# Massive Landsliding in Serbia Following Cyclone Tamara in May 2014 (IPL-210)

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

**Abstract**

The IPL project No 210, titled "Massive landsliding in Serbia following Cyclone Tamara in May 2014", started in 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 collected relevant data, including historic and 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 acquired landslide data, analysing the trigger/landslide relation in a feasible time span and in the May 2014 event, relating the landslide mechanisms and magnitudes versus the trigger, identifying spatial patterns and relationships between landslides and geological and environmental controls, proposing an overview susceptibility map of the event and numerical modelling of the site-specific location and landslide mechanisms. The Project will be 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 preliminary results of the proposed project targets performed by project participants.

**Keywords**

Landslides • Extreme precipitation • Flooding • Republic of Serbia

## Introduction

The Republic of Serbia is located on the Balkan Peninsula in south-east Europe, covers an area of 88,361 km$^2$ and has a population of 7,181,505 (http://stat.gov.rs) (Fig. 1).

Serbia's climate varies between a continental climate in the North, with cold winters, and hot, humid summers with well distributed rainfall patterns, and a 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

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**Fig. 1** Geographical position of the Republic of Serbia

precipitation sums. Annual precipitation increases with altitude. In lower regions, annual precipitation ranges from 540 to 820 mm. Areas with altitudes over 1000 m have on average 700–1000 mm of precipitation, and some of the mountainous summits in the South Western part of Serbia have heavier precipitation of up to 1500 mm. June is the rainiest month, with an average of 12–13% of the total annual rainfall. Because of complex geological history and terrain composition, and morphological and climate characteristics, 15.08% of Serbian territory is affected by landslides (Dragićević et al. 2011).

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 (Fig. 2). Huge amounts of rainfall of 250–400 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, and Morava, as well as their tributaries. In Western and Central Serbia for instance, daily precipitation on May 15 exceeded the expected average of the entire month. Urban, industrial and rural areas were completely submerged under water, 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. The Serbian Recovery Needs Assessment (RNA) revealed that the total effects of the disaster in the 24 affected municipalities cost up to EUR 1.525 billion (equal to 3% of the Serbian Gross Domestic Product).

The initiative to collaborate with the International Consortium on Landslides was started in September 2009. University of Belgrade, Faculty of Mining and Geology

