anthropic factors.

4.2 Towards the Rationale – WP2 outcomes

The Rationale in formation needs input data and constraints to be inserted in the Proof of Concept (PoC). This PoC will be able to use these inputs to generate outputs within the constraints of validity of learning tools derived for each factor/process from the LEs. Between ***June and July 2023***, WPs and TKs spent the research efforts to rationalizing each Factor/Process by learning from the respectively associated LEs to synthesize a homogenized and coherent list of Factors/Process across the LEs.

Within the VS2, the rationalization phase took place in parallel between WP2, WP3 and WP4. To achieve this goal, a specific rationalization sheet was designed for each WP. To optimize the process, WP2 predisposing factors were analyzed with a table approach, while WP3 and WP4 processes and triggers adopted a more descriptive form.

WP2 leaders and TK leaders with continuous exchanges and interactions with the proposing institutions reviewed the Considered Predisposing Factors/Process extracting the "Synthesized Predisposing Factors" (in the most logical and objective way possible) as summarized in the Table 3. To each of these, each proposing institution was asked to associate a "Learning Approach Type" field and another "Learning Approach" field to each one. In the "Learning Approach Type" field each process have been associated to a different potential level of rationalization: quantitative (i.e. through functions, empirical laws, algorithms), semi-quantitative (e.g. through severity indexes2) or qualitative (e.g. through severity classes).

Table 3. Synthesized Predisposing Factors obtained from Considered Predisposing Factors/Process in Table 2.

Macro-Predisposing Factors	Synthesized Predisposing Factors
Geological	Lithology Orientation, spacing, persistence of discontinuity Alteration rate Fracturing Paleolandslides Site amplification (PGA)
Geomorphological	Topography (derived parameters) Curvature Slope Aspect River network characteristics Activity status Riverbed characteristics Piping
Structural	Faults Stratigraphic structure Cavity depth Cavity geometry and dimension Sea/water table distance Karst system activity during floods/storm surges Structural
Tectonics	Tectonics Regional seismic activity
Vegetation	Vegetation typology Root density
Pedological	Soil type Land use Soil thickness Cavity vault substrate thickness

Macro-Predisposing Factors	Synthesized Predisposing Factors
Geotechnical	Mechanical properties Permeability Granulometry Hydraulic parameters Liquefaction inventory
Hydrogeological	Water presence Acidic fluids Groundwater level variation
Climate	Rainfall Climate Sea level variations Wildfires Freeze/thaw cycles Wave motion
Erosion	Coastal erosion Rill erosion Gully erosion Badlands River erosion Soil sealing
Anthropic factors	Anthropic pressure/activity Distance from the water/sewer network Infrastructure distance Anthropic terraces Stabilization/defense works Man-made cavities

An extract from the PFP-LE table for the rationale of WP2 is summarized in Table *4*. A preliminary overview of the LE coverage of the different Predisposing Factors/Process, divided into four Effects is reported in **Errore. L'origine riferimento non è stata trovata.**, Figure 2, Figure 3 and Figure 4 (liquefaction, sinkholes, subsidence, landslides respectively).

Table 4. Extract from the shared Predisposing Factors/Process-LE table of WP2. The green fields represent the contribution from the Institutions.

LE ID	Partner	LEs location	Scale	Instability Type	Predisposing Factors described in the Les	Synthesized Predisposing Factors	Type of Learning Approach	Learning Approach (Methods and Results/Products)
8	UNIBO	Appennino Emiliano-Romagnolo	Regional	Landslides	• Geology. • Topography (and derived parameters). • Land use. • Precipitation. • Soil moisture. • Activity status (meant as the time since the last reactivation).	Lithology.	SemiQuantitative	From RER geological map at 1:5000 scale
						Topography (derived parameters).	Quantitative	GIS analysis on DEM at 10 m
						Land use.	Qualitative	From analysis of high resolution aerial photos
						Rainfall.	Quantitative	Regional rainfall network with hourly data
						Presence of water.	Quantitative	Soil moisture from satellite images
						Activity Status.	SemiQuantitative	From analysis of the historical archive of landslides RER
33	UNIPD	Delta Po	Basin	Subsidences	• Tectonics • Sea level changes • Geotechnical characteristics of recent unconsolidated deposits • Filtration conditions	Tectonics.	Quantitative	Interferometric and GPS data analysis integrated with geophysical and geochronological data on soil samples. A correlation between subsidence and age of Holocenic deposits is demonstrated
						Sea level variations.	Quantitative	
						Mechanical properties.	Quantitative	
						Hydraulic parameters.	Quantitative	
7	UNIBA	Regione Puglia	Regional	Sinkholes	• Depth from the ground level of the vault of the underground cavity. • Geometry and extension of the cavity. • Lithotype and stratigraphic details. • State of fracture of the rock mass. • Proximity of the cavity to the sea and to the groundwater, or water inside. • Processes of degradation and erosion due to exogenous agents. In specific relation to natural contexts, the following should be considered as additional	Depth of the cavity.	Quantitative	From bibliographic data, data deriving from inventories and cadastres, in situ surveys, geophysical surveys
						Cavity geometry and dimension.	Quantitative	From bibliographic data, data deriving from inventories and cadastres, in situ surveys
						Lithology.	SemiQuantitative	From detailed lithostratigraphic analyses, consultation of geological maps, field surveys
						Fracturing.	SemiQuantitative	Field investigations
						State of alteration	SemiQuantitative	Field investigations, laboratory analyses
						Acidic fluids.	Qualitative	Ancillary data, field surveys
						Karst system activity during floods/storm surges.	Qualitative	Ancillary data, field surveys

					predisposing factors: • Presence of acid fluids. • Degree of activity of the karst system during flood events			
37	UNIROMA	Regione Lazio	Regional	Liquefaction	• Land morphology. • Outcropping lithology. • Groundwater subsidence. • Expected PGA values (both seismic bedrock and "real" soil) for different return times	Topography (derived parameters). Lithology. Groundwater level variation. Site amplification (PGA).	Qualitative Qualitative Qualitative Qualitative	Overlapping of indexed maps according to subjective criteria (binary classification: "0" = non-predisposing class, "1" = predisposing class). Output: map of the intrinsic predisposition to the liquefaction phenomenon, subsequently corrected according to the expected PGA for different return times and on the basis of possible topographic and morphological amplification phenomena. Validated study for comparison with MS1 and MS3 products

