Progress in Landslide Research and Technology

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Cover illustration: In the Thompson River valley, south-central British Columbia, Canada, thick (>100 m) accumulations of glacial lake sediments, tills, and outwash have a complex history of sudden rapid translational failure and liquefaction in the past, and slower rotational slumping along toe slopes, head scarps, and tributary channels at present. (Photograph taken by Drew Rotheram-Clarke)

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An Integrated Approach to Landslides Risk Management for Local and National Authorities

Biljana Abolmasov, Miloš Marjanović, Uroš Đurić, and Jelka Krušić

Abstract

The University of Belgrade, Faculty of Mining and Geology has been involved in landslide risk reduction activities at the national, regional, and site-specific levels in Serbia for decades. Since 2011 the Faculty has had several activities closely connected with the International Consortium on Landslides, including the International Programme on Landslides Projects 181, 210 and 248, as well as World Centre of Excellency (WCoE) from 2017. In the past decade the Faculty of Mining and Geology was involved in several national, regional and local projects funded by the People of Japan, UNDP and The World Bank on landslide risk reduction in Serbia, Bosnia and Herzegovina and North Macedonia. They all closely involved many stakeholders from national to local authorities including Ministries, Local Self Governments, Public Enterprises, Emergency Offices and Civil Protection units. In this report, the activities of WCoE for national and local authorities on landslide risk reduction will be presented.

Keywords

Landslides · Risk assessment · Risk management · Authorities

1 Introduction

The University of Belgrade, Faculty of Mining and Geology (UBFMG) has been a full member of the International Consortium on Landslides (ICL) since 2011 and has been gradually intensifying its contributions to the ICL worldwide efforts for landslide risk reduction and international promotion of landslide research. UBFMG has been awarded the title of the World Centre of Excellence (WCoE) in Landslide Risk Reduction (2017–2023). UBFMG has contributed to International Programme on Landslides (IPL) with several research projects approved by the IPL Global Promotion Committee, but also by publishing in the Journal of the International Consortium on Landslides and organizing the second and the sixth Regional Symposium on Landslides in the Adriatic-Balkan Region (Arbanas and Arbanas 2022). Finally, it has contributed through active involvement in the ICL regional networks, i.e., ICL Adriatic-Balkan Regional Network from 2012 (Mihalić Arbanas et al. 2013).

UBFMG has contributed to several UNDP and World Bank and Global Facility for Disaster Reduction and Recovery (GFDRR) activities in Serbia and throughout the Balkan region (Bosnia and Herzegovina, North Macedonia), working on landslides risk reduction projects (national, regional and municipality level), with special attention on climate changing conditions. UBFMG is supporting idea of open landslides data and contributes to ICL World Report on Landslides (Abolmasov et al. 2017a), as well as to the National Landslide Database in Serbia. In the last few years, it is an active member of the Serbian National Emergency Bodies for landslide risk reduction. UBFMG has signed KLC2020 and strongly contributes to the Sendai Framework for Disaster Risk Reduction 2015–2030.

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2 General Data

The Republic of Serbia is located on the Balkan Peninsula in south-east Europe (Fig. 1), covering an area of 88,499 km^2 and with a population of 6,647,000, according to the data from the Statistical Office of the Republic of Serbia from 2022 (http://www.stat.gov.rs/).

It is a parliamentary republic and has a non-symmetric territorial organization. This administrative organization is inherited from the ex-Yugoslavia period and today, it is slightly changed by the National nomenclature of statistical territorial units (NUTS). The Republic of Serbia is divided into 5 regions (NUTS2), 29 administrative districts (NUTS3), 197 municipalities (LAU1) and 6158 settlements (LAU2).

The territory of Serbia is a hilly to low-mountainous country with many lowlands (around 36% of the Serbian territory is below 200 m), mostly in the northern part of the country around the Pannonia plain. Almost 45% of the territory consists of very gentle slopes (up to 5 degrees), while 15% is rugged mountains with slopes greater than 15 degrees mainly in the central and southern parts of the country. The hydrological system in Serbia consists of several international rivers and significant national rivers, almost all of which drain into the Black Sea, except Pčinja River which drains into the Aegean See. Only the Danube (588 km), Sava (206 km) and Tisa (168 km) rivers are navigable all the way through Serbia.

