2018 IPL SYMPOSIUM ON LANDSLIDES

03 December 2018
Kyoto University, Uji campus, Kyoto, Japan

Organized by
International Consortium on Landslides (ICL)

Picture on the cover page
Kure landslide in Hiroshima after the heavy rainfall in July 2018
Taken from UAV by Kyoji Sassa, Khang Dang, and Nguyen Duc Ha

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Supported by
Disaster Prevention Research Institute of Kyoto University

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Kyoto, Japan

This proceedings is registered in the Online Public Access Catalog of the National Diet Library of Japan

ISBN 978-4-9903382-0-6

Published by: The International Consortium on Landslides

IPL Project 210 – Massive landsliding in Serbia following Cyclone Tamara in May 2014 - progress report

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Abstract The IPL project No 210 titled "Massive landsliding in Serbia following Cyclone Tamara in May 2014" started at March 2016. The study area is located in the Western and Central part of the Republic of Serbia territory affected by Cyclone Tamara in May 2014. The project aims to summarize and analyse all relevant collected data, including historic/current rainfall, landslide records, aftermath reports, and environmental features datasets from the May 2014 sequence. Objectives of the proposed project include: collecting all available and acquiring new landslides data, analysing the trigger/landslide relation in affordable time span and May 2014 event, relating the landslide mechanisms and magnitudes versus the trigger, locating spatial patterns and relationships between landslides and geological and environmental controls, proposing an overview susceptibility map of the event and numerical modelling on the site specific location/landslide mechanism. The Project is organized by University of Belgrade, Faculty of Mining and Geology and Faculty of Civil Engineering. Project beneficiaries are local community and local and regional authorities. In this paper we will present progress report of the proposed project targets performed by project participants.

Keywords Landslides, floods, extreme precipitation

Introduction

Republic of Serbia is located on the Balkan Peninsula in south-east Europe and covers the area of 88,361km² and has a population of 7,181,505 (http://stat.gov.rs) (Fig 1).

Serbia's climate varies between continental climate in the North, with cold winters, and hot, humid summers with well distributed rainfall patterns, more Adriatic climate in the South with hot, dry summers and autumns and relatively cold winters with heavy inland snowfall. Differences in elevation and large river basins, as well as exposure to the winds account for climate differences, especially for annual precipitation sums, whichrise with altitude. In lower regions annual precipitation levels range in the interval from 540 to 820 mm. Areas with altitude over 1,000 m have on average 700-1000 mm of precipitation, and some of the mountainous summits in South Western part of Serbia have heavier precipitation up to 1,500 mm. June is the rainiest month with the average of 12-13% of total annual rainfall. Complex geological history and terrain composition, morphological and climate characteristics have caused that 15.08% of the territory of Serbia is affected by landslides (Dragićević et al, 2011).

Figure 1 Geographical position of the Republic of Serbia in Europe

In the third week of May 2014, Serbia and Bosnia and Herzegovina experienced its severest floods in the last 120 years caused by Cyclone Tamara. Huge amounts of rainfall of 250 to 400 mm for three days caused sudden and extreme flooding of several rivers – in particular the Sava River, but also the Drina, Bosna, Una, Sana, Vrbas, Kolubara, Morava - and their tributaries. In the Western and Central Serbia for instance, daily precipitation on May 15th exceeded the expected average of the entire month. Urban, industrial and rural areas were completely submerged under water, cut off without electricity or communications, while roads and other 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 32000 people were evacuated. The Serbian Recovery Needs Assessment (RNA) revealed that the total effects of the disaster in the 24 affected municipalities amounts to

EUR 1.525 billion (equal to 3% of the Serbian Gross Domestic Product).

In March 2016, the Faculty of Mining and Geology applied for the IPL project and during the 11th Session of the IPL-GPC in Kyoto in 2016, a joint project number 210 was approved. It was entitled "Massive landsliding in Serbia following Cyclone Tamara in May 2014" (Abolmasov et al 2017a).