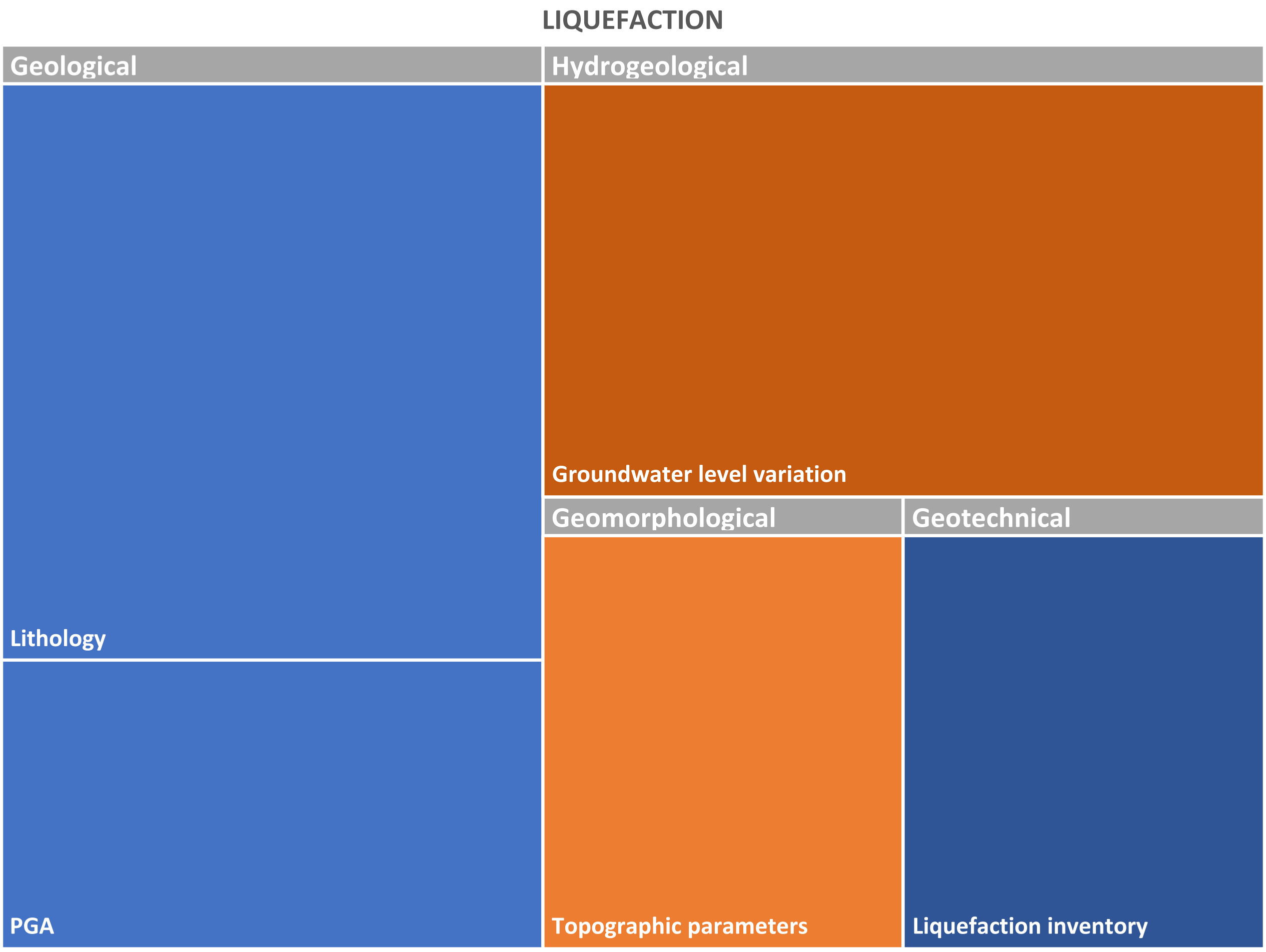

Figure 2. Distribution of the Predisposing Factors of Liquefaction Effect within the analyzed LEs.

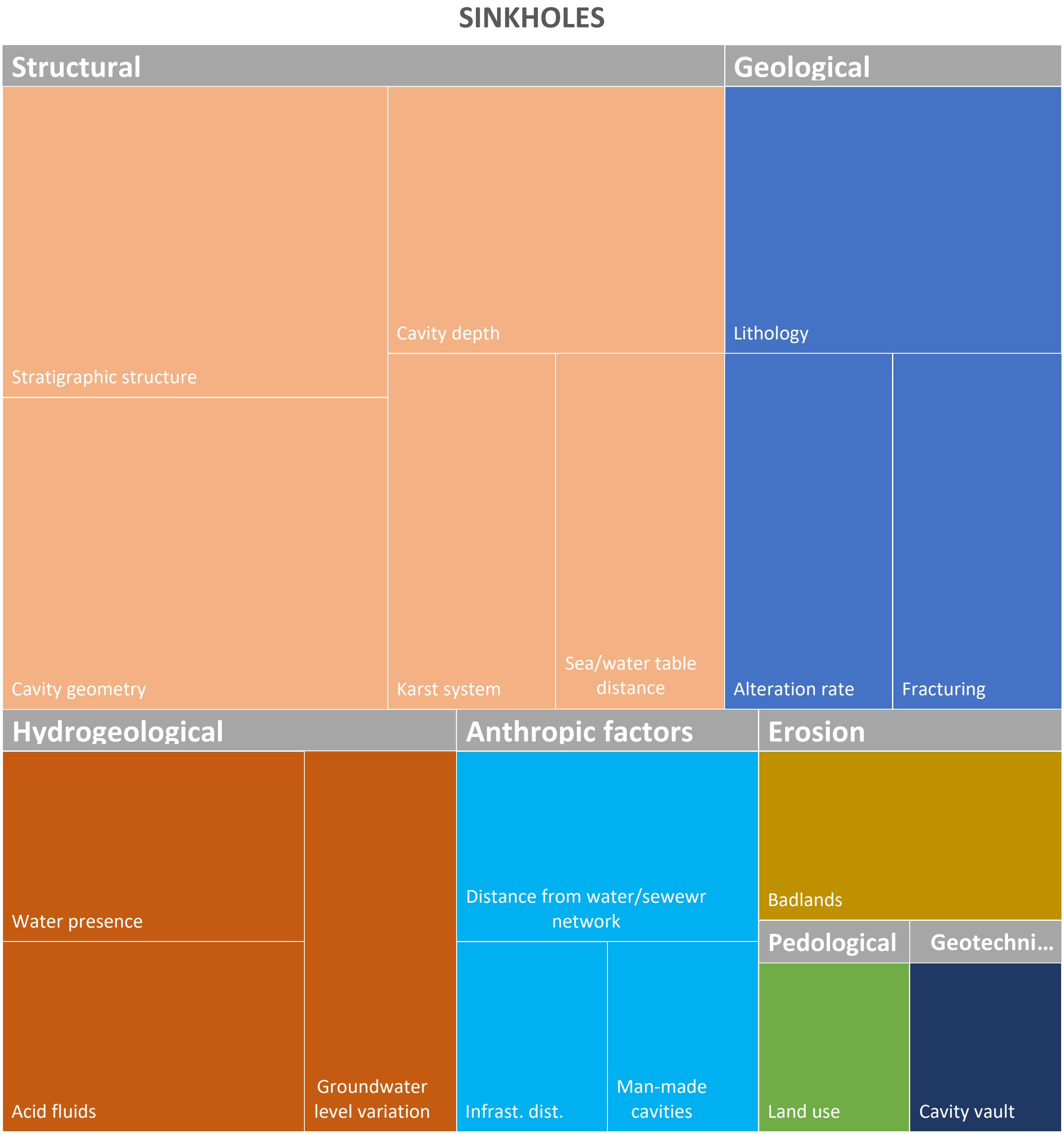

Figure 2. Distribution of the Predisposing Factors of Sinkholes Effect within the analyzed LEs.