Serbia's climate is influenced by the Eurasian landmass, the Atlantic Ocean, and the Mediterranean Sea. Most of the country has a mid-continental climate with cold winters and hot summers and relatively well-distributed rainfall patterns. The recent report from the Hydrometeorological Service of Serbia provides the spatial distribution of annual averages for temperature and precipitation sum across the territory of the Republic of Serbia for the reference period 1981–2010. Annual mean temperature varies, and most of territory has the temperature between 10.1–12.0 degrees. Annual mean precipitation is from 557 mm in Kikinda (north of Serbia) to 1018 mm in Zlatibor (southwest Serbia) for the same reference period. Annual mean precipitation varies from 500–600 mm in the central to 700–1000 mm in the western part of Serbia.

3 Landslides Risk Reduction on a National Level

The Republic of Serbia is prone to natural disasters such as floods, flush floods, and droughts, but also to geological hazards like landslides, rockfalls and flows, which can cause significant damage to infrastructure and livelihoods. The main geological climate-related hazards in Serbia are landslides in general (the common ones being slides, flows and falls). Due to complex geological history and terrain composition, in combination with morphological and climate characteristics, 16% of the territory is affected by landslides (Abolmasov et al. 2017c).

In the third week of May 2014, Serbia and Bosnia and Herzegovina experienced its most severe floods in the last 120 years, caused by Cyclone Tamara. Huge amounts of rainfall of 250 to 400 mm for 3 days caused sudden and extreme flooding of several rivers—in particular, the Sava River, but also the Drina River, the Bosna River, the Una River, the Sana River, the Vrbas River, the Kolubara River, the Morava river and their tributaries. In western and central Serbia for instance, daily precipitation on May 15 exceeded the expected average for the entire month (Marjanović et al. 2018b). Urban, industrial and rural areas were completely submerged, cut off without electricity or communications and roads and transport facilities were damaged. As a result, 1.6 million persons (one-fifth of the population) were directly or indirectly affected in Serbia. The floods and landslides caused 51 casualties and around 32,000 people were evacuated (Abolmasov et al. 2021). The Serbian Recovery Needs Assessment (RNA) revealed that the total effects of the disaster in the 24 affected municipalities amount to EUR 1.525 billion (equal to 3% of the Serbian Gross Domestic Product). The Faculty of Mining and Geology participated in RNA in May–June 2014 (Marjanović et al. 2017; Abolmasov et al. 2017c).

In the aftermath of the 2014 floods, Serbia adopted a National Disaster Risk Management Program (NDRMP) aiming to make a critical paradigm shift towards proactive management of disaster risks and increase the country's resilience to natural disasters. NDRMP was structured under six main pillars of action: (i) institutional strengthening; (ii) risk identification and monitoring; (iii) structural and non-structural risk reduction measures; (iv) preparedness and early warning; (v) disaster risk financing and insurance solutions; and (vi) resilient recovery. The main challenge under the NDRMP was to build an appropriate and longstanding system for Disaster Risk Management (DRM) in the country, where different institutions work together to systematically reduce existing risks, avoid the creation of future risks, and respond more efficiently to disasters.

The Emergency Sector under the Ministry of Interior of the Republic of Serbia 2019 assembled a working group that included specialists in the field of corresponding hazards, primarily floods and landslides to develop scenarios and generate corresponding hazard maps at the national level.

Furthermore, "Natural and Technological Risk Assessment of the Republic of Serbia" has been adopted under the Law on Disaster Risk Reduction and Emergency Management. National Disasters Risk Assessment and the landslide susceptibility map at the national level (1:300,000) reached its finalization in 2020 (Fig. 2). The map was prepared by

Fig. 1 Geographical position of the Republic of Serbia

Marjanović et al. (2020),[1] by using the Analytical Hierarchy Process (AHP) and it is published as hazard layer at Disaster Risk Register of the Republic of Serbia.

The map was used further for national road and railway network exposure assessment. Beneficiaries (Public Enterprise Roads of Serbia and Public Enterprise Railway Infrastructure) and end-users are welcome to include results in other application fields.

4 Contribution to Regional Level Landslide Risk Reduction

Landslides, flash floods and floods are the main natural hazards affecting the road network in Serbia. In May 2014, unprecedented rainfall resulted in damage and loss in the transportation sector of 166.5 million euros. The erosion due to flash floods mainly destroyed bridges, embankments and roads, while landslides and debris flows cut off and disrupted the main and local road systems. A rough estimation by Public Enterprise Roads of Serbia (PERS) reported that more than 2000 landslides/flows were activated along state roads of category I and II and more than 3000 along local-municipality roads, during and immediately after May 2014.

