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Landslide risk management in Croatia: Current state

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Abstract The paper shortly presents concept of landslide risk management with basic definitions of activities belonging to protection and recovery. The intention of the paper is to systematize measures of the Croatian government according to risk management framework. Two groups of measures undertaken by the Croatian Ministry of Construction and Physical Planning are described: (i) national landslide risk assessment; and (2) programmes for landslide disaster recovery. It is concluded that the measures introduced by the Croatian government are in line to the agenda Sendai Framework for Disaster Risk Reduction concerning emerging risk of Multiple Occurrence Regional Landslide Events (MORLE) that is related to climate changes.

Keywords Landslide disaster, MORLE, National risk assessment, Recovery, Hrvatska Kostajnica

Introduction

Disaster risk management is an extension of the more general term "risk management" to address the specific issue of disaster risks. Disaster risk management aims to avoid, lessen or transfer the adverse effects of hazards through activities and measures for prevention, mitigation and preparedness. United Nation International Strategy for Disaster Reduction (UNISDR, 2009) defines disaster risk management as the systematic process of using administrative directives, organizations, and operational skills and capacities to implement strategies, policies and improved coping capacities in order to lessen the adverse impacts of hazards and the possibility of disaster. The same document defines disaster as a serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community of society to cope using its own resources. Disaster impact may include loss of life, injury, disease and other negative effects on human physical, mental and social well-being, together with damage to property, destruction of assets, loss of services, social and economic disruption and environmental degradation.

According to the abovementioned criteria, the Republic of Croatia has experienced disastrous Multiple Occurrence Regional Landslide Events (MORLE) in 2013 at the area of the NW Croatia (Mihalić Arbanas et al., 2013; Bernat et al., 2014a). Disaster impact consisted in a high number of affected people in terms of permanent displacement, economic cost of immediate or longer-term emergency measures, restoration of buildings, public transport system and infrastructure, property, etc., cost of disruption of economic activity, indirect cost for the economy, social cost and other direct and indirect cost, as well as social psychological impact, impact on public order and safety and other factors, such as certain environmental damage. Consequently, most of counties proclaimed a natural disaster in the spring of 2013 that was caused by extreme hydro-meteorological conditions (Bernat Gazibara et al., 2017c), unique in the last 150 years.

From the perspective of the landslide risk management in Croatia, there are two types of activities undertaken at the national level by national bodies and government. The first activity is national landslide risk assessment performed in 2018 that showed that there is very high risk from MORLE in Croatia (Croatian Platform for Disaster Risk Reduction, 2019). The second activity is related to support to people evacuated from homes destroyed by landslides. In the post-disaster period the Croatian government opened two rounds of call for financial support to people facing homelessness due to damages caused by landslide activation.

This paper lists a basic definition of the terms related to risk management according to the UNISDR (2009) terminology. It also gives a short overview of the national landslide risk assessment, methodology and main results, as well as chronology and activities of the processes of support to people affected in terms of permanent displacement from homes. The objective of the paper is to show the current state in the landslide risk management considering MORLE in Croatia.

Risk management cycle

Figure 1 shows risk management cycle that is divided into two parts, before and after disaster occurrence. The main difference between processes before and after the disaster is that first belong to protection and latter to recovery.

Figure 1 Disaster, risk and crisis management cycle (FAO, 2004)

Here are listed definitions of the terms mitigation, prevention, preparedness, early warning system, response and recovery according to the UN terminology (UNISDR, 2009). The definition of reconstruction was taken from the newest terminology published by UN Expert Working Group on Indicators and Terminology Relating to Disaster Risk Reduction (UN, 2016).

Mitigation relates to lessening or limiting of the adverse impacts of hazards and related disasters. The adverse impacts of hazards often cannot be prevented fully but their scale or severity can be substantially lessened by various strategies and actions. Mitigation measures encompass engineering techniques and hazard-resistant construction as well as improved environmental policies and public awareness.

Prevention means outright avoidance of adverse impacts of hazards and related disasters. Disaster prevention expresses the concept and intention to completely avoid potential adverse impacts through action taken in advance. Examples include dams or embankments that eliminate flood risks, land-use regulations that do not permit any settlement in high risk zones, and seismic engineering designs that ensure the survival and function of a critical building in any likely earthquake. Very often the complete avoidance of losses is not feasible, and the task transforms to that of mitigation. Partly for this reason, the terms prevention and mitigation are sometimes used interchangeably in casual use.

