BOOK OF ABSTRACTS

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List of abstracts

BADLANDS CLASSIFICATION FROM THE PERSPECTIVE OF MINERALOGICAL COMPOSITION AND PHYSICO-CHEMICAL PROPERTIES OF SEDIMENT

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Thanks to differences in rock and soil characteristic, areas exposed to wide range of geomorphological processes and absent or sparse in vegetation, known as badlands, can be formed in different climate conditions. Badlands fall under a wide range of geomorphic activities and dynamic behaviors. Wide range of factors as morphological properties, lithology, weathering and erosion processes, have an important role in badland terrains formation. Such a large number of variables implies the diversity of the processes and interactions in badlands origin and evolution. It was noticed that terrains of different lithologies have different erosion rates and general processes, depending on the lithology. In some cases, even areas with same lithology behave differently depending on the environment conditions. Knowing all of that, researchers' aim to link materials physico-chemical and mineralogical properties, weathering and erosion processes and form indices in the literature known as "site signatures". Some of already established ones are the sodium adsorption ratio and electrical conductivity (SAR/EC), sodium adsorption ration and pH (SAR/pH) and sodium adsorption ratio and conten of clay minerals which all define dispersivity of badland materials. Physico-chemical and mineralogical characterization was conducted on 58 unweathered sediments samples taken from different badland areas all over the world, aiming to determine properties of material that are critical for development of these terrains and from which a new materials dispersivity classification arised. Data such as: pH, electrical conductivity, the content of organic carbon (Corg) mineralogical composition, grain size, ions concentrations, formed a large data base further subjected to statistical processing. Results showed that material sorting, porosity, type of clay minerals, and Corg are the most important parameters influencing sediments dispersivity. Furthermore, statistical analyses proved that there is no single parameter that has same importance for all badlands materials, but rather there are multiple parameters important for badlands formed in certain climate regimes. New erodibility indices based on obtained criteria for material erodibility are suggested. These indices will be tested on badland materials that are not part of the database. Overall results of this study will be a true asset for landscape management and planning.

FLUVIAL DENUDATION AND IMPACTS OF GLOBAL WARMING ON SOLUTE AND SEDIMENT DYNAMICS IN THE UPPER DRIVA DRAINAGE BASIN SYSTEM IN CENTRAL NORWAY

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Denudational processes and the relative shares of chemical and mechanical processes and denudation are controlled by a range of environmental drivers and are in most environments and landscapes worldwide significantly affected by ongoing global warming. The upper Driva drainage-basin system in central Norway (Hjerkinn-Oppdal) is situated in a cold-climate and mountainous environment and ranges, with a total drainage basin area of 1630 km^2, from 220 to 2286 m a.s.l. The mean annual air temperature at Oppdal (545 m a.s.l.) is 4.3°C, and mean annual precipitation at Oppdal amounts to 532 mm. The lithology in the drainage basin is complex and varied and is clearly dominated by metamorphic rocks (mostly gneisses and schists). Vegetation cover varies between tundra vegetation in the high and rather flat areas of the uppermost drainage basin area, situated at elevations around 900-1200 m a.s.l., tree vegetation (mostly birch and pine) in the lower parts of the incised tributary valleys of the Driva main river and grasslands in the agriculturally used areas close to the lower sections of the main river Driva. Relevant geomorphological processes include chemical and mechanical weathering, rockfalls, snow avalanches, debris flows, slides, wash processes, fluvial erosion, fluvial streambank erosion and down-cutting, and fluvial solute, suspended sediment and bedload transport. Our research on sediment sources, drivers and rates of chemical and mechanical denudation, and impacts of global warming on solute and sediment dynamics includes field- and remotely-sensed geomorphological mapping, permafrost mapping, and computing of morphometric catchment parameters. This work is combined with detailed statistical analyses of high-resolution meteorological and ground temperature data, and the continuous observation and year-round monitoring of sediment transfers, runoff and fluvial solute and sediment transport using a range of different techniques. Specific focus is on six selected tributary systems of the upper Driva drainage basin. Stationary hydrological stations are monitoring continuously and year-round runoff, fluvial solute and suspended sediment transport. The analysis of fluvial bedload transport includes the application of different tracer techniques together with underwater video-filming and Helley Smith and impact sensor measurements. Discharge in the upper Driva drainage basin occurs year-round with a nival runoff regime and a mean annual runoff of 576 mm. The temporal variability of sediment transfers, runoff and fluvial transport are largely controlled by thermally and/or pluvially determined events. The selected tributary systems display varying solute and sediment yields which are explained by different lithologies, valley morphometries and sediment availabilities. The activation of sediment sources and mechanical denudation are strongly determined by thermally- and/or pluvially-induced events. The highest share of annual sediment transport occurs during the snowmelt period in spring. Altogether, drainage-basin wide chemical denudation dominates over drainage-basin wide mechanical fluvial denudation. It is expected that global warming and the connected shifts in the ratio of snow and rain, the increased frequency of heavy rainfall events, and the continued thawing of permafrost will have complex effects on denudation, with an increasing importance of pluvially-induced denudational events, a decreasing importance of snowmelt-induced denudation processes, and an increasing dominance of chemical denudation over mechanical denudation.

DENDROGEOMORPHOLOGY AND SEDIMENT CONNECTIVITY – THE POTENTIALITY OF TREE RINGS TO DEFINE GEOMORPHIC DYNAMICS IN MOUNTAIN ENVIRONMENTS (VEGLIA DEVERO NATURAL PARK, WESTERN ITALIAN ALPS)

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Small mountain catchments show high differentiation (i.e., high geomorphodiversity) since geomorphic processes may deeply vary from one to another, and within each single basin. In relation to landform distribution and mapping (i.e., geomorphodiversity), complex sediment connectivity patterns are indeed frequent. Therefore, recently, sediment connectivity, an emerging geomorphic system property, has been frequently investigated to characterize sediment dynamic and delivery in mountain environments, taking into account also buffers and barriers. Where human presence is quite limited, arboreal vegetation becomes the primary element influenced by these dynamics. This is particularly noticeable in regions where active processes, despite causing disturbances, create conditions conducive to tree growth. In literature few examples of analysis on the relation between vegetation and sediment connectivity are present. The aim of this work is to discuss the use of tree ring indicators in sediment connectivity analyses in small mountain catchments. Three typologies of geomorphic contexts have been considered in the Veglia-Devero Natural Park (Western Italian Alps). In all the sites specimens of Larix decidua Mill. affected by disturbances were sampled. The first site, located in the Veglia sector, is a slope affected locally by snow avalanches, and potentially connected to the Cianciavero stream. The second one is a snow avalanche slope in the Devero sector, potentially connected downvalley to the Lago delle Streghe. The third, more complex one, is constituted by 4 subsites within the Buscagna catchment: 3 polygenic cones, and a snow avalanche slope, all connected to varying degrees to the hydrographic network. In all the 3 study cases, undisturbed specimens have been sampled in stable areas to build a reference chronology too. The considered dendrogeomorphological indicators are the negative anomaly index, the compression wood, and the traumatic resin ducts. These indicators demonstrate to assume a different meaning in relation to the geomorphological processes, and an integration of all the signals and information is always desirable to obtain a more complete frame of the dynamic.

UNVEILING GEOLOGICAL INSIGHTS THROUGH MAPPING: THE CASE OF SPECIAL NATURE RESERVE OF MONTALBANO JONICO BADLANDS (SOUTHERN ITALY)

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Badlands are characterized by complex hydro-geomorphological features and high intense erosion processes. Runoff can trigger flash floods and landslide movements that are difficult to predict, with potentially devastating consequences. Furthermore, high loads of sediment transferred into streams and downstream water bodies can have important geomorphological and ecological impacts. Monitoring and mapping these areas are crucial for sustainable resource development, land use planning, hazard and risk management.

The interaction between geology and new IT tools provides, through geological mapping, a more efficient way to continuously keep up-do-date the geological knowledge of entire territories, promoting, in addition, geo-tourism and allowing visitors to enjoy the features of landscapes.

Large-scale geological field surveys, combined with satellite imagery photointerpretation and high-tech field equipment (e.g. GPS, FieldMove app) allowed us to produce an original 1:5.000 scale geological and geomorphological map of the most representative area of the Special Nature Reserve of Montalbano Jonico Badlands (Basilicata, Southern Italy). The Reserve is located on the western border of the Southern Apennines Quaternary foredeep (Bradanic Foredeep). The substratum is represented by the argille subappennine, several hundred m thick of muds and muddy silts, with nine thin volcanoclastic intercalations, having a monocline setting gently dipping toward east and an unconformably cover represented by Middle Pleistocene marine terraces and Upper Pleistocene - Holocene alluvial deposits. One of the main geological peculiarity of this area is represented by the excellent exposure of a marine reference section (Ideale Section - IS), straddling the Lower-Middle Pleistocene transition: with a thickness of 74.19 m, it covers the late MIS 20 to early MIS 18 interval. Recently, the IS has been approved as a Standard Auxiliary Boundary Stratotype (SABS) for the Global boundary Stratotype Section and Point (GSSP) of the Middle Pleistocene Subseries/Subepoch and Chibanian Stage/Age at the Chiba section, Japan.

Here, two main morphologies of badlands can be distinguished: Calanchi and Biancane. The distribution of badlands is also controlled by the combination of structural discontinuities (fractures and faults) and mass movements, detected and mapped thanks to several field surveys. Active landslides, localized in the upper part of the slope (in the argille subappennine), are generally triggered by intense and long-term rainfall, with rapid flow movement and retrogressive evolution involving the upper sandy gravel marine terraces with slides and/or rock falls. Ancient landslide bodies are represented by large and very thick (up to several tens of metres) rotated blocks of the continuous succession. Their possible controlling factors could have been of different types (landscape incision during glaciation, deglaciation, exceptional rainfall, seismicity). The age of this large landslide could be broadly referred to as late Pleistocene. Together with desiccation cracks, highly reticulated network of subsurface horizontal pipes and micropipes can also be identified.

With the purpose of representing surface processes and features characterising the Reserve, mapping provides a necessary tool to promote the cultural and environmental values, promoting its potential as a source of tourism resources and environmental education.

ANTHROPOGENIC IMPACT ON GEOMORPHOLOGICAL PROCESSES IN ROME (ITALY): A CASE STUDY OF THE MALAGROTTA EXTRACTION AREA

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Rome's urban landscape presents a clear urban-rural gradient, with diminishing human influence from the historic city center to the surrounding outskirts and peri-urban areas. In the Aeterna Urbs, urban growth and infrastructure expansion occurred over millennia and often resulted in drastic changes or even the complete obliteration of natural landscapes. In this regard, Rome serves as an invaluable case study, providing insights into human-induced changes and their effects on natural geomorphological processes. Despite the importance of understanding these interactions for managing geomorphological risks, the role of human activities in shaping the urban-rural gradient remains poorly understood.

