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Understanding of landslide risk through learning by doing: case study of Koroška Bela community, Slovenia

Abstract Activities toward better understanding and reducing landslide disaster risk are an important part of the voluntary commitment written into the ISDR–ICL Sendai Partnerships 2015–2030. The present study highlights of the learning by doing approach implemented in the case of Potoška planina landslide, which poses a threat for community of Koroška Bela. For the first time in Slovenia, a cooperative team has been established for the purpose of raising awareness and understanding of landslide risk in the community. In addition, a combination of indoor and outdoor training sessions provides both theoretical and practical exercises on how landslides may be identified, together with their key characteristics and methods for landslide monitoring. In order to evaluate the effectiveness of this team, which is made up of different sectors, a questionnaire was drawn up. The responses to the questionnaire showed that understanding of landslide hazards among the members of cooperative team is significantly better than it was before the group was established. The present research proposes a methodology whereby, through cooperative team trainings and mutual cooperation among relevant stakeholders and local authority, important steps toward understanding landslide risks can be achieved, which in particularly is important for local communities and is sure to become a focal point in the coming years, in parallel with the increasing scarcity of financial resources available at the local level.

Keywords Landslide risk · Learning by doing · Cooperative team · Community · Slovenia

Introduction

Landslides pose a serious physical and environmental threat to communities living in landslide-prone areas (UNISDR 2015). Accordingly, activities aimed at better understanding and reducing landslide disaster risk are an important part of the voluntary commitment written into the ISDR–ICL Sendai Partnerships 2015–2030 (Sassa 2015, 2017) that follows on the Hyogo Framework for Action 2005–2015, which began with a multinational plan to set out the work that is required from the many different sectors and actors in reducing the impact of landslides on people, structures and infrastructures (UNISDR 2015). Recently, in order to promote activities envisaged in the Sendai Framework globally, a set of interactive teaching tools was prepared as texts in the form of PPT or PDF tools consisting of published references, papers, reports, guidelines, laws and other topics related to landslide issues (Sassa 2017; Landslide Dynamics 2018). The fundamental aim is to understand "Landslide dynamics" as the default basis for reducing landslide disaster risk, as investigated in a wide body of research (Wieczorek 1984; Cruden 1991; Cruden and Varnes 1996; Cheung and Shiu 2000; Alcántara-Ayala 2002; Dai and Lee 2002; Crozier and Glade 2005; Catani et al. 2005; Hungr et al. 2005; Fell et al. 2008; Wieczorek and Leahy 2008; Sassa and Canuti 2008; Rossi et al. 2010; Petley 2012; Parkash 2013; Tofani et al. 2013; Corominas et al. 2014; UNISDR 2015, 2017; Gariano and Guzzetti 2016). The primary aim is to reduce long-term losses resulting from landslides by improving our understanding of the ground failure causes. A very extensive study on the role and benefits of stakeholder engagement in community-based landslide hazard mitigation measures is described by Anderson and Holcombe (2013). In it, they prepared a comprehensive guide for project managers and practitioners on the entire end-to-end process of community-based landslide risk reduction. The 4th World Landslide Forum in Ljubljana adopted "The 2017 Ljubljana Declaration on Landslide Risk Reduction" (Sassa 2017), which stresses the integration and mutual collaboration of all relevant sectors (e.g. stakeholders, experts, authorities, scientists) with the aim of enhancing landslide disaster risk awareness and mitigation. Similarly, the establishment of cooperative teams aims to address these issues and recognises the importance of supporting multi-sector partnerships in landslide prevention.

Generally speaking, effective approaches to reducing landslide risk consist of developing methodologies to identify landslide-prone areas and developing risk reduction approaches to mitigate the effects of landslides in these areas (Anderson et al. 2008). In order to take advantage of these approaches, it is essential to ensure knowledge transfer and training, as well as capacity building (UNISDR 2007; Parkash 2013; Alcántara-Ayala and Moreno 2016). This approach involves sharing the research findings, lessons learned and field training designed with disaster management experts and professionals, such as planners, engineers, architects, geographers, environmental specialists and university teachers as well as increased resilience at the community level, by engaging and involving communities. Although governments generally have overall responsibility for disaster management, it is often true that considerable knowledge and expertise has developed at the regional or local level, mainly through learning by doing. Furthermore, this knowledge allows regional and local authorities to develop effective strategies and respond for risk reduction (Lee and Moore 1991).