This paper will show progress report obtained during two years of project conduct, as described in project plan and program.

Project description

Objectives

Landslides are amongst the most dangerous natural threats to human lives and property, especially in times of dramatic climate change effects on one hand, and urban sprawl and land consumption on the other.

The project attempts to prove 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.

In this respect, it was essential to produce unified large-scale inventories of May 2014 event and use them for the state-of-the-art hazard analysis. Thus, the project aims to summarize and analyze collected landslide information from the May 2014 sequence. Following these ideas, objectives of the proposed project include: (1) collecting all available (existing) and acquiring new landslides data, (2) analyzing the trigger/landslide relation in affordable time span (past 15 years) and May 2014 event, (3) relating the landslide mechanisms and magnitudes versus the trigger and its aftermath, (4) locating spatial patterns and relationships between landslides and geological and environmental controls, (5) proposing an overview susceptibility map of the event and (6) numerical modeling on the site specific location/landslide mechanism.

Work plan-expected results

The following activities are planned during the project conduct:

- Collecting, review and harmonization of landslides data (Phase 1)
- Analysis of trigger/landslide data (Phase 2)
- Analysis of landslides vs. geological/environmental controls (Phase 3)
- Proposing landslide susceptibility map (Phase 4)
- Numerical modeling on site specific locations/landslide mechanism (Phase 5)
- Compilation and analysis of all results (Phase 6)

After certain activities, it was planned to prepare partial reports, and to prepare a comprehensive report at the end. Preparation of papers for the Landslide journal was also foreseen. Deliverables and time frames are as follow:

- Report 1. Compilation of results of Phase 1 and Phase 2 (end of the 1st year)
- Report 2. Compilation of results Phase 3 (end of the month 18th)
- Report 3. Proposing landslide susceptibility map Phase 4 (end of the month 24th)
- Report 4. Numerical modeling on site specific locations/landslide mechanism Phase 5 (end of the month 30th)
- Report 5. Final report-Phase 6 (end of the 3rd year)

Personel - Beneficiaries

The Project is organized by the University of Belgrade, Faculty of Mining and Geology and Faculty of Civil Engineering. University and staff will provide all necessary documentation for Project finalization. Project Leader is Full Professor Biljana Abolmasov from University of Belgrade, Faculty of Mining and Geology. Core members of the Project are: Assistant Professor Miloš Marjanović from University of Belgrade Faculty of Mining and Geology, Uroš Djurić, PhD student from University of Belgrade Faculty for Civil Engineering, Jelka Krušić, PhD student from University of Belgrade Faculty of Mining and Geology and Katarina Andrejev, PhD student from University of Belgrade Faculty of Mining and Geology.

Direct beneficiaries will be local community – municipalities affected by landslide occurrences during May 2014 event. Local and regional authorities – housing sector, infrastructure authorities, Civil protection units and land/use sectors within affected area.

Progress report

Rainfall event

In the third week of May 2014, a massive low-pressure cyclone Tamara swept through Western Balkan resulting in extensive flood in the Sava River system and partly in the Morava river catchment. The Cyclone moved from Adriatic Sea to Balkan Peninsula very slowly, and from 14 to 16 May was deepened at all altitudes at territory of Serbia and Bosnia and Herzegovina. The result of that unusual cyclone activity was extreme precipitation for short period that caused floods, torrential floods and massive landsliding in the Republic of Serbia, and in the Bosnia and Herzegovina (BiH) (Fig 2).

Fig. 2 MODIS satellite image of Extratropical Storm Yvette (Tamara) taken on May 15, 2014. (Credit: LANCE Rapid Response/MODIS/NASA)

The analysis of precipitation data included available monthly and daily precipitation from Hydro-meteorological Service of the Republic of Serbia, Hydro-meteorological Service of the Republic of Srpska (BiH) and Hydrometeorological Service of the Federation of Bosnia and Herzegovina (BiH) from the Main Meteorological Stations for April and May 2014 (Fig 3).

