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"The Young researchers' contribution to the geomorphological community"

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Mapping urban landslides and ground deformations with MT-InSAR techniques

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Landslides are one of the major natural hazards that hampers the development of the urbanized area and significantly contribute to land degradation in many regions. Iași Municipality is one of the landslide hot spots in Romania that constantly faces problems due to landslide reactivations and slope-related active deformations. Their importance is also recognized by the local authorities who delineated the landslide hazard zonation within the Municipality of Iași. Hence, an updated database of active landslides is necessary to manage the areas and implement sustainable policies properly.

In our study, we aim to identify the active deformations of landslides within the Iași Municipality, which might interfere with the expected development plans. To do that, we are employing Multi-temporal Differential SAR Interferometry techniques (MT-InSAR) capable of detecting the displacement velocities with millimeter accuracy using microwave signals. These techniques use sets of SAR images acquired for a given timespan with specific parameters and geometry to calculate the difference in distance between the satellite's antenna and the ground object.

In terms of results, we used the displacement velocity maps obtained through processing Sentinel-1 SAR images from 2014 to 2018 to identify the landslide-related deformations. Moreover, our results are validated by the recently available products provided by the European Ground Motion Service which also extend our analysis analysis up to 2020. Based on the results of both orbits, we identified the landslide hot-spots within the city and classified their activity state based on the international velocity classification, many of them being very slow-moving landslides with velocities higher than 16 mm/year.

Scientific Sessions

Regional scale coastal erosion vulnerability assessment: application to the Sicilian coastline

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The coastal vulnerability relies on people and places susceptible to perturbations resulting from coastal flooding, coastal storm and erosion phenomena. In this study, coastal vulnerability focuses entirely on erosion related to physical impacts without considering either coastal inundation or socio-economic impacts.
In particular, a modified version of the Coastal Vulnerability Index approach was applied. In this approach, a set of complex and interacting variables, expected to drive system processes, was selected and reclassified, assigning a score to each class based on expected incidence. The sum or combination of the scores gives the final CVI.
The variables selected were Geomorphology and Geology, Slope, Sea storms, Average Annual Maxima Energy Flux and, finally, the estimates of Sediment Supply obtained from applying the WaTEM-SEDEM model.
After segmenting the Sicilian coast by cross profiles (CP) and once a vulnerability class for each variable was assigned to the cross profiles, the overall Coastal erosion Vulnerability Index (CVI) was computed and reclassified into its four quartiles from 1-low vulnerability to 4- very high vulnerability.
Comparing the coastal variation signal to the obtained CVI, one of the first examples of experimental validation on a CVI model was performed. A constant shift towards retreatment conditions for CP classified as more vulnerable (III-IV) was obtained, suggesting a good response to the adopted strategy. At the same time, a comparison between models including and excluding the WATEM parameter was performed to check the role of the sediment factor. It was observed how using the WATEM variable in the model improves the ability to discriminate classes I - II but makes the model less capable of splitting classes III from IV. The obtained CVI results produced a picture coherent with the observed coastline variation record.

Reconstructing the evolution of a post-Little Ice Age deglaciated alpine valley through the DEM of Difference technique

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Since the termination of the Little Ice Age (LIA, ca. 1830), the accelerated glaciers' shrinkage along mid-latitude high mountain areas promoted a quick readjustment of geomorphological processes. For that reason, proglacial areas are among the most sensitive to climate change landscapes on Earth. A potential useful remote-sensing method for investigating such dynamic areas is the DEM (Digital Elevation Model) of Difference techniques (DoD), which quantify volumetric changes of a territory between successive topographic surveys. We have applied this method, coupled with a detailed geomorphological analysis and comparison with historical maps, for reconstructing post-LIA deglaciation dynamic and the onset of fresh paraglacial processes along the Martello Valley (Stelvio National Park, Central Italian Alps). The head of this valley is still glacierized with three main ice bodies resulting from the huge reduction of the glacier present at the apogee of the LIA; aftermath glaciers losed the 60% of the initial surface area and consequently largely modifying the landscape and expanding the surface of the proglacial areas. The DoD analysis of 2006-2015 timeframe highlights deep surface elevation changes ranging from +38m along the foot of rock walls, where gravitative processes are more active, and -47m where the melting of buried ice caused collapses of the proglacial surface. This approach permits estimating the volume of sediments mobilized and reworked by all paraglacial processes. Here, in less than 10 years, ca. 23675 m^3 of sediment were removed along the proglacial area and transported down valley highlighting the dynamicity of proglacial areas.

Mapping the spatial-temporal vegetation response to droughts in northern Italy

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Drought is the most important consequences of climatic change for natural and socioeconomic systems. Northern Italy is historically rich in water resources, and one of the most fertile area. Recently drought events increased, affecting the hydrological behaviour of the Po River and the vegetation growth.

This study aims to quantify the spatial distributions of the drought events and identify its effects on vegetation greenness in northern Italy during the 2000-2020 period using MODIS images at 1 km of spatial resolution. For this purpose, correlation maps between fields of bi-weekly vegetation indices and drought indices were computed.

Firstly, the NDVI and EVI indices, were extracted from the atmospherically corrected MODIS images and vegetation trends were investigated by mean on the Mann-Kendall test. To investigate on drought events, 150 daily precipitation ground series were collected, aggregated at bi-weekly scale, reconstructed, homogenised and spatialised at 1km of resolution by mean of the Universal Kriging with auxiliary variables. Lands Surface Temperature (LST), assumed as air temperature, was collected, pixels with clouds were removed, and its accuracy was determined against the temperature high resolution gridded dataset in northern Italy. The NDVI-LST space was investigated as the yearly investigation of the link between NDVI and LST for 6000 random points in the study area. The evapotranspiration was than estimated by means of the Hargreaves equation and severe and extreme drought episodes were detected by means of drought indices (SPI and SPEI) calculated at 12-, 24- and 36-months. Trends were analysed, and the main drought events were characterised, identifying percentage of area under drought, magnitude, length and frequencies. Finally, each pixel was analysed spatially to investigate on the impacts of severe and extreme drought events on vegetation dynamics, and the Pearson's correlation between NDVI/EVI and SPEI/SPI at different time scales was calculated.