Preparedness includes knowledge and capacities developed by governments, professional response and recovery organizations, communities and individuals to effectively anticipate, respond to, and recover from, the impacts of likely, imminent or current hazard events or conditions. Preparedness action is carried out within the context of disaster risk management and aims to build the capacities needed to efficiently manage all types of emergencies and achieve orderly transitions from response through to sustained recovery. Preparedness is based on a sound analysis of disaster risks and good linkages with early warning systems, and includes such activities as contingency planning, stockpiling of equipment and supplies, the development of arrangements for coordination, evacuation and public information, and associated training and field exercises. These must be supported by formal institutional, legal and budgetary capacities. The related term “readiness” describes the ability to quickly and appropriately respond when required.

Early warning system encompasses a set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss. This definition encompasses the range of factors necessary to achieve effective responses to warnings. A people-centred early warning system necessarily comprises four key elements: knowledge of the risks; monitoring, analysis and forecasting of the hazards; communication or dissemination of alerts and warnings; and local capabilities to respond to the warnings received. The expression “end-to-end warning system” is also used to emphasize that warning systems need to span all steps from hazard detection through to community response.

Response implies provision of emergency services and public assistance during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected. Disaster response is predominantly focused on immediate and short-term needs and is sometimes called “disaster relief”. The division between this response stage and the subsequent recovery stage is not clear-cut. Some response actions, such as the supply of temporary housing and water supplies, may extend well into the recovery stage.

Recovery includes restoration and improvement where appropriate, of facilities, livelihoods and living conditions of disaster-affected communities, including efforts to reduce disaster risk factors. The recovery task of rehabilitation and reconstruction begins soon after the emergency phase has ended and should be based on pre-existing strategies and policies that facilitate clear institutional responsibilities for recovery action and enable public participation. Recovery programmes, coupled with the heightened public awareness and engagement after a disaster, afford a valuable opportunity to develop and implement disaster risk reduction measures and to apply the "build back better" principle.

Reconstruction means the medium and long term rebuilding and sustainable restoration of resilient critical infrastructures, services, housing, facilities and livelihoods required for the full functioning of a community or a society affected by a disaster, aligning with the principles of sustainable development and "build back better", to avoid or reduce future disaster risk.

Landslide risk assessment in Croatia

Landslide risk assessment in Croatia was undertaken in 2018 in the framework of the national risk assessment following recommendations from guidelines of the European Union (EC, 2010) The EU guidelines on national risk assessments and mapping do not advocate any particular risk criteria, benchmarks or standards, but do encourage transparency in this area including use of nomenclature according to the standard ISO Guide 73:2009 (ISO, 2009) and UNISDR terminology (UNISDR, 2009) as well as defined procedures of risk identification, risk analysis and risk evaluation. Risk identification is the process of finding, recognizing and describing risks. It serves as a preliminary step for the subsequent risk analysis stage. Risk analysis is the process to comprehend the nature of risk and to determine the level of risk. Risk evaluation is the process of comparing the results of risk analysis with risk criteria to determine whether the risk and/or its magnitude are acceptable or tolerable. These stages can be compared to the framework of landslide risk assessment and management developed by Fell et al. (2008a,b).

Risk identification

In the stage of risk identification, the landslide risk was recognised and described by a screening exercise covering the geographic context of the whole country (56 594 km2) during a given period of time (last 30 years). This phase has served as a preliminary step for the subsequent risk analysis stage. The methodology for risk identification was qualitative because of lack of systematic historical records necessary for application of quantitative statistical methods. Finding and recognising all likely landslide hazard and significant consequences was performed by analysing relatively frequent multiple-occurrence regional landslide events (MORLE) happened in Croatia (in 2006, 2010, 2013, 2014 and 2018). The screening was based on data about hazardous events from public sources (news from internet), scientific sources (professional and scientific papers) and governmental sources (records from local government), and the selection was based on expert opinions. Spatial and temporal extent of all MORLE was analysed based on catalogue of landslide events and catalogue of precipitation events in NW Croatia in the period from June 2006 till October 2014 (Bernat Gazibara i dr., 2017c). Identification of 85 triggering events (precipitation events) and 73 landslide events was made by temporal analysis of daily precipitation data from 19 meteorological stations in NW Croatia. The duration range of precipitation events is 1-41 days and the range of cumulative precipitation that triggers landslides is 29.5-400.5 mm. Most of the analysed precipitation events had happened during the autumn and winter period (Croatian Platform for Disaster Risk Reduction, 2019).