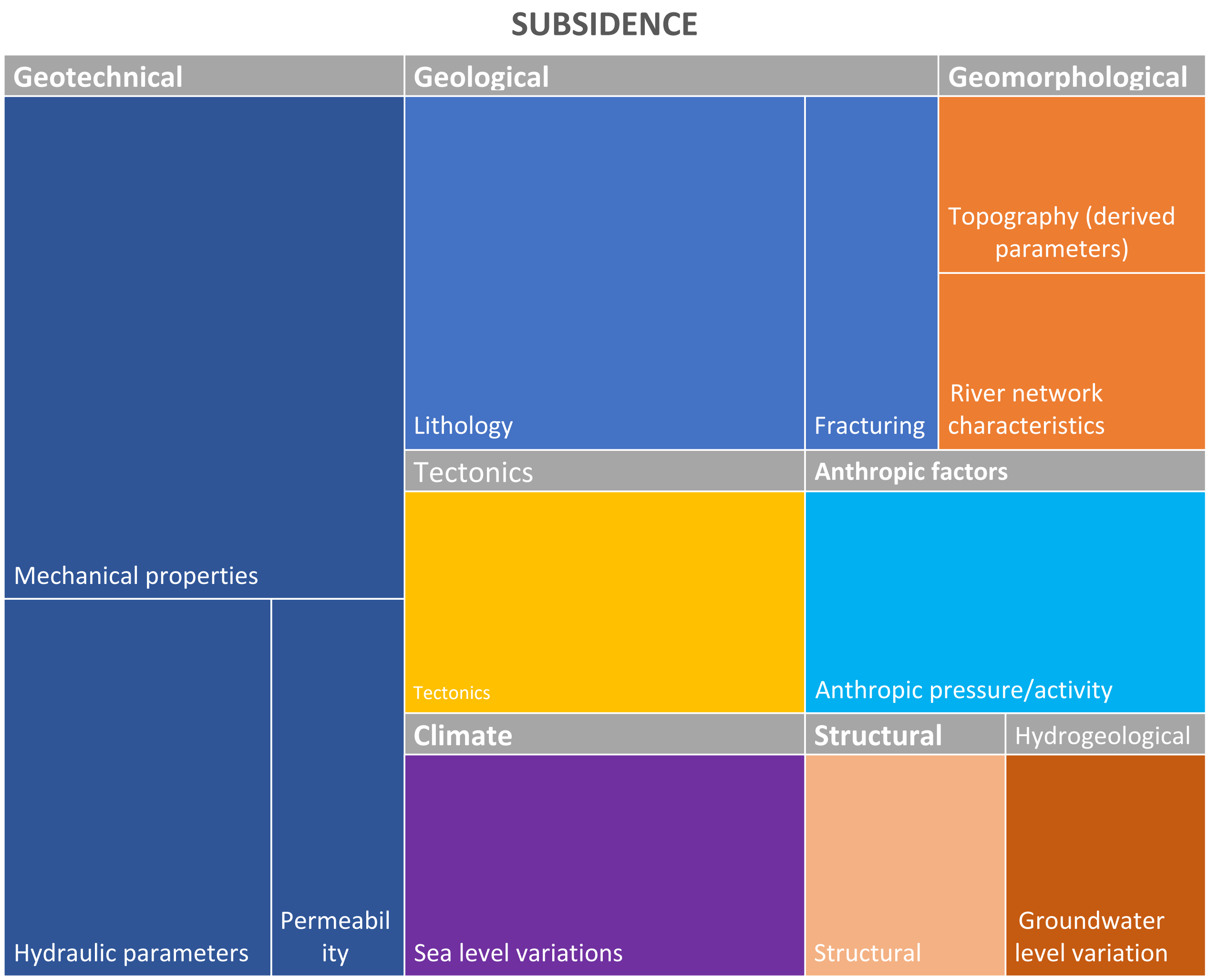

Figure 3. Distribution of the Predisposing Factors of Subsidence Effect within the analyzed LEs.

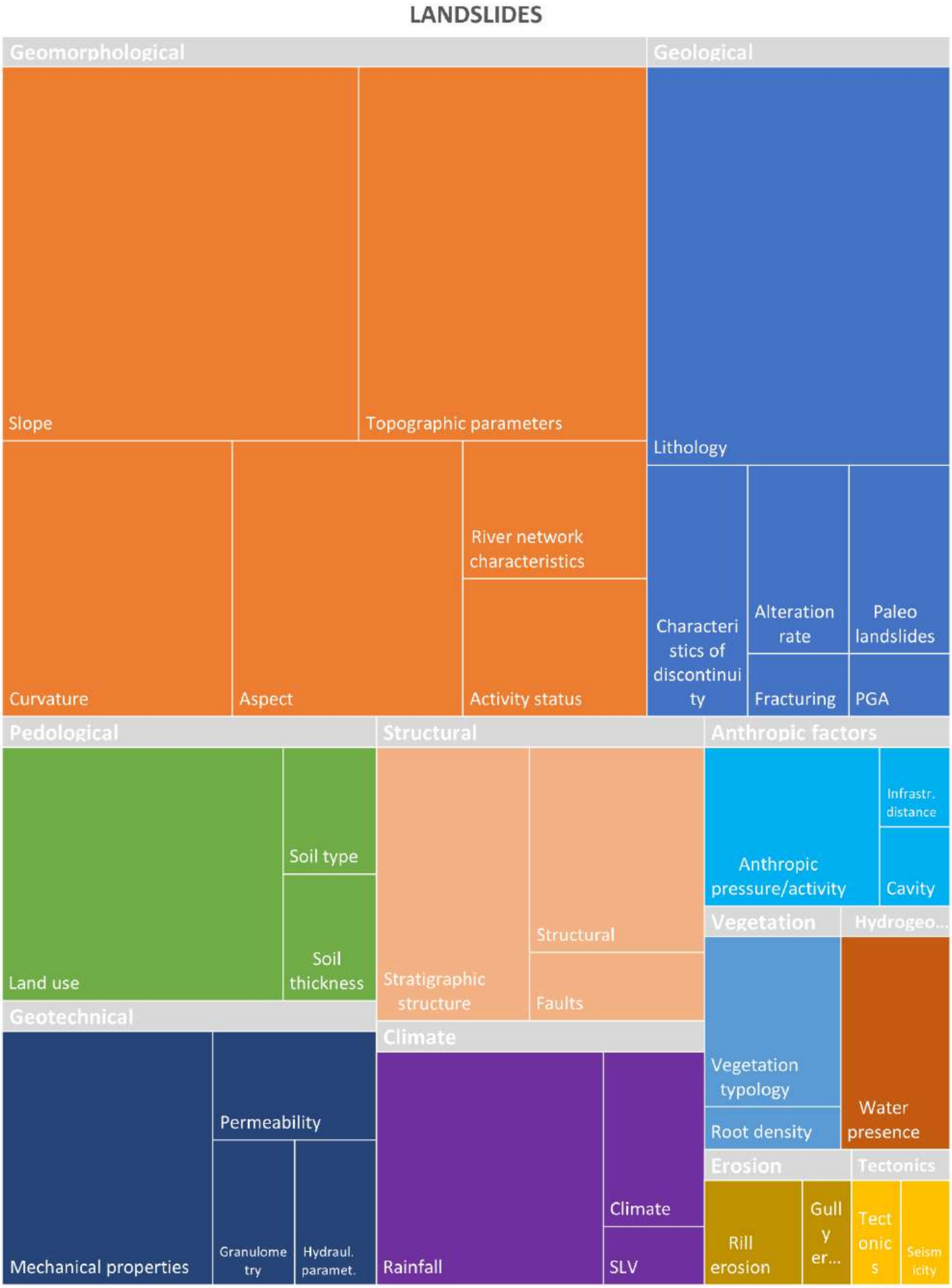

Figure 4. Distribution of the Predisposing Factors of Landslides Effect within the analyzed LEs.