Geomorphological and glaciological research at the Belvedere Glacier (Mt. Rosa Massif): a 4EU+ Alliance project

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The impact of climate change on glaciers and the entire cryosphere has been studied for decades. In the European Alps, the records and observations date back for centuries, which offers the chance to enroot the up-to-date research into a thorough background. Our research project is carried out under the auspices of the 4EU+ Alliance, that requires the combination of research and education. For the study area, we selected the Belvedere Glacier fed by frequent ice, rock and snow-avalanches, located at the foot of the famous northeastern face of Mt. Rosa, as the watershed enables the application of a variety of methods. The poster will be primarily focused on the variety of methods we employed as we commenced the project fieldwork only in summer 2021.

There are two broader research lines: geomorphological mapping and study of climate-related glacier dynamics. The pivotal area of geomorphological mapping includes the tongue of the Belvedere Glacier with its lateral moraines, the terminal moraine of the Locce Glacier damming the homonymous lake, and the sections of the valley originally eroded by Belvedere Glacier during the Last Glacial Maximum. The mapping itself started in 2021 and was supported, in 2022, by dendrogeomorphological samplings and Schmidt hammer measurements. The results have already elucidated some of the recent processes that shape the local relief.

The UAV scanning flights above the glacier with consequent DEM generation will be used for the assessment of glacier dynamics. The flights were realized both in 2021 and 2022 and scanned most of the tongue (the 2022 data cover the entire extent). Thanks to archival photographs and paintings, it was possible to employ the repeated photography and expand the study period beyond the instrument era. The preliminary data inspection confirmed the consequences of the remarkably dry winter and warm first half of 2022.

On the evolutionary patterns of the large river deltas. Examples from Danube delta and other deltaic systems

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Large river deltas are considered to be among the most dynamic and complex natural systems, with a complicated evolution which explain the relative small number of deltas which formation has been fully understood and reconstructed. However, deltas evolution is governed by a series of laws and patterns starting from their formation to the present. The aim of this study is to define the specific growth models of the Danube Delta and to discuss them in association with the other deltas of the world which share similar patterns of evolution. Thus, 7 evolutionary patterns have been identified in the Danube Delta as follows: (i) starting the deltaic units formation (as a bayhead delta around 7500 BP) before the sea-level stabilization, (ii) the preference of delta development into the deeper sectors (of the Danube bay), (iii) the river mouths of the open-coast lobes get a policyclic evolution, (iv) open-coast lobes are asymmetric and share the same evolution, (v) deltaic lobes have large (multi-secular) periods of decay despite the short-time triggering events (i.e. avulsions, sediment reduction), (vi) neotectonic subsidence reshaped the southern delta, (vii) the land-use controls the sediments discharge and impose the rhythms of delta development. Although each delta has its own particularities, certain patterns that are found in the evolution of the Danube Delta have also been found in other deltas, apparently different from the morphological point of view. The specific cases of the large Asian deltas (e.g.: Pearl River, Mekong, Godavari, Krishna, Red River) and many other from around the world (Mississippi, Rhone, Po, Kuban, Rioni) are discussed in relation with different evolutionary patterns identified for Danube. A special attention is paid to the role of human influence (via deforestation, agricultural practices, river damming and channeling) on delta formation and evolution during different historical periods, from Neolithic to modern times.

Hydrological modelling in an intensively used agricultural flat area

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The area of the Ticino valley, in Lombardy region, is an agricultural area characterized by a traditional water resources management system unique in the world. The study area between Abbiategrasso and Pavia sited in the southwest of Milan is consisting in different river terrace levels. The infiltrating water on the uppermost terrace level is subsequently charging springs at the base of the terrace escarpments. The spring water in turn is reused for irrigation on the lowest terrace levels. This way, the system is guaranteeing a sustainable and effective reuse of the irrigation water. Regarding the geomorphology, the terrace areas are flat, except for the escarpments of the river terraces, a consequence of the erosive activity of the Ticino River. There are two orders of terraces with a parallel direction, separated by slopes with moderate inclination, and as mentioned characterized by springs at their base.
The objective of this work is to assess the hydrological dynamics of this unique area applying, calibrating, and validating the hydrological model SWAT (Soil Water Assessment Tool).
During the model set up, the subbasins were delineated based on geomorphological units (river terrace levels), and the sub-basins were divided into 167 HRUs (Hydrological Response Units). For calibration, we apply the SWAT-CUP module using satellite evapotranspiration (ET) data. We chose the Sequential Uncertainty Fitting (SUFI) method for parameter fitting, and the Kling-Gupta efficiency (KGE) as objective function to assess the performance of the model.
First results show that our unique SWAT setup can simulate the general hydrological dynamics with a good correlation between simulated and observed data, despite the complexity of the area. Validation results are promising that the model can be used for water resources assessments, which are urgently needed in this agricultural area, which was strongly hit by this year's drought.

Geomorphological and structural assessment of the coastal area of Capo Faro Promontory, NE Salina (Aeolian Islands, Italy)

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Capo Faro Promontory, located in Salina (Aeolian Islands, southern Italy), is a popular summer destination due to its volcanic morphologies, seaside, and enogastronomy. A flat area, right behind the scarp edge of a coastal cliff, hosts the Capo Faro Estate, one of the most renowned vineyards and residences on Salina Island. The promontory has been characterised in terms of geomorphological features. Remote sensing analysis, after nadir and off–nadir UAV flights, supports the field activities to explore the hazard to which the area is subjected. In particular, the coastal cliff turns out to be affected by a rapid retreat inducing landslides. Therefore, the cliff area has been investigated through a detailed stratigraphic and structural field survey. Using the generated high–resolution Digital Elevation Model, bathymetric–topographic profiles were extracted along the coastline facing the cliff. The thickness of volcanic deposits was evaluated to obtain a geological model of it. The main rock mass discontinuities have been characterised to define the structural features affecting the stability of the rock wall. The obtained results prove the contribution of such research fundamental in planning risk mitigation measures.