The outcome of the risk identification stage was a listing of two different identified risks and risk scenarios, followed by its description. "Reasonable worst case" or MORLE with the worst possible consequences was chosen as most serious credible outcomes as these pose the largest threat and are often of most concern. One more benchmark was chosen to rank a common problem that presents the most probable unfavourable MORLE. Scenario building was based on experiences from the very recent past, because hazardous MORLE from 2013 (Bernat et al., 2014a; Bernat et al., 2014b) was used as MORLE event with the worst possible consequences (Scenario 1) and hazardous MORLE event from 2018 (Bernat et al., 2019) was used as most probable unfavourable MORLE event (Scenario 2). Both scenarios were based on a coherent and internally consistent set of assumptions about key relationships between hazardous event and consequences as well as driving forces in the form of landslide susceptibility, triggering event (precipitation) and its frequency. Like any other simplification of reality, the definition of a scenario entails subjective assumptions about the number of expected landslides and geographic coverage of scenarios. Namely, risk analysis for both scenarios was performed for the area of approx. 15 800 km^2 in NW Croatia that presents union of geographic coverage experienced MORLE in 2013 and 2018.

For other parts of Croatia, MORLE events and impacts, which have so far not occurred, were also considered, assuming extreme hydrometeorological conditions (precipitation) that may happen as a consequence of climate changes and emerging landslide risk. It was essential that all information leading to the definition of scenarios was made explicit so that they can be reviewed and updated (Croatian Platform for Disaster Risk Reduction, 2019). However, the remaining uncertainties in this approach are immense (EC, 2010).

Both risk scenarios were used in the risk analysis stage, aiming to establish quantitative estimates for impacts and probabilities. A single-risk approach has been applied that determined risk from one particular type of hazard, i.e., MORLE. In most geographic areas in Croatia landslide susceptibility is not related to other hazard, e.g., floods. Coinciding hazards, also referred to as follow-on events, knock-on effects, domino effects or cascading events, are limited to very narrow areas in Croatia, such as City of Karlovac which have experienced landslides triggered by a flood in 2014.

Risk analysis

Risk analysis is the process to comprehend the nature of risk and to determine the level of risk, as it is defined by standard ISO 31000:2018 (ISO, 2018). For both risk scenario identified in the previous risk identification stage, the risk analysis process has carried out a detailed estimation of the probability of its occurrence and the severity of the potential impacts. In accordance with guidelines EC (2010), during risk analysis the geographic scope of the risk scenario and of the impacts was established, even though the precise location was left unspecified. Landslide risk analysis was based on quantitative data: (i) the assessment of the probability of two MORLEs (for Scenario 1 and Scenario 2) or hazard was based on historical frequency of triggering events, i.e., statistical analysis of precipitation records presenting the main drivers (rain), which also can help to pick up on accelerating trends, e.g., due to climate change; (ii) the assessment of the level of impact was in quantitative terms based on hazard intensity and estimated losses for few types of elements at risk. The assessment was performed to be as objective as possible, but due to lack of systematic records about historical hazards (i.e., number of landslide events) or consequences (i.e., losses), the main criteria was established based on expert opinion.

Single-risk analysis estimated the risk of a singular hazard in isolation from other hazards or risk scenarios, addressing the following subjects for MORLE from 2013 and 2018: hazard analysis; geographical analysis (location, extent); temporal analysis (frequency, duration, etc.); dimensional analysis (scale, intensity); probability of occurrence; vulnerability analysis; identification of elements and people potentially at risk (exposure); identification of impacts (physical, economic, environmental, social/political); assessment of likely impacts. An analysis of self-protection capabilities reducing exposure or vulnerability is planed to be performed in the next step of national risk assessment.