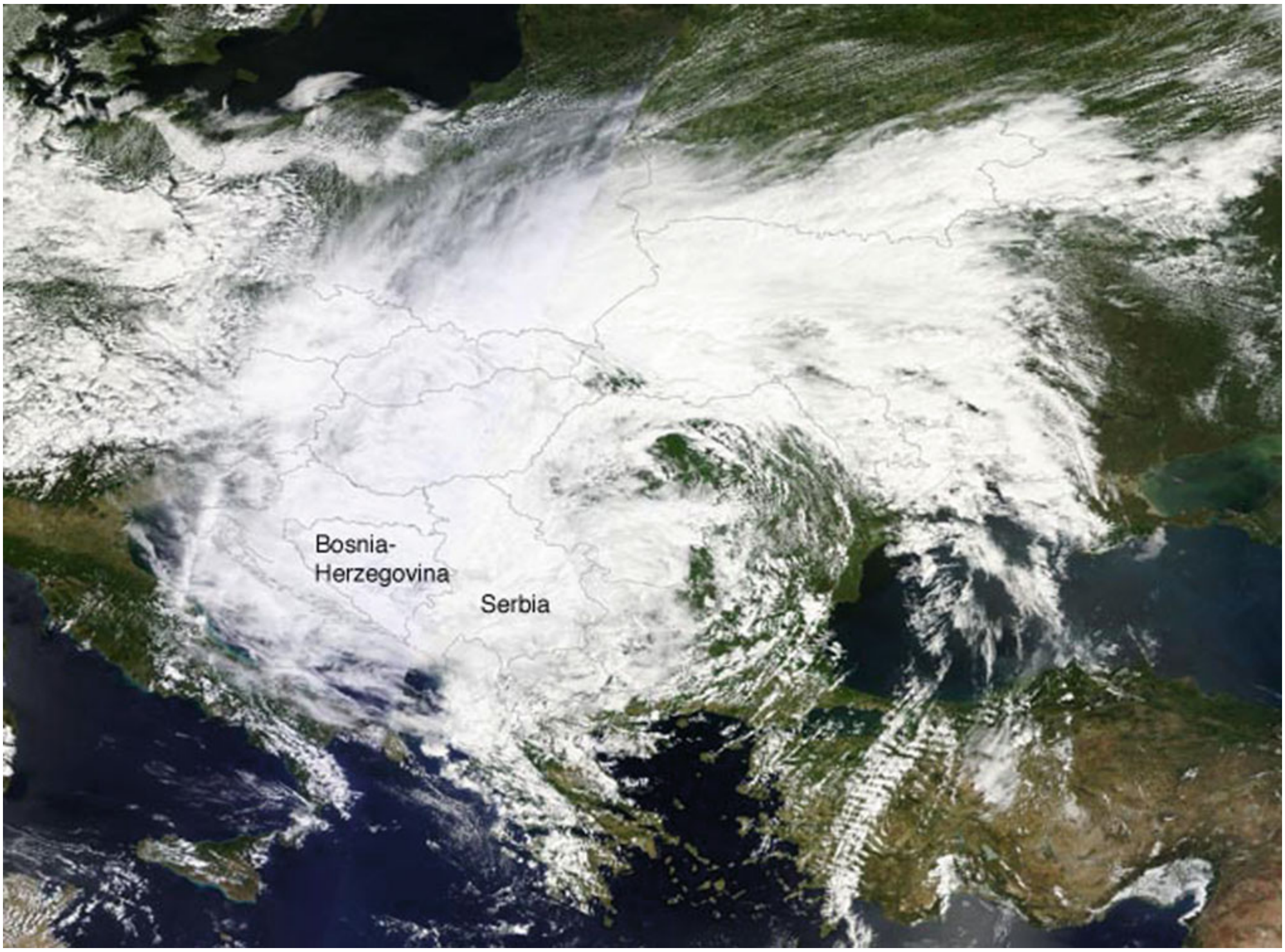


**Fig. 2** MODIS satellite image of extratropical storm Yvette (Tamara) taken on May 15, 2014. (*Credit* LANCE Rapid Response/MODIS/NASA)

became a member of ICL in 2011, and a member of the ICL Adria-Balkan Network in 2012 (Mihalić Arbanas et al. 2013). In March 2016, the Faculty of Mining and Geology applied for the IPL project and during the 11th Session of 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".

This paper will show partial results obtained during less than a year of conducting the project, as described in the 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 determine if the May 2014 extreme landsliding event was preconditioned by soil saturation, caused by a high precipitation yield, within several weeks before the event. All relevant data, including historic and 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 the May 2014 event and use them for the state-of-the-art hazard analysis. Thus, the project aimed at summarizing and analyzing collected landslide information from the May 2014 sequence. Following this, the objectives of the proposed project include: (1) collecting all available (existing) and acquiring new landslide data, (2) analyzing the trigger/landslide relations for a feasible time span (past 15 years) and in the 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 of site-specific locations and landslide mechanisms.

## Work Plan-expected Results

The following activities are planned during the duration of the project:

- Collection, review and harmonization of the landslide data (Phase 1)
- Analysis of trigger and landslide data (Phase 2)
- Analysis of landslides versus geological and environmental controls (Phase 3)
- Proposing a landslide susceptibility map (Phase 4)
- Numerical modeling of site-specific locations and landslide mechanisms (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 1st year)
- Report 2. Compilation of results Phase 3 (end of 18th month)
- Report 3. Proposing landslide susceptibility map Phase 4 (end of 24th month)
- Report 4. Numerical modeling on site specific locations/landslide mechanism Phase 5 (end of 30th month)
- Report 5. Final report-Phase 6 (end of 3rd year).

## Personel—Beneficiaries

The Project will be organized by University of Belgrade, Faculty of Mining and Geology and Faculty of Civil Engineering. The University and staff will provide all necessary documentation for Project finalization. The Project Leader is Associate 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, Ph.D. student from University of Belgrade Faculty for Civil Engineering, Jelka Krušić, Ph.D. student from University of Belgrade Faculty of Mining and Geology and Katarina Andrejev, Ph.D. student from University of Belgrade Faculty of Mining and Geology.

Direct beneficiaries will be local communities and municipalities affected by landslide occurrences during the May 2014 event. Other beneficiaries include local and regional authorities—the housing sector, infrastructure authorities, civil protection units and land-use sectors within the affected area.

# Preliminary Results

## Rainfall Event

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

The analysis of precipitation data included available monthly and daily precipitation from the Hydrometeorological Service of the Republic of Serbia for April and May 2014. The rainfall with highest statistical significance for a 48 h duration was registered at the Loznica Main Meteorological Station (MMS), where precipitation of 160 mm corresponded to a 1000 year return period (Fig. 3), while the MMS in Valjevo (Fig. 4) and Belgrade (Fig. 5) recorded precipitation of a 400 year return period for the same duration (Prohaska et al. 2014). The highest precipitation for a 72 h duration was 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 the massive landsliding was additionally initiated by the antecedent rainfall from April 15 to May 14 (Alleoti 2004). The main triggering factor for all landslide activities was extreme cumulative precipitation from April 15 up to May 18, in which the precipitation amount exceeded one half of the yearly average precipitation for one month in Western and Central part of Serbia (Marjanović and Abolmasov 2015). The analysis of monthly precipitation for April and May 2014 is shown in Figs. 6 and 7.