Debris floods and geomorphic response in mountain rivers during high-magnitude hydrological events

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Sediment transfer in mountain streams occurs via processes classified as debris flows, debris floods, and water flows under the control of the water energy and the amount of involved sediment. Debris floods are water-driven flood flows with high bedload transport, during which a streambed may be destabilized causing massive movement of sediment.
We developed a post-flood survey protocol for distinguishing various flow types on the basis of the geomorphological and sedimentological features of flood deposits. This protocol was applied in the Tegnas catchment (Cordevole basin, Italian Dolomites) to determine the transport processes activated in 2018 by the severe Vaia storm. The analysis of different flow types enabled us to gain new insights on the poorly explored debris flood processes, which were documented at several sub-reaches of the Tegnas Torrent. The upheaval from ordinary water flows to debris floods appeared to be promoted by the presence of tributaries prone to debris flow occurrence connected to a receiving stream and channel sites characterized by high slope and narrow section, where the unit stream power exceeded about 5000 Wm^{-2}.
We then expanded the study area considering five rivers of the Cordevole catchment and analyzing the channel widening induced by the Vaia event. Sub-reaches characterized by intense widening (i.e., ratio between channel widths after and before the flood > 4) were certainly or probably affected by debris floods during the flooding of interest, leading us to infer that these fluid gravity flows can induce geomorphic changes that are more intense than those normally occurring in response to water flows. Given the importance of including geomorphological hazards in flood risk evaluation, the different fluid gravity flows possibly taking place at a sub-reach of a mountain river should be regarded, in addition to hydraulic and morphological constraints, as another driver of channel modifications during high-magnitude floods.

Predicting depositional areas of landslide susceptibility comparing four datasets extracted from landslide area: a case of study after rainfall-induced landslides by Ida Hurricane in 2009 on Ilopango Lake, El Salvador

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Hurricane Ida and low-pressure system 96E crossed Central American countries in 2009. However, in El Salvador, the torrential rainfalls caused many flooding and landslides. As a result, over 200 causalities and the destruction of several villages, and bridges occurred along the mountain slopes. The remote analysis allowed us to prepare an inventory of landslides that occurred after the Hurricane in a basin located in the northern part of Ilopango Caldera. Five groups of data sets were created using selected pixels of each landslide area in order to evaluate the capacity to predict the lowest and the entire landslide area. Multivariate Adaptive Regression Splines (MARS) were employed to model the spatial distribution of the following five data sets: i) the highest cell (data set MAX), ii) the highest 10% of cells (data set SUP), iii) the lowest cell (data set MIN), iv) the lowest 10% of cells (data set INF), and v) the entire landslide area (data set BODY). To calibrate and validate the models were selected randomly in groups of 75% and 25% of the mapped landslides, respectively. In order to evaluate the robustness of the results, ten calibration and validation samples were extracted for each instability data set. The analysis revealed that the most important predictors were Slope Length Factor, Normalized Difference Vegetation Index (NDVI), Terrain Ruggedness Index, Lithology (pyroclastic rocks), Topographic Position Index, and Aspects NE and NW. The receiver operating characteristic (ROC) curves and the area under the ROC curve (AUC), calculated for each of the five instability data sets, indicated that calibrating the models with the lowest landslide pixels (MIN data sets) allows to obtain the most accurate prediction of the validation the depositional area and the entire landslide bodies (BODY and INF data set), achieving AUC values ranging between 0.88 and 0.84.

Reconstructing the Roman Coastal Landscape of Campi Flegrei and its surroundings through a multi-technique and multi-survey approach

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Campi Flegrei is one of the widest and most dangerous active volcanic complexes in the Mediterranean basin with an activity characterized by the occurrence of sudden vertical ground movements (VGMs) of great magnitude influencing the coastal morphology evolution over time.
The whole area and its surroundings lived one of the periods of maximum occupation during Roman Time, in particular between the I century BC and the II century AD, with the construction of an almost uninterrupted sequence of coastal buildings, maritime villas and infrastructures, nowadays completely or partially submerged testifying the ancient splendor of the coastal sector at the time.
This research aims at reconstructing the coastal landscape of Campi Flegrei and its surroundings during Roman Time through the use of a multi-technique approach made of both direct and indirect surveys carried out along the coastal sector ranging from Torregaveta Promontory, along the western border of Campi Flegrei caldera, to Castel dell' Ovo, along the eastern calderic edge, moving through the central caldera along the coast of Bacoli and Pozzuoli.
In particular, high-precision data related to the underwater morphologies were obtained by coupling extensive morpho-acoustic surveys (Multibeam and Side Scan Sonar) with investigations carried out using an Unmanned Surface Vessel, equipped with acoustic and optical sensors, and sedimentological data when available. The indirect investigation techniques were always supported by direct geoarchaeological analysis concerning archaeological features interpreted as sea-level markers. The determination of the local RSL history led to the evaluation of the coastal landscape evolution both in terms of coastline variations and quantification of the effects of the local volcano-tectonic activity. Indeed, by comparing the collected RSL data with different GIA models, it was possible to observe that 2.1 ka BP the central part of the caldera was affected by a general subsiding trend with peak of acceleration up to -3.4 mm a-1 between 2.1 and 1.9 ka BP. On the other hand, along the Posillipo and Chiaia coastal sectors, outside the eastern margin of the Campi Flegrei caldera, the RSL data points testified an overall subsiding trend during the Holocene which indicates general subsidence with rates between -1.2 and -2.5 mm a-1 at least in the last 2.0 ka.
Finally, the multi-technique approach led to the realization of a geoarchaeological map of the coastal landscape of Campi Flegrei and its surroundings between the II century BC and the I century AD, highlighting how volcano-tectonic events not only have influenced the evolution of the coastal landscape but also interfered with human activity in terms of damages and adaptation.

The MITIGO Project: preliminary geological and geomorphological contributions to the knowledge of the area between the Bradano and Basento rivers, southern Italy

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The territory between the towns of Potenza and Matera and the Basento and Bradano rivers is the investigated area of the MITIGO project, a study addressed to the geomorphological risk mitigation with regard to the infrastructural assets of Basilicata. The study area extends from the eastern side of the Apennine chain to the south-western edge of the Apulian Foreland, crossing the entire foreland basin. The Apennine stretch is made up of Mesozoic-Cenozoic units (mainly clay and subordinately sandstone and limestone), organized in several tectonic units. The Bradano foredeep is filled by Pliocene-Pleistocene clastic sediments up to 2000 m in thickness. The lower portion of this succession, outcropping along the slopes of the Basento and Bradano rivers, is made of clayey-silty-sandy deposits, topped by sand and conglomerate. The latter deposits constitute tabular bodies, with a thickness ranging from 50 to 70 m, with a clear geomorphic expression. The town of Potenza is located on the left side of the upper valley of the Basento River. In this sector, this watercourse cuts a landscape characterized by slopes with concave-convex profiles produced by mass movements. At the top of the mountains, relicts of palaeosurfaces are often recognized. In the eastern part, between the towns of Albano di Lucania and Tricarico, the arenaceous ridges are coupled to narrow valleys moulded in clay: in this stretch the Basento River is housed in a V-shaped valley with steep slopes and gorges in sandstone and conglomerate. In the foredeep basin, both Bradano and Basento rivers are featured by flat and up to 2 km-large alluvial plains. The fluvial channels gradually pass from braided stream to meanders, bordered by terraced surfaces. New geological and geomorphological data show the complexity of the entire study area, with superposition of fluvial processes, landslides, and badlands, locally driven by tectonic structures.