Hazard analysis

Hazard analysis encompassed: (a) analysis of spatial landslide probability, i.e., landslides susceptibility assessment resulting in zones potentially prone to landslides; (b) analysis of spatial distribution of number of expected landslides for Scenario 1 and 2; (c) temporal analysis of precipitation conditions resulting in determination of possible triggering events for Scenario 1 and 2; (d) analysis of temporal probability of occurrence of selected triggering event for Scenario 1 and 2. Hazard analyses are described in more details in the paper Bernat Gazibara et al. (2019) and here are listed only the main results important to explain and describe consequence analysis and risk estimation.

Landslide susceptibility assessment was performed in the geographic area covering eight counties in NW Croatia that had experienced MORLE in 2013 and 2018 (Krapina-Zagorje County, Varaždin County, Grad Zagreb, Zagreb County, Koprivnica-Križevci County, Međimurje County, Sisak-Moslavina County and Bjelovar-Bilogora County). The resulting landslide susceptibility map shows zones potentially prone to landslides, depicting locations of where landslides are possible in respect to lithology and relief type prone to sliding in the Pannonian Basin. The total area of landslide susceptible zones is about 3 300 km^2, or 21% of the analysed area.

Analysis of spatial distribution of the number of expected landslides for Scenario 1 and 2 was made based on estimation of the number of landslides for MORLE from 2013 and 2018. The expected number of landslides for the Scenario 1 was estimated based on the number of registered landslides activated in 2013 in Krapina-Zagorje County (Mihalić Arbanas i dr., 2013; Bernat i dr., 2014b) and the expected number of landslides for the Scenario 2 was estimated based on number of registered landslides activated in 2018. Average spatial frequencies of 0.733 and 0.37 landslides per square kilometer of landslide susceptible area were used to estimate the expected number of landslides in all eight counties for the Scenario 1 and 2. Assuming this number, it was possible to perform dimensional analysis of landslide hazard (scale, intensity) that was important for determination of extent and severity of consequences. Landslide type and size was estimated given specific geomorphological and geological settings of the analysed area in the Pannonian Basin (Mihalić Arbanas et al., 2017). Hilly areas in NW Croatia are susceptible to very small to moderate small (<10^5 m^3) superficial to moderate shallow (<20 m) landslides, mostly in soils (Bernat Gazibara i dr., 2017b). Despite small volume, landslides in soil cause significant damages on buildings, infrastructure and crops because of high landslide density. For example, Bernat Gazibara (2019) identified 702 landslides at the area of only 21 km^2 in hilly area of the City of Zagreb that are endangering people, buildings, infrastructure or environment. Main initiator of MORLE is precipitation, rain and snow (Bernat Gazibara et al., 2017a,c). Besides typical landslides, there is only one active large deep-seated landslide in NW Croatia, the Kostanjek landslide (Mihalić Arbanas et al., 2013), that needs to be treated separately because it significantly increases the intensity of landslide hazard as well as severity of consequences in one of the analysed counties, the City of Zagreb. Scientific studies of activity of the Kostanjek landslide, based on continuous monitoring in the period 2012-2018 (Krkač et al., 2019), showed that it was activated by means of accelerated displacement during MORLE in 2013 (max. velocity 4.5 mm/day) and 2018 (max. velocity 2 mm/day).

Temporal analyses of precipitation conditions were performed by estimation of precipitation conditions using Standard Precipitation Index, SPI (McKee et al., 1993) that is in common use in national meteorological services. SPI values have been calculated for both Scenarios 1 and 2 for temporal scales of 10-100 days (from date of landslide activation) at selected meteorological stations that are representative for precipitation conditions in the analyzed period in NW Croatia. The intention was to define possible critical temporal scales of rainfall events relevant for MORLE 2013 and MORLE 2018. The resulting critical temporal scale for Scenario 1 was 100-days cumulative precipitation that was extremely high at Varaždin and Zagreb-Grič meteorological stations (344.4-365.4 mm). These values present the highest measured 100-days precipitations for the end of March in the period 1961-2018. The resulting critical temporal scale for Scenario 2 were 40 and 100 days because both cumulative precipitations (177.2 and 362.6 mm) were extremely high at Sisak meteorological stations. These values represent the second highest measured 40- and 100-days precipitations for mid of March in the period 1961-2018.