By 2017–2021, a comprehensive project funded by the World Bank was conducted and involved the preparation of a more resilient road network design in climate-changing conditions. In short, the project started with localizing the hotspots of landslides, flows, flash floods, and flood hazards

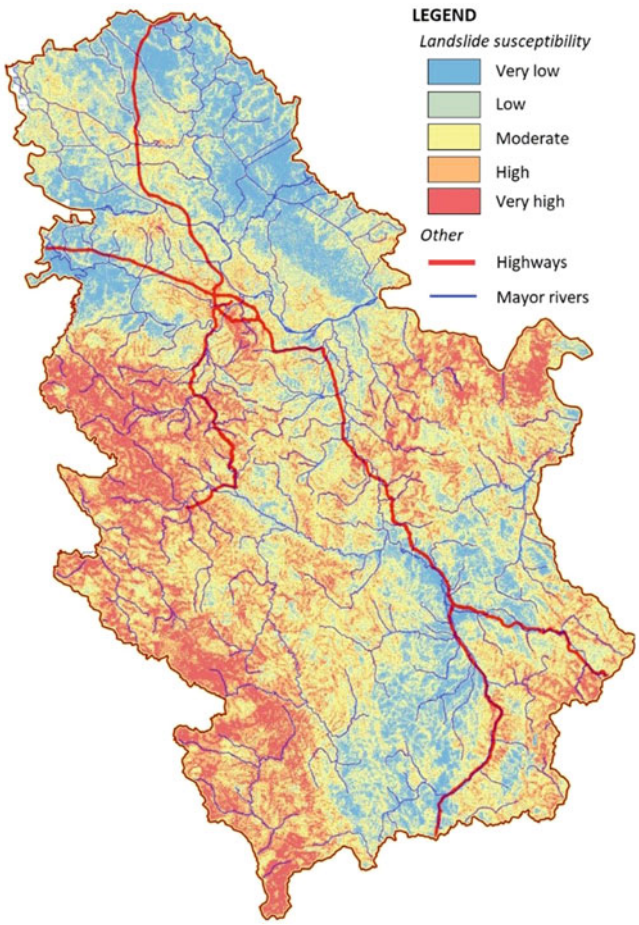

Fig. 2 Landslide hazard map of the Republic of Serbia (https://drr.geosrbija.rs/drr/map)

[1] http://prezentacije.mup.gov.rs/svs/html/licence/Procena%20rizika%20od%20katastrofa%20u%20RS.pdf