The highest statistical significance of 48-h duration in Serbia was registered at the Loznica Main Meteorological Station (MMS), where precipitation of 160 mm corresponded to a 1000-y return period, while MMS in Valjevo and Belgrade recorded precipitation of a 400-y return period for the same duration (Prohaska et al, 2014). The highest precipitation for 72-h duration recorded at Loznica (213 mm), Valjevo (190 mm) and Belgrade (174 mm) MMS. The flood event (14-15 May 2014) and landslides occurrences (15-18 May 2014) were caused simultaneously by extreme Cyclone Tamara activity, but massive landsliding was additionally initiated by antecedently introduced rainfall from April 15 to May 14 (Alleoti, 2004). The main triggering factor for all landslides activities was extreme cumulative precipitation from April 15 up to May 18, where precipitation amount exceeded one half of a yearly average precipitation for just one month in Western and Central part of Serbia (Marjanović and Abolmasov, 2015). The analysis of monthly precipitation for April and May 2014 was shown on Fig 3.

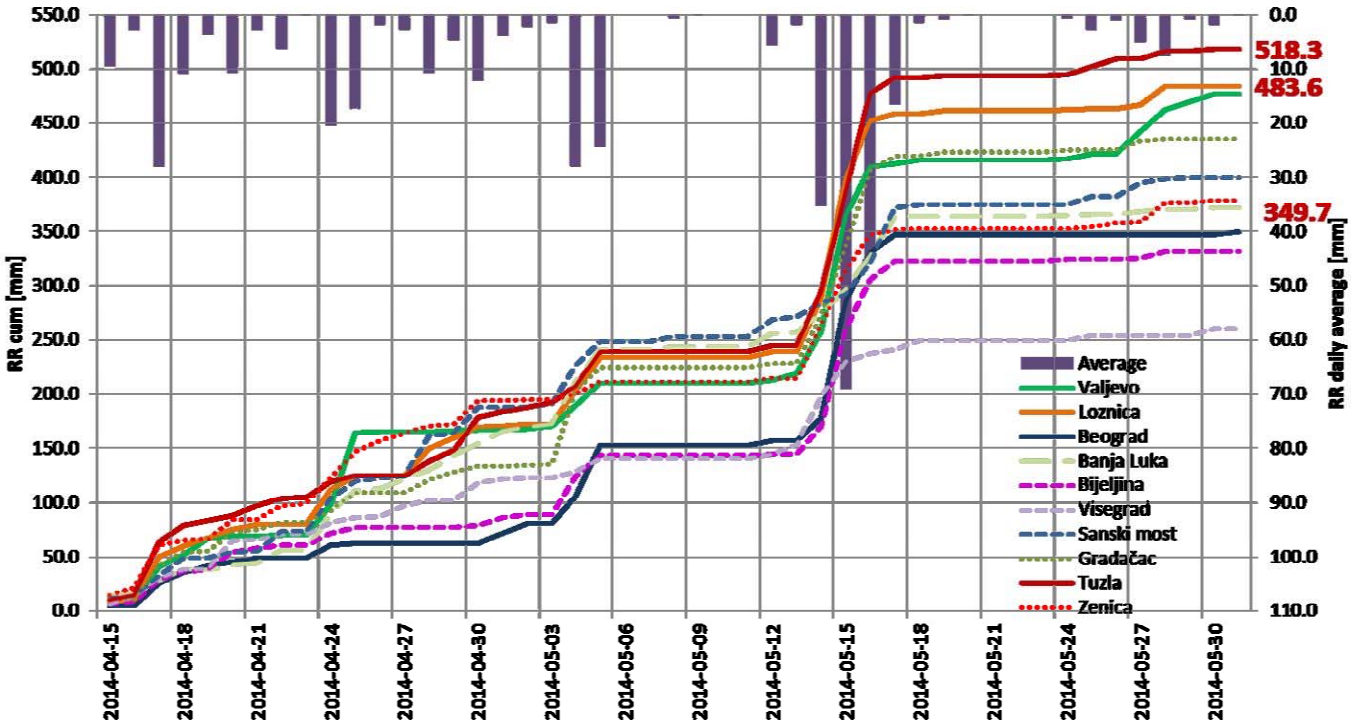

Figure 3. Precipitation data from Main Meteorological Stations in Serbia and Bosnia and Herzegovina for April and May 2014