Late Quaternary fluvial terraces along the Tesino River valley (piedmont sector of the Marche Apennines, Italy): geomorphology, chronology, and morphoevolutive implications

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Along the Adriatic piedmont sector of the Marche Apennines (Italy), the combination of tectonic uplift with climate changes caused the alternating phases of fluvial incision and deposition that eventually produced during late Quaternary at least four levels of fill (depositional) terraces.
The Tesino River valley (southern Marche Apennines) can be considered as exemplary. Indeed, it preserves a well exposed fill terraces staircase whose altimetric distribution and along-valley development can be potentially helpful for understanding the late Quaternary morphoevolution of the area, as well as for studying the intra-valley morphodynamics due to interrelation between fluvial processes and the gravity-induced ones. Although the fluvial terraces in the area are object of several research since the first half of the last century, chronological constraints of their deposits are still scarce, especially for the ancient terrace generations, representing the main limit to the use of fill terraces as geomorphic markers of active tectonics and/or continental records of climate change. Therefore, many scientific questions are still open and stimulate further investigations in the area.
This work presents the main results obtained in the area and synthesized in a geomorphological map at the scale of 1:20,000 completed by a new terraces chronology. The latter has been obtained through the dating of three sandy samples belonging to three different terrace generations, middle and upper Pleistocene in age, using the Optical Stimulated Luminescence (OSL) dating technique.
The geomorphological mapping has been fulfilled combining field surveys, the visual inspections of hillashade map, and a series of morphometric data extracted from a high-resolution (1m/pixel) Digital Terrain Model (DTM), like the automatic extraction of terrace surface.
The main findings from this research provide new geomorphological and chronological constraints for unravelling the contributions of tectonics and climate on the late Quaternary evolution of river valleys along the Adriatic margin of the Apennines.

Identification and assessment of sediment sources and sediment transfer processes in a Mediterranean Agroecosystem in the Northern Apennines, Italy

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The management of Mediterranean agroecosystems is crucial to prevent and mitigate sediment-related threats like soil erosion, water quality issues, or reservoir sedimentation. Hence, the assessment of sediment dynamics at catchment scale is essential for identifying hotspot areas susceptible to sediment loss. Therefore, the identification of type, extent, and location of sediment sources and sinks is a key prerequisite for assessing sediment yield and transport.
This preliminary study is aimed at elaborating an integrated georeferenced inventory map of sediment sources and sinks and related sediment transfer processes within the upper Val d'Arda catchment (Emilian Apennines, Italy), by means of geomorphological field mapping, photointerpretation and remote sensing. Subsequently, the morphological features and the temporal evolution of some representative landforms were analysed using proximal sensing methods and an orthophoto time series analysis covering a fourty six-years period.
The results highlight that the study area is highly heterogeneous in terms of type and extent of sediment transfer processes. In particular, the area is widely characterized by several active gravitative processes, e.g. slides, rock/debris falls, debris flows and mudflows, but also wide ancient complex earthflows with evidence of partial reactivation and retrogressive evolution during the observed time period. Moreover, we identified several rill-interril, piping and gully systems, whose genesis and evolution appeared to be mainly controlled by lithology and land-use. In some cases these systems have evolved into badlands, with a high potential of soil loss and sediment production. Finally, we identified several bank erosion source areas within the main fluvial systems.
In this study we implemented an integrated cascade methodology in order to identify the main processes involved in the sediment production and the related downslope transfer of sediments. Further analysis will be carried out in order to investigate process-specific susceptibilities and the role of different environmental variables as controlling factors.

Geomorphological survey in Muccia (central Italy): an application of the new geomorphological legend

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In recent years, the need to update the tools for the cartographic representation of geomorphological landforms and processes, to make them more functional to the civil society in terms of territorial planning and management of natural risks, has increasingly emerged also due to the ongoing climate changes.
In 2013, a National Commission composed of members of the Italian Association of Geomorphologists (AIGeo), the National Geological Council (CNG), and the National Institute for Environmental Research and Protection (ISPRA) developed a new legend for the drafting of 1:50,000 scale geomorphological maps of Italy. Nowadays, few studies have been carried out to test the applicability of this tool.
The present work aims to verify this possibility, by applying the new legend in a study area located in the central Marche Region, which includes part of the drainage basin of the Chienti river between the villages of Gelagna Bassa (MC) and Pontelatrave (MC). It has been organized in an initial phase of geomorphological field survey with cartographic restitution on the 1:10'000 scale topographic map. Subsequently, the geomorphological map has been digitalized in the QGIS™ environment according to the new legend (ibid.) guidelines. During the digitization phase some issues were found: the absence of the legend symbols in vector graphic format for the output standardization and the requirement of attribute fields in the geomorphological strata associated to the legend symbol's orientation.
The study, although carried out in a limited area with few morphogenetic agents (gravity, fluvial and litho-structural), can be considered an excellent starting point for the application of the new legend (ibid.).