This study explores human-induced geomorphic changes, focusing on erosion, transport, and sedimentation processes that threaten ecosystem health and challenge sustainable land use. The Malagrotta quarrying and dumping area in Rome offers a compelling context for examining the effects of topographical modifications on geomorphic systems. By applying the well-established relationship between drainage area (A in m^2) and slope (S in m/m), we identify local process domains and better understand process interactions. Utilizing digital elevation models, the slope-area relationship is applied to the same watershed across different time periods, revealing evolving geomorphic domain dynamics influenced by human activities.

In conclusion, we found that areas exhibiting converging morphology deviations typically coincide with regions subjected to excavation and quarrying activities. Conversely, divergent flow patterns are observed in areas where depressions have been filled due to quarrying and dumping operations.

DENUDATION IN THE AREA OF MINING SUBSIDENCE - AN EXAMPLE FROM SOUTHERN POLAND

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One of the results of underground mining is the lowering of the land surface above the collapsed mining workings. There are subsidence troughs in the relief, which exclude part of the catchment area from fluvial outflow. Over 230 such drainless depressions with a total area of over 120 km^2 have been recognized in the Upper Silesian Coal Basin, southern Poland. With their creation, the conditions of matter circulation changed because the surface runoff was directed to the center of the troughs, where deposits from the denudation of their slopes accumulated. The work attempts to determine the scale of denudation using cesium (137Cs) dating of sediments. It is an artificial radioisotope introduced into the environment in the 1950s due to nuclear test explosions. In Poland, most 137Cs were introduced into the soil after the accident at the Chernobyl nuclear power plant 1986. Soil particles move with the absorbed cesium, which allows the modern erosion and accumulation rate to be determined. Cesium concentration was determined for 116 samples from nine sites in the subsidence troughs in the Miechowice and Siemianowice Uplands. In the samples tested, the activity of the 137Cs isotope ranged from 2.8 Bq/kg to 171.9 Bq/kg. In most sites, the highest concentration of 137 Cs, correlated with 1986, occurred at a depth of 5-10 cm, and a clear decrease and finally disappearance (identified with 1954) occurred at a depth of 20 cm to 50 cm. The analysis of the results was supported by, among others, cartographic materials from the period after World War II, data on land use, and the scale of mining subsidence. It was calculated that the rate of sediment deposition in the studied sites was 3.8–9.4 mm/year in the last several dozen years. Considering the area of individual drainless catchments and the volume of deposited material, it was calculated that the denudation rate is, on average, 0.9 mm/year.

ESTIMATING VALLEY FILL OF THE GREATER CAUCASUS MOUNTAINS USING TOPOTOOLBOX AND ARTIFICIAL NEURAL NETWORKS

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Compared to other major European mountain ranges, such as the Alps, there is a significant lack of research relating to the glacial history and geomorphology of the Caucasus mountains. The Greater Caucasus Mountains (GCM) form the natural border between southern Russia and Georgia and Azerbaijan, stretching from the Black Sea in the west to the Caspian Sea in the east. As with other mountainous regions across Europe, they have hosted significant glaciation within the Holocene, the relicts of which still remain at the highest altitudes. Intermontane valleys in presently or previously glaciated areas are often characterised by a'U-shape' and are dominated with glacially-eroded sediments. There have been numerous attempts in previous studies to estimate sediment storage in mountain ranges using a variety of techniques (e.g. Blöthe and Korup, 2013; Straumann and Korup, 2009; Otto et al., 2008). However, these studies either rely on support from direct geophysical methods – which are lacking in less accessible areas such as the Caucasus – or the oversimplification of natural systems. These issues were identified by Mey et al. (2015) and lead to their development of a method to more accurately estimate valley fill in the Alps using artificial neural networks (ANNs). This study will adapt from this method and apply it to valleys in the GCM in order to estimate the valley sediment fill deposited from the most recent glaciation. This will be done first by generating a data set of swaths in TopoToolbox from a principal valley within the GCM. The data obtained from this will then be used to train an ANN to estimate valley fill which can then be applied across a wider area of the mountains. This will give detail of how the quantity and distribution of glacial sediments vary throughout the length of valleys, as well as the total volume of sediment stored within a large area of the northern Caucasus. Part of the rationale behind this study was to work towards a larger research project aiming to gain insight into the isostatic rebound associated with glacial retreat in the Caucasus. However, in order to achieve this there is a significant amount of research needed into the geomorphology of the mountains since the Last Glacial Maximum (LGM) in order to begin to investigate any isostatic readjustment. This study will act as the first step within this bigger potential research project as it would be necessary to establish how much sediment has been eroded from the mountains in order to calculate crustal loads prior to ice melt and rebound. Knowledge and understanding of sediment fill is also critical due to the seismic hazards that impact tectonically-active regions like the Caucasus as unconsolidated sediment causes liquefaction and increased shaking during earthquakes.

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MAKHTESH HATZERA EROSION CIRQUE, THE NEGEV DESERT – LANDFORMS AND SEDIMENT DYNAMICS

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Makhtesh Hatzera Erosion Cirque is a deep oval-shaped depression (5 km × 7 km) with a northeast–southwest long-axis developed in the center of the Hatzera anticline of the Negev Desert Israel. It is surrounded by 300-400 m high, almost vertical cliffs composed of Lower Cretaceous quartz sandstone covered by Upper Cretaceous carbonate rocks. These vertical slopes are partly covered with active talus at the bottom of the escarpment. Transitional colluvial-alluvial units (pediments), connect and integrate the lower parts of slopes with Pleistocene –Holocene alluvial terraces covering most of the area of the cirque. The bottom of the cirque is, therefore mostly covered by coarse sandy and gravelly alluvial sediments and a few exposures of Jurassic dolomite and Lower Cretaceous sandstone.

Quantitative GIS-based analysis of the morpho-stratigraphic map of the Makhtesh Hatzera Erosion Cirque, together with systematic thermo-luminescence dating of the eight alluvial terraces (Plakht 2003) and a few optical stimulation luminescence were used to calculate the volumes and rates of sediments transported outside the cirque through its opening, specifically during the last >500 ka and since its initiation in the Pliocene (5 Ma). The calculated rates of sediment transport for the entire Erosion Cirque are 1840 $m^3 yr^{-1}$. For the alluvial terraces, the rates range between 344 and 1328 $m^3 yr^{-1}$, which are similar to the present-day rates as documented at a small reservoir in the erosion cirque. An earlier study showed that floods such as the 2004 flood (470 $m^3 s^{-1}$) can transport boulders up to 2.1 m and weighing up to 15 ton at least once in 120 years. This size is about the maximum boulder size that was found on the terraces within the cirque. Field survey across the terraces show, as expected, that (a) the desert pavement and soil parameters systematically and gradually change from the active channel and the sub-recent terrace to the oldest terrace due to the increasingly longer intervals of weathering, dust accumulation and pedogenesis; (b) the boulder size is reduced up the alluvial terraces sequence – i.e. with time, due to desert weathering and they almost completely disappear within about 100 ka. Sediment evacuation from the erosion cirque as well as the size of the opening are highly controlled by the flood regime which transports the sediments that are directly related to the climatic conditions. Periods of slow sediment aggradation coincide with the build-up the alluvial terraces and correlate with more humid periods, whereas rapid incision phases characterize more arid conditions.

CLIMATE SIMULATION EXPERIMENTS ON SEDIMENTS AND SOILS – USAGE AND UTILITY

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Geoscientists have taken upon a task to understand, and explain, Earth processes, which, in a very generalized way, means looking for a connection between time and space. By time we mean rate of processes, and by space we think of an area. To be even more concrete, when studying erosion processes, we need to know what type of rock is exposed to weathering processes, and under which climate conditions and hillslope properties. Generally, this can be studied under two different, but interconnected and equally important, scales. Observing these processes, and their outcome in nature, on a large scale, is essential part of any research. But for understanding processes on small scale, observation under controlled conditions is necessary. And that is where the value of laboratory weathering experiments gets incomparable. One can argue that the scale is small (sample size), climate conditions limited (raindrop impact, temperature range, occurrence of wind, etc.), unevenness of the terrain is hard to replicate, and it is all true. But the point is singling out parameters that are chosen to be monitored and being aware of limitations is crucial and justifies all limitations. And results, i.e. knowledge obtained, is irreplaceable, which we will show in this study. For example, using image analyses during climate simulation experiments we can find out how cracks form, connect and develop, and using fractal geometry it can be quantified; or the number, shape and size of pieces formed during mechanical disintegration can be determined. The change in physico-chemical properties and mineralogical composition that occur in the sample during weathering, and the leachate properties, can readily be quantified. Furthermore, influence of biochar or any material such as geotextile used for stabilization can be monitored and its efficiency assessed. On the other side of that bar, addition of pollutants allows not only measurements of the changes they make but allows determination and prediction of pollution transport. In our research so far, and in the one that is planned to be conducted, we continue to use close observations of changes on a small scale.

APPLICATION OF UAV-LIDAR TO ASSESS GEOMORPHIC CHANGES IN A RAPIDLY DEVELOPING SMALL LOESS GULLY CATCHMENT

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Assessing geomorphic changes occurring in small loess catchments by means of remote sensing methods and tools poses many difficulties due to dense vegetation cover hindering measurements. Broad-leaved trees and tall shrubs shade the gully bottoms during the vegetation period, which is usually from April to November. In winter, on the other hand, measurements are hampered by snow cover. Therefore, the optimal conditions for remote sensing measurements for these forms occur in early spring (before the start of the growing season) and late autumn (after the leaves have dropped). The period of the turn of winter and spring is optimal, also due to the 'smothering' of herbaceous vegetation to the ground surface by the snow cover. At this time, the 'the ground points' obtained during measurements are most faithful to the actual topographic surface. The study was carried out in a small loess gully sub-basin with an area of 1.24 km^2, representing 9.4% of the catchment area of the Stocki Creek (Lublin Upland, SE Poland). In 2013/2014, the area was covered by LiDAR measurements as part of airborne missions related to the ISOK project. The UAV-LiDAR mission, carried out 10 years after these surveys, succeeds in assessing the quantitative extent and directions of geomorphic changes occurring in the subcatchment. The survey, using a DJI M300RTK platform and a DJI L1 sensor, carried out 3 missions on February 22, 2024 in different parts of the subcatchment covering its entire surface. Both UAV-LiDAR and photogrammetric measurements were made during the flights at the same time and in the absence of foliage. The flight was made at line-of-sight with the option to take vertical images for later point cloud coloring. The flights were made in partly cloudy weather from an altitude of about 70 m AGL with terrain tracking. This ensured a constant distance between the sensor and the topographic surface. With reference to the parameters of the ISOK base point cloud, the acquisition of up to three reflections during a raid was set. The missions of the different parts of the raids were performed transverse to the wind direction (4m/s; W) with a cruising speed of about 8m/s. DJI Pilot software was used to implement the missions. The raid was performed in the N-S axis in order to optimize the raid conditions relative to the wind direction. A total of 424,693,451 points (pts) were acquired in 3 clouds, which corresponds to an average density of 726 points/m^2. Data preprocessing involving alignment of individual raid lines and generation of a combined *.las point layer was performed in DJI Terra software, while classification of points lying on the ground was performed in Terrasolid software. The result was 228,904,358 points of points on the ground (54% of the total points in the cloud), corresponding to an average density of 432 pts/m^2. This is about 100 times denser coverage than the ISOK baseline data. High-resolution DTMs were generated from both the 2013/2014 and UAV-LiDAR 2024 baseline data, which were then analyzed using Geomorphic Change Detection software. The results indicate dynamic development of gullies manifested by both erosion along their axis , as well as the development of lateral branches.