5. Second Section

5.1 Strengths and Weaknesses of the approach

The approach used in the WP2 provides valuable insights into the strengths and weaknesses of the method employed in analysing the predisposing factors of ground instabilities. Additionally, it offers valuable recommendations for improvement in the subsequent project phases. Throughout the analysis, certain aspects have emerged, shedding light on the strengths of the methodology, but also exposing potential limitations that need to be addressed.

One of the primary strengths observed in the approach is the exemplary selection of Learning Examples (LEs) by the project partners. The LEs serve as a foundation for the analysis, offering real-world case studies that have been meticulously studied and analysed by the researchers. This hands-on approach ensures that the dataset is not based on a generic state-of-art, but rather on empirical evidence derived from actual fieldwork and research.

Furthermore, the thorough examination of the selected LEs provides a wealth of in-depth information on the predisposing factors of ground instabilities. By scrutinizing the geological, hydrological, climatic, and anthropogenic parameters of each case study, the researchers gain a comprehensive understanding of the complex processes that contribute to ground instability. This detailed analysis facilitates the identification of cause-and-effect relationships, enhancing the accuracy of the results and conclusions drawn from the dataset.

Despite these strengths, it is important to acknowledge the limitations inherent in the approach. The selection of LEs, while exemplary, is not exhaustive and may not encompass the full spectrum of ground instability scenarios. This incompleteness poses a challenge in making generalized conclusions about the predisposing factors of ground instabilities. Some rare or unique cases may have been excluded, potentially leading to incomplete analyses or biased results.

Addressing this limitation requires a concerted effort to expand the dataset through the involvement of additional skills and the inclusion of more diverse case studies. Collaborations with other partners (through the cascade funding tools) can contribute valuable data from different regions and geological settings. This expansion will improve the dataset's representativeness and enhance the analysis's credibility and reliability.

Another crucial aspect that merits attention is the need for careful consideration of uncertainties in the analysis. Ground instability is a complex and multifaceted phenomenon, influenced by numerous variables and interactions. As a result, there is inherent uncertainty associated with the analysis of predisposing factors. By conducting sensitivity analyses and quantifying uncertainty, researchers can provide a more nuanced and cautious interpretation of the results.

6. Conclusions

In conclusion, the approach used in the WP2 for analysing the predisposing factors of ground instabilities has provided valuable insights into the strengths and weaknesses of the methodology. The exemplary selection of Learning Examples, the thorough examination of the dataset, and the collaborative, multidisciplinary approach have been instrumental in advancing the research. However, the limitations, including the incompleteness of the dataset, the uncertainties in the analysis, and potential biases in the datasets, require attention and improvement.

But in addition to this, which can subsequently be improved through specific actions, including as mentioned the involvement of additional skills and the expansion of the databases (through cascade funding), another aspect appears to be of particular importance.

The adopted collaborative analysis, involving multiple steps of data collection, synthesis, commenting, and further synthesis, exhibited an unforeseen characteristic. In fact, the process displayed a strong inclination to avoid reaching a definitive shared synthesis; instead, it consistently generated new avenues for comparison and re-examined previously discussed points, forming a cyclical pattern. This challenging aspect of identifying shared focal points must be carefully considered in the subsequent phases of developing the Rationales and conceptualizing the Proof of Concept.

Main critical points derived from WP2 research work, and in particular in the detection and classification of potentially threatening ground instabilities, are summarized together with some proposed solutions, in Table 5.

Table 5. Main critical points derived from WP2 research work of January - July 2023 and proposed solutions.

Critical point	***Solution to be implemented***
Lack of marine and underwater LEs for the definition of a comprehensive Rationale for the related predisposing	Dedicated ***cascade funding call*** to recruit new researchers with specific expertise in the marine environment.
Minor representation of liquefaction, subsidence and sinkhole effects with respect to landslide studies and LEs.	***Internal recall*** for LEs devoted to these analyses and eventual ***target search*** for international bibliographic data and processing methods.
Lack of coverage with sufficient LEs for some predisposing factors.	***Internal recall*** for LEs devoted to these analyses and eventual ***target search*** for international bibliographic data and processing methods.
Tendency of the cooperative process not to reach a shared point of synthesis	Establishment of small working groups and move towards adopting top-down approaches

WP2 LEs Sheets (TK1)

The original working documents (WP2 LEs Sheets) have been classified and are available on the VS2 sharing platform (Microsoft Teams). They may be provided as a further appendix at a later stage of the Project.

7. WP2 LEs References

Agnesi, V., Rotigliano, E., Tammaro, U., Cappadonia, C., Conoscenti, C., Obrizzo, F., Di Maggio, C., Luzio, D. & Pingue, F. (2015). GPS monitoring of the Scopello (Sicily, Italy) DGSD phenomenon: Relationships between surficial and deep-seated morphodynamics, Engineering Geology for Society and Territory-Volume 2: Landslide Processes. Springer, pp. 1321-1325.

Berti, M., Bernard, M., Gregoretti, C. & Simoni, A. (2020). Physical interpretation of rainfall thresholds for runoff-generated debris flows. Journal of Geophysical Research: Earth Surface, 125(6): e2019JF005513.

Berti, M., Martina, M., 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).

Bianchini, S., Confuorto, P., Intrieri, E., Sbarra, P., Di Martire, D., Calcaterra, D. and Fanti, R., 2022. Machine learning for sinkhole risk mapping in Guidonia-Bagni di Tivoli plain (Rome), Italy. Geocarto International, 37(27): 16687-16715.

Borgatti, L., Guerra, C., Nesci, O., Romeo, R. W., Veneri, F., Landuzzi, A., Benedetti, G., Marchi, G., & Lucente, C. C. (2015). The 27 February 2014 San Leo landslide (northern Italy). Landslides, 12(2), 387–394. https://doi.org/10.1007/s10346-015-0559-4

Bossi, G., Schenato, L., & Marcato, G. (2017). Structural Health Monitoring of a Road Tunnel Intersecting a Large and Active Landslide. Applied Sciences, 7(12), 1271. https://doi.org/10.3390/app7121271

Bouma, T. J., van Belzen, J., Balke, T., Zhu, Z., Airoldi, L., Blight, A. J., Davies, A. J., Galvan, C., Hawkins, S. J., Hoggart, S. P. G., Lara, J. L., Losada, I. J., Maza, M., Ondiviela, B., Skov, M. W., Strain, E. M., Thompson, R. C., Yang, S., Zanuttigh, B., … Herman, P. M. J. (2014). Identifying knowledge gaps hampering application of intertidal habitats in coastal protection: Opportunities & steps to take. Coastal Engineering, 87, 147–157. https://doi.org/10.1016/j.coastaleng.2013.11.014

Bovolenta, R., Federici, B., Marzocchi, R. & Berardi, R. (2018). A new GIS-based multivariate statistical analysis for landslide susceptibility zoning. In: A.e. al. (Editor), Landslides Engineered Slopes. Experience, Theory Practice, Roma, pp. 511-516.

Bozzano, F., Esposito, C., Franchi, S., Mazzanti, P., Perissin, D., Rocca, A. & Romano, E. (2015). Understanding the subsidence process of a quaternary plain by combining geological and hydrogeological modelling with satellite InSAR data: The Acque Albule Plain case study. Remote Sensing of Environment, 168: 219-238.