Study area

Study area covered 11.840 km^2, i.e. 23 of 27 municipalities affected by different type of landslides in Western and Central part of the Republic of Serbia. These municipalities were recognized as most vulnerable to floods, torrential floods and landslides by UNDP Office in Serbia during the post-disaster phase after May 2014 event. Four municipalities were excluded from the IPL 210 Project activities because no landslides occurrences linked to May 2014 rainfall episode were found, and there were only flood damages. Geological and geomorphological settings are very complex as well as other environmental conditions in such a wide area. The type of movement and the type of material involved (Cruden and VanDine, 2013) were depending on lithological type, local geomorphological characteristics, engineering geological properties, degree and depth of

weathering substratum etc. as well as precipitation amount received during May 2014 event.

Landslide data

Usual landslide triggers are floods and high-yield rainfall, which was the case in the catastrophic cyclone Tamara episode that stroke Serbia and surrounding countries in May 2014. At the time, disastrous effects were closely followed by media and public and handled by responsible state services, such as Civil Protection offices, and volunteers, but little has been done after the waters retreated and landslides settled, especially regarding landslide analysis and mitigation. Landslide reports (in analogue form) greatly understated the realistic number of landslides (concentrating more on urgent/acute cases), while report quality standard and consistency was uneven (because they were collected by different institutions, depending on the acute needs), so resulting inventories remain incomplete and far from standardized. In this respect, it was essential to produce unified large-scale inventories of May 2014 event and beyond, and use them for the further analysis.

According to the classification (Cruden and VanDine 2013) a harmonized landslide data report was created. The total number of 2203 landslides are mapped as an open data file reports, according to the BEWARE Project deliverables (Abolmasov et al 2017b). Different type of movement and type of involved material were registered during extensive field campaign and analysis of remote sensing data (Đurić et al 2017). A total number of 1888 different type of movement were certified by supervisor (1539 slides, 78 flows, 48 falls, 1 topple, 23 complex, 138 flows and slides, 55 falls and slides and 6 falls and flows). According to the material involved 925 type 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 municiaplities shows that the highest number of landslide occurrences were recorded in the Western part of Serbia (Fig 4).

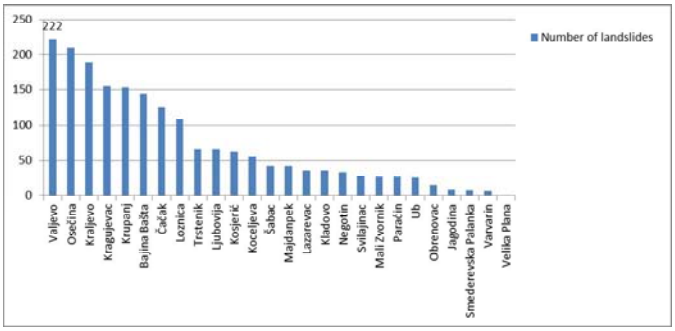

Figure 4. Number of landslides per municipality included in BEWARE project http://geoliss.mre.gov.rs/beware/

Analysis rainfall data vs. landslides

The analysis rainfall data vs. landslides attempted to examine the hypothesis that massive landsliding is preconditioned by soil saturation, caused by high cumulative precipitation yield within several days to several weeks prior to the activation (mid/ long-term conditioning). It was first reasonable to identify the areas where rainfall conditions for massive landsliding are met (Marjanović et al, 2018). Therein, Loznica (Western Serbia) area was both, anomalous in terms of long-term spatial rainfall patterns (Fig 5) and sufficiently covered with landslide reports in a desired period (2001-14). The idea was to predict the pattern of rainfall-induced landsliding in respect to antecedent rainfall data, and thereby, predict/extrapolate additional landslide-triggering rainfall events that have not been reported in 2001-14. Predictions were implemented via Machine Learning (ML) classification task, using Decision Tree (DT) algorithms in particular. Extrapolated events were then used to establish approximate thresholds, by benchmark procedures. In addition, the DT model itself was used as a criterion for defining the upper/lower threshold (Fig 6).