FIRST RESULTS FROM TEN YEARS OF MONITORING ROCKWALL TEMPERATURES IN STEEP MOUNTAIN VALLEYS IN WESTERN NORWAY

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It can be expected that permafrost and seasonal frost regimes will react differently to ongoing and projected climate changes, which will have different effects on mechanical weathering and associated rockfall supply. Most existing studies on rockwall frost regimes, frost weathering and erosion of rockwalls focus on permafrost-affected rockwalls. However, most of the current rockwall surface areas in Norway are permafrost-free. It is therefore of interest to see how these permafrost-free rockwall systems react to future changes in air and ground temperature. Here, we add measurements carried out on rockwalls beneath the current permafrost limit and study thermal regimes at rockwalls that include both rockwall areas with and without permafrost. Rock temperature measurements play a pivotal role in assessing the thermal regime of rockwalls. It is therefore crucial to supplement the existing measurements of rockwall temperatures, both in terms of spatial distribution and longer-term data. We present a unique dataset of up to ten years of rockwall temperature measurements from ten temperatures sensors installed in two mountain valleys in western Norway, covering different elevation ranges, rockwall aspects and slope inclinations. Based on that dataset, we provide an analysis of the different rockwall thermal regimes with respect to rock weathering and associated rockfall supply for both, permafrost-affected rockwalls and rockwalls without permafrost. Our results indicate a strong interplay of elevation- and aspect-dependent weathering regimes of rockfall source areas. Although, the frost weathering regime dominates over sun-induced thermal weathering, the importance of thermal effects for rockwall weathering should not be underestimated also in cold climate environments. Our data show that the lowest rock temperatures occur during the longest lasting frost phases. It can be expected that the possible increase in air and rock temperatures will lead to more frequent interruptions of long-lasting frost phases in the future, whereby the resulting higher number of shorter frost phases is likely to be less relevant for frost weathering than the previous lower number of longer-lasting frost phases. At the same time, permafrost degradation/thawing is expected to be enhanced, resulting in larger thaw depths at permafrost-affected rockwalls and increased rockfall activity at these rock surfaces.

Overland Flow: From "Sheet Flow" to "Partial Area Contribution" and "Dynamic Discontinuity" Terminology Development under different geo-hydrological processes and climate zones

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In the 1930s, Horton (1933, 1937, 1945) developed the classical model of overland flow. In his view, the soil surface is a kind of sieve so that during a rain event, when rainfall intensity is higher than the soil infiltration rate, part of the rain will infiltrate, and the rest will remain on the surface and will flow downslope as a "sheet flow", which he considered a thin, uniform, and continuous flow.

Betson, in 1964, claimed that not all the area of even small watersheds is participating in contributing runoff to the outlet.

In the late 1960s and during the 1970s, Hewlett & Hibbert (1967), Ragan (1968), Dickinson & Whiteley (1970) and Dunne & Black (1970) found, in humid areas, where the infiltration rate and soil moisture are high and the hillslopes drainage is mainly via in-soil subsurface flow, that overland flow is generated on the very low parts of hillslopes where and when the soil is saturated. This spatial pattern is known as "partial area contribution" and in its dynamic version as "Variable Source Area" (Hewlett & Nutter, 1970; Dunne, Moore & Taylor, 1975).

During the 1970s and early 1980s, a pattern of partial area contribution was found in the arid areas of Sinai, the Negev and the Judean deserts. In these areas overland flow is generated by rainfall intensity excess over infiltration rate, and the partial area contribution is not connected to the spatial distribution of saturated areas but to the discontinuity of overland flow at the hillslope scale. Such discontinuity is controlled by two main factors: 1. The spatial distribution of the soil properties that determine infiltration rate, both lateral variations (such as the intermittent existence of gullies and interfluves on the lower part of scree slopes (Lavee, 1973; Yair & Lavee, 1974)) and downward variations (such as the existence of colluvium at the lower part of the hillslope (Yair, Sharon & Lavee 1978; Lavee, i982)). 2. Rainfall properties, the typical short rain events (rain showers of 5 - 30 minutes) in which overland flow that was generated on the hillslopes at a distance of more than 30m from the channel has almost no chance to reach the channel and to contribute to the channel flow, as it infiltrates into the soil before reaching the channel and therefrom evaporates (Lavee, 1982; Lavee & Yair 1990).

In the 1990s, the role of the spatial distribution of surface components at the patch scale and their temporal dynamics, especially in semi-arid areas, was emphasized. In the semi-Arid area of the Judean Desert, patches of low infiltration rate (bare soil, sometimes covered by mechanical crust or big stones, especially when partly embedded in the topsoil (Lavee & poesen, 1991)) versus those having high infiltration rate (soil covered by shrubs, mosses or small stones that lie on the soil surface) have been recognized, and the "Source-sink model" was applied (Lavee, Imeson & Sarah 1998). This combines both models "Partial Area Contribution" and "Overland Flow Discontinuity".

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ASSESSMENT OF TRAIL EROSION BY MOUNTAIN BIKING USING MULTITEMPORAL HIGH-RESOLUTION TOPOGRAPHY: FROM SINGLE RACE TO MULTI-ANNUAL SCALES

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Soil degradation and loss is an irreversible process on a human scale and constitutes one of the greatest environmental challenges today. In this sense, Mediterranean mountain environments are particularly sensitive to erosion processes due to soil fragility, topography, climatic conditions, and human disturbances. The recreational use of natural spaces and protected areas is extensive and has been increasing in recent years. However, little is known about the impact of sport activities on nature, specifically those caused by the use of mountain biking, and there are very few studies that quantify erosion rates in the Mediterranean mountains due to this activity. The main objective of this work is to analyse and quantify the effect of sports activities related to mountain biking on soil erosion in the Sobrarbe-Pirineos UNESCO Global Geopark (south face of the Central Pyrenees). To this end, different short trails (200 m) with contrasted climatic and geological characteristics have been selected to analyse erosion at different time scales: single race, semestral and multi-annual scales. The methodology selected to monitor these changes consists of high-resolution topographic surveys using Terrestrial Laser Scanning and close-range SfM (Structure from Motion) techniques. Likewise, climatic variables (i.e., temperature and precipitation) are also monitored in both study areas.

Preliminary results indicate that the methods selected to monitor erosion at short time scales (i.e., high-resolution topography) allow to represent changes of very low magnitude (i.e., <2cm). The erosion observed at the race scale in the two selected segments may be locally high due to bikes trace, especially in steeper areas, but in general it has a low intensity effect on the whole segment. It is expected that the results of the project will make it possible to establish criteria for the sustainable use of sports activities related to the use of bicycles in mountain areas.

QUARTZ GRAINS REVEAL A SEDIMENTARY PALAEOENVIRONMENT: AN EXAMPLE OF GLACIAL-LAKE OUTBURST FLOOD (GLOF) FROM NE POLAND

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Quartz is one of the most common minerals in sediments and rocks, on the surface of which environmental changes related to sediment origin and post-sedimentation processes can be recorded. Analysis of the shape and character of the surface of quartz grains, particularly in the sandy fraction, therefore allows the reconstruction of the environment in which sediments were transported and deposited. The subject of this study is the quartz-rich clastic sediments of a glacial-lake outburst flood (GLOF) that had taken place at the end of the last glaciation in NE Poland (the so-called Suwałki Megaflood; Weckwerth et al., 2019). Detailed analyses of grain-size distribution and the shape and character of the surface of quartz grains (method of Cailleux (1942) with modification according to Mycielska-Dowgiałło and Woronko (1998)) were carried out on sediments building megaripplemarks (megadunes) whose ridges are perpendicular to the direction of the palaeoflow of GLOF. Sediments from four study sites representing the megadunes ridges (two sites) and the upstream slope were analysed. The results of the analyses made it possible to propose three environmental indexes to identify the sedimentation environment of the sediments forming the megariplemars or the geological processes transforming the morphology and sediments of these bedforms. Based on the results of the cluster analysis, differences in the dominant grain types of the sediments building the different morphological elements of the megadunes were indicated. The sediments of GLOF are characterised by a significant predominance of cracked and non-abraded quartz grains, indicating a high-energy environment for their deposition. Given the mixing of different grain types during a short-lived GLOF transporting sediment over a short distance, megadunes sediments also contain quartz grains with fluvial, aeolian and periglacial characteristics that are inherited from past sedimentary environments.

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GEOCOMES: A PROJECT FOR RESEARCHING GEOMORPHOLOGICAL DYNAMICS AND FUNCTIONAL CONNECTIVITY IN MEDITERRANEAN MOUNTAINS AND THE EFFECTS ON ECOSYSTEM SERVICES IN THE CONTEXT OF GLOBAL CHANGE.

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This work introduces the GEOCOMES project, that is in its starting stage, and present its first relevant outcomes. The project is contextualised on a global scale, namely, in the consideration the Mediterranean and mountain regions are identified as highly vulnerable to changes of different nature as global warming and human activity. Because of this, Mediterranean Mountains should be considered doubly vulnerable to the effects of global change. The ecosystem services facilitated by Mediterranean mountains are crucial for humanity and can be affected by global change related processes. The main aim of GEOCOMES is the spatial analysis of recent and current changes in the geomorphological dynamics and functional connectivity in Mediterranean mountains, their driving forces, and consequences on soil erosion control, flood control and water supply ecosystem services, as well as to provide proposals to mitigate global change effects and strengthens the resilience of Mediterranean mountains.

