Date of Submission	11 April 2023

IPL Project (IPL - 248) Annual Report Form 2022

1 January 2022 to 31 December 2022

1. PROJECT NUMBER (approved year) AND TITLE:

IPL – 248 (2019): Innovation in slow-moving landslide risk assessment of roads and urban sites by combining multi-sensor multi-source monitoring data

2. MAIN PROJECT FIELDS

(1) Technology Development

A. Monitoring and Early Warning,

B. Hazard Mapping, Vulnerability and Risk Assessment

3. NAME OF PROJECT LEADER: Dario Peduto, PhD

Affiliation: Associate Professor, Geotechnical Engineering Group (GEG), Dept. of Civil Engineering, University of Salerno (Italy), ICL Associate Member

Contact: Via Giovanni Paolo II, 132 - 84084 - Fisciano (SA), Office: +39089964120; email: dpeduto@unisa.it

Core members of the Project

- ✓ Biljana Abolmasov, Full Professor, Department of Geotechnics, Faculty of Mining and Geology (FMG), University of Belgrade (UNIBG), Serbia.
- ✓ Uroš Đurić, Teaching Assistant, Department of Geotechnical Engineering, Faculty of Civil Engineering (FCE), University of Belgrade (UNIBG), Serbia
- ✓ Settimio Ferlisi, Full Professor, Geotechnical Engineering Group (GEG), University of Salerno
- ✓ Diego Reale, Researcher, National Research Council, Institute for Electromagnetic Sensing of the Environment (CNR-IREA), Naples (Italy)

Contributors

- ✓ Gianfranco Nicodemo, Assistant Professor, Geotechnical Engineering Group (GEG), University of Salerno
- ✓ Fornaro Gianfranco, Research Leader, National Research Council, Institute for Electromagnetic Sensing of the Environment (CNR-IREA), Naples (Italy)
- ✓ Miloš Marjanović, Assistant Professor, Faculty of Mining and Geology, University of Belgrade.
- ✓ Davide Luongo, Associate Researcher, Geotechnical Engineering Group (GEG), University of Salerno

4. OBJECTIVES: (5 lines maximum)

The project is aimed at developing and testing appropriate procedures for the use of innovative multi-temporal multi-sensor monitoring techniques jointly with multi-source field data for the landslide hazard, vulnerability and risk assessment in (slow-moving) landslide-affected areas. The proposed procedures will be double-tested in different geo-environmental contexts taking advantage of previous/ongoing studies carried out by the Project members in selected areas in both Italy and Serbia.

5. STUDY AREA: (2 lines maximum)

Some study areas severely affected by slow-moving landslides were selected in both countries: Calabria region and Cilento area, southern Italy; and SW Belgrade suburb (Umka landslide) in Serbia.

6. PROJECT DURATION (1 line maximum)

3 years

7. REPORT

7.1 Progress in the project: (30 lines maximum)

According to the approved proposal, the Project was arranged in six phases. The first two phases (see Annual Report 2020), concerned: *i)* the collection, review and harmonization of all available information on landslides in the selected case studies in southern Italy and in Belgrade (Serbia) area; *ii)* the filling in and collection of ad-hoc prepared damage fact-sheets for the exposed buildings/roads in both study areas; *iii)* the generation of surface displacement temporal time series at the full available spatial resolution – through the Multipass Differential Interferometric (DInSAR) technique via the SAR Tomography approach – of Synthetic Aperture Radar (SAR) dataset acquired by both the Italian COSMO-SkyMed constellation and the ESA Copernicus Sentinel-1 mission over the Belgrade city and its surroundings including the Umka landslide.

In the second year of the project (see the Annual Report 2021) the three involved institutions worked on the definition of a common approach (Fig.1) aimed at assessing the slow-moving landslide hazard and investigating the vulnerability of structures and infrastructures in landslide-affected urban areas (Peduto et al., 2020). Specifically, the proposed approach consists of three main phases (Fig. 1) including: step I) the detection of the elements (i.e. buildings and road) exposed to landslide risk; step II) the assessment of a damage severity level (DL) and the intensity parameter (IP) computed using the available monitoring data; step III) the vulnerability analysis by combining the above DL and IP information selected according to the scale and type (i.e. empirical or numerical) of analysis, and deterministic (i.e. cause-effect relationships) or probabilistic (i.e. aimed at generating consequence forecasting tools such as fragility and/or vulnerability curves) approaches.

