Final dissertation: Master of Science in Geomatics

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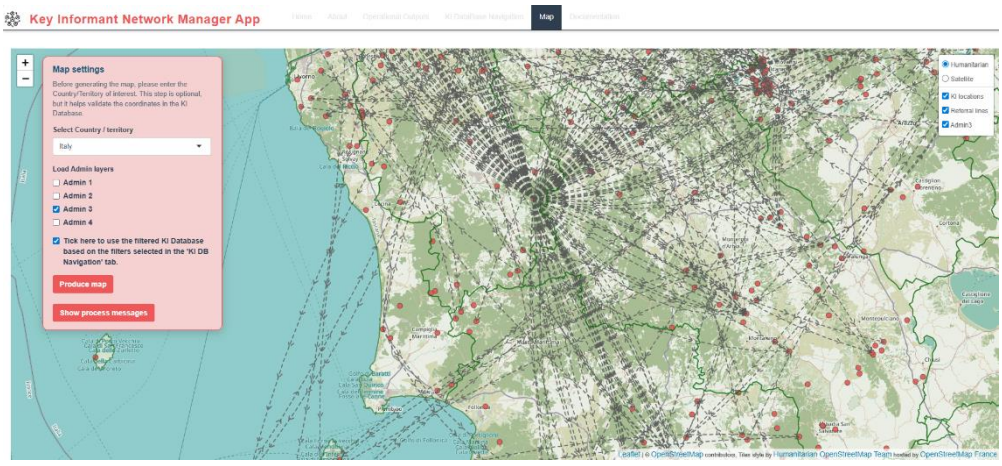
Dr. Gianluca Blaco

Enhancing Humanitarian Decision-Making through WebGIS: An R Shiny Application for Key Informant Network Mapping

Internship at GReD s.r.l. – Geomatics Research & Development s.r.l.

Key Informants (KIs) are individuals with direct knowledge of specific communities or contexts who can provide timely, high-value ground-level information. In humanitarian settings, their insights are essential for rapid assessments, monitoring needs, and supporting evidence-based decision-making, particularly where access to direct information is limited by security or environmental constraints.



Despite the significant operational value of Key Informant (KI) information in humanitarian contexts, the management of KI networks is affected by several structural challenges, including data fragmentation across multiple sources, difficult database maintenance, limited tracking of KI activity over time, insufficient data protection practices, weak integration with operational tools, and the underutilisation of geographic data for spatial analysis and mapping of KI network coverage.

This thesis addresses these challenges through the design and development of an interactive application for the consolidation, visualisation, and protection of KI data. Developed in the R environment using Shiny and its associated spatial libraries, the application supports interactive data exploration and spatial analysis of KI networks, allowing users to assess geographic coverage, identify gaps, and provide a foundation for integrating KI information with remote sensing data, such as environmental or hazard indicators.

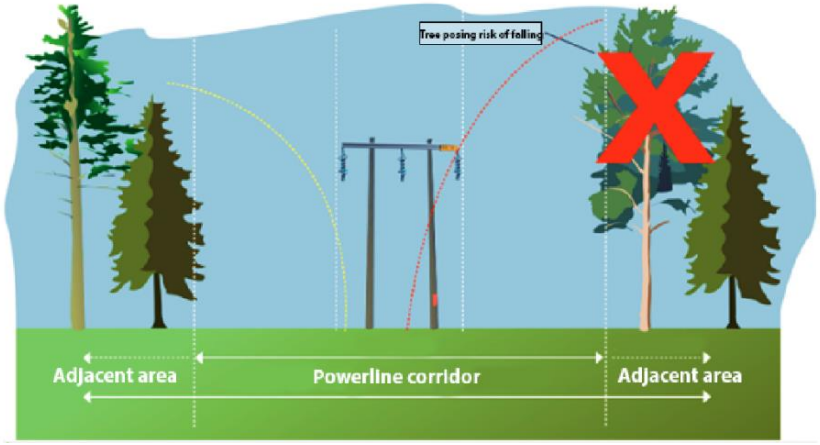
By transforming fragmented datasets into a structured and interactive system, the application contributes to improving data accessibility, reliability, and operational usability, ultimately supporting more informed and spatially aware decision-making in humanitarian contexts.

