

Date of Submission	<u>22.12.2021.</u>
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IPL Project Proposal Form 2022

1. Project Title: Optimisation of landslide susceptibility assessment for land-use planning in Croatia: from national to local scale
2. Main Project Fields
 - (1) Technology Development
 - A. Monitoring and Early Warning, B. **Hazard Mapping, Vulnerability and Risk Assessment**
 - (2) Targeted Landslides: Mechanisms and Impacts
 - A. Catastrophic Landslides, B. Landslides Threatening Heritage Sites
 - (3) Capacity Building
 - A. Enhancing Human and Institutional Capacities
 - B. **Collating and Disseminating Information/ Knowledge**
 - (4) Mitigation, Preparedness and Recovery
 - A. Preparedness, B. **Mitigation**, C. Recovery
3. Name of Project leader: Sanja Bernat Gazibara, PhD
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4. Objectives: The main objective of the proposed Project is to reach methodologies for practical solutions in landslide susceptibility assessment on three different scales for different types of Croatian environments. In addition, landslide susceptibility maps will be used by the national, regional, and local administration, policy, and decision-makers in spatial planning processes.
5. Background Justification: The need of researching the landslide susceptibility assessment for application in land use planning arises from the national landslide risk assessment (Croatian National Platform for Disaster Risk Reduction, CNPDRR, 2020) that recognized landslides as a second natural risk in Croatia. The preliminary regional landslide susceptibility analysis showed that approx. 20% of the Republic of Croatia area is potentially prone to sliding. Furthermore, the same landslide susceptibility analysis arises that 60% of cities/municipalities (local administrative units) are endangered by Multiple Occurrence of Regional Landslide Events (MORLE) in case of extreme hydrological events. However, despite long-term investigation on landslides, the main problem in the existing landslide risk management practice in the Republic of Croatia is the lack of detailed and sustainable complete landslide inventories and prognostic landslide hazard and risk maps. Based on collaboration with stakeholders from the national, county and local authorities through numerous round

table discussions in the framework of previous projects, it was concluded that it is necessary to implement landslide maps in the Croatian spatial planning system and define the use of maps for the new spatial plans development.

6. Study Area: Landslide susceptibility assessment will be carried out for 7 pilot areas: (i) the Republic of Croatia; (ii) Zagreb County, Karlovac County and Primorje-Gorski Kotar County; and (iii) the pilot areas in the City of Zagreb (20 km²), Hrvatsko Zagorje (20 km²), Karlovac City (50 km²) and Istria (20 km²).
7. Project Duration: 4 years (January 1, 2022 – December 31, 2025)
8. Resources necessary for the Project and their mobilization: The project budget is approx. 150.000 EUR, approved in 2020 by the Croatian Science Foundation in the framework of project *Methodology development for landslide susceptibility assessment for land-use planning based on LiDAR technology* (LandSlidePlan, HRZZ IP-2019-04-9900) and European Structural and Investment Funds in the framework of project *Applied landslide research for development of risk mitigation and prevention measures* (PRI-MJER, KK.05.1.1.02.0020), covering the purchase of LiDAR data and terrain verification costs.
9. Project Description:

In the proposed Project, we attempt to focus on the primary purpose of landslide susceptibility maps to assist spatial, urban, and infrastructure planning and to avoid areas of potential slope instability and locations of existing landslides. The research aims to compare different landslide susceptibility models and methods due to available input data, reclassification of landslide conditioning factors, and application of different mapping units. The purpose of comparing these landslide susceptibility models is to define the most suitable landslide maps for application in spatial planning at national, regional, and local levels. The research will be based on innovative technologies, realistic limitations related to the availability of spatial data in Croatia (limited amount of geological data), and urgent needs for efficient solutions applicable in the Croatian system of spatial planning in line with European and global requirements related to sustainable development, human and environmental protection. Furthermore, the landslide susceptibility assessment will be carried out due to different natural conditions and land use types in different parts of Croatia. Therefore, the proposed Project will result in a large number of landslide susceptibility maps for various pilot areas: (i) Landslide susceptibility map of Croatia on a scale of 1:100.000; (ii) Landslide susceptibility maps of Zagreb County, Karlovac County and Primorje-Gorski Kotar County on a scale of 1:25.000; (iii) Landslide susceptibility maps of the pilot areas in the City of Zagreb, Hrvatsko Zagorje, Karlovac City and Istria on a scale 1:5.000. Planned methodology of scientific research includes (i) data collection for landslide susceptibility assessment; (ii) data analyses using heuristic approach or statistical methods; (iii) verification of landslide susceptibility models using Receiver operating characteristic (ROC) curve; (iv) classification of resulting susceptibility maps according to spatial planners requirements, i.e., comparing susceptibility zoning with land use and cadastral data; (v) implementation of the resulting landslide susceptibility maps in the Croatian spatial planning system. Methodology development for landslide susceptibility assessment on national and regional scales will be carried out using a heuristic approach

(Fuzzy Logic method) and available topographical and geological data. Methodology development for landslide susceptibility assessment on a local scale will be carried out using statistical methods (bivariate statistical methods, including Information Value method and Weights of Evidence method, multivariate statistical methods, including Logistic Regression and Discriminant Analysis, and machine learning methods, including Support Vector Machine and Random Forest), airborne LiDAR data and available geological data. Landslide susceptibility models will be computed using different scenarios of input data (mapping units and causal factors). The final goal is to define the methodology for landslide susceptibility assessment in Croatia based on specific environmental/engineering geological conditions, landslide types and level of zonation, and the application of final landslide maps in spatial planning.

10. Work Plan/Expected Results:

1st phase: Preparation of input data sets: (i) Landslide causal factors for landslide susceptibility modeling on national and county scale; (ii) LiDAR-derived DEM and LiDAR-based landslide inventory for landslide susceptibility modeling on a local scale, field verification of the landslides interpreted based on LiDAR DTM; Milestone: Prepared input datasets for susceptibility modeling.

2nd phase: Landslide susceptibility modeling and verification. Milestone: Conducted landslide susceptibility modeling based on a heuristic approach and different statistical methods, input datasets, mapping units, and level of zonation.

3rd phase: Classification and validation of landslide susceptibility maps for land use planning. The organization of round tables with stakeholders at the national, county, and local level; Milestone: Classified landslide susceptibility maps for each pilot area based on the optimal classification method and spatial planners requirements.

4th phase: Round Table Discussions and Work Meetings with spatial planners regarding implementation of the resulting landslide susceptibility maps in the Croatian spatial planning system; Milestone: Feedback from spatial planners after using landslide susceptibility maps. Project results will be shared on the Projects Web Page (<https://landslideplan.eu/en/home/>; <https://pri-mjer.hr/>) and on social media.

11. Deliverables/Time Frame:

1st phase: Input datasets for landslide susceptibility modeling at the national, county, and local scale. Time duration: within the first year of the Project.

2nd phase: Selected the most accurate landslide susceptibility map for each pilot area. Time duration: within the first two years of the Project.

3rd phase: Classified landslide susceptibility maps for each pilot area. Time duration: during the second and third years of the Project.

4th phase: Implemented landslide susceptibility maps in the Croatian spatial planning system. Time duration: during the last year of the Project.

12. Project Beneficiaries: Ministry of Physical Planning, Construction and State Assets, county and local authorities and spatial planners, landslide-affected population, and landslide scientists.

13. References: Bernat Gazibara et al (2022) - LandSlidePlan - Scientific research project on landslide susceptibility assessment in large scale. Proceedings of the 5th ReSyLAB 'Landslide Modelling & Applications', 99-104.