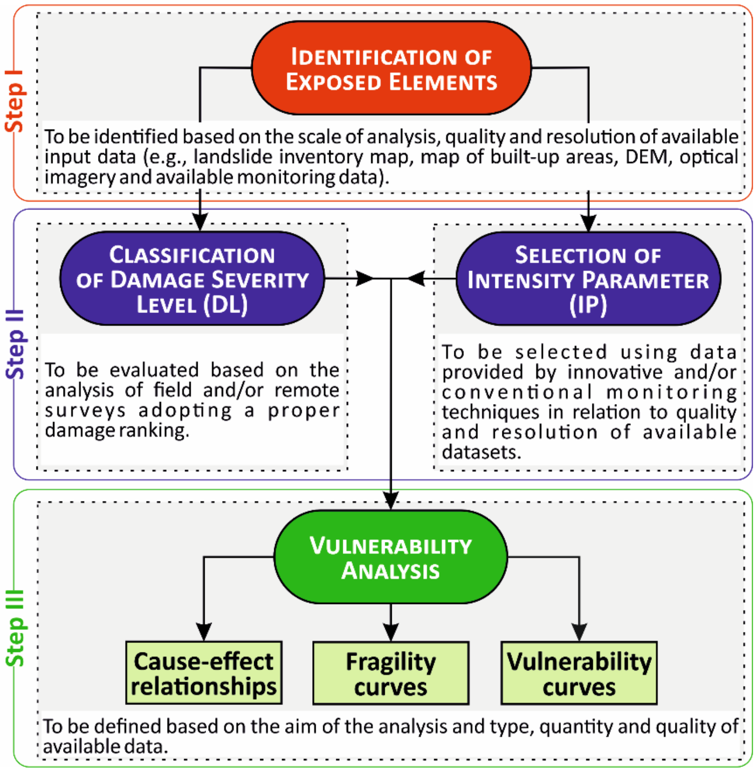

Fig.1 *Flowchart of the proposed approach (modified from Peduto et al., 2020).*

In agreement with the project proposal, in the third year of the project the three institutions applied the proposed approach to the selected case studies. With reference to Italian case studies, via the joint use of conventional monitoring data (GPS and damage surveys) and remote sensing (DInSAR and Google StreetView) empirical cause (displacement) – effect (damage) relationships were derived for both buildings and roads interacting with slow-moving landslides (Peduto et al., 2021a, b). As for roads, the risk was quantitatively assessed in terms of repair costs under fixed scenarios. Furthermore, a numerical analysis aimed at investigating the response of a masonry building undergoing slow-moving landslide-induced displacements was carried out (Nicodemo et al., 2021) and the results obtained successfully compared with the information collected during multi temporal damage surveys on the modeled building. As for the Umka landslide case study, multi-source monitoring data allowed a data-driven landslide characterization (Samardžić Petrović et al., 2020; Abolmasov et al., 2021) that was validated against the landslide geomorphological-geotechnical model, which was previously outlined based on geomorphological criteria and geotechnical investigations. The processing of very high resolution X-Band COSMO-SkyMed data was also supported by a complementary processing of C-Band Sentinel-1 data: the high intensity rate of the movement in the area of interest of the Umka landslide, coupled with the heavy presence of vegetation pose challenges in the effective monitoring capability at X-Band, consequently the processing has been integrated with Sentinel-1 trading off between lower spatial resolution but with the advantage of higher robustness against both temporal decorrelation as well as deformation signal ambiguities.

7.2 Planned future activities or Statement of completion of the Project (15 lines maximum)

In 2020 and 2021, the full exchange of best practice and expertise among the different partners has been slowed down because of Covid pandemic that did not allow the scheduled joint technical visits to the study areas due to travelling problems among European countries.

During 2022 joint activities restarted and collaboration among the involved groups allowed achieving the fixed goals. Importantly, the cooperation will go on trying to deepen a comprehensive comparison of results from different study areas in both countries. Some of the results will be presented orally within the upcoming 6th World Landslide Forum in Florence (Italy) by the research groups.

7.3 Beneficiaries of Project for Science, Education and/or Society (15 lines maximum)

Direct beneficiaries of the project are community/municipalities affected by landslides. Local and regional authorities in both Italy and Serbia – housing sector, infrastructure authorities, Civil protection departments – were contacted and informed about the results of the project during the third year of the project development.