Bozzano, F., Esposito, C., Mazzanti, P., Patti, M. & Scancella, S. (2018). Imaging multi-age construction settlement behaviour by advanced SAR interferometry. Remote Sensing, 10(7): 1137.

Bozzano, F., Martino, S. & Priori, M. (2006). Natural and man-induced stress evolution of slopes: the Monte Mario hill in Rome. Environmental Geology, 50: 505-524.

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): Agricultural Terraces and Slope Instability at Cinque Terre (NW Italy). Land Degradation & Development, 29(3), 630–642. https://doi.org/10.1002/ldr.2672

Brenna, A., Marchi, L., Borga, M., Ghinassi, M., Zaramella, M. & Surian, N. (2021). Sediment–water flows in mountain catchments: Insights into transport mechanisms as responses to high-magnitude hydrological events. Journal of Hydrology, 602: 126716.

Brezzi, L., Carraro, E., Pasa, D., Teza, G., Cola, S. & Galgaro, A. (2021). Post-Collapse Evolution of a Rapid Landslide from Sequential Analysis with FE and SPH-Based Models. Geosciences, 11(9): 364.

Cadrobbi, L., D'Anastasio, F., Duranti, D., Falconi, I., Fiore, A., Frumento, S., Garbin, F., Gennari, E., & Gisotti, G. (n.d.). CONSIGLIO DIRETTIVO NAZIONALE.

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 Science, 15(8): 1785-1806.

Cama, M., Lombardo, L., Conoscenti, C. & Rotigliano, E. (2017). Improving transferability strategies for debris flow susceptibility assessment: Application to the Saponara and Itala catchments (Messina, Italy). Geomorphology, 288: 52-65.

Casalbore, D., Passeri, F., Tommasi, P., Verrucci, L., Bosman, A., Romagnoli, C. & Chiocci, F.L. (2020). Small-scale slope instability on the submarine flanks of insular volcanoes: The case-study of the Sciara del Fuoco slope (Stromboli). International Journal of Earth Sciences, 109: 2643-2658.

Ceramicola, S., Praeg, D., Coste, M., Forlin, E., Cova, A., Colizza, E. & Critelli, S. (2014a). Submarine mass-movements along the slopes of the active Ionian continental margins and their consequences for marine geohazards (Mediterranean Sea), Submarine mass movements and their consequences: 6th international symposium. Springer, pp. 295-306.

Ceramicola, S., Tinti, S., Zaniboni, F., Praeg, D., Planinsek, P., Pagnoni, G. & Forlin, E. (2014b). Reconstruction and tsunami modeling of a submarine landslide on the Ionian Margin of Calabria (Mediterranean Sea), Landslide Science for a Safer Geoenvironment: Volume 3: Targeted Landslides. Springer, pp. 557-562.

Cevasco, A., Pepe, G. & Brandolini, P. (2014). The influences of geological and land use settings on shallow landslides triggered by an intense rainfall event in a coastal terraced environment. Bulletin of Engineering Geology the Environment, 73: 859-875.

Chiocci, F.L. & Ridente, D. (2011). Regional-scale seafloor mapping and geohazard assessment. The experience from the Italian project MaGIC (Marine Geohazards along the Italian Coasts). Marine Geophysical Research, 32(1-2): 13-23.

Chiocci, F.L., Romagnoli, C., Tommasi, P. &d Bosman, A. (2008). The Stromboli 2002 tsunamigenic submarine slide: characteristics and possible failure mechanisms. Journal of Geophysical Research: Solid Earth, 113(B10).

Ciuffi, P., Bayer, B., Berti, M., Franceschini, S. & Simoni, A. (2021). Deformation detection in cyclic landslides prior to their reactivation using two-pass satellite interferometry. Applied Sciences, 11(7): 3156.

Colantoni, P., Gennesseaux, M., Vanney, J., Ulzega, A., Melegari, G. & Trombetta, A. (1992). Processi Dinamici Del Canyon Sottomarino de Gioia Tauro (Mare Tirreno). Giornale di Geologia.

Colombero, C., Baillet, L., Comina, C., Jongmans, D. & Vinciguerra, S. (2017). Characterization of the 3-D fracture setting of an unstable rock mass: From surface and seismic investigations to numerical modeling. Journal of Geophysical Research: Solid Earth, 122(8): 6346-6366.

Colombero, C., Comina, C., Umili, G. & Vinciguerra, S. (2016). Multiscale geophysical characterization of an unstable rock mass. Tectonophysics, 675: 275-289.

Colombero, C., Godio, A., & Jongmans, D. (2021). Ambient Seismic Noise and Microseismicity Monitoring of a Prone-To-Fall Quartzite Tower (Ormea, NW Italy). Remote Sensing, 13(9), 1664. https://doi.org/10.3390/rs13091664

Confuorto, P., Del Soldato, M., Solari, L., Festa, D., Bianchini, S., Raspini, F. & Casagli, N. (2021). Sentinel-1-based monitoring services at regional scale in Italy: State of the art and main findings. International Journal of Applied Earth Observation Geoinformation, 102: 102448.

Corradino, M., Morelli, D., Ceramicola, S., Scarfì, L., Barberi, G., Monaco, C. & Pepe, F. (2023). Active tectonics in the Calabrian Arc: Insights from the Late Miocene to Recent structural evolution of the Squillace Basin (offshore eastern Calabria). Tectonophysics, 851: 229772.

D'Angiò, D., Fantini, A., Fiorucci, M., Iannucci, R., Lenti, L., Marmoni, G. M., & Martino, S. (2021). Environmental forcings and micro-seismic monitoring in a rock wall prone to fall during the 2018 Buran winter storm. Natural Hazards, 106(3), 2599–2617. https://doi.org/10.1007/s11069-021-04556-5

D'Effremo, M., Desideri, A., Martínez, M.G., Gottardi, G., Ricceri, G., Selleri, A., Simonini, P. & Torsello, P. (2018). Analysis and monitoring of a tunnelling-induced deep landslide reactivation, Landslides and Engineered Slopes. Experience, Theory and Practice. CRC Press, pp. 735-742.

de Magistris, F.S., Lanzano, G., Forte, G. & Fabbrocino, G. (2013). A database for PGA threshold in liquefaction occurrence. Soil Dynamics Earthquake Engineering, 54: 17-19.

De Vita, P., Carratù, M.T., La Barbera, G. a&nd Santoro, S. (2013). Kinematics and geological constraints of the slow-moving Pisciotta rock slide (southern Italy). Geomorphology, 201: 415-429.

De Vita, P., Di Clemente, E., Rolandi, M. & Celico, P. (2007). Engineering geological models of the initial landslides occurred on the April 30th, 2006, at the Mount Di Vezzi (Ischia Island, Italy). Italian Journal of Engineering Geology Environment (2): 119-141.

Delchiaro, M., Della Seta, M., Martino, S., Dehbozorgi, M., & Nozaem, R. (2019). Reconstruction of river valley evolution before and after the emplacement of the giant Seymareh rock avalanche (Zagros Mts., Iran). Earth Surface Dynamics, 7(4), 929–947. https://doi.org/10.5194/esurf-7-929-2019

Delchiaro, M., Della Seta, M., Martino, S., Nozaem, R., & Moumeni, M. (2023). Tectonic deformation and landscape evolution inducing mass rock creep driven landslides: The Loumar case-study (Zagros Fold and Thrust Belt, Iran). Tectonophysics, 846, 229655. https://doi.org/10.1016/j.tecto.2022.229655

Del Prete, S. & Mele, R. (2006). Il contributo delle informazioni storiche per la valutazione della propensione al dissesto nell'Isola d'Ischia (Campania). Rendiconti Società Geologica Italiana, 2: 29-47.