As regards regulations, which are designed to oversee planning and construction in areas prone to landslide risk, Slovenian legislation remains insufficient: Slovenian legislation adopted the EU Flood Directive in 2007, but this only served to improve flood risk management in Slovenia and did nothing to change landslide risk management (Mikoš et al. 2014). Legislative acts, such as the national act on natural and other disasters, deal largely with warning, rescue and remediation issues instead of prevention measures, and are mainly divided into prevention, intervention and permanent measures adopted in the process of remediation (Jemec Auflič and Komac 2011).

The current protection strategy against landslides is a part of The Waters Act (Official Gazette of RS 2002), which follows the Water Frame Directive of the European Parliament and Council 2000/60/EC, where developments in landslide-prone areas are specified primarily in terms of adverse effects of water—meanwhile, spatial planning in areas that could be the source of or stand to increase the risk of landslides is entirely overlooked. However, landslide risk management in Slovenia generally follows the guidelines of the Sendai Framework for Disaster Risk Reduction 2015–2030 (Fig. 1).

The present study highlights two complementary methods for understanding landslide risk and raising awareness in a community using the "learning – by – doing" approach. The first method is the establishment of a cooperative team that may play a leading role in raising awareness in the local community; and the second is a method of training sessions through which the group members participate in several indoor and outdoor training sessions. In order to evaluate the effectiveness of this team, consisting of different sector representatives, a questionnaire is drawn up. In the conclusion, the proposed methods for understanding landslide risk and raising awareness will be evaluated.

Landslide causes and triggers in Slovenia

Many of the geological processes that have shaped Slovenia over the past few million years remain active today. When these natural processes endanger life and property, we refer to them as geologic hazards. In Slovenia, the most frequent among them are earthquakes, landslides, surface changes due to ground swelling, subsidence and collapsing and ground and groundwater pollution. Slovenian territory has experienced loss of life and property damage from geologic hazards throughout history—and may expect more of the same in the future. The main reasons for numerous landslides are the hillslope morphology, unfavourable geological and tectonic conditions, as well as climatic diversity. All listed factors are related to the fact that Slovenia is located on the still active boundary of the African and Eurasian plates and is composed of five major tectonic divisions: the Adriatic-Apulian Foreland, Eastern and Southern Alps and the Dinarides and Pannonian basin (Placer 2008), which makes the area heavily dissected by faults and thrusts, resulting in reducing the mechanical properties of rocks (Komac and Hribernik 2015). In Slovenia, fatal landslides have claimed 16 victims in the last 25 years (Haque et al. 2016). Major pre-historic earthquakes also triggered huge rock avalanches in the Vipava Valley. Recently, some of these earthquakes have triggered landslides, like the earthquake on April 12, 1998 (MS 5.6), which triggered more than 100 slope failures, among them 50 rock falls; and the earthquake 6 years later, on July 12, 2004 (MS 4.9), registered 50 relatively superficial slope failures, including 38 rock falls (Mikoš et al. 2006, 2013). Since the year 2000, extreme precipitation events have occurred almost annually, frequently several times over the course of a year. Consequently, the number of slope mass movements has increased significantly. More than 10,000 landslides have been recorded in the past 25 years by the Administration for Civil Protection and Disaster Relief (ACPDR) and the Geological Survey of Slovenia (GeoZS). Most of these slope mass movements can be categorised as landslides, ranging in size from 10 to 1200 m^3, most of which have caused damage to buildings, infrastructure and agricultural land (Jemec Auflič et al. 2016). Among many slope failures that have been recorded are also those landslides whose volumes exceeded one million m^3 and which, in addition to the damage done to buildings, also endangered the lives of hundreds of people and even resulted in human casualties (Jemec Auflič et al. 2017). Similarly, rockfalls pose a risk to more than 600 km of road links. The damage caused by landslides and snow avalanches in the period 1994–2008 amounted to 99 million Euros in Slovenia (Statistical Office of Slovenia). Nevertheless, appropriate prevention measures can reduce the damage caused by geologic hazards enormously.