To do this, GEOCOMES propose one the detailed study of the geomorphological dynamics using cutting-edge technologies, that can generate key indicators to assess water supply and morpho-sedimentary regulation ecosystem services, difficult to obtain with other methodological approaches. It is reasonable to expect that major geomorphic changes such as gullies, debris flows or anthropogenic topographic changes cause major shifts in sediment and water connectivity, influencing water supply and morpho-sedimentary regulation ecosystem services in mountainous regions. Thus, to conduct the project successfully this will take advantage of the currently available extensive coverage and high-spatial resolution datasets as well as new photogrammetric developments and archival aerial images to assess recent geomorphic dynamics (since the 70s), producing maps of geomorphic changes and functional connectivity for 6 representative catchments of Mediterranean mountains from the Iberian Peninsula.

The assessment of water supply, soil erosion and flood control ecosystem services dynamics and their interaction (synergies and trade-offs) are based on state-of-the-art GIS and high-resolution data-fed modelling methods. Also, the relationship between geomorphological dynamics and ecosystem services evolution is being studied and the use of functional connectivity as a surrogate of ecosystem services change is explored as well. In a final stage, it is expected the tools developed during the project besides climatic data and land use-land cover simulations will support the representation of future scenarios for the assessed ecosystem services. All the outcomes will be share and transmit to policymakers, stakeholders, and inhabitants in the study areas to carry out participatory activities that will allow the most important agents to provide proposals to mitigate the negative consequences of global change in Mediterranean mountains.

GULLIES AND BADLAND SURFACES IN A HIGH MEDITERRANEAN MOUNTAIN ENVIRONMENT: FEATURES AND OBSERVATIONS ON SPATIAL AND TEMPORAL DYNAMICS.

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The Mediterranean region is rich in landscapes with gully and badland morphologies. However, they are not so common in high mountain environments above 1,500 m a.s.l. Here we present an example of them: gullies and badlands located in the Sierra de las Nieves National Park at 1,600-1,800 m a.s.l. Both do not cover a large area, but have a remarkable impact from different points of view (landscape geomorphology and geodiversity, soil and vegetation). However, these morphologies have not received much attention and questions about their age and origin, as well as their eco-geomorphological dynamics, remain unresolved.

As mentioned above, the study is carried out in the upper area of the Sierra de las Nieves National Park, where gullies and badlands are located in a high calcareous plateau massif, where hills are separated by shallow valleys of lower slopes filled with marls and quaternary sediments, where these morphologies are observed. The climate is Mediterranean mountain (more than 1,000 mm y-1, wet and cold winters and dry and mild summers). The vegetation is typical of high mountain scrub and grassland, with an open mixed vegetation formation of Quercus Faginea and Abies pinsapo Boiss. The current land use is a natural reserve, although sheep and goats are allowed to graze. Prior to being declared a protected area, grazing pressure was high, resulting in a remarkable deforestation process over centuries.

This study presents recent and current advances in the knowledge of the characteristics and spatial and temporal dynamics of these morphologies, taking into account geomorphology, soil and land use. This knowledge is obtained through different field, laboratory and GIS techniques carried out since 2019:

- Parameter characterisation of parent material in badland surfaces: field sampling and laboratory analysis to determine parameters such as mineralogy, grain size distribution, texture, organic matter and carbon content, aggregate stability fraction, pH, electrical conductivity, C/N ratio and cations.
- Spatial and temporal seasonal variability of water content and bulk density in wasteland material.
- Soil properties and soil degradation in the spatial interaction between grassland and gully/badland surface as a consequence of grazing and trekking.
- Detection of spatio-temporal changes in the topography of hillslopes, gullies and badlands in relation to water erosion using UAVs and LIDAR analysis.
- C14 dating of sediments sampled from profiles in Quaternary alluvial deposits to determine the origin and age of gully morphologies and reconstruct the eco-geomorphic landscape.

VALLEY AND CHANNEL INITIATION IN POSTGLACIAL LANDSCAPE (POMERANIAN LAKELAND, NW POLAND)

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In the humid temperate zone, in a high permeability landscape, groundwater outflows and seepage erosion/groundwater sapping can be the primary mechanism that controls channel initiation (so-called seepage channel). Around groundwater outflow, as a result of the erosional processes, develops an amphitheatrical alcove, often of steep slopes, separated from the slopes of the initial depression with clear edges. As a result of seepage erosion and mass movements, alcoves gradually widen, and vertical erosion leads to the levelling and deepening of the initial landforms. Based on morphometric and geomorphological studies in postglacial landscape (Pomeranian Lakeland, NW Poland), I found in seepage channels some denudational processes that are or can be generated with the contribution of groundwater outflows. They differ in their contribution to the supply of clastic material to the stream channels. Despite the small size, channel heads play an important role in the direct delivery of sediments from the slope system to the river channel, being good evidence of the connectivity of the two systems.

A MULTI-SCALE FRAMEWORK TO INVESTIGATE THE FREQUENCY, EXTENT, AND MAGNITUDE OF GULLY EROSION ON LARGE SPATIAL EXTENTS

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Gully erosion poses a significant threat to land and water resources, with profound environmental and socio-economic implications. However, due to its complexity and the myriad of influencing factors, our ability to investigate gully erosion on large spatial scales remains limited. In this study, we propose a multi-scale framework aimed at elucidating the frequency, extent, and magnitude of gully erosion, with a focus on leveraging local case studies to inform broader insights.

We fundamentally applied this framework to South Africa, a country with diverse geographical and climatic characteristics, we first develop a regional-scale gully susceptibility map using physiographic properties derived from local case study sites. This map facilitates the identification of moderate to highly susceptible zones (13.8% was classified with high gully susceptibility), within which semi-automated detection methods are employed to delineate gully perimeters. Notably, our approach exhibits reasonable accuracy for gullies of varying sizes and geo-environmental settings, although performance reduces with increasing planimetric size and geomorphological complexity of the gullies.Further, by integrating remote sensing, fieldwork, and qualitative assessments at representative local field sites, we observed a correlation between gully dimensions and rates with annual rainfall along the East-West climate gradient of South Africa. This trend underscores the impact of climatic variability on gully evolution, providing valuable insights for sustainable land management practices.

Our findings reveal that gully erosion is a prevalent issue in South Africa. Gully headcuts are the main focus of current mitigation efforts. However, these measures may inadvertently contribute to renewed gullying, highlighting the need for comprehensive and context-specific strategies.

Overall, our multi-scale framework offers a robust approach to investigating gully erosion over large spatial extents, utilising local case studies to extrapolate findings. While our study demonstrates promising results, further refinement and comprehensive validation are essential to enhance the efficacy of the framework and applicability across diverse landscapes and climatic conditions.

SEDIMENT ALTERATIONS DUE TO HUMAN IMPACTS AND THE LANDSCAPE CHANGES CAN AFFECT THE GEOMORPHOLOGICAL EVOLUTION OF A RIVER: THE STUDY CASE OF THE TARO RIVER (NORTHERN APENNINES)

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Geomorphological evolution of river systems is influenced by natural and anthropic factors that can act at different temporal and spatial scales. Human activity may impact river dynamics directly, through the construction of works within the channel (e.g., dams, weirs, bank defences) and in-channel gravel mining, and indirectly, through catchment land use changes and mass wasting stabilizations that may influence sediment supply to the channel network. The reconstruction of the past evolutionary trajectories and the temporal analysis of driving factors is considered fundamental to understand present river conditions and to support a sustainable channel network management.

This study aims to investigate the driving factors that have impacted the geomorphological evolution of the Taro River (Northern Apennines, Italy) starting from 1954, along a segment about 90 km long. The reconstruction of the historical planimetric channel changes were based on multi-temporal orthophoto (1954, 1976, 1988, 1994 and 2020) analysis in GIS environment. Historical bed level changes were examined by analyzing the differences in elevations of fluvial landforms (e.g., active channels or floodplains) active in different ages, as recognized from the comparison of topographic cross sections with multitemporal orthophotos. Analyses of anthropogenic factors that may have influenced changes in the active channel included analyses of: (i) land use changes at the catchment scale, (ii) changes in the extension of sediment sources in the connected areas of the catchment, (iii) gravel mining activities in the channel, and (iv) in-channel work constructions. Furthermore, the channel evolution was compared with the precipitation trends at a gauging station located in the basin and with the dataset of most impacting flood events.

Results showed that between 1954 and 1976 the Taro River channel width decreased by 39% on average, mainly in response to gravel mining activities, and subsequently to the increase of in-channel works construction. To the contrary, as a result of mining activities abandonment in the early 1980s, and of the occurrence of an extreme flood event in 1982, an increase of 18% in the active channel width was observed in 1988. The decreases in active channel width in the last 30 years (since the end of the 1980s) were correlated with the increasing stabilization of channel banks and with the increase in forested areas in the catchment. Increase in forest cover leads to slope stabilization (landslides and badlands) with decrease in sediment production. Multi-temporal analyses of topographic sections showed widespread incision along the river. A strong correlation between highly incised reaches (up to 11 m) and reaches most affected by in-channel gravel mining was observed.

These studies are fundamental to identify correct management solutions in degraded rivers and to anticipate impacts in such rivers still featuring poorly impacted channel morphologies.

LATERAL EROSION IN THE VALLEY CHANNEL OF THE SERIO RIVER AND IMPACTS ON ITS MORPHOLOGICAL EVOLUTION

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River erosion involves sediment supply from the banks and sediment movement from the riverbed. This sediment displacement, often related to flood events, may be localised or diffuse. Over time, lateral erosion is the most effective process through which a river recovers its equilibrium changing its morphology, pattern, and longitudinal profile.

This work aims to investigate the historical and present geomorphological evolution and to map the erodible corridor area along an 80 km long segment of the Serio River (Lombardia, Italy). In particular, we focused on the valley portion of the Serio River where bank erosion, which has intensified in recent years, is leading to the damage of several bank defence structures and the gradual erosion of parts of the cycle path that runs next to the river. We investigate the planimetric evolution of the active channel from 1954 through the analysis of: (i) channel morphological configuration, (ii) channel width changes, and (iii) bank erosion rates.

Analyses were carried out through multi-temporal mapping of the active channel from orthophoto in GIS environment.

