

Date of Submission	16 July 2024
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IPL Project Annual Report Form 2023

01 January 2023 to 01 July 2024

1. Project Title (IPL-210)

“Massive landsliding in Serbia following Cyclone Tamara in May 2014”

2. Main Project Fields

(1) Technology Development

B. Hazard Mapping, Vulnerability and Risk Assessment

(2) Targeted Landslides: Mechanisms and Impacts

A. Catastrophic Landslides

3. Name of Project leader: Biljana Abolmasov, PhD

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Core members of the Project - Names/Affiliations: (4 individuals maximum)

- Miloš Marjanović, PhD, Associate Professor, University of Belgrade, Faculty of Mining and Geology
- Mileva Samardžić Petrović, PhD, Associate Professor, University of Belgrade, Faculty of Civil Engineering
- Uroš Djurić, PhD, Assistant Professor, University of Belgrade, Faculty of Civil Engineering
- Jelka Krušić, PhD, Teachnig Assistant, Ksenija Micić, PhD student, University of Belgrade, Faculty of Mining and Geology,

4. Objectives: (5 lines maximum)

The project attempts to accomplish that the May 2014 extreme landsliding event was preconditioned by soil saturation, caused by a high precipitation yield, within several weeks to the event. All relevant data, including historic/current rainfall, landslide records, aftermath reports, and environmental features datasets, have to be analyzed for characterizing the extreme nature of the event and identifying key environmental controls of landslide occurrences.

5. Study Area: (2 lines maximum)

The study area is Western and Central part of the Republic of Serbia - territory of 15000 km² affected

by Cyclone Tamara during May 2014. Project Duration (1 line maximum)

Project duration - March 2016 - ongoing

6. Report

1) Progress in the project: (30 lines maximum)

Project IPL 210 – “Massive landsliding in Serbia following Cyclone Tamara in May 2014” was approved in March 2016. Collecting, review and harmonization of landslides data were conducted nine months afterwards, as per the Project Plan. Different types of movement and types of material involved were registered during extensive field campaign and satellite data analysis. A total number of 1888 different types of movement were certified by supervisor (1539 slides, 78 flows, 48 falls, 1 topple, 23 complex, 138 flows/ slides, 55 falls/slides and 6 falls/flows). According to the material involved 925 types of movement were formed from debris, 894 from earth, 20 from rock, 33 from mixed and 16 from artificial material. The simple analysis performed based on landslide distribution by municipalities shows that the highest number of landslide occurrences were recorded in the Western part of Serbia.

Research results from the IPL 210 Project are presented in the papers, both internationally and locally (see references), as well as IPL Progress reports on ICL/IPL Conferences and WLF5. Results from satellite data images were published in Landslides Journal. Team additionally conducted detail field geodetic survey by UAV techniques and collected samples from debris flows material on two site specific sites - Selanac and Leva Reka within IPL 210 Project activities. Historical precipitation data from nearest rain gauge stations were collected and analyzed. Modelling and simulation of debris flows was performed in RAMMS, and preliminary results were published and presented on 3rd, 4th and 5th ReSyLAB in Ljubljana 2017, Sarajevo 2019, and Rijeka 2022 as well as on the XVI ISSMGE Danube Symposia in Skopje (2018), SCG-XIII International Symposium on Landslides. Cartagena (2021), Colombia and local symposia and Journals (on Serbian) (see references). PhD student Jelka Krušić was included in Erasmus+ exchange program with UPM ETS Ingenieros de Caminos, Department of Applied Mathematics, Madrid, Spain, and he was supervised by Professor Manuel Pastor in her research and modelling. Additionally, we included climate changing conditions, especially extreme climate events in research objectives in 2022. Jelka Krušić, PhD student was finalized her PhD Thesis (“Numerical modelling on debris flow with special attention on rheological models”) in May 2024.

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

The project aims to summarize and analyzing collected landslide information from the May 2014 sequence and other extreme climate conditions. The analysis, correlation, and synthesis of large volume of data are currently being performed. Following the Project proposal the Project

activities were focused on analyzing: (1) the trigger/landslide relation in extreme climate conditions, (2) relating the landslide mechanisms and magnitudes versus the trigger and its aftermath and (3) numerical modelling and simulation of flow/fall mechanism for chosen sites. PhD researchers are focusing on debris flow mechanism and modelling both in RAMMS and using SPH code, as well as rockfall simulation in RAMMS. The last Project activities were finalized during the 6th Regional Symposium on Landslides in the Adriatic-Balkan Region (6th ReSyLAB) held in May 2024, as well as papers published in the Proceedings. The last activity will be manuscript (as a Review paper) which will be submitted on the Landslide Journal in 2024-2025. **It is planned to complete Project 210 until the end of 2024.**

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

- a. Direct beneficiaries will be local communities – municipalities in Western and Central parts of Serbia affected by landslide in extreme climate conditions
- b. Local and regional authorities – housing sector, infrastructure authorities, Civil protection and Emergency response units and land-use sectors within affected areas