The analysis of probability of occurrence of Scenario 1 and 2 was performed by probability analysis of occurrence of triggering events identified in the previous stage. Statistical probability analysis of two selected critical precipitations was based on parameters of theoretical distributions generated from precipitation data for referent climatological sequence, i.e., for the period 1981-2010. Probability of occurrence of the Scenario 1 was estimated to once in 98 years (based on precipitation data from Varaždin station) and once in 130 years (based on precipitation data from Zagreb-Grič station). This relates to probability of extreme 100-days precipitation that has preceded activation of landslides on 30th March 2013. Similarly, probability of occurrence of the Scenario 2 was estimated to once in 15 years (based on precipitation data from Zagreb-Grič station) and once in 22 years (based on precipitation data from Varaždin station). This was derived for the extreme wet rainfall conditions during 100-days precipitation event that had preceded activation of landslides on 13th March 2018.

Consequence analysis

Consequence analysis was performed for two aforementioned scenarios of landslide hazard, for the geographic extent of all eight counties in NW Croatia. For the purpose of the national risk assessment, three types of impacts are analysed, according to requirements from guidelines (EC, 2010): human impact; economic and environmental impact; and political/social impacts. Human impacts were estimated in terms of number of affected people, and economic/environmental impacts in terms of costs/damage in Kuna. The political/social impacts were generally referred to a semi-quantitative scale comprising a number of classes, e.g. (1) limited/ insignificant, (2) minor/substantial, (3) moderate/serious, (4) significant/ very serious, (5) catastrophic/disastrous. To make the classification of such latter impacts measurable, the classes were based on objective sets of criteria established by the Croatian Platform for Disaster Risk Reduction.

The characterization of consequence scenarios was based on the expected number of elements at risk per county which was estimated from the expected number of landslides and their intensity. The analysed elements at risk were affected people, forest, agricultural land, urban land, buildings, traffic infrastructure, hospitals and schools. Cost of losses was estimated for all eight counties using specific combinations of elements at risk presenting three aforementioned types of impact. Scenario 1 was characterised by approx. 2 000 affected people and total losses of about 4 460 million Kuna related to material damages. Scenario 2 was characterised by approx. 970 affected people and total losses of about 2 310 million Kuna related to material damages.

Risk estimation

Risk estimation was performed by classification of likelihood and impact of two hazardous scenarios. The impact of the Scenario 1 presenting MORLE with the worst possible consequences was estimated to have catastrophic human impact (more than 1 500 affected people), significant economic and environmental impact (losses in range of 1 500-7 000 million Kuna); and minor or significant political/social impacts (depending on observed elements at risk). The impact of the Scenario 2 presenting the most probable unfavourable MORLE was estimated to have significant human impact (501-1 500 affected people), significant economic and environmental impact (losses in the range of 1 500-7 000 million Kuna); and limited, minor or moderate political/social impacts (depending on observed elements at risk).

Risk evaluation

Risk evaluation is the process of comparing the results of risk analysis with risk criteria to determine whether the risk and/or its magnitude is acceptable or tolerable. Risk criteria are the terms of reference against which the significance of a risk is evaluated. Risk evaluation is used to make decisions about the significance of risks whether each specific risk should be accepted or treated. Risk evaluation was performed using the risk matrix recommended by guidelines EC (2010) and the results are presented in Fig. 2. The matrix is also used as a visualisation tool for multiple risks that have been identified in the national risk assessment, to facilitate comparing the different risks.

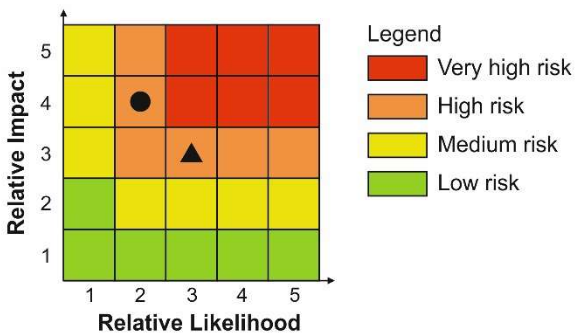

Figure 2 Results of risk evaluation in the form of risk matrix for: (a) landslide hazard with the worst possible consequences (circle); and (b) landslide hazard with the most probable unfavourable consequences (triangle).