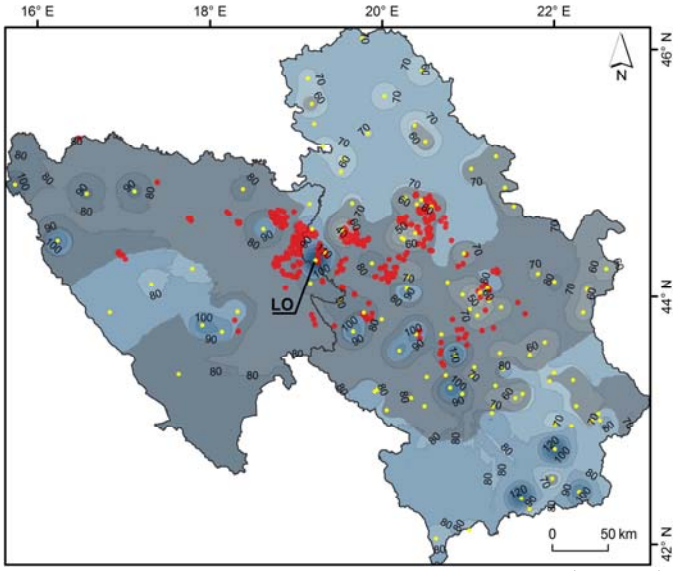

Figure 5. Average monthly rainfall for 2001-14 (in mm), transected with the baseline monthly average (1961-90). Zones higher than this baseline values are non-shaded. Landslide events are depicted as red dots. Yellow dots are weather stations used for the interpolation (station Loznica is labeled - LO)

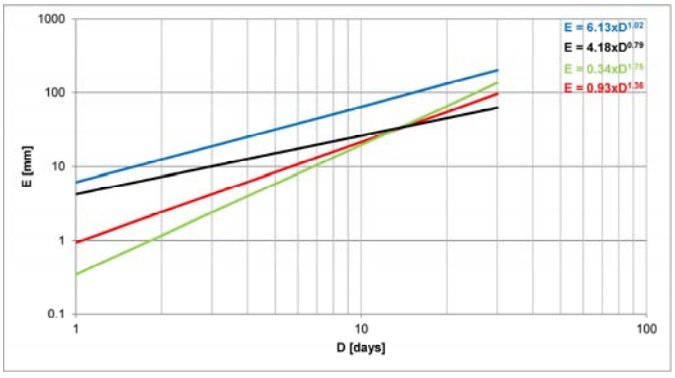

Figure 6. Threshold for LO extracted from Random Tree model minimal – black curve, and maximal thresholds – blue curve, with corresponding curve formulas

Conclusion

Further research within IPL210 will be focused on analyzing: (1) the trigger/landslide relation in affordable time span (past 15 years) for other areas and May 2014 event; and (2) relating the landslide mechanisms and magnitudes versus the trigger and its aftermath.

Raised landslide awareness in Serbia offers better information resources for 2014 onward, through: municipal legislative (activities and reports of recently established emergency response teams in each municipality), media, and social media.

Acknowledgments

IPL Project 210 will be not possible without Project BEWARE (BEyond landslide aWAREness) funded by People of Japan and UNDP Office in Serbia (grant No 00094641). The project was implemented by the State Geological Survey of Serbia, and the University of Belgrade Faculty of Mining and Geology. All activities are supported by Ministry for Energy and Mining and Ministry for Education, Science and Technological Development of the Republic of Serbia Project No TR36009, too.

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