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

The list of publications in the framework the project is as follows:

- Krušić J. (2024) Numerical modeling on debris flow with special attention on rheological models. PhD Thesis, University of Belgrade, Faculty of Mining and Geology, Belgrade, The Republic of Serbia. p 132.
- Micić K, Marjanović M, Abolmasov B. (2024) Debris-flow Susceptibility Assessment in Flow-R: Ribnica River Case Study, Debris-flow Susceptibility Assessment in Flow-R: Ribnica River Case Study. Proceedings of the 6th Regional Symposium on Landslides in the Adriatic-Balkan Region 15-18 May 2024, Belgrade, Serbia, University of Belgrade, Faculty of Mining and Geology. pp 231-237. <https://doi.org/10.18485/resylab.2024.6.ch34>
- Marjanović, M., Abolmasov, B., Krušić, J., Đurić, U. (2024). Regional Debris Flow Hazard Assessment of the Grdelica Gorge (Serbia). In: Abolmasov, B., *et al.* Progress in Landslide Research and Technology, Volume 3 Issue 1, 2024. Progress in Landslide Research and Technology. Springer, Cham. https://doi.org/10.1007/978-3-031-55120-8_15
- Marjanović M., Abolmasov B., Đurić U., Krušić J., Bogdanović S. (2022) Regional rockfall exposure assessment, experience from Serbia. In: Peranić J., Vivoda Prodan M., Bernat Gazibara S., Krkač M., Mihalić Arbanas S. and Arbanas Ž. (eds). Landslide Modelling & Applications. Proceedings of the 5th Regional Symposium on Landslides in the Adriatic-Balkan Region. Croatian Landslide Group University of Rijeka, Faculty of Civil Engineering University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering, pp 145-150. https://5resylab.uniri.hr/wp-content/uploads/2022/04/2_Proceedings-of-the-5th-ReSyLAB.pdf

- Krušić J., Abolmasov B., Marjanović M., Pastor M., Tayebi S.M. (2021). Numerical modelling of Selanac debris flow propagation using SPH code. SCG-XIII International Symposium on Landslides. Cartagena, Colombia- June 15th-19th-2020. ISL2020-109.pdf. <https://www.issmge.org/publications/online-library>
- Abolmasov B., Petrović M.S., Stanković R., Marjanović M., Krušić J., Đurić U. (2021) Extreme Rainfall Event and its Aftermath Analysis—IPL 210 Project Progress Report. 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. Springer, Cham. Pp. 267-273. https://doi.org/10.1007/978-3-030-60196-6_19
- Krušić J., Abolmasov B., Marjanović M. (2021) Numerical Models of Debris Flows with Entrainment Analysis-Case Studies from the Republic of Serbia. In: Tiwari B., Sassa K., Bobrowsky P.T., Takara K. (eds). Understanding and Reducing Landslide Disaster Risk. WLF 2020. ICL Contribution to Landslide Disaster Risk Reduction. Springer, Cham. https://doi.org/10.1007/978-3-030-60706-7_25
- Marjanović M., Abolmasov B., Sandić C., Mulać M., Begović P. (2021). Quantitative landslide risk assessment in the city of Tuzla. SCG-XIII International Symposium on Landslides. Cartagena, Colombia- June 15th-19th-2020. ISL2020-102.pdf. <https://www.issmge.org/publications/online-library>
- Krušić J., Abolmasov B., Samardžić Petrović M. (2019). Influence of DEM resolution on numerical modelling of debris flows in RAMMS - Selanac case study. Uljarević M., Zekan S., Ibrahimović Dž. (eds.): Proceedings of the 4th Regional Symposium on Landslides in the Adriatic Balkan Region, 23-25 October 2019, Sarajevo, Bosnia and Herzegovina. Geotechnical Society of Bosnia and Herzegovina, 2019. doi: https://doi.org/10.35123/ReSyLAB_2019, 163 - 168. ISBN 978-9926-8400-0-6
- Marjanović M., Abolmasov B., Milenković S., Đurić U., Krušić J., Samardžić Petrović M. (2019). Multi-hazard Exposure Assessment on the Valjevo City Road Network. Spatial Modeling in GIS and R for Earth and Environmental Sciences, pp 671-688. (2019) Elsevier Inc. ISBN 978-0-12-815226-3 DOI: <https://doi.org/10.1016/B978-0-12-815226-3.00031-4>
- Marjanović M., Krautblatter M., Abolmasov B., Đurić U., Sandić C., Nikolić V. (2018). The rainfall-induced landsliding in Western Serbia: A temporal prediction approach using Decision Tree technique. *Engineering Geology* 232: 147–159. ISSN 0013-7952 <https://doi.org/10.1016/j.enggeo.2017.11.021>
- Marjanović M., Bajat B., Abolmasov B., Kovačević M. (2018). Machine Learning and Landslide Assessment in a GIS Environment. In (Eds: Jean-Claude Thill and Suzana Dragicevic). Geo Computational Analysis and Modeling of Regional Systems, Part of Advances in Geographic Information Science Book Series (AGIS), pp 191-213. ISBN 978-3-319-59509-2 ISBN 978-3-319-59511-5 (eBook) DOI 10.1007/978-3-319-59511-5. Springer International Publishing Ag, Part of Springer Nature. https://link.springer.com/chapter/10.1007/978-3-319-59511-5_11