## Study Area

The study area covered 11,840 km$^2$, i.e. 23 of 27 municipalities affected by different type of landslides in the Western

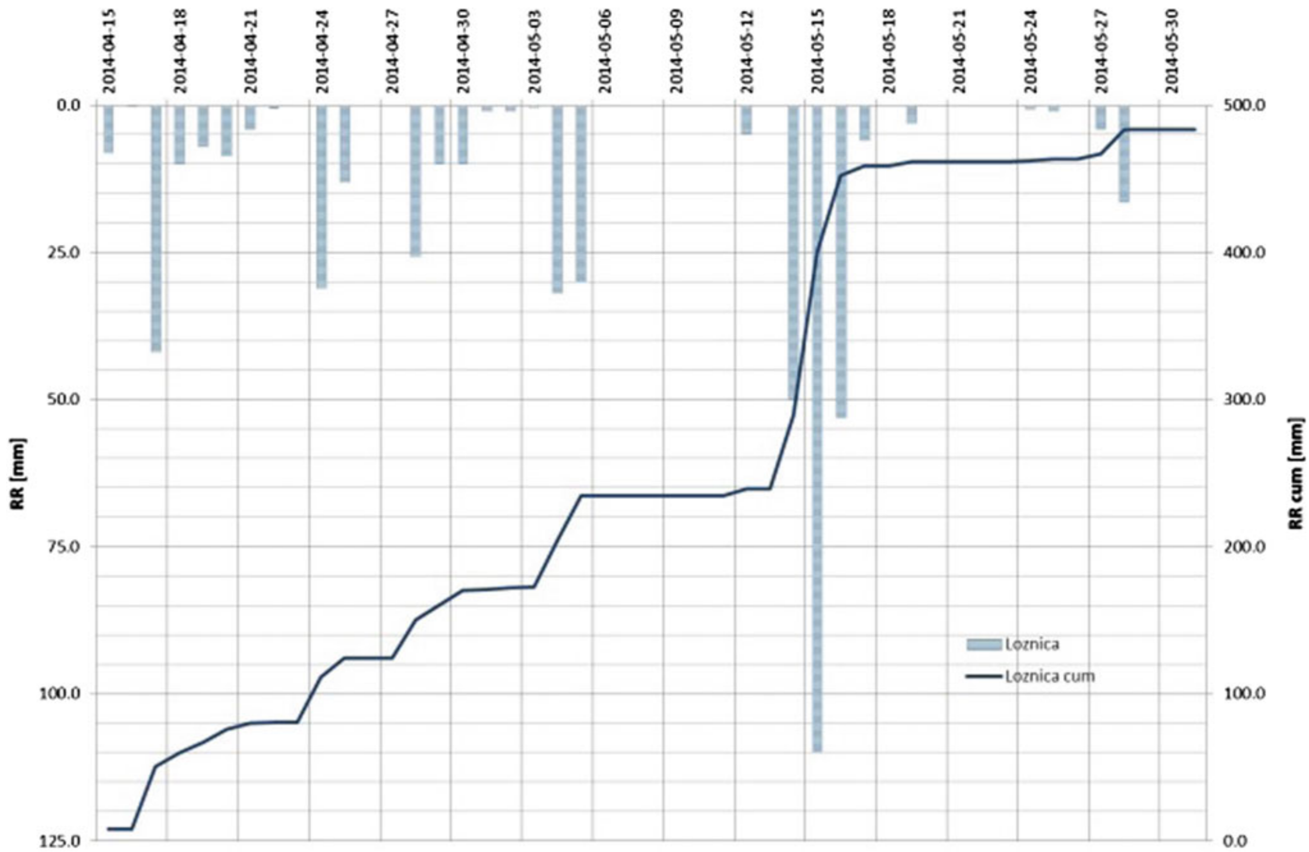


**Fig. 3** Cumulative precipitation for MMS Loznica (Western Serbia) from April 15 to May 30 2014

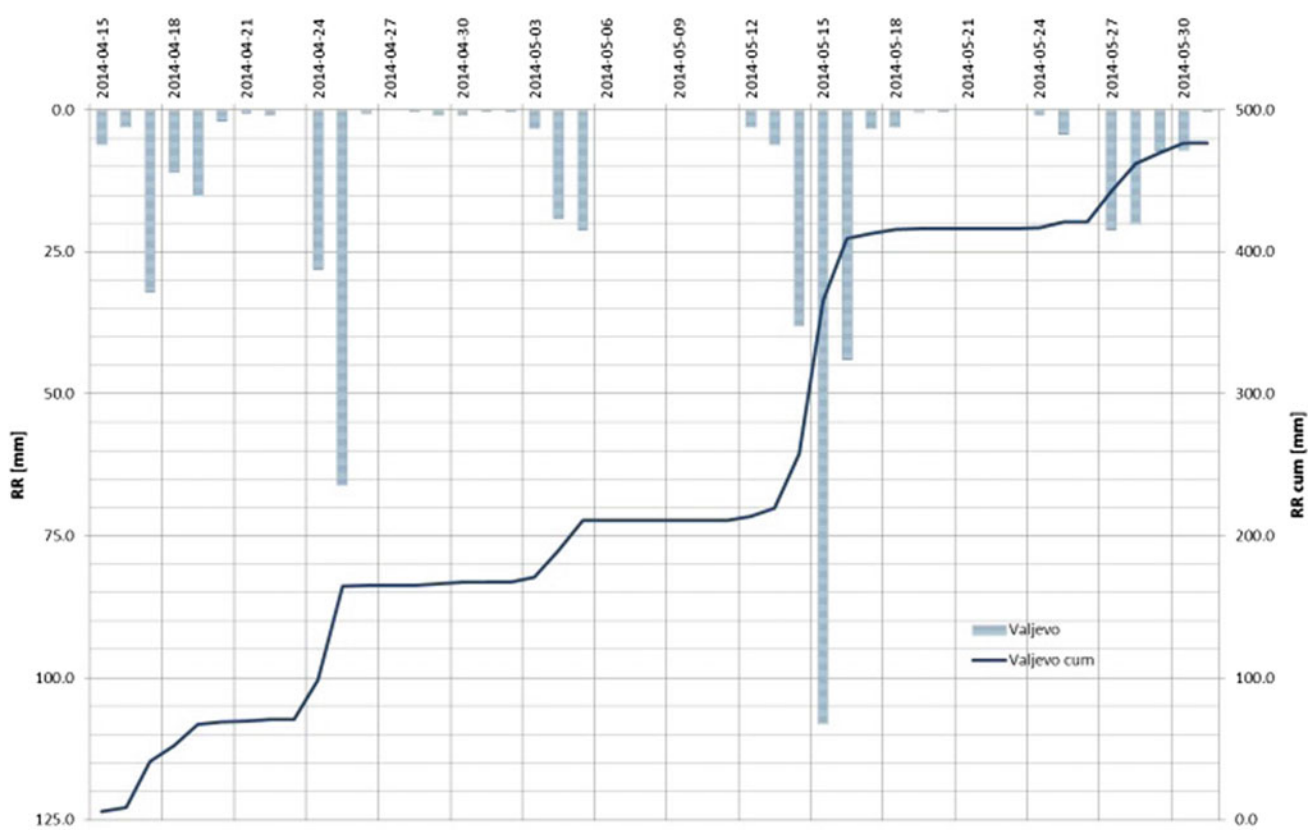


**Fig. 4** Cumulative precipitation for MMS Valjevo (Western Serbia) from April 15 to May 30 2014

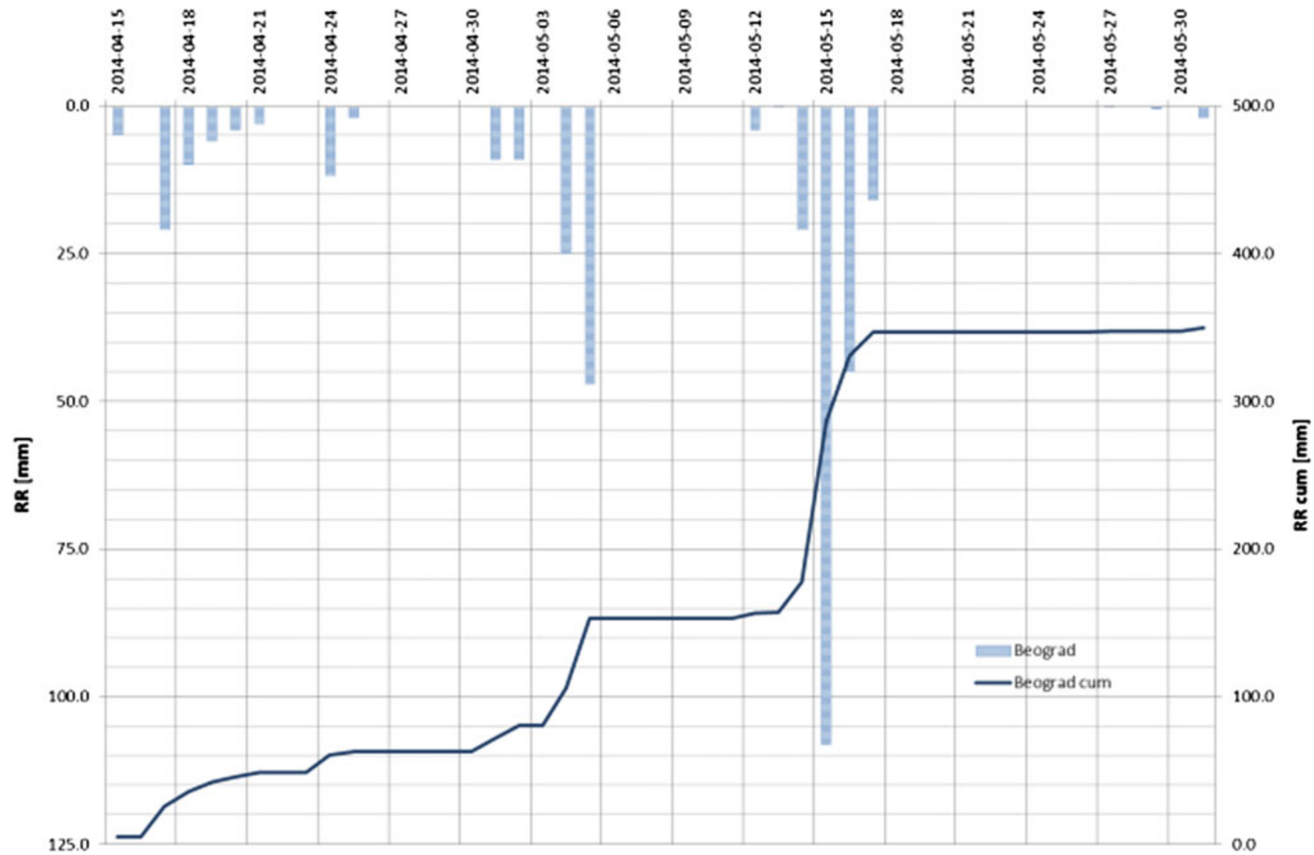


**Fig. 5** Cumulative precipitation for MMS Belgrade (Central Serbia) from April 15 to May 30 2014

and Central part of the Republic of Serbia (Fig. 8). These municipalities were recognized as the most vulnerable to floods, torrential floods and landslides by the UNDP Office in Serbia during the post-disaster phase after the May 2014 event. Four municipalities were excluded from IPL 210 Project activities because no landslides occurred during the May 2014 rainfall episode; there was only flood damage. The geological and geomorphological settings are very complex, as well as other environmental conditions in such a wide area. The type of movement and type of material involved (Cruden and VanDine 2013) were dependent on lithological type, local geomorphological characteristics, engineering geological properties, degree and depth of weathering substratum, as well as the amount of precipitation received during the May 2014 event.

## Landslide Data

The most common landslide triggers are floods and high-yield rainfall, which was the case in the catastrophic cyclone Tamara episode that struck Serbia and surrounding countries in May 2014. At the time, the effects of the disasters were closely followed by the 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 the landslides settled, especially with regard to landslide analysis and mitigation. Landslide reports (in analogue form) greatly understated the realistic number of landslides (concentrating more on urgent and acute cases), while report quality standard and consistency was uneven (because they were collected by different institutions, depending on the acute needs), so the resulting inventories remain incomplete and far from standardized. In this respect, it was essential to produce unified large-scale inventories of the May 2014 event and beyond, and use them for further analysis.

Based on the classification of Cruden and VanDine (2013), a harmonized landslide data report was created (Fig. 9). The total number of 2203 landslides are mapped as open data file reports, according to the BEWARE Project deliverables. Different type of movement and type of material involved were registered during an extensive field campaign (Fig. 10). A total number of 1888 different type of movement were certified by supervisors (1539 slides, 78