Dr. Gianmaria Brianese

Vegetation Hazard Assessment in Power Lines: from LiDAR to GIS

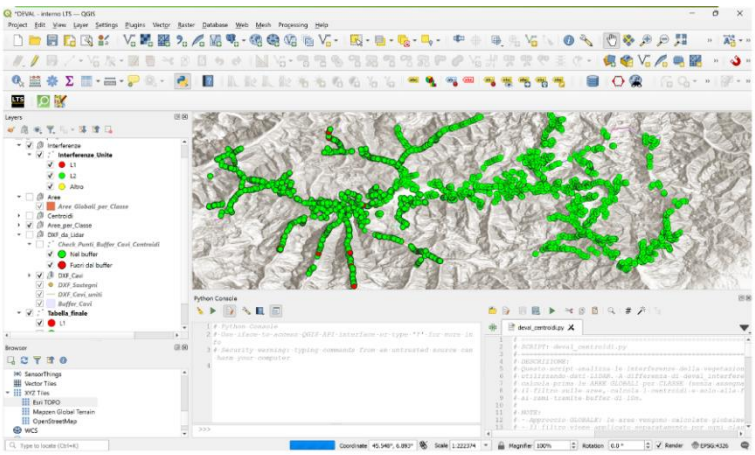
Internship at LTS Land Technology & Services srl

This report documents the methodologies and outcomes of 2 projects focused on automating vegetation hazard assessment along power line corridors, conducted during an internship at LTS Land Technology & Services S.r.l. The work addresses the limitations of traditional manual GIS analysis, which is labour-intensive, prone to operator error, and poorly scalable to networks spanning hundreds of kilometres.



Two distinct, semi-automated PyQGIS workflows were developed to process LiDAR-derived vegetation interference point features for two Italian Distribution System Operators (DSOs). The first, applied to a ~550 km regional grid traversing predominantly flat terrain, implements a span-by-span methodology in which interference point features are assigned to individual spans via a 6 m Euclidean buffer and Spatial Join with predicate CONTAINS. The second, developed for an ~850 km branching Alpine distribution network, implements an object-based geospatial analysis paradigm: approximately 9.5 million individual interference point features are aggregated into ~6,500 discrete vegetation patch objects through morphological buffer-dissolve clustering, which are then assigned to multiple network branches via a one-to-many Spatial Join with predicate INTERSECTS, enabling robust management of hazards at complex junction zones.

The automated pipelines achieved an approximately 70% reduction in processing time, enhanced standardisation, and improved data quality by minimising manual errors. Client-ready deliverables include formatted management tables (XLSX) and KMZ packages for field crew navigation. This work demonstrates the critical importance of adapting automated geospatial analysis to specific geographic, topological, and operational requirements, successfully transitioning from manual, operator-dependent processes to reproducible, scalable data-driven workflows for critical infrastructure management.



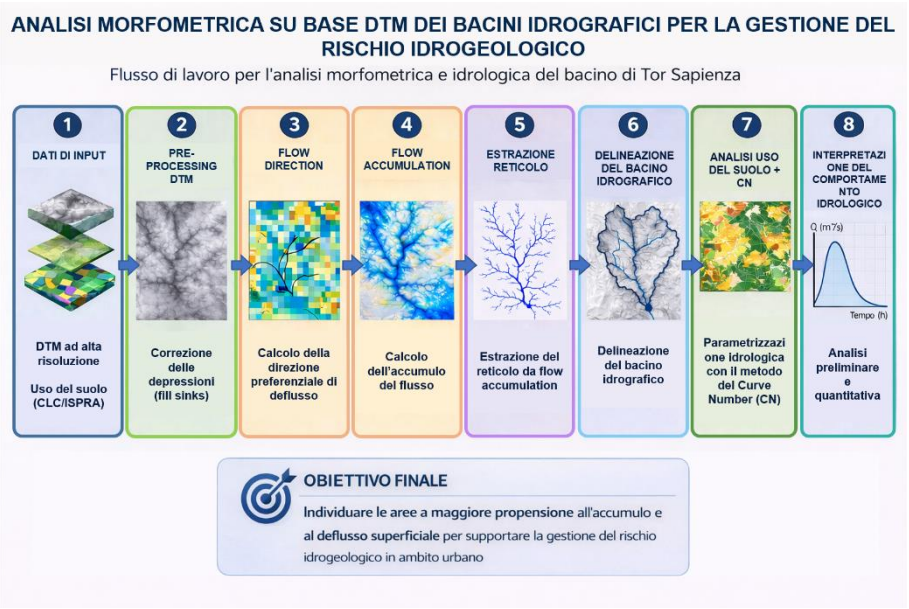
Dr. Damiano Costa

DEM-based morphometric analysis of river basins for hydrogeological risk management

Internship at IDRAN Ingegneria e Tecnologia S.r.l.