Della Seta, M., Martino, S. & Mugnozza, G.S. (2013). Quaternary sea-level change and slope instability in coastal areas: Insights from the Vasto Landslide (Adriatic coast, central Italy). Geomorphology, 201: 462-478.

Desideri, A. (2021). Gallerie e movimenti di versante. Rivista Italiana di Geotecnica, 1: 5-41.

Di Maio, R., De Paola, C., Forte, G., Piegari, E., Pirone, M., Santo, A. & Urciuoli, G. (2020). An integrated geological, geotechnical and geophysical approach to identify predisposing factors for flowslide occurrence. Engineering Geology, 267: 105473.

Di Martire, D., De Rosa, M., Pesce, V., Santangelo, M.A. & Calcaterra, D. (2012). Landslide hazard and land management in high-density urban areas of Campania region, Italy. Natural Hazards Earth System Sciences, 12(4): 905-926.

Di Martire, D., Novellino, A., Ramondini, M. & Calcaterra, D. (2016). A-differential synthetic aperture radar interferometry analysis of a deep seated gravitational slope deformation occurring at Bisaccia (Italy). Science of the Total Environment, 550: 556-573.

Di Napoli, M., Marsiglia, P., Di Martire, D., Ramondini, M., Ullo, S.L. & Calcaterra, D. (2020). Landslide susceptibility assessment of wildfire burnt areas through earth-observation techniques and a machine learning-based approach. Remote Sensing, 12(15): 2505.

Donati, D., Stead, D., Elmo, D., & Borgatti, L. (2019). A Preliminary Investigation on the Role of Brittle Fracture in the Kinematics of the 2014 San Leo Landslide. Geosciences, 9(6), 256. https://doi.org/10.3390/geosciences9060256

Esposito, C., Belcecchi, N., Bozzano, F., Brunetti, A., Marmoni, G.M., Mazzanti, P., Romeo, S., Cammillozzi, F., Cecchini, G. & Spizzirri, M., (2021a). 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.

Esposito, C., Di Luzio, E., Baleani, M., Troiani, F., Della Seta, M., Bozzano, F. & Mazzanti, P. (2021b). Fold architecture predisposing deep-seated gravitational slope deformations within a flysch sequence in the Northern Apennines (Italy). Geomorphology, 380: 107629.

Evangelista, L. & Santucci de Magistris, F. (2011). Upgrading the simplified assessment of the liquefaction susceptibility for the city of naples, Italy, 5th International Conference on Earthquake Geotechnical Engineering, Santiago, Chile, pp. 13.

Fazio, N., Perrotti, M., Andriani, G., Mancini, F., Rossi, P., Castagnetti, C. & Lollino, P. (2019). A new methodological approach to assess the stability of discontinuous rocky cliffs using in-situ surveys supported by UAV-based techniques and 3-D finite element model: a case study. Engineering Geology, 260: 105205.

Fiaschi, S., Fabris, M., Floris, M. & Achilli, V. (2018). Estimation of land subsidence in deltaic areas through differential SAR interferometry: The Po River Delta case study (Northeast Italy). International Journal of Remote Sensing, 39(23): 8724-8745.

Flora, A., Bilotta, E., Chiaradonna, A., Lirer, S., Mele, L. & Pingue, L. (2021). A field trial to test the efficiency of induced partial saturation and horizontal drains to mitigate the susceptibility of soils to liquefaction. Bulletin of Earthquake Engineering, 19: 3835-3864.

Florida Geological Survey & Tetra Tech, Inc. (2020). [No title found]. In National Cave and Karst Research Institute, L. Land, C. Kromhout, & M. Byle (Eds.), Proceedings Of The 16th Multidisciplinary Conference On Sinkholes And The Engineering And Environmental Impacts Of Karst. National Cave and Karst Research Institute.

Floris, M., Fontana, A., Tessari, G. & Mulè, M. (2019). Subsidence zonation through satellite interferometry in coastal plain environments of NE Italy: a possible tool for geological and geomorphological mapping in urban areas. Remote Sensing, 11(2): 165.

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: 105137.

Forte, G., Verrucci, L., Di Giulio, A., De Falco, M., Tommasi, P., Lanzo, G., Franke, K.W. & Santo, A. (2021). Analysis of major rock slides that occurred during the 2016–2017 Central Italy seismic sequence. Engineering Geology, 290: 106194.

Gargiulo, F., d’Onofrio, A. & Silvestri, F. (2021). Approccio multi-livello per le verifiche a liquefazione: un'applicazione all'Isola di Ischia, Incontro annuale dei Ricercatori di Geotecnica 2021.

Giacomelli, S., Zuccarini, A., Amorosi, A., Bruno, L., Di Paola, G., Severi, P., Martini, A. & Berti, M. (under review). 3d Geological Modelling of the Bologna Urban Area (Italy).

Guadagno, F. & Mele, R. (1995). La fragile isola d’Ischia. Geologia Applicata e Idrogeologia, 30(1): 177-187.

Guarino, P.M., Santo, A., Forte, G., De Falco, M. & Niceforo, D.M.A. (2018). Analysis of a database for anthropogenic sinkhole triggering and zonation in the Naples hinterland (Southern Italy). Natural Hazards, 91: 173-192.

Guerriero, L., Confuorto, P., Calcaterra, D., Guadagno, F.M., Revellino, P. & Di Martire, D. (2019). PS-driven inventory of town-damaging landslides in the Benevento, Avellino and Salerno Provinces, southern Italy. Journal of Maps, 15(2): 619-625.

La Salandra, M., Roseto, R., Mele, D., Dellino, P. & Capolongo, D. (2022). Probabilistic hydro-geomorphological hazard assessment based on UAV-derived high-resolution topographic data: The case of Basento river (Southern Italy). Science of The Total Environment, 842: 156736.

Lazzari, M., Piccarreta, M., Capolongo, D. (2013). Landslide Triggering and Local Rainfall Thresholds in Bradanic Foredeep, Basilicata Region (Southern Italy). In: Margottini, C., Canuti, P., Sassa, K. (eds) Landslide Science and Practice. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-31445-2_88

Lo Iacono, C., Sulli, A., Agate, M., Lo Presti, V., Pepe, F. & Catalano, R. (2011). Submarine canyon morphologies in the Gulf of Palermo (Southern Tyrrhenian Sea) and possible implications for geo-hazard. Marine Geophysical Research, 32: 127-138.

Lollino, P., Pagliarulo, R., Trizzino, R., Santaloia, F., Pisano, L., Zumpano, V., Perrotti, M. & Fazio, N.L. (2021). Multi-scale approach to analyse the evolution of soft rock coastal cliffs and role of controlling factors: A case study in south-eastern Italy. Geomatics, Natural Hazards and Risk, 12(1): 1058-1081.

Lollino, P., Santaloia, F., Amorosi, A. & Cotecchia, F. (2011). Delayed failure of quarry slopes in stiff clays: the case of the Lucera landslide. Géotechnique, 61(10): 861-874.