- Marjanović M., Abolmasov B., Đurić U., Krušić J. (2018). Assessment of landslide-related hazard and risk on the road network of the Valjevo city, Serbia. Proceedings of the 16th Danube-European Conference - Geotechnical hazards and risks: Experiences and practices, vol. 1, Skopje, Macedonia. Willey and Sons. pp 365-370
- Krušić J., Samardžić Petrović M., Marjanović M., Abolmasov B., Miljković S. (2018). Preliminary results of numerical modelling of debris flow - case study Leva reka, Serbia. Proceedings of the 16th Danube-European Conference - Geotechnical hazards and risks: Experiences and practices, vol. 2, Skopje, Macedonia. Willey and Sons. pp 707-712
- Abolmasov B., Marjanović M., Đurić U., Samardžić Petrović M., Krušić J. (2018). IPL Project 210 – Massive landsliding in Serbia following Cyclone Tamara in May 2014 - progress report. Proceeding of 2018 IPL Symposium on Landslides, Organized by International Consortium on Landslides (ICL), 03 December 2018, Kyoto, Japan
- Krušić J., Andrejev K., Abolmasov B., Marjanović M. (2018). Preliminary results of the Selanac debris flow modelling in RAMS - a case study. Proceeding of the 3rd Regional Symposium on Landslides in the Adriatic-Balkan Region, Ljubljana 2017, 11 - 13 October 2017 Ljubljana, Slovenia, pp95-100. Geological Survey of Slovenia. ISBN 978-961-6498-58-6
- Аболмасов Б., Крушић Ј., Андрејевић К., Марјановић М., Станковић Р., Ђурић У. Примена АНР и WoE методе у процени подложности терена на клижење за подручје општине Крупањ. (2017). Изградња 7-10: 239-246. ISSN 350-5421. (on Serbian).
- Марјановић М., Аболмасов Б., Миленковић С. (2017). Процена ризика од клизишта на путној мрежи општине Крупањ. Зборник радова петог научно-стручног саветовања Пут и животна средина, Вршац 28-29 септембар 2017. стр. 491-500. ISBN 978-86-88541-08-4 (on Serbian).
- Đurić D., Mladenović A., Pešić-Georgiadis M., Marjanović M., Abolmasov B. (2017). Using multiresolution and multitemporal satellite data for post disaster landslide inventory in the Republic of Serbia. *Landslides* 14 (4): 1467-1482. DOI 10.1007/s10346-017-0847-2, <https://doi.org/10.1007/s10346-017-0847-2>
- Abolmasov B., Marjanović M., Đurić U., Krušić J., Andrejev K. (2017). Massive Landsliding in Serbia Following Cyclone Tamara in May 2014 (IPL-210) In: K. Sassa et al. (eds.), Advancing Culture of Living with Landslides, Proceedings of 4th World Landslide Forum, Ljubljana 29 May-02 June 2017, Vol. 1. pp. 473-484. Springer International Publishing. DOI 10.1007/978-3-319-59469-9_4
- Andrejev K., Krušić J., Đurić U., Marjanović M., Abolmasov B. (2017). Relative Landslide Risk Assessment for the City of Valjevo. In: M. Mikoš et al. (eds.), Advancing Culture of Living with Landslides, Proceedings of 4th World Landslide Forum, Ljubljana 29 May-02 June 2017. Vol 3. pp. 525-523. Springer International Publishing. DOI 10.1007/978-3-319-53483-1_62
- Marjanović M., Abolmasov B. (2015). Evidencija i prostorna analiza klizišta zabeleženih u maju 2014. Časopis Izgradnja 69 (5-6). pp 129-134. ISBN 0350-5421. UDC 551.435.627(497.11) (on Serbian).
- Marjanović M., Abolmasov B., Đurić U., Bogdanović S., Krautblatter M. (2017). Landslide events in Serbia in May 2014: An overview. Proceedings of 2nd Regional Symposium on Landslides in the

Adriatic-Balkan Region - 2nd ReSyLAB 2015, Eds: Abolmasov B., Marjanović M., Đurić U.,
University of Belgrade, Faculty of Mining and Geology, Belgrade, Serbia, pp. 239-244. ISBN
978-86-7352-296-8 <http://resylab2015.rgf.rs/>

Note:

- 1) If you will change items 1)-6) from the proposal, please write the revised content **in red**.

The Project should be completed by the end of 2024.