This work investigates the hydrological behaviour of the urban catchment of Tor Sapienza (Rome) using GIS-based techniques, with particular focus on the relationship between terrain morphology, land use, and surface runoff dynamics.

The study area is characterized by a high degree of urbanization, which has led to significant soil sealing and consequently to an alteration of natural hydrological processes. In such environments, reduced infiltration capacity and the presence of artificial surfaces enhance surface runoff and increase the susceptibility to water stagnation and flooding, especially during intense rainfall events.



The analysis was carried out using a Digital Terrain Model (DTM), which represents the fundamental dataset for describing the morphology of the basin. From the DTM, key morphometric and hydrological parameters were derived, including flow direction and flow accumulation, through the application of standard hydrological algorithms within a GIS environment. These processes allowed for watershed delineation, drainage network extraction, and identification of the main surface flow pathways.

The analysis was then integrated with land use data (Regione Lazio, 2020), organized according to a classification consistent with INSPIRE standards, in order to evaluate the spatial distribution of different surface covers within the basin. For each land use class, the main morphometric parameters, such as slope and mean elevation, were analysed, highlighting the relationships between topographic characteristics and land cover distribution.

The integration with the Curve Number (CN) parameter allowed for the estimation of the basin response to rainfall events, relating the degree of soil impermeability to the potential for surface runoff generation.

The results highlight a clear relationship between terrain morphology, land use, and surface runoff distribution. In particular, low-slope and highly urbanized areas are more prone to water accumulation and flooding, while steeper sectors promote flow concentration and rapid runoff propagation along the main drainage lines.

The comparison with available hydraulic hazard maps (ISPRA) shows a good agreement between the areas identified as potentially critical and those classified as high-risk, confirming the reliability of the adopted approach.

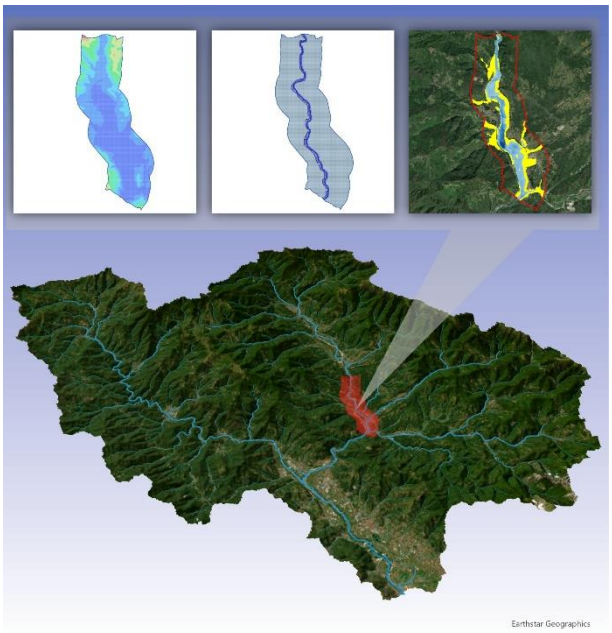
Overall, the integration of morphometric analysis, land use data, and hydrological parameters represents an effective framework for preliminary hydrogeological risk assessment in urban environments. Future developments may include the integration of two-dimensional hydraulic models (e.g., FLO-2D) in order to simulate flood propagation in greater detail and to quantify key hydraulic parameters such as water depth and flow velocity.

Dr. Giacomo Garau

Hydraulic modeling using FLO-2D for the analysis of floodplains in the Magra River basin

Internship at IDRAN Ingegneria e Tecnologia S.r.l.