Mangano, G., Zecchin, M., Civile, D., Ceramicola, S., Donato, A., Muto, F., Tripodi, V. & Critelli, S. (2022). Mid-miocene to recent tectonic evolution of the punta stilo swell (calabrian arc, southern Italy): an effect of calabrian arc migration. Marine Geology, 448: 106810.

Margiotta, S., Marini, G., Fay, S., D'Onghia, F.M., Liso, I.S., Parise, M. & Pinna, M. (2021). Hydro-stratigraphic conditions and human activity leading to development of a sinkhole cluster in a Mediterranean water ecosystem. Hydrology, 8(3): 111.

Marmoni, G. M., Fiorucci, M., Grechi, G., & Martino, S. (2020). Modelling of thermo-mechanical effects in a rock quarry wall induced by near-surface temperature fluctuations. International Journal of Rock Mechanics and Mining Sciences, 134, 104440. https://doi.org/10.1016/j.ijrmms.2020.104440

Martinello, C., Cappadonia, C., Conoscenti, C., Agnesi, V. & Rotigliano, E. (2021). Optimal slope units partitioning in landslide susceptibility mapping. Journal of Maps, 17(3): 152-162.

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: 1-15.

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. https://doi.org/10.1038/s41598-022-06508-w

Meena, S.R., Puliero, S., Bhuyan, K., Floris, M. & Catani, F. (2022). Assessing the importance of conditioning factor selection in landslide susceptibility for the province of Belluno (region of Veneto, northeastern Italy). Natural Hazards and Earth System Science, 22(4): 1395-1417.

Mele, R. & Del Prete, S. (1998). Fenomeni di instabilita dei versanti in Tufo Verde del Monte Epomeo (isola d'Ischia, Campania). Bollettino della Società geologica italiana, 117(1): 93-112.

Miele, P., Di Napoli, M., Novellino, A., Calcaterra, D., Mallorqui, J.J. & Di Martire, D. (2022). SAR data and field surveys combination to update rainfall-induced shallow landslide inventory. Remote Sensing Applications: Society Environment, 26: 100755.

Migliazza, M., Carriero, M.T., Lingua, A., Pontoglio, E. & Scavia, C. (2021). Rock mass characterization by UAV and close-range photogrammetry: a multiscale approach applied along the Vallone dell'Elva Road (Italy). Geosciences, 11(11): 436.

Modoni, G., Darini, G., Spacagna, R.L., Saroli, M., Russo, G. & Croce, P. (2013). Spatial analysis of land subsidence induced by groundwater withdrawal. Engineering geology, 167: 59-71.

Monti, L., D'Elia, G. & Toccaceli, R., Analisi del dissesto da frana in Campania.

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, pp. 2113-2117.

Occhiena, C., & Pirulli, M. (2012). Analysis of Climatic Influences on Slope Microseismic Activity and Rockfalls: Case Study of the Matterhorn Peak (Northwestern Alps). Journal of Geotechnical and Geoenvironmental Engineering, 138(8), 1012–1021. https://doi.org/10.1061/(ASCE)GT.1943-5606.0000662

Occhiena, C., Pirulli, M., & Scavia, C. (2014). A microseismic-based procedure for the detection of rock slope instabilities. International Journal of Rock Mechanics and Mining Sciences, 69, 67–79. https://doi.org/10.1016/j.ijrmms.2014.02.020

Parise, M., Federico, A. & Palladino, G. (2012). Historical evolution of multi-source mudslides, Landslides and Engineered Slopes. Protecting Society through Improved Understanding, edited by: Eberhardt, E., Froese, C., Turner, AK, and Lerouil, S., Proceedings 11th Int. Symp. Landslides, Banff (Canada), pp. 3-8.

Parise, M. & Vennari, C. (2017). Distribution and features of natural and anthropogenic sinkholes in Apulia. In: P. Renard and C. Bertrand (Editors), EuroKarst 2016, Neuchâtel: Advances in the Hydrogeology of Karst and Carbonate Reservoirs. Springer, pp. 27-34.

Pennino, V., Sulli, A., Caracausi, A., Grassa, F. & Interbartolo, F. (2014). Fluid escape structures in the north Sicily continental margin. Marine and Petroleum Geology, 55: 202-213.

Pepe, P., Pentimone, N., Garziano, G., Martimucci, V. & Parise, M. (2013). Lessons learned from occurrence of sinkholes related to man-made cavities in a town of southern Italy. In: D.H.D. Lewis Land, and J. Brad Stephenson (Editor), 13th Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts of Karst.

Piacentini, D., Troiani, F., Daniele, G. & Pizziolo, M. (2018). Historical geospatial database for landslide analysis: the Catalogue of Landslide OCcurrences in the Emilia-Romagna Region (CLOCkER). Landslides, 15(4): 811-822.

Pignalosa, A., Forte, G., Budetta, P. & Santo, A. (2022). Topographic amplification and debris remobilization as a cause for increasing rockfall hazard in seismic areas: A case study in Central Italy. Geomorphology, 403: 108160.

Pirone, M., Di Maio, R., Forte, G., De Paola, C., Di Marino, E., Salone, R., Santo, A., & Urciuoli, G. (2023). Study of the groundwater regime in unsaturated slopes prone to landslides by multidisciplinary investigations: Experimental study and numerical modelling. Engineering Geology, 315, 107045. https://doi.org/10.1016/j.enggeo.2023.107045

Pontoglio, E., Colucci, E., Lingua, A., Maschio, P., Migliazza, M. & Scavia, C. (2020). UAV and close-range photogrammetry to support geo-mechanical analysis in safety road management: The "vallone d'elva" road, The International Archives of the Photogrammetry, Remote Sensing Spatial Information Sciences, pp. 1159-1166.

Puglisi, C., Falconi, L., Gioè, C. & Leoni, G. (2015). Contribution to the runout evaluation of potential debris flows in Peloritani Mountains (Messina, Italy), Engineering Geology for Society and Territory-Volume 2: Landslide Processes. Springer, pp. 509-513.

Raimondi, L., Pepe, G., Firpo, M., Calcaterra, D. & Cevasco, A. (2023). An open-source and QGIS-integrated physically based model for Spatial Prediction of Rainfall-Induced Shallow Landslides (SPRIn-SL). Environmental Modelling Software, 160: 105587.

Refice, A., Partipilo, L., Bovenga, F., Lovergine, F., Nutricato, R., Nitti, D. & Capolongo, D. (2022). Remotely Sensed Detection of Badland Erosion Using Multitemporal InSAR, IGARSS 2022-2022 IEEE International Geoscience and Remote Sensing Symposium. IEEE, pp. 5989-5992.

Renard, P., & Bertrand, C. (Eds.). (2017). EuroKarst 2016, Neuchâtel: Advances in the Hydrogeology of Karst and Carbonate Reservoirs. Springer International Publishing. https://doi.org/10.1007/978-3-319-45465-8

Romeo, S., Cosentino, A., Giani, F., Mastrantoni, G. & Mazzanti, P., (2021). Combining ground based remote sensing tools for rockfalls assessment and monitoring: The Poggio Baldi Landslide Natural Laboratory. Sensors, 21(8): 2632.

Ronchi, L., Fontana, A., Cohen, K.M. & Stouthamer, E. (2021). Late Quaternary landscape evolution of the buried incised valley of Concordia Sagittaria (Tagliamento River, NE Italy): A reconstruction of incision and transgression. Geomorphology, 373: 107509.

