Date of Submission	16.7.2024.

IPL Project (IPL-Number) Annual Report Form

Period of activity under report
from 1 January 2022 to 31 December 2023

1. **Project Number and Title:** Optimisation of landslide susceptibility assessment for land-use planning in Croatia: from national to local scale (IPL-257)

2. **Main Project Fields**

   Select the suitable topics. If no suitable one, you may add new field.

   (1) Technology Development

   B. Hazard Mapping, Vulnerability and Risk Assessment

   (2) Targeted Landslides: Mechanisms and Impacts

   A. Catastrophic Landslides

   (3) Capacity Building

   B. Collating and Disseminating Information/ Knowledge

   (4) Mitigation, Preparedness and Recovery

   A. Preparedness

3. **Name of Project Leader:** Assist. Prof. Sanja Bernat Gazibara, PhD

   Affiliation: University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering, Pierottijeva 6, 10000 Zagreb, Croatia; Telephone: +38515535760; Email: sbernat@rgn.hr

   Core members of the Project: Prof. Snježana Mihalić Arbanas (UNI-ZG, Faculty of Mining, Geology and Petroleum Engineering); Assos. Prof. Martin Krkač (UNI-ZG, Faculty of Mining, Geology and Petroleum Engineering); Hrvoje Lukačić, Assistant (UNI-ZG, Faculty of Mining, Geology and Petroleum Engineering); Marko Sinčić, Assistant (UNI-ZG, Faculty of Mining, Geology and Petroleum Engineering).

4. **Objectives** (5 lines maximum)

   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. **Study Area**

   Landslide susceptibility assessment will be carried out for eight 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 km^2), Hrvatsko Zagorje (20 km^2), Karlovac City (50 km^2) and Istria (20 km^2).

6. Project Duration

4 years (January 1, 2022 – December 31, 2025)

7. Report

1) Progress in the project (30 lines maximum)

During the first and second year of the Project, comprehensive landslide susceptibility modelling was carried out for eight pilot areas. The first step was the preparation of input data sets: (i) landslide causal factors for landslide susceptibility modelling on national and county level; (ii) LiDAR-derived DEM and LiDAR-based landslide inventory for landslide susceptibility modelling on a local level, filed verification of the landslides interpreted based on LiDAR DTM. The second step was comprehensive landslide susceptibility modelling and verification based on prepared input datasets for all pilot areas. The modelling included defining optimal input data quality, landslide sampling strategies, mapping units, applied statistical method, and zonation method for providing final landslide susceptibility maps in different scales. Finally, all landslide susceptibility models were evaluated based on model fitting performance, model prediction performance, and model uncertainty. The purpose of comparing landslide susceptibility models was to define the most suitable methodology for modelling small and shallow landslides in Croatia. The main conclusion from the derived landslide susceptibility assessment for three Croatian counties is that the medium-scale spatial probability estimated using a Fuzzy heuristic approach (lack of representative landslide inventory) showed satisfactory prediction results (verification performed by incomplete landslide inventory). The main conclusions from the derived comprehensive large-scale landslide susceptibility analysis are: (i) relevant and high-resolution input data with sufficient spatial accuracy will result in highly reliable LSM (Krkač et al. 2023); (ii) pixel-based models are more appropriate mapping units for the local-level spatial planning system than slope unit-based models, resulting in more detailed susceptibility information, but also require "post-processing" of the susceptibility zones to produce more clustered and homogeneous information for the final purpose (Bernat Gazibara et al., 2023a); (iii) optimal method selection remains an open question and generally should be considered regarding the final applicability of the LSA (Bernat Gazibara et al., 2023a); (iv) qualitative assessment, alongside commonly used quantitative metrics, is mandatory to verify spatial accuracy and to test the applicability of derived LSM. One of the most significant results is the guidelines for the compilation and application of large-scale landslide maps in Croatia's spatial planning system.

2) Planned future activities or statement of completion of the Project:

1. Determining and defining the optimal classification method for landslide susceptibility zonation in different geomorphological environments in Croatia. Time duration: during the third year of the Project.

2. Implementation of landslide susceptibility zonation maps in the Croatian spatial planning

system. Time duration: during the last year of the Project.

3. Preparing several scientific publications regarding the results of conducted research.

3) Beneficiaries of Project for Science, Education and/or Society

1. *Guidelines for Creating Landslide Maps in the Republic of Croatia* were created as part of this Croatian Science Foundation project as a publication that brings together all the project's most important results in one place. The guidelines are intended for landslide susceptibility map makers and include chapters on input data, recommendations for making maps for local application, examples of landslide maps made within the framework of the LandSlidePlan project, and the use of maps in spatial planning.

2. Professional Conference of the LandSlidePlan project LANDSLIDES IN SPATIAL PLANNING, 18.12.2023, Croatian Chamber of Architects,– more than 160 architects from all over Croatia participated.