Results show high river dynamic, especially in the multi-channel reaches, with a continuous lateral migration of the active channel, resulting in bank erosions that locally reaches up to 100 m in a time interval of 1-5 years. Multi-channel reaches narrowed from a maximum of about 350 m in 1954 to a minimum of about 130 m in 1988, with decrease in braiding index. From 1997 they alternated widening and narrowing, with values ranging from about 10 to 40 m. At the present, in these reaches, erosion affects up to 56% of the banks, with bank erosion rates ranging from 1 to about 3 m/y. Single-channel reaches narrowed from a maximum of about 80 m in 1954 to a minimum of about 35 m in 1975. By the mid-1980 they alternated widening and narrowing, with maximum of about 15 m. In these reaches, where the morphology configuration did not change over time, erosion affects from 15 to 40% of banks (up to 95% in a reach), with bank erosion rates under 0.6 m/y.

The final outcome was the delineation of (i) the corridor of historical channel shifting, starting from the multi-temporal active channel mapping, and (ii) the future potential erosion areas, estimated by calculating the bank retreat rates. The combination of these two areas has allowed to map the erodible corridor area, defined the area where future channel dynamic – mainly related to lateral bank erosion- is expected.

UNDERSTANDING HUMAN-INDUCED CHANGES IN SOLUTE FLUXES IN HEADWATER CATCHMENTS

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The relationship between human activities and natural ecosystems is a critical aspect of contemporary scientific research, particularly in the fields of hydrology and geomorphology. Understanding the response of headwater catchments to increasing anthropogenic influences is paramount in this context. These catchments are often considered the driving force behind larger river systems and serve as important indicators of environmental health and resilience. The aim of this study was to investigate the complex dynamics that govern surface water chemistry and solute fluxes in vulnerable ecosystems by monitoring the natural environment and analyzing changes in environmental parameters. Two headwater catchments, each with distinct human impacts on the environment, were selected to assess alterations in surface water chemistry and solute fluxes. In one catchment, 22% of the forest area was cleared in 2013. In the other catchment, 75% of arable land was converted to grassland and forest over the past 25 years. The study analysed atmospheric input and solute mass balance using the homogeneity Pettitt test. The results suggest that soil disturbance was a significant factor influencing solute fluxes in both areas. In the partially clear-cut catchment, despite a small clear-cut area and adequate soil cover protection, there was minimal impact on stream water chemistry. The total solute mass balance remained unchanged throughout the study period. However, the use of de-icing salts during winter notably affected solute fluxes, leading to a 62% increase in total solute flux. This increase was primarily due to the introduction of significant amounts of Na+, Cl-, as well as Ca2+, Mg2+, and K+. Conversely, in the catchment where arable land was reduced, there was a 55% decrease in total solute mass balance in the stream. This is likely due to reduced soil erosion and fertilization. This decrease included various ions such as Ca2+, Mg2+, Na+, K+, NH4+, SO4-, NO3-, and Cl-. Both catchments experienced a decrease in total monthly atmospheric input, with a significant reduction in NH4+, SO4-, and NO3- inputs by 53% and 21% respectively over the study period. In summary, the use of road salt increased solute transport in the stream and worsened surface water chemistry, while the reduction of arable land decreased solute transport in the stream and improved surface water quality.

COMBINING DENDROGEOMORPHIC METHODS AND NUMERICAL MODELLING TO RECONSTRUCT DEBRIS-FLOW FREQUENCIES AND MAGNITUDES

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In mountain regions worldwide, debris flows (DFs) are one of the main geomorphic processes. Along the track followed and on the debris cone surfaces, DFs might occur with various frequencies and magnitudes. In forested unmonitored mountain catchments, where historical records regarding the past DF events are lacking or incomplete, dendrogeomorphic methods combined with numerical modelling might be used to reconstruct debris-flow frequencies and magnitudes. In the Sancy Massif (1885 m a.s.l.), one of the extinct stratovolcanoes of the French Massif Central, DFs are triggered during extreme rainfall events, being know to cause socio-economic issues in the Mont Dore tourism resort. Within an active torrential catchment located in the central part of the massif, DFs recurrently initiate on steep slopes of unconsolidated volcaniclastic materials, following downstream along a channel and cross a forested debris cone on the bottom of Mont Dore valley. In this study we attempted to reconstruct DF frequencies, return periods and magnitudes using dendrogeomorphic methods and numerical modelling. Based on a detailed geomorphic mapping and the identification of growth anomalies found within 73 disturbed silver fir trees (*Abies alba* Mill.) sampled, a minimum chronology of debris-flow events was reconstructed spanning the period 1900 - 2023. The information regarding the reconstructed DF frequencies and their spatial extent was then used to calibrate numerical models, allowing to estimate magnitudes of past DF events in the study area. Further similar investigations will be extended in other catchments, to test the possibilities and limitations for reconstructing DF frequencies and magnitudes using the combined dendrogeomorphic methods and numerical modelling. Meteorological data recorded by the nearby weather station will be also analysed, to estimate possible rainfall thresholds for DF triggering events, and to better understand the frequency-magnitude relationships of DFs.

THE IMPACT OF EXTREME EVENTS ON THE GEOECOSYSTEMS OF SMALL RIVERS IN THE ŚWIĘTOKRZYSKIE MOUNTAINS

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Selected physico-chemical parameters and chemical composition of water were monitored in 2015-2018 in eight profiles, located in small river catchments in the northern part of the Świętokrzyskie Mountains (SE Poland). Factors, which could affect water quality, such as geology, land cover, point sources of pollution, road network density in catchments and hydromorphological state of rivers, were analysed. To assess the reaction of the geoecosystem to the identified pressures, Thick-shelled River Mussel Unio crassus was selected as a bioindicator species.

Principal Component Analysis indicated four main components connected with geological structure of catchments (electrolytic conductivity, concentration of Ca, Mg, HCO3 and Sr), seasonal dynamics of parameters (temperature, concentration of NO3 ions), as well as human pressure (concentration of metals: Zn, Co, Ni, Cu and ions: K, Na, Cl). The studied rivers did not comply with the standards for the first class of water quality, due to exceeded values of one or several parameters of ecological status. Concentrations of heavy metals were low; however, elevated values were detected in the upper course of the Lubrzanka River, affected by acid mine drainage from "Wiśniówka" quartz sandstone quarry. The values of numerous parameters in the analysed leachate from waste heaps exceeded environmental standards for industrial wastewater, including pH (3,6), concentrations of sulphates (10x higher) and metals – Cr, As, Cu, Ni and Al (even 100x higher in the case of Al). Acidification and elevated concentrations of metals and ions deteriorated the quality of water, classified below the thresholds for the second class. High concentrations of chloride, sodium, copper, zinc and cobalt and acidification of river water were among the factors limiting populations of the thick-shelled river mussel.

The monitoring of water quality in the Lubrzanka River should be continued, as the ecosystem is still affected by acid mine drainage. The research should be conducted also in the middle and lower course of the river, and bottom sediments of beaver ponds and anthropogenic reservoirs in the catchment should be examined for the content of heavy metals.

SNOW-AVALANCHE FREQUENCY IN RODNA MOUNTAINS (EASTERN CARPATHIANS, ROMANIA) RECONSTRUCTED FROM TREE-RINGS

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Snow-avalanche (SAs) is a widespread geomorphic process in mountain areas worldwide being a threat to human life, property, and infrastructure due to their sudden occurrence and destructive force. Snow-avalanches can transport large amounts of debris down to lower elevations being a significant sedimentary transport process. Past avalanche activity is often not recorded or unknown in remote mountainous areas, like the Eastern Carpathians. However, the presence of disturbed forests and tree-ring records can help fill this gap by providing the possibility to reconstruct past avalanche activity with annual resolution. In this study, we reconstruct SA activity using tree-ring analyses in the Rodna Mountains (Pietrosul Peak, 2303 m a.s.l). We sampled 238 disturbed Norway spruce (Picea abies (L.) Karst.) trees within three distinct channeled avalanche paths in the northern part of Rodna Mountains, on the left side of Buhăescu valley. Based on growth anomalies found in tree rings we obtained an avalanche chronology at the subregional scale spanning the 1970–2019 period. We reconstructed 14 avalanche winters in path 1 and path 2 between 1970 and 2019, and 12 avalanche winters in path 3 covering the period 1979–2019. The tree-ring-based reconstructed avalanche winters can further support hazard management decision-makers regarding the past frequency and spatial extent of SAs in the affected areas. From the perspective of the applicability of the research findings presented in this study, our reconstructions may be useful for the managers of the protected areas, particularly for the Administration of the Rodna Mountains National Park, in their effort to mitigate the SA hazard and to implement adequate avalanche hazard planning and tourism activities.

MORPHOEVOLUTION AND SEDIMENT DYNAMICS IN MEDITERRANEAN SUB-HUMID BADLANDS THROUGH MULTITEMPORAL UAV-BASED MONITORING.

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Sub-humid badlands can be found in various Mediterranean regions; locally in Italy, they are known as "calanchi" and "biancane." In Southern Tuscany (central Italy), the morphodynamics of badland areas have been extensively studied in order i) to quantify erosion rates over time, employing both traditional methods like erosion pins and advanced techniques such as UAV-based digital photogrammetry, ii) to investigate the role of chemical and physical characteristics of the parent material or iii) to understand the role of the human impact on the landscape evolution. In Mediterranean regions, sub-humid badland areas exhibit rapid and intricate morphoevolution driven by several geomorphological processes that occur simultaneously, such as sheet, rill, and gully erosion, along with mass movements. The coexistence of gravitational and water erosion processes results in significant sediment mobilization along the catchment, characterized by intermittent transport dynamics. Indeed, mobilized materials often form temporary deposits that are subsequently re-mobilized by future denudational processes in a cut-and-fill cycle.

The aim of this study is to analyze the results of 10 years of UAV-based photogrammetric surveys (using Structure from Motion with Multi-View-Stereo technique) conducted in a small badlands hillslope (~0.23 km2) located in Southern Tuscany, within the Orcia River Basin. High-resolution monitoring of this sub-basin leads to the creation of a multi-temporal dataset from which high-resolution Digital Elevation Models (HR-DEMs) are extracted, and subsequently, high-resolution thematic maps of topographic predisposing factors (HR-TMs) are derived. Hillslope processes are mapped, through a geomorphological analysis of multitemporal orthophotos, and characterized based on topographic factors and erosion rates obtained from comparison of DEMs (DEM of Difference), aiming to identify the topographical signatures of the denudation processes. Finally, significant focus is dedicated to analyzing connectivity within the sub-basin, including the examination of various indices, and the erosive power of flowing waters. This analysis aspires to understand the transfer of sediment from sources on the hillslopes and low-order streams to the main channel network, taking into account the role of precipitation as triggering factors.