Landslide disaster recovery in Croatia

During MORLE in 2018, one catastrophic landslide has happened in the city of Hrvatska Kostajnica in March 2018 (Podolszki et al., 2019). Sudden collapse of large moderate dip landslide completely destroyed all houses placed in the foot part of the landslide resulting in large material damage causing losses with high economic as well as environmental impact. Figure 2 presents two completely destroyed houses placed in the foot part of the landslide in Hrvatska Kostajnica that was activated on 13th March 2018.

Immediately after occurrence of the disaster, Government of the Republic of Croatia had started the recovery programme to help people in Hrvatska Kostajnica endangered by this landslide and also introduced a new follow-up recovery programme for all people endangered by landslides in Croatia. Recovery includes restoration and improvement where appropriate, of houses, livelihoods and living conditions of affected people, including efforts to reduce disaster risk factors by remedial measures. The recovery task of rehabilitation and reconstruction in Hrvatska Kostajnica began soon after the emergency phase had ended.

Figure 3 Houses destroyed by collapse of the Hrvatska Kostajnica landslide on 13th March 2018.

Recovery programme after disastrous landslide in Hrvatska Kostajnica

In March 2018, government of the Republic of Croatia proclaimed natural disaster conditions and immediately after the disastrous event in Hrvatska Kostajnica they adopted a Conclusion with recovery actions. The main decisions were related to supply of permanent housing together with removal of destroyed houses and other buildings. Governmental decision of 15th March 2018 referred to the same type of restoration or improvement, where appropriate, or removal of houses destroyed or damaged by landslides in all other parts in Croatia. The programme has been fully financed by Croatian national budget.

Systematic implementation of the Governmental Conclusion was facilitated by two Decisions: (1) *Decision About Criteria and Modes of Housing Supply for Inhabitants and Removal of Destroyed Family Houses Remnants and Other Buildings Destroyed or Damaged by Landslides in Hrvatska Kostajnica and in Other Parts of the Republic of Croatia* (of 5th July 2018); (2) *Decision About Adoption of the Program of Housing Supply for Inhabitants and Removal of Destroyed Family Houses Remnants and Other Buildings Destroyed or Damaged by Landslides in Hrvatska Kostajnica* (of 15th March 2019). The listed documents served as a basis for implementation of housing supply in joint cooperation of the Croatian Ministry of Construction and Physical Planning, Croatian Agency for Transactions and Mediation in Immovable Properties (APN) and Central State Office for Reconstruction and Housing of the Republic of Croatia. One month later, on 15th April 2019, President of the Republic of Croatia consigned new houses to owners of destroyed homes in Hrvatska Kostajnica. Duration of the whole process of improvement of livelihoods and living conditions of disaster-affected people was 13 months.

Recovery programme after MORLEs in Croatia

Just before all innovation introduced after disastrous landslide in Hrvatska Kostajnica, Ministry of Construction and Physical Planning had opened public call for co-financing landslide remediation design on 22nd February 2018 for the purpose of remediation and mitigation of landslide consequences,. Based on this call, Ministry has co-financed 37 projects dealing with execution of landslide remedial works and/or preparation of design documentation for landslide remediation, with the total value of 10 million Kuna. The maximum amount of co-financing was 80% of eligible cost or maximal 600 000 Kuna. Totally 97 local government administrations delivered 139 project proposals with a total amount of co-financing exceeding 69 million Kuna. This showed exceptional interest and need at the local level. After the administrative verification process had been completed, 129 project proposals satisfied completeness and acceptability criteria. The Committee evaluated, ranked and suggested 37 projects for co-financing.