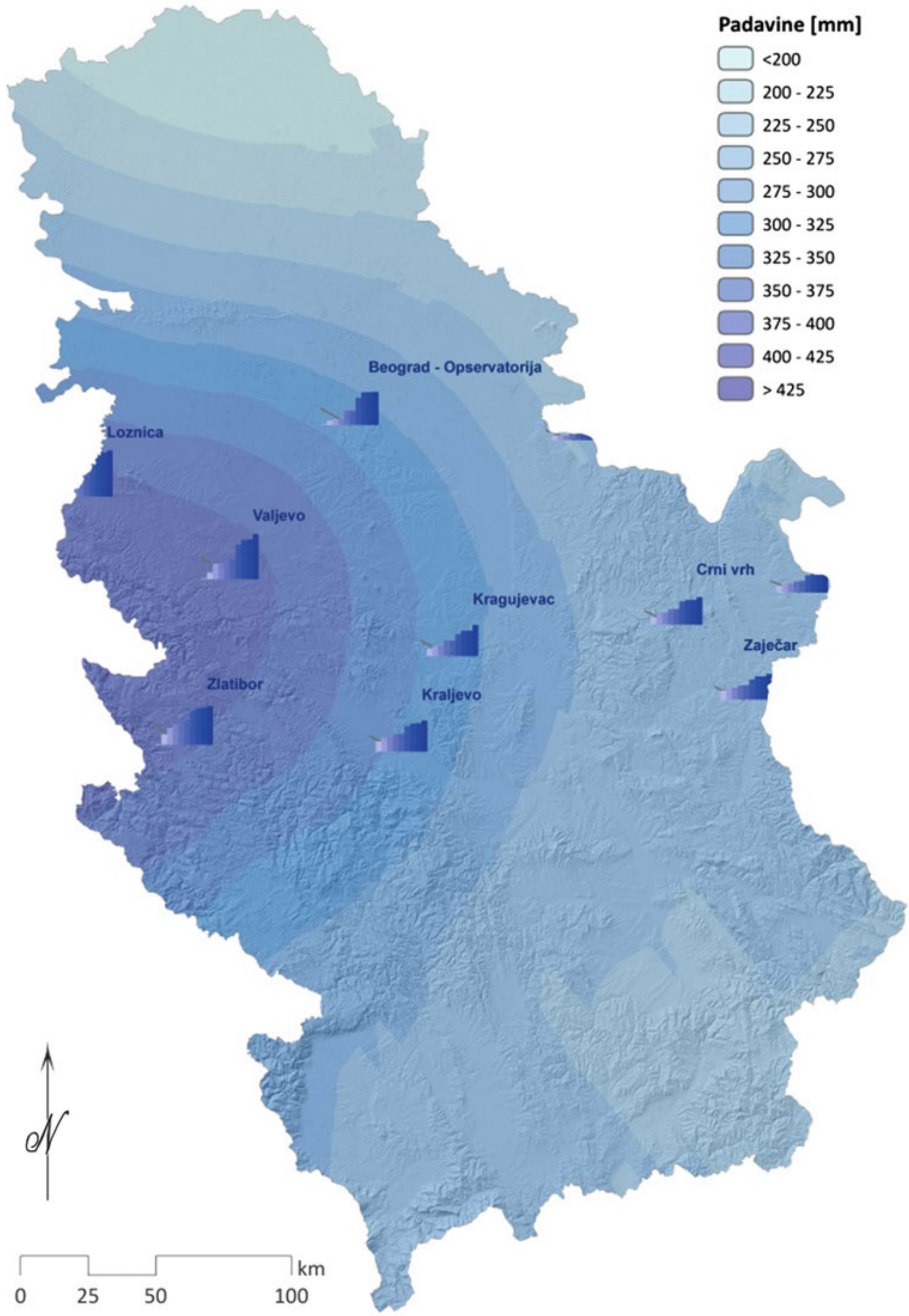


**Fig. 6** Distribution of sum of precipitation for April 2014

flows, 48 falls, 1 topple, 23 complex, 138 flows and slides, 55 falls and slides and 6 falls and flows). Based on 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 municipalities shows that the highest number of landslide occurrences were recorded in the Western part of Serbia (Fig. 11).