THE AFTERMATH OF AN EXTREME PRECIPITATION EVENT ON SEDIMENT TRANSPORT IN THE ORTLES- CEVEDALE MASSIF (EASTERN ITALIAN ALPS)

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In the Eastern Italian Alps, the summer of 2023 has been particularly severe in terms of precipitation, with many intense thunderstorms concentrated in July and August. Several river basins within the Ortles-Cevedale massif, the largest glacierized mountain group in the area, were hit, and have been affected by landslides, debris flows, and floods, which occurred over multiple days during the summer.

Here, we describe the effects of a severe thunderstorm that hit the Ortles-Cevedale area on August 27th - 28th, 2023, reporting a few examples of the events registered in different locations. Data analysis of the precipitation event indicated a 48-hours cumulated rainfall ranging between 95 mm and 144 mm. Temperatures were always above zero, and the zero-degree isotherm ranged between 3'725 m a.s.l. and 3'330 m a.s.l. (the two highest tops, Ortles and Cevedale, are 3'905 m a.s.l. and 3'739 m a.s.l. respectively).

Most severe transport events were registered in the Sulden, Trafoi, and Forni valleys, and seem to have been directly influenced by the dynamics acting in the proglacial and periglacial areas of the corresponding glaciers. In the Trafoi and Sulden regions, the sediment-transport events were initiated as erosion on the moraines, either as deepening and widening of existing gullies, as well as moraine toe erosion by the proglacial stream. First estimates of the volumes mobilized during this rainfall event amounted to ca. 120'000 m^3 (60'000 m^3 in each catchment). In Trafoi, the sediment accumulated in the valley bottom damaged an old church, a famous touristic destination with an important historical and cultural significance. In the Sulden proglacial area, the sediment mobilized during this event completely outbalanced the system, for which previous estimates indicated a total mobilized volume of ca. 108.000 m^3 for the 2005-2021 time period.

In the Forni and Sulden (i.e., Rosim tributary) areas, small debris flows seem to have been triggered by the overtopping of small glacial lakes, or by enhanced ice melting. Moreover, in the Forni area the terminus of the glacier was directly affected by the rainfall event, and the collapse of a large portion of ice likely triggered a sediment wave that reached the artificial lake located near the Forni Refuge, filling it by more than half.

Considering the morphological evolution of proglacial areas, and the potential amount of sediment that can be mobilized in these regions, the understanding of the sediment dynamics linked to extreme precipitation events will become crucial in a warming world, as intense rainstorms will likely become the primary triggers for severe and important sediment-transport events.

ARE MORPHOLOGICAL CHANGES IN ALPINE RIVERS RELATED TO HUMAN ALTERATIONS OF COARSE SEDIMENT FLUXES? A REGIONAL-SCALE ANALYSIS FROM SOUTH TYROL (EASTERN ITALIAN ALPS)

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Channel incision and narrowing have occurred over the 20th century in most Alpine rivers, especially after the 1950s. However, the causal links between sediment-related pressures and morphological changes in rivers have been poorly investigated. This study presents a regional scale analysis of human-induced alterations and their impact on the channel evolutionary trajectories of main rivers in South Tyrol (Eastern Italian Alps). Channel planform variations were quantified in 15 rivers using multi-temporal analysis of historical maps and aerial photos. Coarse sediment yields from catchments of varying drainage area (from about 0.1 km^2 to >1000 km^2) were estimated by multiple sources (hydropower reservoirs, sediment retention basins, monitoring stations, technical documentation relative to post-flood interventions). In terms of human pressures, data regarding the sediment volumes excavated from river channels were analyzed, beside geospatial information regarding hydraulic works, hydrological alterations and land use variations.

Results indicate that the studied rivers underwent both (slight) narrowing and widening from the mid-19th century to the 1950s. From the 1950s to the late 1990s, severe variations in terms of narrowing and morphological simplification took place in most of the studied rivers, although with a marked inter-river variability. Since the 2000s, channel changes have become negligible in the whole study area. Indeed, in-channel gravel mining was banned in the late 1990s, and the widespread installation of erosion control works in the tributaries was mostly completed by the 1990s. The analysis of channel changes in relation to human pressures shows that each river has been impacted by a specific combination of gravel mining, sediment trapping (by dams and retention check-dams) and channelization. Nonetheless, gravel mining carried out in the period 1970s - 1990s appears to have been the main cause of sediment imbalance in the rivers which narrowed (and incised) the most, as well as in the main Etsch river channel. Since the 2000s (after gravel mining was banned by law), the trapping of a large share of coarse sediment fluxes at the river basin scale by retention check-dams and hydropower dams has been impeding rivers to recover from the previous degradation phase, but at the same time has not led to further morphological changes.

USE OF THE TRIANGULAR GREENNESS INDEX (TGI) AND HIGH-RESOLUTION UAV DATA TO ANALYSE THE VEGETATION DEVELOPMENT (2014-2022) IN A CALANCHI BADLAND IN SOUTHERN TUSCANY (VAL D'ORCIA)

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Badlands are of great significance for humans and the environment due to the rapid geomorphic development. The establishment of vegetation is a significant factor in the stabilisation of these geomorphic highly dynamic landscapes, and thus represents a crucial step in the restoration of these ecosystems. In Italy, these landscapes are pervasive throughout the entire Apennine region. This study examines the use of the Triangular Greenness Index (TGI) in combination with high-resolution UAS data to analyse the vegetation development in a calanchi badland in southern Tuscany (Val d'Orcia) between 2014 and 2022. Furthermore, the study defines limitations and potentials of the RGB-based index in such complex landscapes. In order to ascertain the vegetation, it was first necessary to establish the requisite threshold values on the basis of both the prevailing lightning conditions and the corresponding colourisation of the respective orthophotos. Subsequently, binary grids (vegetation/no vegetation) were calculated in order to facilitate the automated mapping of the vegetation cover. To validate the automated mapping, a series of plots were delineated, and the vegetation within them was mapped manually with high precision. In the case of vital vegetation, high correspondences of 83- 95% were observed. The results show an increase in vegetation cover of 10% over the entire study period. However, the development of the vegetation is very dynamic. While the period from 2014 - 2016 shows a decline of -21% in vegetation development, the following years are characterised by a phase of strong vegetation growth (36% between 2016 and 2018) and stabilisation (2018 – 2022: +1%). From a spatial perspective, this results in the extensive growth of vegetation in the areas of the valley floor of the main valley and the northern exposed slopes. In particular, areas affected by earlier landslides and mass movements demonstrate a notable increase in vegetation growth within a few years. In light of the aforementioned findings, it can be posited that the TGI represents an efficacious and cost-effective methodology for the semi-automatic mapping of vegetated regions with high precision over a large spatial extent (badlands). Nevertheless, the TGI is not free from limitations. In particular, the quality of the results is influenced by the lighting conditions (shading) and the phenological status (chlorophyll contect), which is expressed in the green value of a pixel. These limiting factors are particularly pronounced in topographically complex study areas, such as calanchi, and delimit the vegetation analysis in these areas. In these areas, the validation plots demonstrate a low level of agreement, with a value of only 23%. However, this is limited to severely damaged or dead vegetation, which represents a relatively small proportion of the total vegetation. In conclusion, the TGI is a suitable index for the automated mapping of vegetation in calanchi badlands on basis of highresolution UAS-data, particularly when data collection is conducted under optimal lightening conditions.

SOURCE TO SINK SEDIMENT FINGERPRINTING IN A LIMESTONE/BASALT MIXED CATCHMENT

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Nahal Sa’ar catchment (54 sq.km) is located at the boundary between the basaltic plateau of the Golan Heights and the Mesozoic sedimentary rocks of Mt. Hermon anticline in Israel.

Long-term denudation: The latest evolution history of this special, mixed lithology channel, developed at the border of a large basaltic province in an active tectonic environment. The total incision rate of the Sa'ar channel during the last 760 ka is at least 19.7 cm/ka. Over the past 100 ka, the incision rate was 22–30 cm/ka, and the back-erosion of the Sa'ar highest knickpoint occurred at 68 cm/ka. Its fluvial adjustment was determined first by the interplay of construction and incision processes throughout alternating cycles of volcanic activity and quiescence. While the tectonic factor determined the high relief and slope angles, the highly erodible sedimentary rocks at Mt. Hermon’s piedmont enhanced fast slope erosion and significant river incision (Shtober-Zisu et al., 2017).

Contemporary denudation: The lithology is an extremely important factor in determining the type and rate of erosion. We hypothesize that the main channel alluvium of Nahal Sa’ar stream will demonstrate sedimentary traits that reflect different degrees of resistance to erosion of each lithology. The study focuses on sediment sources, controls, and variability of fluvial bedload transport in an attempt to understand to what degree the competing lithologies are reflected in the sediments transported in the basin.

Seven different sampling sites were chosen along the main channel. At each site we surveyed (1) an extensive grain size distribution (GSD), (2) a visual differentiation between limestone and basalt clasts and (3) the roundness and sphericity of both fine and coarse sediments. The results were then plotted against the longitudinal profile, to determine the spatial sedimentary characteristics.

Results show that the competing lithologies are remarkably reflected in the sediments transported in the basin. Nahal Sa’ar begins at its headwaters of Mt. Hermon as a karstic stream with only limestone alluvium but when it reaches its outlet it’s almost entirely a basalt channel. The inflection point occurs within the canyon. The alluvium lithology is closely correlated with the adjacent slopes, implying on sediment transport over short distances, especially of the sandstone particles which encounter fast fragmentation and pulverization. The percentiles extracted from the GSDs show spatial downstream coarsening as the basalt is not eroded as quickly as the limestone. Typical downstream fining occurs near the headwaters and close to the basin’s outlet.

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DENUDATION RATE ASSESSMENT IN THE YOUNG GLACIAL AREA USING CS-137 ON THE EXAMPLE OF THE SUWALKI LAKE DISTRICT (NE POLAND)

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The aim of studies conducted in the Suwałki Lake District in NE Poland was the recognition of the denudation considering water soil erosion and tillage translocation. This study was performed in the typical last glacial relief. Two slopes of small hills were selected for the study: a sandy one 12 m high and a sandy loamy hill 15 m high. The Cs-137 inventory was analyzed along hillslope profiles and at footslopes in 2009 i 2015. The value of soil erosion and sedimentation was calculated using the proportional model and the simplified mass balance model. Studies showed that eroded soil from upper and middle segments of the slopes was re-deposited on concave segments of the slopes. The erosion rate based on Cs-137 measurements in 2009 was 0.5-1.6 mm on the top of hills and 0.8-3.2 mm on their slopes. The deposition occurs on the concave slope at rate of 3.8-6.6 mm per year on average. Erosion-deposition balance indicate that the small part of eroded soil was exported to the valley bottom and bottom of depression. From the hill in Łopuchowo, 1.3-7% of eroded soil could reach the bottom of the depression. In Udziejek, 16-18% of eroded soil could reach the valley floor. These results were compared with those obtained from soil loss measurements on slopes using small collectors. The share of the water rill and interrill erosion in the total of topsoil erosion is range from below 1% to 10%. Tillage translocation was the main process shaped a small hills in the last glacial areas.