Direct numerical cartography on Quincinetto (TO) landslide system (north-wester Italy) – The application of GOGIRA (Ground Operative-system for GIS Input Remote-data Acquisition) system

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The evolution of Geomorphological Numerical Cartography techniques had a significant but slow improvement during the last decades. This slowness is largely due to the lack of practical-use and economic devices and methodologies. To bridge this gap, GOGIRA (Ground Operative-system for GIS Input Remote-data Acquisition) has been realized. It is a suite of hardware and software tools, algorithms, and procedures for easier and cheaper DNC.
GOGIRA has been tested on the Quintetto landslide system, located in Aosta Valley (north-western Italy), at the boundary between Piedmont region and Aosta Valley region. The case study was chosen in the context of the active monitoring of a complex landslide system close to an important highway that connects Italy, France and Swiss. It was possible to remotely map an area of limited access due to steep slopes, high scarps and rockfall hazard. Field mapping survey required only few hours and it was possible to map high-detailed geomorphological elements not detectable from the base-map at scale 1:10k. Data collected were elaborated with GOGIRA algorithm and the import and categorization procedure allow to fast visualize the results in QGIS project.
In conclusion, GOGIRA proved to be a valid system for safe geomorphological DNC applied to a complex landslide system. Considering the early stage of developing results for linear and point mapping was excellent, as for polygonal elements more studies can be conducted to improve accuracy and precision. The aim of the GOGIRA system was the realization of an accessible DNC system that allows for safely generating reliable geomorphological maps in risky conditions, with low-cost components and user-friendly procedures.

Deglaciation History of Central Italian Alps since Last Glacial Maximum

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The analysis and reconstruction of glacial fluctuations after the Last Glacial Maximum allow us to better understand the environmental and climatic changes that have occurred since then to get a better view of that may happen in this period of climatic changes, but the knowledge about their timing and extent in the mountain areas of the Alps is still limited.
Four study areas have been considered in the study, all in the Italian Central Alps, Upper Valtellina: the Forni, the Gavia Pass, the Stelvio Pass, and the Viola Pass Areas.
Multiple methods have been used in these areas in order to obtain deglaciation ages and past glacier extents: the Iron Crystallinity Ratio (CRF) on podzols and the Schmidt's Hammer R-values (SH) on roches moutonneés both calibrated with absolute ages, and the analysis of peatland cores.
A multidisciplinary approach is suggested to reconstruct glacial events as both the CRF and the SH have been demonstrated suitable methods for dating the glacial history. While CRF calibration may be considered regional, the local variation in calibration for SH may be due to site-specific temperature and precipitation.
Eleven glacial events have been identified before the LIA: 16.7-14.7ka, 13.7ka, 12.3-11.8ka, 11ka, 10.2-9.5ka, 9ka, 7.5ka, 5.5ka, 4.1ka, 3.2ka, and 1.9-1.5ka. These events were not ubiquitarian, and happened differently in each different study area. Comparisons with other glaciers in the Alps showed that the morphology of the catchments was more important than proximity in the glacial evolution during the Holocene.

Medium-term geomorphological changes along rivers in urban areas: the lower Bisagno and Polcevera Valleys in Genova city (Italy)

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People have traditionally settled next to rivers modifying over time the natural environment into the anthropogenic landscape we see today. This contribute presents the geomorphological changes associated with urban sprawl that have affected the lower Bisagno and Polcevera Valleys since the first half of the 19th century. We performed geomorphological surveys and considered historical maps, present-day aerial images, high-resolution topographic data, and archival document. From the 10th century to 1815 the urban development of Genova was limited to the hills surrounding the so-called Porto Antico Bay, which correspond to the former historical centre. From the 19th century onwards, Genova has developed over the Bisagno and Polcevera valleys, Est and West of the Porto Antico Bay, respectively. The cultivated narrow and elongated alluvial-coastal plains close to the seaside were progressively turned into industrial and residential areas. Meanwhile, the Polcevera and Bisagno lower reaches experienced relevant narrowing, simplification of fluvial landforms and complete channelization. The downstream-most section of the Bisagno River was culverted in the 1930s; at the mouth of the Polcevera, a progradation of the coastline to the sea occurred, completely due to the filling of the seaside to realize flat surfaces for industrial activities. Nowadays, the surface behind bank protections overall corresponds to made ground or landscaped ground and no pristine landforms are recognizable. Minor tributaries were squeezed, diverted, channelized, and culverted. In conclusion, the anthropogenic interventions completely reshaped the earlynineteenth-century landscape leading to the current geomorphological setting. This research is framed in a larger project concerning (i) the quantitative analysis of urban river morphological dynamics at medium- and short-term temporal scales and (ii) the geomorphological evolution of the waterfront of Genova, which aims to support proper management of urban areas and geohydrological risk mitigation within a city of historical and cultural value that is very prone to flash floods.

Is the landslide inventory good enough for statistical landslide susceptibility evaluation? A test for studying the effect of incomplete landslide inventory by different statistical methods

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Landslide susceptibility assessment implemented by statistical methods relies on a basic concept according to which past and future landslides depends on the same causes of past failures. Consequently, statistical inference can explore the relationships between past phenomena and geo-environmental variables to spatially recognize landslide-prone areas. Coherently, the quality and the prediction skill of the model and the relative prediction image heavily depend on the completeness of the landslide scenario exploited.
This research aims to evaluate the effect of incomplete inventories in assessing landslide susceptibility, by using conditional analysis (Weight of Evidence, WoE; Frequency Ratio, FR) and inference-based (Binary Logistic Regression, BLR; Multivariate Adaptive Regression Splines, MARS) methods. We analysed the effects in terms of prediction skill of each of the four methods by reducing and randomly hiding the training calibration cases (and increasing the related validation cases).
The study was conducted in the Imera Settentrionale river basin (Sicily, Italy), by exploiting a 1608 rotational/translational slides inventory and a set of 10 physical-environmental predictors.
As general assumptions, MARS and BLR modeling resulted as markedly more performing with moderately and asymptotically AUC improving up to 30-40% of the whole dataset, corresponding to the reaching of the relative optimal performance. A similar asymptotic AUC-increasing trend is described for WoE and FR, but with a lower performance. In particular, the optimal AUC values for rotational/translational slides range between 0.77 and 0.90, for BLR, 0.82 and 0.90, for MARS, 0.78 and 0.80, for FR, 0.76 and 0.78, for WoE. Furthermore, differences in the selected predictors produced by the cases reduction were also explored through the analysis of the variable importance and the response curves.