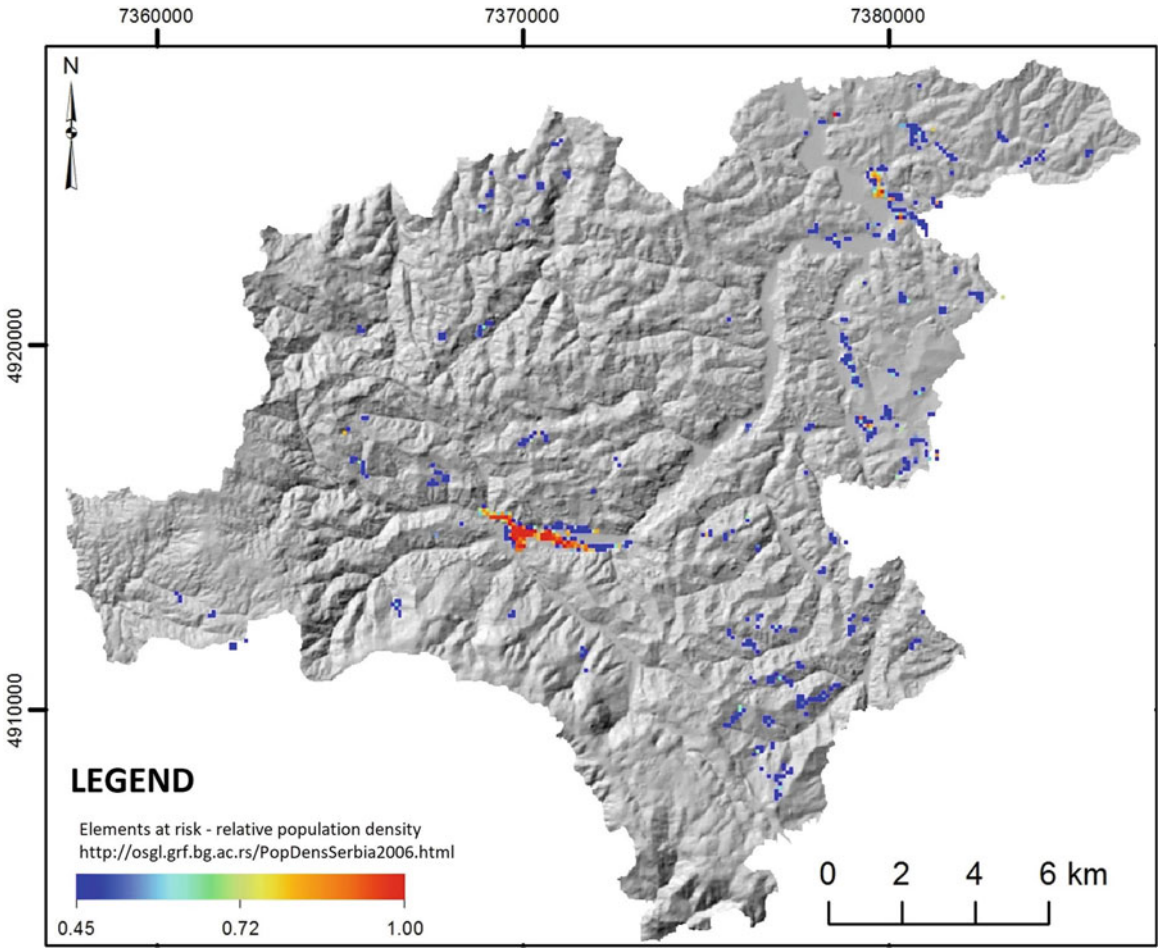

Fig. 3 Elements at risk—relative population density for Krupanj pilot area

and estimating the exposure of the road network over time in two test areas (the Valjevo and Kraljevo region). The main objective of the Project was to support the Government in establishing a foundation for mainstreaming climate resilience considerations in the road transport sector management in Serbia by developing an effective methodology for assessing the vulnerability of the road transport network to climate-related risks, improving capacities of key stakeholders in road network climate resilience planning, and setting the path for the development of structured and systematic response plans. Key beneficiaries from the Project were recognized as PERS and Ministry for Construction, Transport and Infrastructure (MCTI). As a result of Project activities (nicknamed CliRtheRoads), 750 km of state regional roads of categories I and II were mapped. Landslides, rockfalls, flash floods and floods hazard were assessed, as well as exposure, vulnerability and risk in climate-changing conditions (Marjanović et al. 2019, 2018a, 2022). Main stakeholders were also provided with a separately developed Android mobile application for recording of landslides, rockfalls, flows, flash floods, and floods events, with great potential to include it in day-to-day work, and successively and systematically accumulate the data in the Road Asset Management System (RAMS).

5 Improving Landslide Risk Reduction on the Local: Municipality Level

UBFMG was included in several projects related to landslide inventory, susceptibility, hazard and risk assessment on local-municipality level, both in Serbia and Bosnia and Herzegovina, but only activities within the Project BEWARE will be presented.

The project on harmonization of landslide data and training of municipality staff for its monitoring, named BEWARE (BEyond landslide aWAREness) was designed to standardize post-event landslide database and closely involve 27 local communities affected by May 2014 events in Serbia, and prepare them to cope with catastrophic events in the future