After the disastrous landslide in Hrvatska Kostajnica Government of the Republic of Croatia had recognized needs for recovery actions in March 2018 that resulted with new measures related to recovery and reconstruction. Amendments of the Water Management Financing Act in December 2017 created a prerequisite for permanent provision of resources for remediation of landslide consequences. This Act prescribes that the revenue from water contribution is resource for co-financing of landslide and rock fall remedial measure cost. The Act relates to unfavourable effects of erosion and flush flood processes and losses on public infrastructure caused by all types of landslides. For the purpose of landslide remediation in 2019, Croatian Water reserved 50 million Kuna and the same politics will become common practice.

Following abovementioned legislative changes, contracts about co-financing of geotechnical design documentation and landslide remedial works were signed between Croatian Water and counties, cities and municipalities on 2nd July 2019. Total value of all contracts is 54.9 million Kuna for 112 landslides and Croatian Water will co-finance 32.5 million Kuna.

On 27th July 2018 Ministry of Construction and Physical Planning had opened a new public call for the purpose of housing of all people in Croatia that are owners of houses damaged by landslides. This call was entitled: *Public call for submission of applications for realisation of the right to housing provision of inhabitants of buildings and removal of remnants of demolished family houses and other residential buildings destroyed or damaged due to landslides in the territory of the Republic of Croatia*. There were totally 75 applications for that call, including few families from Hrvatska Kostajnica. The Committee members inspected the sites of the landslides and the residential buildings of applicants, and in the fall of 2019, upon having carried out an analysis of all collected data, the adoption of the Programme of Housing Provision also to other Inhabitants of the Republic of Croatia is expected, by which an appropriate manner of housing provision to inhabitants who have followed the Public call and are eligible for housing provision shall be established.

Discussion and conclusions

In 2018 Ministry of Construction and Physical Planning undertook valuable specialised expertise for landslides, as particular types of risk in Croatia for the Croatian Platform of Risk Reduction. Based on results of landslide risk assessment, landslides are included in the national document "Disaster risk assessment of the Republic of Croatia" (Croatian Platform for Disaster Risk Reduction, 2019) that include risks which are of sufficient severity to entail involvement by national governments in the response, in particular via civil protection services. Elaboration of national landslide risk assessment was performed according to guidelines published by European Commission (2010), addressed to national authorities and other actors. The main purpose of these guidelines is to improve coherence and consistency among the risk assessments undertaken in the Member States at national level in the prevention, preparedness and planning stages and to make these risk assessments more comparable between Member States. National risk assessment and mapping, carried out in Croatia, within the broader context of disaster risk management can also become essential inputs for planning and policies in a number of areas of public and private activity. Following the development of the national risk assessment and maps, the involved authorities should seek to interface in an appropriate way with the ensuing processes of risk management, including capacity analysis and capability planning, monitoring and review, and consultation and communication of findings and results, as well as with the appropriate policy levels involved in developing building design criteria, land use planning, community disaster mitigation and response plan.

In 2018 Ministry of Construction and Physical Planning undertook few programmes of recovery to help people endangered by landslides. Based on experience from recovery actions related to the catastrophic landslide in the city of Hrvatska Kostajnica in 2018, the Ministry introduced a set of new measures with the intention to introduce new strategy and policy that facilitate clear institutional responsibilities for recovery action and enable public participation. Recovery programmes, coupled with the heightened public awareness and engagement after a disaster, afford a valuable opportunity to develop and implement disaster risk reduction measures and to apply the "build back better" principle. It can be concluded that the measures introduced by the Croatian government are in line to the agenda Sendai Framework for Disaster Risk Reduction concerning emerging risk of Multiple Occurrence Regional Landslide Events (MORLE) that is consequence of changed meteorological conditions caused by climate changes. Therefore, governmental recovery programmes is also related to measures of adaptation to climate changes within the meaning of contribution to transverse sector of risk management.

The Croatian scientist, as a stakeholder of the "Sendai Framework for Disaster Risk Reduction 2015–2030" from academic, scientific and research entities, need to increase research for regional, national and local applications on landslide hazard prediction and monitoring. The results of scientific research in the form of landslide maps and monitoring systems (Mihalić et al., 2010; Mihalić Arbanas et al., 2018; Arbanas et al., 2018; Bernat Gazibara et al., 2018; Krkač et al., 2018; Sečanj et al., 2019) are required to support action by local communities and authorities, as well as to support the interface between policy and science for scientifically based options for decision making.

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