The aim of this paper is to analyze flooding phenomena related to the overflow of the Magra River in a specific stretch within the basin, between the towns of Aulla and Villafranca in Lunigiana, an area characterized by recurring hydraulic criticalities.



The study is based on the simulation of flood events through the development of a two-dimensional hydraulic model using the FLO-2D software and on the comparison beetween the resulting flood maps and the hazard and risk maps defined by the Flood Risk Management Plan (PGRA) of the Northern Apennines Basin Authority.

In the first part, a general overview of the Magra basin is provided, describing its main geographical, climatic, hydrographic, geological, and geomorphological characteristics, with reference to its evolution over time.

Subsequently, the procedures adopted for the hydrological analysis of the basin are illustrated, starting from the processing of a digital elevation model and the extraction of the basin and hydrographic network within the QGIS environment, aimed at calculating the main morphometric parameters.

The hydraulic modeling was performed considering two different configurations: one that explicitly represents the river channel through a simplified geometry and another without this element, in order to evaluate the differences in flood propagation.

Particular attention was also given to the quality of the elevation data, highlighting how any errors in the digital elevation model may significantly affect the simulation results.

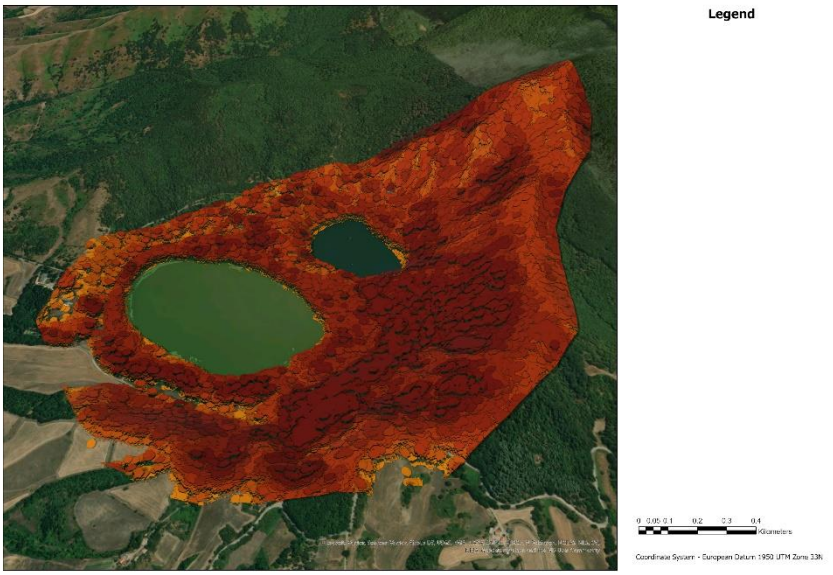
The comparison between the flood maps obtained from the two models and the official PGRA maps allowed us to assess the consistency of the models and to identify the configuration most representative of the hydraulic behavior of the river system, highlighting the crucial role of methodological choices and data quality in flood modeling.

Dr. Tommaso Parenti

Estimating solar radiation, focusing on the effects of the topography and surrounding features, using LiDAR data to optimize the performance of floating photovoltaic systems

Internship at ENEA - Geomatics Lab.

Precise characterization of solar radiation at possible floating photovoltaic (FPV) sites depends upon consideration of both the effects of surrounding topography and vegetation on shading — factors which cannot be sufficiently represented by typical terrain-only models. This research investigates and compares three methodologically differing approaches to solar radiation modeling using LiDAR-derived geospatial data to evaluate their capability to quantify insolation variability at the surfaces of two lakes in Basilicata, Italy. The main research inquiry concerns how the choice of surface representation — i.e., bare earth terrain, first return LiDAR surface, or explicit 3D vegetation model — will affect characterization of the spatial distribution of solar resources and magnitude of canopy shading.