Landslide susceptibility evaluation at regional scale: an integrating approach for using public landslide inventory

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In this research, an integrated approach for using public landslide inventory is proposed. The analysis was carried out in the Torto River basin (420 km2, central-northern Sicily) and in the contest of SUFRA project. The public available inventory of slides and flows and a set of ten geoenvironmental predictors, were exploited for preparing two susceptibility models (for slides and flows, respectively) by applying Multivariate Adaptive Regression Splines (MARS). The prediction images produced were validated both with cross-validation procedures and with a "stress test" in a randomly selected small sub-catchment (Sciara stream, 21.5 km2) where a new systematic inventory was prepared by exploiting remote and on field surveys. Despite the high performance of the basinscale models, the results at the local scale showed a poor capacity of the models in detecting the two systematic archives, with a non-acceptable sensitivity (0.67 and 0.57 for slide and flow, respectively) and AUC (Area Under the Curve) values (0.47 and 0.65 for slide and flow, respectively).
Then, by exploiting a score weighted random selection of 30% of the slope units of the Torto River basin, a stable/unstable status of the selected cases was assigned by remote and on field surveys. Two new basin-scale models were implemented by using these new "hybrid" archives. The two prediction images compared with the systematic inventories of the Sciara area reveal an increment of the models' performance, with high accuracy in predicting positive cases both for slide and flow types. At the same time, persistent precision in detecting stable cases for flow arises (~0.8), while a decrease in specificity suggests potentially new future activations for slide phenomena. However, the important increment of the AUC values (from 0.79 to 0.94 and from 0.8 to 0.94, for slide and local flow, respectively) testifies to a general improvement of the main models.

Soil heritage assessment and promotion: the role of soil trails

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Soil is a component of geodiversity and considering its role as archive useful in reconstructing the environmental evolution of an area can also be considered as a component of geoheritage.
To better promote soil as component of geoheritage, the planning of a soil trail could be an adequate and common approach.
In this light, we propose the planning of two possible soil trails located in two different mountain areas: the Buscagna hydrographic basin in the Veglia-Devero Natural Park (Lepontine Alps, Italy) and the area of Mt. Cusna, within the Tuscan-Emilian Apennine National Park (Northern Apennines).
Based on literature data available for each area, we plan a multidisciplinary trail, which runs along already existing touristic paths.
The multidisciplinary and multi-analytical approach used to study and characterize the areas allowed selecting soil profiles as site of pedological interest. In each selected site, the soil evidence allows reconstructing the paleo-environmental and paleo-climatic conditions, and/or retrace the human impact that have affected the area over time.
In detail, the soil mainly records, through its physical and chemical properties and pedological features, the influence of climatic variations, the changes in vegetation cover and geomorphological processes. Moreover, in some soil sites of the Mt. Cusna study area, the presence of traces and/or archeological findings highlights how Man has affected the area over time.
In order to communicate the information about the soil features along the trail, illustrative panels were prepared for each site of pedological interest, to be installed, in a near future, on site or preferably made available in digital version.
Providing a proper key to read exposed soils located along the paths, the trails allow increasing awareness towards the importance of geoconservation with a focus on soil in mountain landscape.

Combination of preparatory and triggering factors for the prediction of earthquake-induced landslides: a case study of February 2001 earthquake that occurred in El Salvador (C.A.)

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On 13th February 2001, El Salvador was hit by an earthquake of magnitude 7.7, which triggered thousands of seismically-induced landslides, causing 315 fatalities. The analysis of aerial images, taken a few days after the event, allowed us to map 5,371 seismically-induced landslides in a study area extended for 305 km2. The objective of this work was to verify whether it is possible to predict the spatial distribution of these landslides through a stochastic approach that combines a rainfall-induced landslide susceptibility (SUSC) model, which is based on preparatory factors, and an earthquake-triggered landslide predictive (TRIGGER) model, which is based on seismic parameters such as Peak Ground Acceleration (PGA) and distance to the epicenter (ED). The SUSC model was calibrated by using an inventory of 5,609 landslides that occurred in November 2009 in the area of the San Vicente volcano, due to the action of the 2009 IDA/12E storm event. The TRIGGER model was instead trained with the 20% earthquake-triggered landslides, whereas the remaining 80% was used to validate both the SUSC and TRIGGER models, among an ENSEMBLE model obtained by using as predictors PGA, ED and the landslide probability calculated by the SUSC model. Multivariate adaptive regression splines (MARS) was used as modeling technique. The validation results revealed the better performance of the TRIGGER model (AUC = 0.71) in relation to the SUSC model (0.66). Moreover, the analysis highlighted that the ENSEMBLE model achieves the best predictive ability (AUC = 0.75). These results suggest that, if only some of the landslides triggered by an earthquake are known, as usually happens shortly after the event, it is possible to use the approach proposed in this study to identify those sites where the other landslides are more likely to have occurred. This work is a part of the CASTES project, which is funded by the Italian Agency for Development Cooperation (AICS).

Prediction of spatial distribution of landslides generated from rainfalls and earthquakes by using an approach which combines static with seismic parameters: a test in El Salvador (C.A.)

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The complex geodynamic context in which El Salvador is situated and the lithological characteristics of the volcanic outcropping rocks were decisive factors in the occurrence of thousands of seismically-induced landslides caused by a massive earthquake on 13th February 2001 (6.6 M, 10 km depth), which, together with an earthquake 7.7 M occurred on the previous month, resulting in more than 1,150 fatalities. Thanks to aerial photos obtained the days after the event, we have developed a landslide inventory, where each gravitational phenomenon is represented by a polygon and its Landslide Identification Point. In particular, static landslide susceptibility models were prepared for the Ilopango (1594 landslides in around 40km2) and the San Vicente (1602 landslides in around 108 km2) sectors, by regressing the spatial distribution of the seismically-induced landslides on a set of explanatory variables obtained by a 10-m pixel DEM, a geologic map and a land use map. Furthermore, shaking-dependent models were also prepared by including Peak Ground Acceleration (PGA) and the epicentral distance (ED) among the predictors. For both areas, there was a marked improvement in performance (AUC from 0.70 to 0.77, for Ilopango, from 0.73 to 0.78, for San Vicente) from the static to the shaking-dependent models, emphasizing the role of seismic acceleration in the initiation of landslides. Moreover, for the Ilopango sector, a rainfall-induced susceptibility model was prepared, exploiting a landslide inventory available for the 2009 IDA/12E storm event. The obtained score was then combined with PGA and ED to predict the spatial distribution of the seismically induced landslides, obtaining a higher performance than its static model (AUC from 0.70 to 0.75). The results obtained from the research suggest the possibility of coupling the susceptibility scores obtained from static modeling to mechanical shaking for the seismically-induced susceptibility assessment. This work is part of the CASTES project, funded by the Italian Agency for Development Cooperation (AICS).