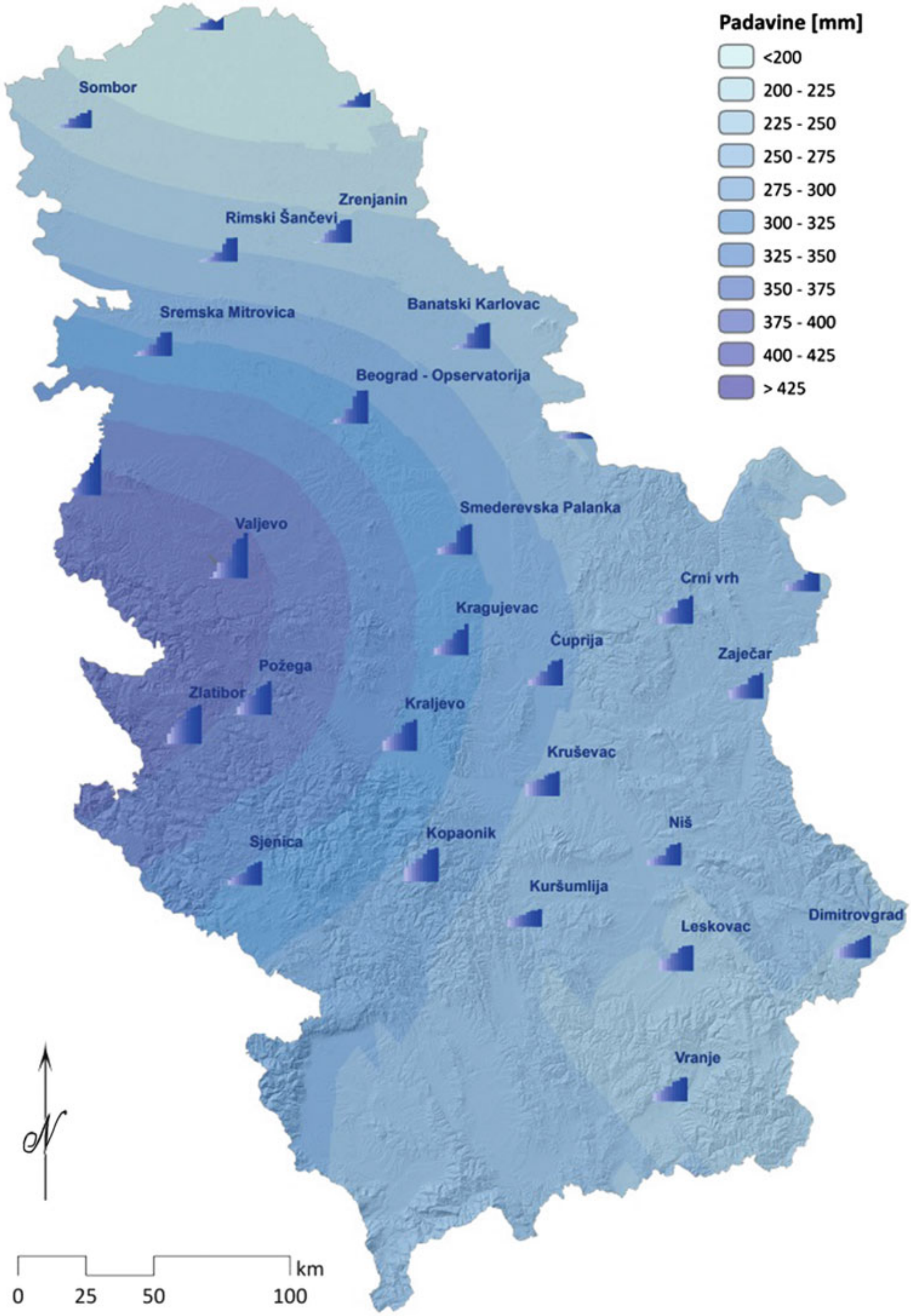


**Fig. 7** Distribution of sum of precipitation for May 2014

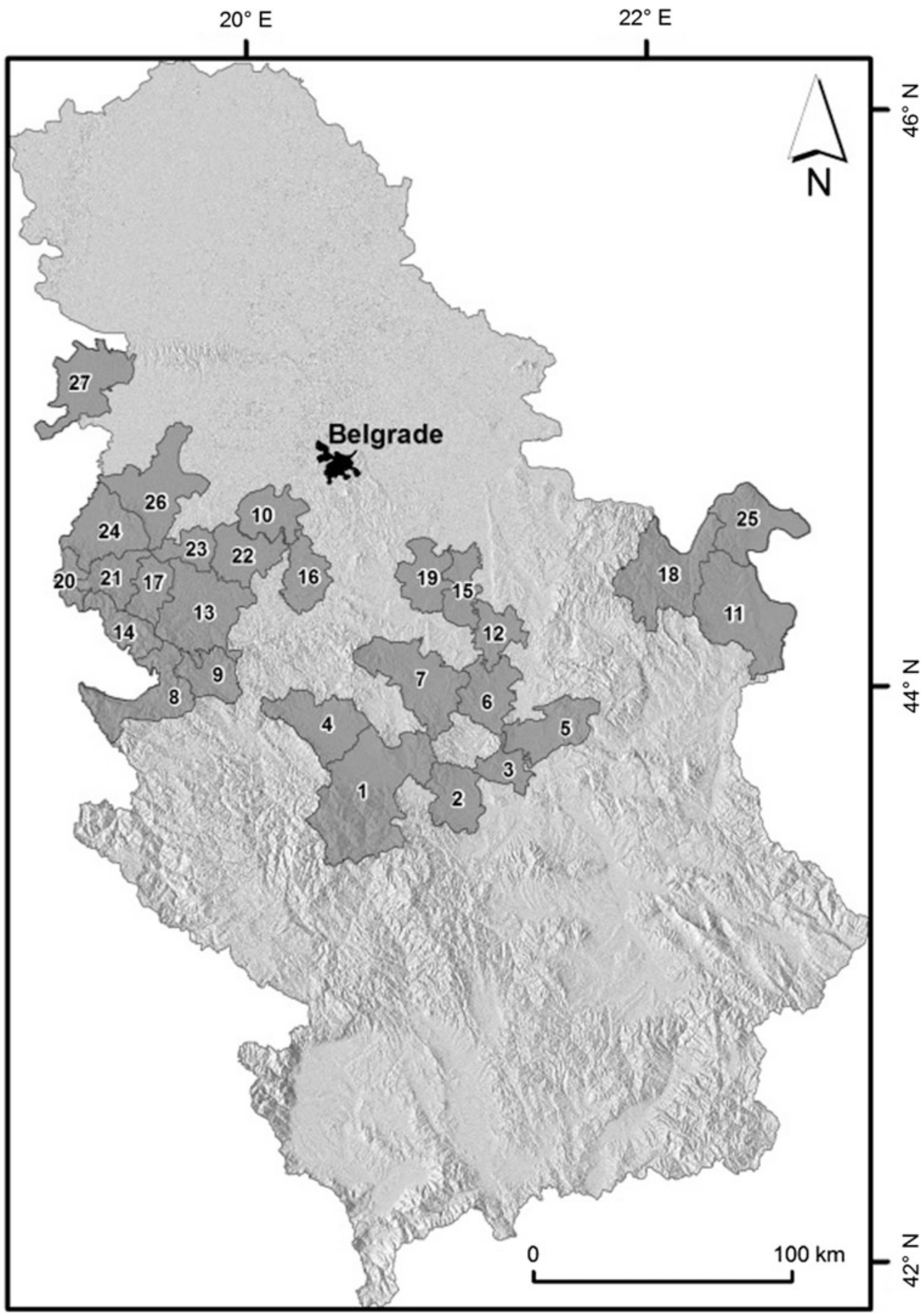


**Fig. 8** Geographical position of 23 municipalities included in the IPL 210 Project analysis (four municipalities were excluded–No 11, 18, 25 and 27)

**BEWARE**

KATASTARSKI LIST EVIDENTIRANOG
KLIZIŠTA – POJAVE NESTABILNOSTI

ID BROJ*

| 1. OPŠTI PODACI | | | 2.1 OPŠTI PODACI O PROCESU | | | | | |
|---|---|---|---|---|---|---|---|---|
| Opština* | | | Tip pojave* | | Vrsta pokrenutog materijala* | | | |
| Lokalnost* | | | Odronjavanje | ☐ | Stena | | | ☐ |
| Koordinate* | | | Prevrtanje | ☐ | Drobina | | | ☐ |
| Datum registr.* | | | Klizenje | ☐ | Organski materijal | | | ☐ |
| Datum aktiviranja | | | Bočno širenje | ☐ | Antropogeni materijal | | | ☐ |
| Datum reaktiviranja | | | Tečenje | ☐ | Heterogeni materijal | | | ☐ |
| Odgovorni istraživač: | | | Složeno | ☐ | Tlo | Glina ☐ | Pesak | ☐ |
| | | | BEWARE | | | Prašina ☐ | Šljunak | ☐ |