The results were disseminated to PhD students and Young Doctors attending the last three editions of LARAM2020, LARAM2021, LARAM2022 "LAndslide Risk Assessment and Mitigation" International School – which is yearly organized by GEG-UNISA with the contribution of several ICL members – by Prof. Dario Peduto during his lessons on "DInSAR-based landslide characterization" (on 15 September 2020) and "Landslide vulnerability assessment" (on 16 September 2020); and "Multi-source data-based monitoring" (on 15 September 2021) and "Innovation in landslide vulnerability analysis" (on 15 September 2021).

During the upcoming edition of LARAM2023 in September 2023 both Prof. Biljana Abolmasov and Prof. Dario Peduto have been invited to deliver lessons that will deal with the results of the project.

Additional dissemination activities dealt with a short course – organized by Profs. Abolmasov, Đurić and Marjanović - on "*Innovation in geotechnical monitoring of slow-moving landslides and subsidence*" that Prof. Dario Peduto and Dr. Gianfranco Nicodemo delivered at the University of Belgrade.

7.4 Results: (15 line maximum, e.g. publications)

Abolmasov B., Đurić U., Popović J., Pejić M., Samardžić Petrović M., Brodić N. (2021) Results of Recent Monitoring Activities on Landslide Umka, Belgrade, Serbia—IPL 181. In: Sassa K., Mikoš M., Sassa S., Bobrowsky P.T., Takara K., Dang K. (eds) Understanding and Reducing Landslide Disaster Risk. WLF 2020. ICL Contribution to Landslide Disaster Risk Reduction. Vol 1"Sendai Landslide Partnerships and Kyoto Landslide Commitment", pp.225-234., Print ISBN 978-3-030-60195-9, On-line ISBN 978-3-030-60196-6, © Springer Nature Switzerland AG 2021. https://doi.org/10.1007/978-3-030-60196-6_14

Samardžić Petrović M., Popović J., Đurić U., Abolmasov B., Marjanović M. (2020). Pemanent GNSS monitoring of landslide Umka. Borković A., Malinović M., (eds.): Proceedings of the XIVth International Conference of Contemporary Theory and Practice in Construction, 11-12 June 2020, Banja Luka, Bosnia and Herzegovina. University of Banja Luka, Faculty of Architecture Civil Engineering and Geodesy, 2020, pp 91 - 98. ISSN 2566-4484

Gullà G., Nicodemo G., Ferlisi S., Borrelli L., Peduto D. (2021) Small-scale analysis to rank municipalities requiring slow-moving landslide risk mitigation measures: the case study of the Calabria region (southern Italy) Geoenvironmental Disasters (2021) 8:3, 25 pages https://doi.org/10.1186/s40677-021-00202-1

Peduto D., Nicodemo G., Nappo N., Gullà G. (2021a) Innovation in Analysis and Forecasting of Vulnerability to Slow-Moving Landslides. In: Guzzetti F., Mihalić Arbanas S., Reichenbach P., Sassa K., Bobrowsky P.T., Takara K. (eds) Understanding and Reducing Landslide Disaster Risk. WLF 2020. ICL Contribution to Landslide Disaster Risk Reduction. Volume 2 "From Mapping to Hazard and Risk Zonation", pp.441-446. Springer, Cham. https://doi.org/10.1007/978-3-030-60227-7_51, Print ISBN978-3-030-60226-0, Online ISBN978-3-030-60227-7, © Springer Nature Switzerland AG 2021

Peduto D., Santoro M., Aceto L., Borrelli L., Gullà G. (2021b). Full integration of geomorphological, geotechnical, A-DInSAR and damage data for detailed geometric-kinematic features of a slow-moving landslide in urban area. Landslides, 18(3):807–825, DOI: 10.1007/s10346-020-01541-0

Nicodemo G., Ferlisi S., Peduto D., Aceto L., Borrelli L., Gullà G. (2022). Numerical analysis of the nonlinear behaviour of a masonry building undergoing slow-moving landslide-induced displacements. In: Rahman and Jaksa (Eds.). Proceedings of the 20th International Conference On Soil Mechanics And Geotechnical Engineering, 1-5 May 2022, Sydney, Australia, pp. 2535-2540, Australian Geomechanics Society, ISBN: 978-0-9946261-4-1