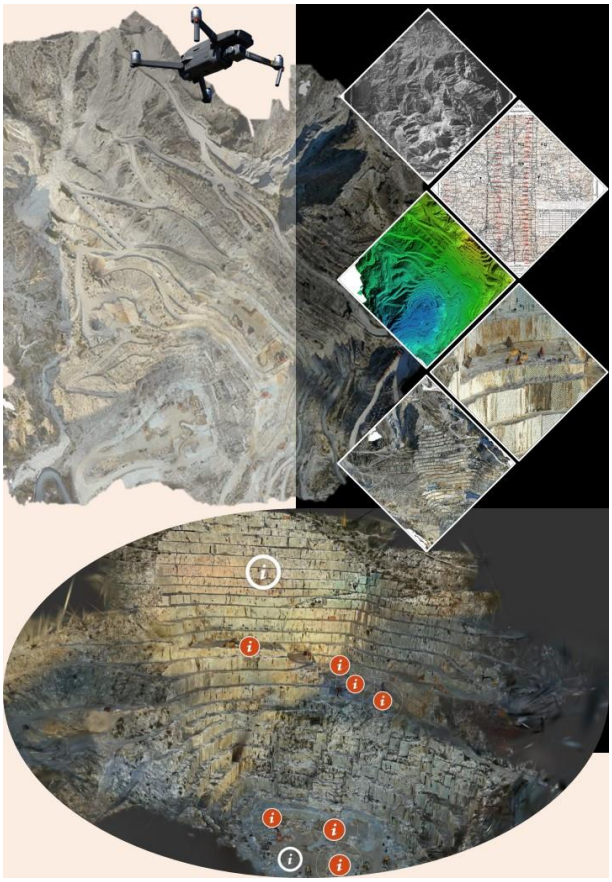


Three models were developed and applied in ArcGIS Pro: a DTM-based terrain model, a DSM-based model using first-return LiDAR, and a combined model consisting of the DTM plus a 3D multipatch canopy derived from the normalized Digital Surface Model (nDSM). A statistical comparison across 23,028 lake surface pixels indicates that while there exists agreement among all three methods regarding mean annual total insolation (~1,235 – 1,265 Wh/m^2), they differ substantially in terms of spatial variability and shading severity. The DSM approach produces excessive estimates of canopy obstruction compared to those produced by the explicit 3D canopy model, whereas expectedly, the DTM alone underestimates them. The study thus presents a replicable, LiDAR-based procedure for developing 3D vegetation models in solar radiation studies that could be employed in FPV site evaluation contexts where access to raw LiDAR data is unobtainable.

Dr. Corrado Vaccarella

Digital photogrammetry, BIM and gaussian splatting for the surveys of a quarry located in the Apuan Alps

Internship at CGT of University of Siena - Geomatics Lab.



The marble quarries located in the Carrara area remain a primary resource for the local economy; their exploitation has ancient origins, dating back to the 2nd century BC, coinciding with the founding of the Roman colony of Luni.

The complexity and breadth of the topic of quarrying have prompted the introduction, for explanatory purposes, of a summary of the main extraction methods, highlighting their evolution from Roman times to the contemporary era. In this context, not only the analysis of extraction techniques is particularly important, but also the study of the transport systems used to transport the stone material to the seaports, a prerequisite for its commercialization.

Over the centuries, marble has profoundly influenced the morphological and landscape transformation of the Apuan Alps. To provide the most complete picture possible of the exploitation dynamics, the aerial photography archive of the National Aerophoto Library (AFN) was consulted. The analysis of numerous images from the MAPRW, EIRA, AM, and VB archives allowed us to reconstruct, in a diachronic perspective, the evolution of the quarrying areas from the Second World War to 1962.

The core of the project was dedicated to the acquisition and processing of photogrammetric surveys using drones, a well-established methodology for detailed surveys in contexts characterized by limited accessibility. This activity aimed to determine the excavated volumes in the quarry located in the marble basin of the Apuan Alps. The survey operations were conducted through the integration of photogrammetric systems and GNSS technologies, used to determine Ground Control Points (GCPs) on the ground.

The photogrammetric data was processed using Structure from Motion (SfM) software, supported by open-source tools for volumetric calculation, such as CloudCompare. To validate the results obtained and explore further methodological approaches for calculating extraction volumes, with a view to integrating them into a quarry lifecycle management workflow, BIM methodologies were also employed for possible data review and coordination within a shared environment (ACDat).

Given the client's frequent unavailability of adequate hardware and software tools for verifying and validating digital products, it was deemed appropriate to propose, on an experimental basis, the use of the Gaussian Splatting technique to

generate 3D models that can be navigated and queried via hotspots. This solution appears to be particularly effective in making content accessible to non-specialist users, promoting broader access to the information.