| 2.2 OPŠTI PODACI O PROCESU | | | | | | | |
|---|---|---|---|---|---|---|---|
| Sadržaj vode* | | Brzina kretanja* | | Aktivnost* | | | |
| Suvo | ☐ | Ekstremno sporo | ☐ | Uslovno stabilna padina | | | ☐ |
| Vlažno | ☐ | Vrlo sporo | ☐ | Aktivan | | | ☐ |
| Vlažno na granici tečenja | ☐ | Sporo | ☐ | Trenutno umiren | | | ☐ |
| U tečnom stanju | ☐ | Umereno | ☐ | Reaktiviran | | | ☐ |
| | | Brzo | ☐ | Neaktivan | | | |
| | | Veoma brzo | ☐ | Privremeno umiren | ☐ | Saniran-stabilizovano | ☐ |
| | | Ekstremno brzo | ☐ | Umiren | ☐ | Fosilan | ☐ |

| 2.3 OPŠTI PODACI O PROCESU | | | | Skica klizišta u preseku |
|---|---|---|---|---|
| Trend kretanja* | | Način kretanja* | | |
| Progresivno uz padinu | ☐ | Pojedinačno | ☐ | |
| Progresivno niz padinu | ☐ | Sukcesivno | ☐ | |
| Progresivno bočno | ☐ | Višestruko | ☐ | |
| Progresivno u dva pravca | ☐ | Mešovito | ☐ | |
| Smirivanje | ☐ | Kompleksno | ☐ | |

| 3 OPŠTI PODACI O TERENU | | | | | |
|---|---|---|---|---|---|
| Genetski tip reljefa | | Morfološki oblik | | | Geološka građa |
| Fluvijalni tip reljefa | ☐ | Čelenka | | ☐ | Vrsta osnovne stene - litološki sastav: |
| Padinski reljef | ☐ | Kosa | | ☐ | |
| Jezerski | ☐ | Brdo | | ☐ | Starost: |
| Tektonski | ☐ | O padini | | | |
| | | Visina | | m | Struktura: |
| | | Nagib | | ° | |

| Hidrologija | | | | Stepen raspadnutosti stenske mase | |
|---|---|---|---|---|---|
| Vodotoci: | | | | Zemljasta raspadina | ☐ |
| Stalni | ☐ | Povremeni | ☐ | Sitna drobina | ☐ |
| Ostalo: | | | | Drobina | ☐ |
| | | | | Blokovi | ☐ |

| Hidrogeološka funkcija | | | | | | | |
|---|---|---|---|---|---|---|---|
| H.G. funkcija: | | | | | | | |
| Tip izdani (nivoi, hranjenje, pražnjenje): | | | | | | | |
| Pojave: | | | | | | | |
| Oka | ☐ | Izvori | ☐ | Ištevine | ☐ | Difuzno pražnjenje | ☐ |

*MOLIMO VAS DA OBRAZAC POPUNITE ČITKO - ŠTAMPANIM SLOVIMA - HEMIJSKOM OLOVKOM*

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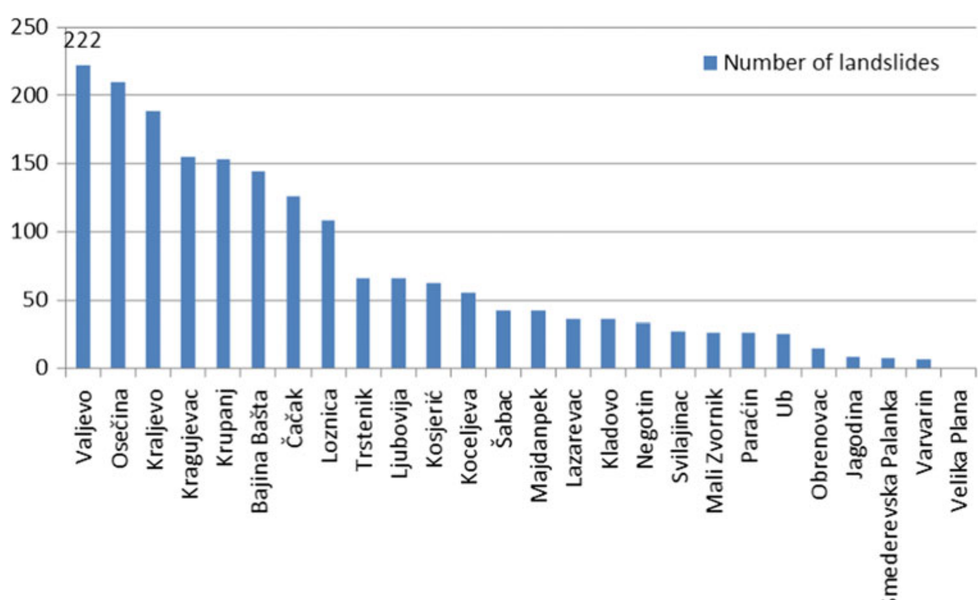
* OBAVEZNA POLJA ZA UNOS PODATAKA

**Fig. 9** Unified landslide data report from BEWARE Project (in Serbian)

**Fig. 10** The Valjevo municipality earth flow

**Fig. 11** Landslide distribution by municipality http://geoliss.mre.gov.rs/beware/



## Conclusion

First research results from the IPL 210 Project after six months of project conduct are presented in the paper. The analysis, correlation and synthesis of large volumes of data are currently being performed. Following the Project activities, the next steps will be focused on analyzing: (1) the trigger/landslide relation in a feasible time span (past 15 years) and in the May 2014 event and (2) relating the landslide mechanisms and magnitudes to the trigger and its aftermath.

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