3. Two educational workshops, four info days, six round tables, and one final conference in the frame of the PRI-MJER project - all events refer to the application of landslide susceptibility maps in spatial planning system.

4) Results

1. Bernat Gazibara, S., Sinčić M., Rossi M., Reichenbach, P., Krkač, M., Lukačić, H., Jagodnik., P., Šarić, G., Mihalić Arbanas, S. (2023a). Application of LAND-SUITE for Landslide Susceptibility Modelling Using Different Mapping Units: A Case Study in Croatia. In: Alcántara-Ayala, I., et al. Progress in Landslide Research and Technology, Volume 2 Issue 2, 2023. Progress in Landslide Research and Technology. Springer, Cham. https://doi.org/10.1007/978-3-031-44296-4_19
2. Bernat Gazibara, S., Jagodnik, P., Lukačić, H., Sinčić, M., Krkač, M., Šarić, G., Arbanas, Ž., Mihalić Arbanas, S. (2023b) Landslide and Soil Erosion Inventory Mapping Based on High-Resolution Remote Sensing Data: A Case Study from Istria (Croatia). In: Alcántara-Ayala, I., Arbanas, Ž., Cuomo, S. et al. (eds.): Progress in Landslide Research and Technology Volume 2 Issue 1, Switzerland: Springer Cham, 2023, 363-375.. doi:10.1007/978-3-031-39012-8_18
3. Krkač, M., Bernat Gazibara, S., Sinčić, M., Lukačić, H., Šarić, G., Mihalić Arbanas, S. (2023) Impact of Input Data on the Quality of the Landslide Susceptibility Large-Scale Maps: A Case Study from NW Croatia. In: Alcántara-Ayala, I. Arbanas, Ž.Cuomo, S. et al. (eds.): Progress in Landslide Research and Technology Volume 2 Issue 1, Switzerland: Springer Cham, 2023, 135-146. doi:10.1007/978-3-031-39012-8_4
4. Bernat Gazibara, S., Sinčić, M., Krkač, M., Lukačić, H., Mihalić Arbanas, S. (2023c): Landslide susceptibility assessment on a large scale in the Podsljeme area, City of Zagreb (Croatia) // Journal of Maps, 19 (2023), 1, 11. doi:10.1080/17445647.2022.2163197

5. Mihalić Arbanas, S., Bernat Gazibara, S., Krkač, M., Sinčić, M., Lukačić, H., Jagodnik, P., Arbanas, Ž. (2022): Landslide Detection and Spatial Prediction: Application of Data and Information from Landslide Maps. In: Alcantara-Ayala, I., Arbanas, Ž., Huntley, D. et al. (eds.). Progress in Landslide Research and Technology, Volume 1 Issue 2, Fullerton, CA, USA: Springer, 2023, 195-212. doi: 10.1007/978-3-031-18471-0_16
6. Krkač, M., Bernat Gazibara, S., Sinčić, M., Lukačić, H., Mihalić Arbanas, S. (2022): Landslide inventory mapping based on LiDAR data: A case study from Hrvatsko Zagorje (Croatia). In: Peranić, J., Vivoda Prodan, M., Bernat Gazibara, S.et al. (eds.): Proceedings of the 5th ReSyLAB 'Landslide Modelling & Applications', Rijeka, 2022, 81-86.
7. Sinčić, M., Bernat Gazibara, S., Krkač, M., Mihalić Arbanas, S. (2022a): Landslide susceptibility assessment of the City of Karlovac using the bivariate statistical analysis. Rudarsko-geološko-naftni zbornik, doi: 10.17794/rgn.2022.2.13
8. Sinčić, M., Bernat Gazibara, S., Krkač, M., Lukačić, H., Mihalić Arbanas, S. (2022b): The Use of High-Resolution Remote Sensing Data in Preparation of Input Data for Large-Scale Landslide Hazard Assessments // Land (Basel), 11 (2022), 8; 1360, 37. doi: 10.3390/land11081360
9. Bernat Gazibara, S., Damjanović, V., Krkač, M., Sinčić, M., Lukačić, H., Mihalić Arbanas, S. (2022a) Landslide susceptibility map of Croatia based on limited data and Fuzzy logic approach In: Peranić, J., Vivoda Prodan, M., Bernat Gazibara, S.et al. (eds.): Proceedings of the 5th ReSyLAB 'Landslide Modelling & Applications', Rijeka, 2022, 27-28.
10. Bernat Gazibara, S., Mihalić Arbanas, S., Sinčić, M., Krkač, M., Lukačić, H., Jagodnik, P., Arbanas, Ž. (2022b) LandSlidePlan - Scientific research project on landslide susceptibility assessment in large scale. In: Peranić, J., Vivoda Prodan, M., Bernat Gazibara, S.et al. (eds.): Proceedings of the 5th ReSyLAB 'Landslide Modelling & Applications', Rijeka, 2022, 99-106