Multi-temporal analysis of mobilization volumes and velocity field of a complex landslide

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Mapping and monitoring the displacement of unstable slopes is crucial for hazard prevention and evaluation. Quantifying landslide dynamics is difficult due to the stochastic nature of the environment, but geomorphological analysis based on traditional and innovative approach such as multitemporal analysis of high-resolution images, field geomorphological survey and geophysical prospection can help to understand these dynamics and unravel the evolution of complex unstable slopes. Innovative geomatics techniques provide a valid contribution to detect topographic change induced by erosion or landslide processes. In this work, we investigate the complex evolution of an impressive earthflow located in the frontal sector of the southern Apennines chain, Italy. The study area includes an unstable slope affected by a complex landslide showing a high variability of its active sectors in space and time. Our analysis follows a workflow including the detailed multitemporal mapping of the state of activity of the landslide. More specifically, we use hybrid remote sensing data and methods to recover the four-dimensional surface motions during 1954–2022. Multitemporal analysis of historical aerial-photos (year: 1954, 1974, and 2003), satellite orthophotos (year: 2008, 2013, and 2017), UAV-based data (2020 and 2022) and seismic survey (i.e. MASW, seismic refraction, HVSR) was carried out. Our data provide new and interesting information about the changes in spatial distribution of active sectors of the earthflow in the observation period. Moreover, the reconstruction of the geometry and depth of the active flow area was extracted by the integration between UAV and seismic data, providing an estimation of the volume of landslide body and a reconstruction of the dip surfaces and for analyzing the spatial and temporal evolution of the landslide.

Using the landform "molard" to identify permafrost degradation and landslide processes at a global scale

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This study looks at how to use the landform called "molard" as a marker of permafrost degradation and landslide processes in arctic, sub-arctic and mountain environments worldwide. Molards in permafrost terrains are mound of loose debris that derive from the degradation of blocks of ice-rich sediments mobilised by a landslide. Such molards cannot form without ground ice, which cements the source material, allowing it to behave like solid during transport. Once the ground ice has thawed, its cementing action is lost, inducing collapse of the material into molards. We reconstruct the permafrost, geological, geographical settings of more than 50 landslides characterised by molards. We apply quantitative terrain analysis using high-resolution DEMs to describe, quantify and compare their topographic characteristics, morphometry, dynamics, and molards distribution and density. Our results show that landslides with molards can occur in terrains characterised by various permafrost distribution, from continuous to isolated. These landslides show a variety of morphological and morphometric characteristics, source materials often composed of loose debris or rheologically weak bedrock, and their molard distribution reflects the dynamics of the landslide. In this study, we show that molards are an indicator landform of permafrost degradation under different permafrost, geomorphological and geological conditions, and that they can be used to decipher landslide dynamics in cold environments.

Remote sensing from the Alps to the Antarctic: geomorphic analyses through photogrammetry, thermography and satellite imagery.

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Recent climate change is known to impact systems that are more susceptible, such as high-altitude and high-latitude geo-ecosystems. Both on the Italian Alps and in Antarctica, where the climatic conditions and remoteness of places are severe, geomorphic processes can be investigated through remote sensing techniques. In particular, different-range photogrammetry, RGB satellite imagery and thermography can provide a delineation of both the dynamics and types of periglacial processes that dominate the Alps and continental Antarctica at different spatial scales. On the Alps, needle ice is a poorly studied process but able to prevent the vegetation establishment and provide surficial displacements of up to 10.8 cm per season. Moreover, also depending on the aspect and on the bending phenomenon, the frost creep amount is dissociated from the frost heave intensity. In Antarctica the spatial variability of surface temperatures of tafoni, acquired via thermography, helped to define which are the thermal or chemo-physical processes involved in the formation of the cavities. Surprisingly, no thermal events are involved but it is a matter of chlorides content in the air humidity. In perennially frozen lake Antarctic landscapes, UAV and helicopter structure from motion were exploited to retrieve centimetric inflation and deflation of frost blisters and associate their dynamics with the lake ice and the water supply, shortly affected by the climatic change. Lastly, Antarctic shorelines have been demonstrated to be susceptible to rapid high oceanic wave events. Helicopter photogrammetry and archive imagery collections permitted to temporally locate the "surge", map the developed landforms and quantify the beach vertical changes on a long temporal scale.

An up to date benthic habitat map of the Campania Region (Italy)

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In this work, we present the latest benthic habitat map of the Campanian seabed (southern Italy), focusing on seagrass and coralligenous beds. The map is the result of the analysis and integration of heterogeneous geophysical datasets (side scan sonar and multi beam echosounder data), acquired in the last 25 years, and seabed samples (grabs) and images.
In particular, we recovered geophysical raw data collected in the Campania Region from previous projects (e.g. CARG project) and reprocessed them with new technologies. After a gap analysis, we acquired, processed and interpreted new multi beam data where seafloor acoustic reflectivity data were fragmented or absent. Spatial information on benthic habitats and species occurrences we collected from scientific papers and reports, and samples and images acquired during the above-mentioned marine surveys.
We integrated these data and interpreted them to produced three maps for the Campanian seafloor at regional scale: geomorphological map, substrate map, and biological map. The final benthic habitat map has been generated from the combination of these three factors.
This work has been carried out in the framework of the FEAMP ISSPA (Innovation, development and sustainability in the fishery and aquaculture sector for the Campania Region) Project, financed by the Campania Region under the European Fund for Fisheries and Aquaculture (EMFF) and aiming at identifying the most suitable areas for aquaculture farms, taking into account the protection of vulnerable marine ecosystems.
Finally, the present work represented an excellent opportunity to capitalize on already existing information, collecting new data only in presence of critical gaps. In the era of Maritime Spatial Planning and Marine Strategy Framework Directive and open science, this effort should be exported across Italian regions to allow a sustainable use of marine resources.