In 2010-2011, extreme rainfall events occurred. Annual precipitation ranged 737 and 622 mm respectively, and their erosivity was 1600 mm and 2620 mm. Analyzes of Cs-137 concentration performed in 2015 indicated a much greater export of colluvium beyond the slope in Udziejek, used as arable land, and a minor one in Łopuchowo, the use of which changed in 2009 to the pasture

LONG-TERM DYNAMICS OF SOIL EROSION BY WATER IN FOOTHILL AGRICULTURAL AREAS

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Soil erosion by water in agricultural areas is a serious problem, causing many adverse effects, which include a reduction in the thickness of the soil layer leading sometimes to its complete removal. Soil erosion leads to permanent and irreversible changes in the relief of the land. On slopes, eroded soil accumulates at the foot of the slopes or on valley bottoms. In the long term, this process changes the shape and length of slopes and builds up the valley bottoms. Often, as a result of intense linear erosion, slopes become fragmented with rills, ephemeral gullies and gullies, leading to such destruction of the land that cultivation becomes impossible. It is important to remember that soil is essentially a non-renewable resource, as its removal by erosion can occur rapidly, while the processes of soil formation and repair are very slow.

The research was conducted in the lowest marginal zone of the Carpathian Foothills (Poland). Due to the type of relief (low and medium hills, gentle convex-concave slopes, flat and wide valley bottoms) favourable for settlement and the type of soils (fertile soils which developed on loess formations), this area has been subjected to strong anthropogenic transformations since the Middle Ages, resulting from deforestation of the land and its subsequent cultivation.

This paper presents the results of more than thirty years of soil erosion research carried out in the area, involving stationary surveys on four runoff plots during the hydrological years 2007−2021. The plots were situated on a convex-concave north-facing slope. All plots were 2 m wide and 22.1 m long. The slope of the plots was 8°. The plots were fenced with plastic edging, enclosed by a Gerlach gutter that captures water and eroded soil from each plot and drains into a separate water tank. Surface flow and soil erosion measurements were taken after each rainfall event. The weather station that collected the precipitation data used in this work is located close to this plot. Throughout the study period, one of the plots was maintained as fallow land and the other as grassland. The use of the other two varied from year to year. The crops grown were mainly wheat, oats, potatoes, sugar beet, oilseed rape and soya beans. Cultivated slopes respond very quickly to any changes in the environment and are one of the most dynamically developing forms of relief. The amount of eroded material depends on rainfall characteristics, soil moisture and the type of crop and cultivation method. Soil erosion rarely occurs simultaneously on all slopes of the catchment and its intensity varies along the longitudinal section of the slope.

STUDY OF FLUVIAL DEPOSITS ALONG THE LUDA YANA RIVER CHANNEL

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The present study analyzes the river network and fluvial deposits along the Luda Yana River catchment, located in the central part of Bulgaria. The analysis was carried out through the application of GIS-methods to determine the main geometric characteristics of the river network within the scope of the studied area. A quantitative morphometric analysis within the limits of the selected drainage basin was carried out. Various descriptive parameters of the river network were calculated such as area of the basin, perimeter of the basin, number of river channels, total sum of river channel lengths, drainage density, main channel length, shape factor, circularity ratio, uniformity index or compactness coeffcient, elongation ratio, sinuosity index, first order channels frequency, bifurcation ratio, direct bifurcation ratio, bifurcation index, hierarchical anomaly number, hierarchical anomaly index, hierarchical anomaly density, as well as the mean turbid transport of streams (Tu).

In order to characterize the materials, transported within the river channel, grain size analysis and morphoscopic study of pebble-sized grains were used. Samples from different sites along the catchment at the upper, the middle and the lower part of the stream were taken to overview the changes in river transport at different levels.

DIGITAL MODELLING AND HYDRO-GEOMORPHOLOGICAL ANALYSES TO CHARACTERIZE SEDIMENT DELIVERY FROM THE AURONA AND LEONE PROGLACIAL AREAS (ALPE VEGLIA, CENTRAL-WESTERN ALPS, ITALY)

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Proglacial areas, lying between current glacier snouts and Little Ice Age (LIA) moraines, are undergoing continuous evolution and thus represent hot spots of geomorphological dynamism and sediment delivery. To better explain the sediments behaviour in such environments, we have been monitoring sediment sources, and both waters and sediment discharge in an Alpine basin. The study site (Rio Aurona) drains the western portion of the Alpe Veglia basin, in the Western Italian Alps. The basin hosts the Aurona, Leone and Rebbio glaciers, which covered 20% of the basin in 1872 but currently are reduced to only ~ 5% of it. Their proglacial areas exhibit signs of permafrost degradation and widespread erosional processes. Permafrost and dead-ice degradation led to the formation of proglacial lakes and led to increased efficiency of weathering and degradation processes, which are particularly affecting LIA moraines. To assess water and sediment fluxes in the basin, a multiparametric station was established in 2021 at 1740 m a.s.l., about 3 km downvalley from the Aurona and Leone proglacial plains (lying at ~ 2250 m a.s.l.). The station records water discharge (Q) and suspended sediments concentration (SSC), as well as Electric Conductivity (EC) and water temperature. Rainfall is also monitored in the basin. Relationships among the monitored variables (mainly Q vs. -SSC and Q vs. EC) were analysed for the 2021–2022 period to characterize the ablation period at a monthly scale. Semi-automatic algorithms were employed to detect each hydrometric event and derive two hysteresis indexes between an independent (Q) and two dependent variables (EC and SSF). To provide an independent proxy of water and sediment sources, and assess the ablation period across and between the monitoring seasons, snow and ice cover trends were analysed using the NDSI index of 2021-22 Sentinel-2 images. As for the morphological changes in the proglacial area, the integration of digital modelling and hydrogeomorphological analyses allowed to assess the evolution trend of the Aurona catchment over long, medium, and short-term intervals. A long-term analysis since 1872 was also conducted through photointerpretation, offering detailed insights of morphological changes over the last 150 years. Medium-term analysis of the last twenty years involved comparisons of digital terrain models (2.5D) and morphometric analyses, primarily focusing on the evolution of sediment sources and their structural connectivity. Erosion rates up to ~ 0.3 $m^3y^{-1}m^{-2}$ in the Leone proglacial area and ~ 0.2 $m^3y^{-1}m^{-2}$ in the most dynamic parts of the Aurona area were estimated by comparing different terrain models. Short-term analysis (2021-2023) was conducted using 3D cloud comparisons and hydrogeomorphological analyses to

evaluate water and sediment loads from sources to the outlet. These latter show ablation periods highly influenced by the spring snow abundance (i.e., snowmelt period) where the riverbed, the riverbanks, and the nearest slopes act as main sediment sources, with Suspended sediment yields (SSY) ~5-t km^{-2}The early glacier and glacier melt periods exhibit increased sediment transport efficiency, SSY up to 30-ton km^{-2}m^{-1}, and progressive exhaustion of nearby sediment sources, in favour of the farthest ones (such as the Aurona and Leone proglacial areas). The recession period (late summer-early autumn) is marked by general sediment exhaustion (SSY ~5-t km^{-2}, primarily replenished by rainfall, renewing the nearest sources' functional connectivity This study, considering the importance of high mountain environments as sensors of ongoing climate changes, reflect the complex interplay between glacial dynamics and paraglacial adaptations in terms of hydrogeomorphological processes. It provides integrated data, with the aim of better understanding the ongoing evolution of glaciers and proglacial areas, and the coupled water and sediment dynamics through the sediment cascade.

A SEDIMENT BUDGET OF THE DONGUZ-ORUN LAKE CATCHMENT, NORTHERN CAUCASUS, RUSSIA

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Studies aimed at quantifying sediment transfer in the mountains are essential from fundamental and practical perspectives. This is especially relevant now during global climate change and the adaptation of geomorphological systems to new conditions. However, quantitative assessments of sediment transport in proglacial areas are relatively rare worldwide, particularly in the Caucasus. This paper aimed to quantify 1) the total amount of mobilized sediments, 2) the portion of sediments that finally reaches the catchment outlet, and 3) the contribution of different processes to the sediment load in the high-mountain catchment of the Donguz-Orun Lake (northern slope of the Central Caucasus), composed of two tributary valleys. The annual volume of transported sediments was determined by geomorphological processes mapping and information on their rates obtained from monitoring work, as well as reviewing published materials in similar geological and geomorphological settings. To estimate the volume of material reaching the catchment outlet, we used the sediment delivery ratio calculation. This approach has an advantage in differentiating denudation by particular processes, but verification of results is required. The lake was formed by the damming of streams by a lateral moraine, which enabled us to quantify sedimentation rates. Additionally, sediment source fingerprinting allowed us to verify the contribution of sub-catchments. The total volume of mobilized material is 29300 mm yr -1 m 3 , corresponding to a denudation rate of 2.2 mm yr -1 . With an average sediment delivery ratio of 58%, the sediment volume transported outside the catchment should be about 17000 m^3 , and the denudation rate (adjusted for accumulation) should be 1.3 mm yr -1 . Gully erosion (67.5%), sheet wash (12.2%), rockfalls (10.9%), and glacial and fluvioglacial processes (8.6%) together contribute to 99% of the sediment load. On the other hand, channel erosion, rock creep, soil creep, and solifluction only contribute about 1% combined. Since the lake was created, 5×10 6 m^3 of sediments have accumulated in its basin. This corresponds to sedimentation rates of 0.54 to 1.07 mm yr -1 , depending on the age of the dam. Therefore, a denudation rate of 1.3 mm yr -1 is greater than the higher assessment of the sedimentation rate in the lake. However, with possible correction for removing a portion of suspended sediments, this is an adequate estimate of the denudation rate in the catchment area. Also, the source sediment fingerprinting results show that the sediment delivery ratio of the southern sub-catchment must be approximately 1.4 times less than calculated. Thus, only about 14000 m^3 enters the lake basin annually from both valleys, which gives a denudation rate of 1.05 mm yr -1 . This value fits into the estimated range of sediment volume (0.54-1.07 mm yr -1) in the lake basin. Our findings indicate that only 50-60% of the mobilized sediments reach the catchment outlet. The study was supported by Ministry of Science and Higher Education of Russian Federation under the Agreement 075-15-2024-614.