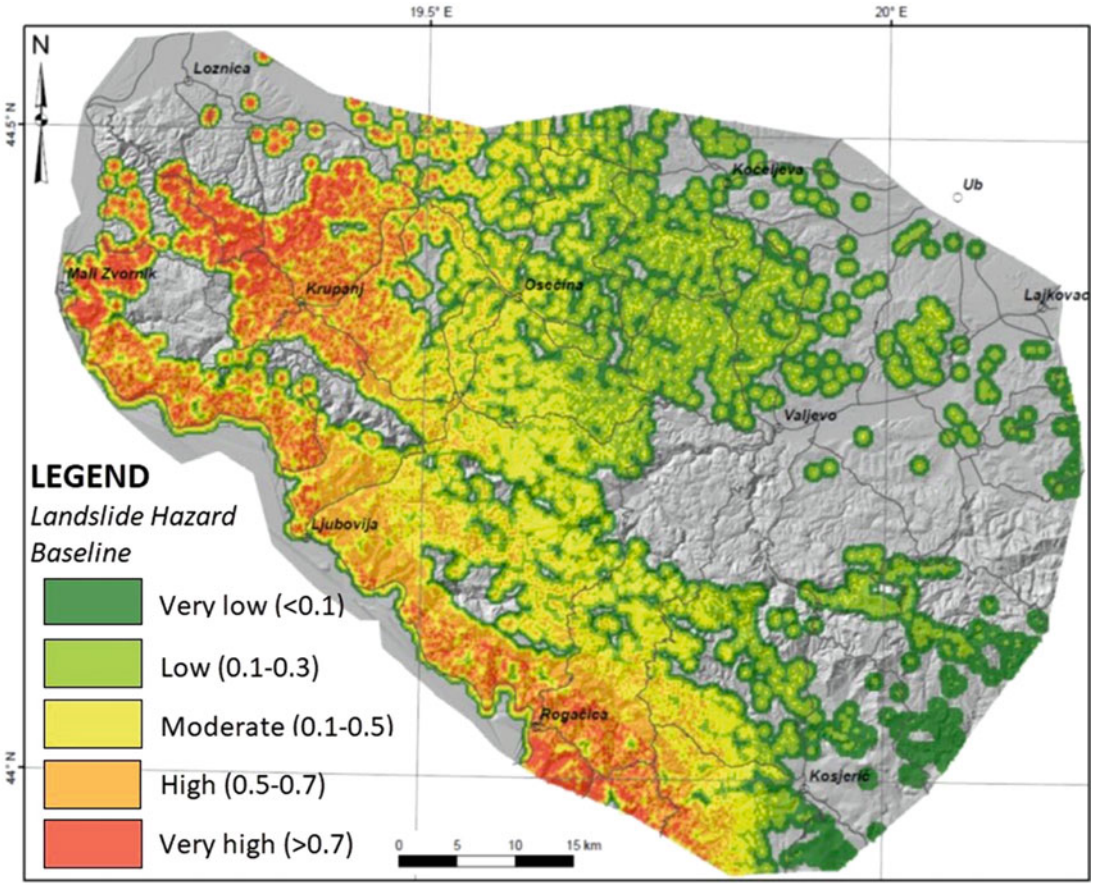

Fig. 4 Landslide susceptibility map for Valjevo pilot area

(Abolmasov et al. 2017b). The project BEWARE was realized from May 2015 to February 2016. Several Work Packages (WP) were posted to realize the project objectives (Đurić et al. 2017), but most important were Landslide Susceptibility Maps for every municipality, Landslide Vulnerability and Risk Assessment Map for population for two municipalities, and open landslide data in WEB GIS Project portal.

Landslide susceptibility maps were prepared in 1:25,000 scale (scale of Municipality Master Plan according to the Law) and provided for each of 27 municipalities as a support for Master Plans documents and as a part of non-structural measures. AHP was used for modeling and assessing landslide susceptibility for selected municipalities. Landslide vulnerability and relative risk assessment to population were prepared for Krupanj (Fig. 3) and Valjevo (Fig. 4) municipalities by using open access Serbian population density data in regional scale (Andrejev et al. 2017). All maps are available to municipal land-use and urban authorities as open access data.

Also, 12 critical sites were chosen for implementation of structural remedial measures, based on affected people and property that have not been already subjected to intervention in post-event responses. Detailed geotechnical investigations were performed, and remedial measures were proposed and implemented.

Participants of BEWARE project were selected among Faculty of Mining and Geology, University of Belgrade staff/associates and Geological Survey of Serbia staff. Direct beneficiaries are local authorities and Civil Protection/Emergency management units, related governmental institutions, insurance and assessment agencies, municipal enterprises, and general public. Follow up activities are included and supported through the Geological Information System of Serbia http://geoliss.mre.gov.rs/.

6 Conclusion

The University of Belgrade, Faculty of Mining and Geology covers technical disciplines of mining and geological engineering, and fundamental geology. The Faculty of Mining and Geology has been involved in landslide risk reduction activities at the national, regional, and site-specific level in Serbia for decades. For more than 40 years, UBFMG has been supporting activities of the national and local authorities

in the field of landslides disaster risk reduction. In the field of capacity building, UBFMG offers courses for graduate and postgraduate students in landslide mechanics, dynamics, monitoring, and landslide risk mitigation, including hazard assessment. In the last ten years, the Faculty has offered courses for PhD students in the field of landslides hazard, vulnerability and risk assessment with special attention to climate changing conditions.

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