Video monitoring and Convolutional Neural Networks for the assessment of meteo-marine parameters

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Coastal monitoring is a continuously developing topic, which has been addressed using different approaches. Among the different techniques, coastal video monitoring coupled with the recent machine learning and computer vision techniques are becoming of common use to assess the meteo-marine features. On the other hand, video monitoring allows to obtain large spatially and temporally datasets well-distributed along the coasts. The video records allow to obtain a series of continuous frames where tide phases, wave parameters and storm features are clearly observable. In this work, video records of Mediterranean coasts have been acquired through surveillance cameras located in the proximity of south-eastern Sicily coasts (Italy). Tide, wave and storm parameters were assessed through a combined approach between Convolutional Neural Network (CNN) and optical flow techniques. Tide phases and storm surge were obtained through CNN classification techniques, while optical flow techniques were used to assess the wave flow and wave height impacting on the coasts. Neural network predictions were compared with tide gauge records. Furthermore, water levels and wave heights were validated through spatial reference points obtained from topographic surveys in the proximity of surveillance cameras. This approach served to improve the calibration between network results and field data. Results were evaluated through a Root Mean Square Error analysis and by analyses of the correlation coefficient between results and field data. Subsequently, CNN and optical flow were applied on the Atlantic coasts of Portugal through action cameras, in order to show the difference in terms of wave setting respect the Mediterranean coasts. The application of CNN and optical flow techniques allowed to automatically obtain a continuous record of data that are usually not densely distributed along the coasts.

A coastal journey along the western surroundings of Campi Flegrei Caldera between the I century BC and the I century AD

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Campi Flegrei Caldera, located within the Gulf of Pozzuoli (SW Italy), is one of the most dangerous volcanic areas and a typical example of a coastal sector affected by sudden vertical ground movements of volcanic origin, such as the one occurred during the Holocene (bradyseismic crisis).
In this research, we carried out a geoarchaeological study of the coastal sector between Torregaveta Promontory and the western margin of Miseno Cape, located in the peripherical area of Campi Flegrei caldera and characterized by an alternation of high and lower coast.
Despite the high-volcanic risk, the area has been densely inhabited since the Greek-Roman Times, and it shows archaeological evidence linked to importance had in the past, such as the Vatia Villa at Torregaveta, thermae and much more. Part of these findings can be interpreted and measured as sea-level index points (SLIPs) and marine/terrestrial limiting points (MLPs and TLPs, respectively) depending on the type of indicators and their level of accuracy.
We used a multi-technique approach and investigated different archaeological sites (Torregaveta, Dragonara and Punta Pennata) in order to reconstruct the paleo-geographic scenario during the Late-Republican age. This certainly is the most effective method for the study of those kinds of archaeological remains, as it combines direct and indirect (carried out by using a prototype of marine drone, ARGO) surveys, always supported by an extensive study of the available bibliography.
Finally, we crossed all the data with bibliographic studies on Fusaro and Miliscola low-coast sectors, where relative sea level rise was not only compensated but even overwhelmed by coastal progradation (for a maximum of ~250 m) thanks to the sedimentary inputs coming from the Volturno river. The consolidation of the dune cordon at Fusaro is well documented by Strabo and Seneca.

A tool to assess the susceptibility of high coasts: Case studies from Cilento coast (southern Italy)

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Cliffs are the most widespread geomorphic coastal environment, occurring along about 75% of the world's shorelines. Considering that, in the present accelerated sea-level rising scenario, these landforms are suffering huge impacts in terms of erosion and landslides, reliable assessment tools to evaluate their susceptibility are required. The aim of this research is to test a speditive tool, avoiding data redundancy and high-specialized surveys, aimed to determine high coasts susceptibility, a first step to support sound suitable management actions for their protection. The set of indicators used in the susceptibility matrix has been chosen according to previous studies mainly focused on coastal erosion/flooding or sea-level rise-related hazards. Variables used have been classified on a 1–5 scale where 1 indicates a low susceptibility, while 5 indicates a high one. Additionally, a weight has been assigned to each indicator based on its importance in the index evaluation. The approach, validated in a large number of test sites was then applied to the study of the Cilento promontory (southern Tyrrhenian coast). The analysis shows that high coasts in this area can be classified as follows: 4 sites belong to the high susceptibility class, 5 sites belong to the medium susceptibility class and 2 sites belong to the low one. Among them, the Agropoli site and San Marco site (northern and central part of the study area) show a high susceptibility value (SpV 1.9) mainly due to their easily erodible lithology and to particular geomechanical features. Instead, Punta Ogliastro site, in the southern part, belongs to the medium susceptibility class (SpV 1.4) due to its resistant lithology and its low exposure to marine agents. Finally, Punta Licosa site (central part) belongs to the low susceptibility class due to the low value of height and slope and the presence of natural elements of protection (SpV 1.2). The sites showing a high level of susceptibility can be considered "hotspots" requiring increased monitoring and protective action.

Geographical factors in the study of COVID-19. Does physical geography matters? A review

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Admittedly, COVID-19 outbreak is linked to geographical factors and its diffusion across the globe reflects a geographic control, showing different impacts according to the scale considered (e.g. global, regional, national, sub-national).
The purpose of this work is to make a literature review of geographical studies dealing with the COVID-19 pandemic. The aim of the study is to: i) understand the role of the geographic determinants (e.g., geographic location, climatic characteristics, topography, altimetry, morphological and morphometric features) in the spread of COVID-19; ii) identify common approaches, materials, and methods used in the study of the COVID-19 outbreak from a geographical perspective; iii) recognize possible research gaps to address future in-depth analyses. To achieve these goals a systematic review was made of the COVID-19 literature exploring different fields of geography, using the main academic databases and with special attention to physical geography. More than 120 scientific articles were reviewed assisted by qualitative data analysis software, categorizing them according to their focus, methodologies, and main results.
This research is part of an interdisciplinary project of the University of Modena and Reggio Emilia, "DISCOV19", that is aimed at identifying the main vulnerability and risk factors related to COVID-19 spread and at formulating proposals for prevention and management actions at different scales of investigation particularly focusing on the Province of Modena (Northern Italy). The investigation is carried out from a multidisciplinary perspective: i) public health epidemiology, studying the contagion modalities and health and socio-demographic predisposing factors; ii) economic-statistical methodology, identifying the structural characteristics of the networks that drive the contagion and the main social, technological and management vulnerabilities with respect to COVID-19 spread; iii) geography and geomorphology, for integrated mapping and analysis of COVID-19 outbreak and identification of environmental and physical-geographical factors in COVID-19 incidence. The review here presented fits into this context being one of the first outputs of the project implementation.