CONTROLS ON FLANK EROSION RATES DURING VALLEY WIDENING: AN APPLICATION OF COSMOGENIC NUCLIDES IN ANDEAN AND FRENCH VALLEYS

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Any keen observer has noticed that valleys show a large variability in their shapes: mountain rivers flow in valleys ranging from dramatic narrow gorges to valley floors that are several times river width. This geometry implies that the river has not only carved vertically but has also laterally eroded the valley flanks, depending on the action of lateral and vertical erosion on the flanks and valley floor respectively. Valley widening occurs when a river channel comes into contact with the valley edges and erode them, therefore, it depends on processes acting at the scale of a river bank but also at the scale of the river.

However, valley widening processes and rate are still poorly documented while valley evolution has a key role in landscape evolution. Lateral erosion during catastrophic floods can drive valley flank erosion. Valleys are also wetlands with a voluminous aquifer and where ecosystems evolve as valleys widen or narrow over millennia. Moreover, the storage of carbon increases in wide valleys which, therefore, play a role in the carbon cycle and in the evolution of the global climate. Valley width strongly affects sediment residence times on continents, with large valleys potentially buffering sediment fluxes exported to the oceans. Finally, valleys widening is responsible for the formation of abrasion terraces and contribute to the development of pediments. The dynamics of valley widening is therefore a fundamental component of the evolution of relief and sediment flux.

Given these challenges, it is becoming necessary to better understand valley widening rate and its controls. We have used and further developed the approach presented and tested in northern Chile by Zavala et al. (2021). For that, we focused on 13 river valleys (in the Arequipa Province, Peru, and in the plateau of Valensole, France) where geomorphic, geological and climatological parameters offer a wide range of conditions to compare with erosion rates. In total, we analysed 79 samples of sands from valley flanks to measure the millennial erosion rates, by using in-situ produced Beryllium-10 (10-Be) and Aluminium-26 (26-Al). We used the detrital mean 10-Be concentration to calculate a mean local valley flank erosion rate, in a similar way that cosmogenic nuclide concentrations have been used to quantify catchment wide denudation rates.

We also extracted factors that may control widening rate (valley width, slope of flanks and valley floors, incision and drainage area) for comparison with 10-Be and 26-Al concentrations. Our preliminary results in 31 samples show comparable 10-Be concentrations along a single stretch of valley, except for several outliers, for different valleys in the Andes and France, indicating some robustness in the sampling method. These results are promising and should provide new constraints on factors that control the widening rate of valleys.

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BAD2BED ITALIAN NATIONAL PROJECT PRIN2022 - BADLAND MORPHODYNAMICS ASSESSMENT AND HILLSLOPE-CHANNEL BED COUPLING IN THE CONTEXT OF GLOBAL CHANGE

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Badland areas in non-arid landscapes can be ideal sites to investigate the role of human activities in triggering erosion processes in the current context of global change, as their origin has been related to scenarios of widespread land degradation. So far, little attention has been given to the relationship between slope processes and river morphodynamics in badland landscapes.

The BAD2BED project is aimed at monitoring and understanding the coupling of hillslope and channel morphoevolution in Italian badland landscapes, with a focus on the impact of human activities and climatic fluctuations, at hillslope and catchment scales, in modifying the natural fluvial system sediment dynamics. Three study areas are investigated, located in northern, central and southern Italy, in order to disentangle the relative importance of climate vs human controlling factors in driving the observed historical changes of denudation rates in badlands. Specific frameworks for each study area will be gained and the integration of all results will be used to assess and model the hillslope-channel coupling morphodynamics valid in non-arid badlands.

The BAD2BED investigations are organized at multispatial and temporal scales, and developed through different Working Packages (WP).

WP1 is focused on the factors and effects of the different geomorphic processes responsible for the shaping of the relief of the studied badland areas, during the long-term scale (where possible starting from the XIX century); a geodatabase containing multitemporal geomorphological maps, land use maps and NDVI maps is the main deliverable.

WP2 will be devoted to hillslope erosion monitoring during the project duration time interval (short-term), with the aim of delineating the present geomorphological dynamics at hillslope scale. The topographic change detection will be generated after Structure-from-Motion (SfM) or Terrestrial Laser Scanner Technology (TLS).

WP3 is aimed at the reach scale monitoring, in order to detect the possible changes in the stream bed morphology during the short-term. Where possible, hydrological and suspended sediment yield monitoring data will be obtained.

The integration of the data obtained in WP 1-3 will be achieved in WP4, aimed at conceptual and quantitative modelling. Geomorphometry analyses, aimed at the erosion and slope-channel connectivity modelling, will be applied, in order to investigate the effects of additional variables potentially influencing water and sediment transport: for each study area, the relative role of each erosion factor will be explored and compared, with the main aim of resolving the long-term morphoevolution. Thus, on one hand, specific frameworks for each study area will be gained and, on the other, the integration of all results will be used to assess and model the hillslope-channel coupling morphodynamics valid in non-arid badlands.

MULTITEMPORAL MAPPING OF BANDLANDS TO DETECT CHANGES IN VEGETATION COVER AND LAND USE

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Badlands landscapes are typical of semiarid regions, with a high runoff rate and a low vegetation cover. They are characterized by clayey, silty-clay slopes, where accelerated erosion is caused by water washout. The observed geomorphic processes are rilling, gullying, piping and gravitational mass movements, frequently depending on the type of vegetation cover. Two main morphologies of badlands can be distinguished: 'Calanchi' and 'Biancane'. Biancane , in particular, were traditionally used for grazing, while other farming activities took place where the pediments were larger and thicker. In the last century, the reclamation of land for durum wheat and cereals cultivation implies changes in the landforms that can activate soil erosion processes. Therefore, Badland areas can be ideal sites to investigate the role of man in triggering erosion and represent natural laboratories for the study of land degradation.

To understand the impact of various land use practices on the dynamics of badlands, it is essential to establish clear criteria for mapping.

We monitored a study area situated in the central portion of the Agri River Basin, near the Sauro River confluence, ranging from 180 m to about 250 m a.s.l. The landscape is characterised by NE-dipping monoclines sequence with typical badland features exposed to the south-east. The arable areas are generally between monoclines and pasture, grassland and bushy grassland lie on top and on north-western sides of the monoclines. Moreover, in this area, reclamation of bushy lands and badlands for durum wheat cultivation have been allowed by agricultural policy. Then, the subsequently abandonment of much of this land, associated with regional changes in precipitation, promote land degradation and soil erosion.

We investigated the area by creating two GIS layers aiming to describe both vegetation type and geomorphological processes acting on Bandland. We used aerial photos taken about every twenty years starting from the 50's of last century as basemap to map the land use.

The multitemporal land use mapping allows to quantify changes that have affected the study area during the past decades. Decrease or increase in vegetation cover, in the extension of cultivated, pasture and in badland areas can aid to detect flattening and remodelling lands or restoration of gullies and shallow mass movements that increase soil erosion and sediment budget into the drainage network.

OBSERVATIONS OF PARAGLACIAL PROCESSES ON GLACIER FORELANDS AND POTENTIAL IMPLICATIONS FOR REGIONAL DENUDATION RATES, SOUTHERN ALPS, NEW ZEALAND.

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In line with the global trend of glaciers in mid-latitude mountain ranges, the majority of mountain glaciers in the Southern Alps of New Zealand experienced both substantial frontal retreat and vertical downwasting during the past few decades. Placed within a geomorphological regime characterised by generally very dynamic process-systems and various efficient triggers such as major storm event or frequent seismic activity events, their glacier forelands are currently affected by substantial paraglacial modification. These paraglacial modifications can be connected to the development of proglacial lakes at the often extensively debris-covered lower glacier tongues and comprise several individual processes, for example gully development on the typical prominent lateral moraines, glaciofluvial erosion, slope failures/slumping, or deflation on non-vegetated moraine slopes and glacial outwash plains.

During the past 20+ years of fieldwork on those forelands, albeit primarily focusing on reconstructing Holocene glacier chronologies, these paraglacial processes have been regularly observed and photographically documented by the author. A few studies on the recent impact and possible future consequences of paraglacial landform modification on touristic infrastructure in the touristic hotspot areas (accessibility of established tramping routes, survival of threatened tourist huts and shelters, maintenance and future management of walkways etc.) have been carried out. Detailed approaches to quantify the contribution of paraglacial processes to regional denudation rates or explicitly characterise the effect of paraglacial pre-conditioning for denudation connected to major storm or seismic events are, however, very rare. This is somehow surprising as the efficiency of paraglacial erosion in the specific natural environment of the Southern Alps is very high compared to other mountain regions.

Selected examples of paraglacial processes and related landform modification on glacier forelands in the Aoraki/Mount Cook and Westland National Parks will be presented. These include gully development and rill erosion on the proximal slopes of lateral moraines, related substantial retreat of erosion scars at their crests in order of several metres in a few years, or lateral bank erosion and incision of proglacial meltwater streams. Whereas some of the eroded sediment will temporarily be stored in local sinks in form of proglacial lakes, it remains an interesting and open question to what extent paraglacial pre-conditioning effects denudation rates compared to non-glaciated drainage basins. Future quantitative studies are necessary to develop reliable predictions for the future development in the light of the current environmental change and are explicitly encouraged.

Finally, one aim of the presentation is to create inspiration among the respective geomorphological community and to highlight promising opportunities for future studies targeting the role of the paraglacial process-system for regional denudation rates in the Southern Alps - in particular as the next International Conference on Geomorphology will be held in Christchurch/New Zealand in February 2026.

DISTRIBUTION OF DENUDATION PROCESSES IN MORPHOCLIMATIC ZONES

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Based on several classifications of morphoclimatic zones (including Peltier 1950, Büdel 1963, 1974, Tricart, Cailleux 1965, Hagedorn, Poser 1974, Wilhelmy 1974, Beyer 1981, Gregory 2010, Starkel 2016), which differ in their initial classification assumptions, the morphoclimatic zones of the world will be characterized in terms of dominant and secondary denudation processes. Denudation processes, which involve the wearing away of the Earth surface by processes such as weathering, erosion, and mass wasting, vary significantly across morphoclimatic zones on Earth. Morphoclimatic zones refer to regions characterized by distinct combinations of climate, geology, and landforms, which influence the rate and intensity of denudation processes. The distribution of denudation processes across morphoclimatic zones reflects the complex interactions between climate, geology, vegetation, and human activities. Understanding these processes is crucial for managing land use, conservation efforts, and mitigating the impacts of natural hazards such as erosion and landslides. Morphoclimatic zones illustrate the diverse range of environmental conditions and denudation processes that occur across the Earth's surface. Understanding the dynamics of these zones is essential for studying landscape evolution, geodiversity and biodiversity patterns, and the impacts of climate change on Earth geoecosystems and their services.