Rosi, A., Tofani, V., Agostini, A., Tanteri, L., Tacconi Stefanelli, C., Catani, F. & Casagli, N. (2016). Subsidence mapping at regional scale using persistent scatters interferometry (PSI): The case of Tuscany region (Italy). International journal of applied earth observation geoinformation, 52: 328-337.

Rosi, A., Tofani, V., Tanteri, L., Tacconi Stefanelli, C., Agostini, A., Catani, F. & Casagli, N. (2018). The new landslide inventory of Tuscany (Italy) updated with PS-InSAR: geomorphological features and landslide distribution. Landslides, 15: 5-19.

Rosone, M., Ziccarelli, M., & Ferrari, A. (2020). Displacement Evolution of a Large Landslide in a Highly Fissured Clay. In F. Calvetti, F. Cotecchia, A. Galli, & C. Jommi (Eds.), Geotechnical Research for Land Protection and Development (Vol. 40, pp. 195–204). Springer International Publishing. https://doi.org/10.1007/978-3-030-21359-6_21

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. https://doi.org/10.1016/j.enggeo.2018.01.016

Salvatici, T., Tofani, V., Rossi, G., D'Ambrosio, M., Tacconi Stefanelli, C., Masi, E.B., Rosi, A., Pazzi, V., Vannocci, P. & Petrolo, M. (2018). Application of a physically based model to forecast shallow landslides at a regional scale. Natural Hazards Earth System Sciences, 18(7): 1919-1935.

Sansò, P., Gianfreda, F., Leucci, G. & Mastronuzzi, G. (2016). Cliff evolution and late Holocene relative sea level change along the Otranto coast (Salento peninsula, southern Apulia, Italy). GeoResJ, 9: 42-53.

Santucci de Magistris, F., Lanzano, G., Forte, G. & Fabbrocino, G. (2014). A peak acceleration threshold for soil liquefaction: lessons learned from the 2012 Emilia earthquake (Italy). Natural hazards, 74: 1069-1094.

Scardino, G., Anzidei, M., Petio, P., Serpelloni, E., De Santis, V., Rizzo, A., Liso, S.I., Zingaro, M., Capolongo, D. & Vecchio, A. (2022). The Impact of Future Sea-Level Rise on Low-Lying Subsiding Coasts: A Case Study of Tavoliere Delle Puglie (Southern Italy). Remote Sensing, 14(19): 4936.

Scardino, G., Sabatier, F., Scicchitano, G., Piscitelli, A., Milella, M., Vecchio, A., Anzidei, M. & Mastronuzzi, G. (2020). Sea-level rise and shoreline changes along an open sandy coast: Case study of gulf of Taranto, Italy. Water, 12(5): 1414.

Scotto di Santolo, A., Forte, G. & Santo, A. (2018). Analysis of sinkhole triggering mechanisms in the hinterland of Naples (Southern Italy). Engineering geology, 237: 42-52.

Silvestri, F., Aiello, V., Barile, A., Costanzo, A., Puglia, R., Pescatore, T.S., Lo Russo, E., Pinto, F. & Tornesello, D. (2006). Analisi e zonazione della stabilità dei pendii in condizioni sismiche: applicazioni di metodi tradizionali ed avanzati ad un'area di studio. Questioni di Ingegneria Geotecnica–Scritti in onore di Arturo Pellegrino, 2: 617-660.

Simoni, A., Bernard, M., Berti, M., Boreggio, M., Lanzoni, S., Stancanelli, L.M. & Gregoretti, C. (2020). Runoff-generated debris flows: Observation of initiation conditions and erosion–deposition dynamics along the channel at Cancia (eastern Italian Alps). Earth Surface Processes and Landforms, 45(14): 3556-3571.

Spalluto, L., Fiore, A., Miccoli, M.N. & Parise, M. (2021). Activity maps of multi-source mudslides from the Daunia Apennines (Apulia, southern Italy). Natural Hazards, 106(1): 277-301.

Sulli, A., Agate, M., Zizzo, E., Gasparo Morticelli, M., & Lo Iacono, C. (2021). Geo-hazards of the San Vito peninsula offshore (southwestern Tyrrhenian Sea). Journal of Maps, 17(3), 185–196. https://doi.org/10.1080/17445647.2020.1866703

Surian, N., Righini, M., Lucía, A., Nardi, L., Amponsah, W., Benvenuti, M., Borga, M., Cavalli, M., Comiti, F. & Marchi, L. (2016). Channel response to extreme floods: insights on controlling factors from six mountain rivers in northern Apennines, Italy. Geomorphology, 272: 78-91.

Tacconi Stefanelli, C., Casagli, N. a&nd Catani, F. (2020). Landslide damming hazard susceptibility maps: a new GIS-based procedure for risk management. Landslides, 17: 1635-1648.

Tacconi Stefanelli, C., Segoni, S., Casagli, N. & Catani, F. (2016). Geomorphic indexing of landslide dams evolution. Engineering Geology, 208: 1-10.

Teatini, P., Tosi, L. & Strozzi, T. (2011). Quantitative evidence that compaction of Holocene sediments drives the present land subsidence of the Po Delta, Italy. Journal of Geophysical Research: Solid Earth, 116(B8).

Tinti, S., Pagnoni, G., & Zaniboni, F. (2006). The landslides and tsunamis of the 30th of December 2002 in Stromboli analysed through numerical simulations. Bulletin of Volcanology, 68(5), 462–479. https://doi.org/10.1007/s00445-005-0022-9

Tonni, L., Gottardi, G., Amoroso, S., Bardotti, R., Bonzi, L., Chiaradonna, A., D'Onofrio, A., Fioravante, V., Ghinelli, A. & Giretti, D. (2015). Analisi dei fenomeni deformativi indotti dalla sequenza sismica emiliana del 2012 su un tratto di argine del Canale Diversivo di Burana (FE). Rivista Italiana di Geotecnica, 49(2): 28-58.

Tufano, R., Guerriero, L., Annibali Corona, M., Bausilio, G., Di Martire, D., Nisio, S. & Calcaterra, D. (2022). Anthropogenic sinkholes of the city of Naples, Italy: An update. Natural Hazards, 112(3): 2577-2608.

Vennari, C., Salvati, P., Bianchi, C., Casarano, D., Parise, M., Basso, A. & Marchesini, I. (2022). AReGeoDatHa: Apulian Regional GeoDatabase for geo-hydrological Hazards. Journal of Environmental Management, 322: 116051.

Zaniboni, F., Armigliato, A., Pagnoni, G. & Tinti, S. (2014). Continental margins as a source of tsunami hazard: the 1977 Gioia Tauro (Italy) landslide–tsunami investigated through numerical modeling. Marine Geology, 357: 210-217.

Zanuttigh, B., Simcic, D., Bagli, S., Bozzeda, F., Pietrantoni, L., Zagonari, F., Hoggart, S., & Nicholls, R. J. (2014). THESEUS decision support system for coastal risk management. Coastal Engineering, 87, 218–239. https://doi.org/10.1016/j.coastaleng.2013.11.013

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(9): 3526.

Zumpano, V., Ardizzone, F., Basso, A., Bucci, F., Cardinali, M., Fiorucci, F., Parise, M., Pisano, L., Reichenbach, P., Santangelo, M., Wasoski, J. & Lollino, P. (2020). Spatio-temporal analysis of landslides in the Daunia Apennine (Apulia, SE Italy). Example from Motta Montecorvino, Geologia dell'Ambiente.