URGERE - URban GEodiversity for a Resilient Environment

Abstract

The URGERE project is concerned with resiliency of cities and **urban areas in Italy**, with respect to **geo-hydrological hazards** and environmental impact on ecosystem services, human life and infrastructure. To do that, it first focuses the variety of the abiotic parameters, mostly geomorphological: namely “geomorphodiversity”, as a measure of the **potential of morphological evolution** of the landscape. **Human presence** contributes substantially to the **modification of the landscape**, especially in urban areas. Urbanization is a growing phenomenon, and human presence and activities enhance environmental fragilities in cities. We propose a **quantitative geodiversity index**, GmI, focused only on geomorphological parameters, calculated at national scale with high-resolution set of elevation and thematic data, homogeneously available all over Italy. The focus is mostly on the use of digital elevation data, for they are the basis for geomorphometric analysis and for an automated classification of landforms, in addition to thematic information. Interpretation of the resulting index is straightforward, allowing a wide range of applications, at relatively low cost. Implications of different values of the index, in combination with geo-hydrological hazard, are prominent within urban areas. To this end, we single out urban areas with a novel, parameter-free technique, and we **aggregate results** of statistical models for geohazards at **slope unit level**. Within this framework, we can **describe geodiversity**, the **degree of urbanization**, and **hazards**, at **comparable resolution** at the **national level**. At intermediate/regional and local/urban level we rely on a different class of data, stemming from advanced use of **aerial photographs and LiDAR** measurements with airborne drones, exploiting existing datasets and newly acquired data at very high resolution within this research, in selected locations. Recently developed photogrammetry techniques applied to historical aerial photographs provide digital models of vegetation surface, showing its change in time in the last century and allowing study of the **links with local geodiversity and hazards**. On similar grounds, processing existing and newly acquired digital LiDAR point clouds to obtain digital surface and terrain models and environmental data **in urban and suburban areas**. The national GmI and local analysis in data rich locations can be matched thanks to the high-resolution of GmI, providing a truly multi-level and validated approach. Moreover, geomorphological mapping and numerical modeling of hazards with very-high-resolution data in selected urban areas elucidates the role of geodiversity and its impact on the environment and human life for a meaningful planning of urbanization and infrastructure. Candidate locations of local, high-resolution analysis are in **Umbria and Campania regions**, mostly due to existing rich datasets and great expertise of the proposed research team in the areas.

State of the Art

Geodiversity refers to the **variety of natural abiotic features**, as the natural variety of **geological** (rocks, minerals), **geomorphological** (landforms, physical processes), **hydrological** and **soil properties**. The geomorphological parameter (geomorphodiversity) is a measure of the dynamics of the Earth's surface and it has a key role in conservation of biodiversity and **sustainability of ecosystems**. Thus, it affects evolution of the biotic world and of human life. A measure of geomorphodiversity in time relates to the evolutionary stage of the **physical processes shaping the landscape**. This is particularly relevant in an era of **pervasive anthropic actions** and even more so with the onset of climate change.

Several qualitative and quantitative methodologies exist to measure geodiversity. Definition of a numerical geodiversity index (GmI) provides a comprehensive, objective and reproducible measure of abiotic parameters. Recently a few of us defined a geomorphodiversity index for the Italian territory, a quantity mostly involving topographic data in combination with subsurface data. This approach includes several morphometric variables, derived from digital elevation models (DEMs), allowing **applications in wide areas in a highly reproducible and systematic way**. The method is relatively cheap in terms of data and computational demand in a geographical information system (GIS) framework.

The tools of geomorphometry - a science of quantitative land surface analysis - were applied in that piece of work, and will be used extensively, here. A specific tool, relevant to topographic classification and to different environmental aspects, consists of particular mapping units - as an alternative to DEM grid cells - called **slope units** (SUs). They were first introduced a few decades ago, but never used in a systematic way, due to the burden of manually delineating their boundaries. A piece of work recently published by some of us allows a parametric, automatic delineation of SUs - and various such maps, including Italy, are available. SUs are a **powerful tool** for they have an actual **correspondence with the topography**, **at variance with raster maps**, and allow meaningful **aggregation of topographic and environmental data**. Polygonal SU maps, generated at different scales, are one key tool for investigating geodiversity and natural hazards on large areas.

Geodiversity, as a proxy for the future evolution of geomorphological dynamics, is **undoubtedly relevant to geo-hydrological hazards**, at different levels of resolution. For example, floods and landslides are very clear evidences of the dynamics of the topographic surface. Recently, several groups published research on areas as large as the whole of Italy, using data with comparable spatial detail in a consistent way. These data availability and computational capabilities open to the possibility of systematically investigating the topics of **geodiversity** and **natural hazards and their mutual interactions**, starting at national down to regional and local level, to provide information with different detail about **populated areas and infrastructure**.

Human presence is one relevant factor in shaping the Earth's surface, at least on one-third of the Earth's surface above the sea level, whose impact is concentrated in urban areas. The UN Department of Economic and Social Affairs projections suggest that 68% of the global population will be resident in urban areas by 2050. Study of **geomorphology in urban areas** and of the **complex interactions between natural and anthropic environments** thereof, is of great relevance. Urban geomorphology suggests methods, techniques and procedures for modeling anthropic effects. The very delineation of cities and urban boundaries, at variance with administrative limits, is still an open issue.

Selection of **proper data** is key for meaningful spatial analysis, particularly for applications involving **heterogeneous sources**. GIS technology can now consistently process national and continental scale high resolution spatial data from remote sensing using commodity, high-end and even high-performance computing facilities. At smaller scale, various techniques provide very-high-resolution (VHR) data. The Italian Ministry of Environment collected **LiDAR data** from a massive aerial campaign, in a substantial portion of Italy, which we acquired as raw data within completed projects. Dedicated campaigns, at local scale, are possible thanks to relatively low-cost unmanned aerial vehicles (UAVs) carrying LiDAR sensors and high-end cameras. Processing of **point clouds** and images with **photogrammetric techniques** provides VHR elevation data for spatial and environmental analysis.

The mutual relationship among urban centers, geodiversity and geo-hydrological hazards from the national down to the local level, is the main subject of this project.

Essential references

Burnelli et al. (2023) https://doi.org/10.1002/esp.5679

Alvioli (2020a) https://doi.org/10.1016/j.landurbplan.2020.103906

Alvioli et al. (2020b) https://doi.org/10.1016/j.geomorph.2020.107124

Schrodt et al. (2019) https://doi.org/10.1073/pnas.1911799116

Melelli et al. (2017) https://doi.org/10.1016/j.scitotenv.2017.01.101

Jasiewicz et al. (2013) https://doi.org/10.1016/j.geomorph.2012.11.005

Open positions:

Junior post-doc (Italian PhD equivalent): University of Perugia, Italy, one year, end within September 2025.

Degree: geology, geological sciences or certified equivalent for foreign degrees.

Topical Expertise: Geomorphology, Urban Geology.

Technical Expertise: GIS software, remote sensing, aerial photographic and satellite image interpretation.

Senior post-doc (Italian PhD equivalent + two years post-doc) CNR IRPI, Perugia, Italy: 1.5 + 0.5 years.

Degree: geology, physics, statistics or certified equivalent for foreign degrees.

Topical Expertise: Geomorphology, geomorphometry, landforms, spatial analysis, numerical modeling.

Technical Expertise: GRASS GIS, working knowledge of Linux OS, use of point clouds; optional: working knowledge of Python, R.

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