Potoška planina landslide

The Potoška planina landslide is located in the Karavanke mountain range (NW Slovenia) above the densely populated settlement of Koroška Bela, which has almost 2200 inhabitants. Current landslide activity is evidenced by the "pistol butt" trees, scarps and the deformation of local roads. Similarly, historical sources describe a severe debris flow at the end of the eighteenth century that destroyed nearly 40 houses in the settlement of Koroška Bela. In total, the landslide covers an area of 0.2 km^2 with an estimated maximum sliding mass volume of roughly 1.8×10^6 m^3 (Jež et al. 2008; Komac et al. 2015; Peternel et al.

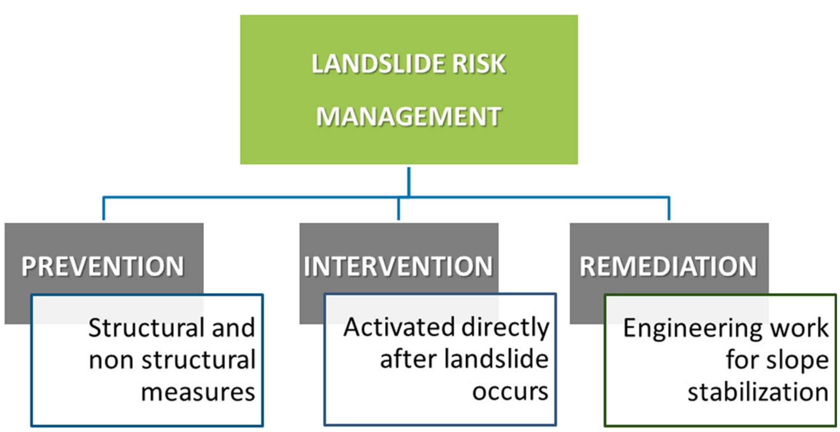

Fig. 1 The general concept of landslide risk management in Slovenia

2017a). In general, the broader area of the Potoška planina area exhibits highly complex geological and tectonic characteristics that exert an influence on various slope mass movements. The upper part of the landslide consists of carbonate rocks and scree deposits that are largely prone to rock slides, while the main body of the landslide consists of heavily deformed Upper Carboniferous and Permian clastic rocks, which are characterised by complex dynamic movement, and is presumed to be a rotational, deep-seated slow-motion slide accelerated by percolation of surface and groundwater. Due to several springs at the contact point between scree and clastic rocks, the landslide area is partially covered by wetlands, and the Bela stream increases the possibility of mobilisation of the material into debris flow. On the basis of UAV photogrammetry and tachymetric measurements, Peternel et al. (2017b) monitored the toe of the landslide, where, during an observation period of nearly 2 years, the assessed displacements ranged in size from 0.9 to 17.9 m. The Ministry of Environment and Spatial Planning financed the project "Implementation of the urgent engineering geological, hydrogeological, geophysical and geomechanical and geodetic monitoring system for determination of the objective level of risk for the population due to slope mass movements in the area of Potoška planina (above the Koroška Bela settlement) and the preparation of an expert base with proposals for mitigation measures", according to which appropriate counter-mitigation measures will be proposed (Peternel et al. 2017a). Figure 2 shows the simplified geological settings of the Potoška planina landslide with landslide section profile, both modified from Peternel et al. (2017a).

Methodology

Establishment of the cooperative team

Under the DG ECHO project "Resilient European Communities Against Local Landslides" (RECALL), the cooperative team for the Koroška Bela community was established in December 2015, following the composition of group proposed by Anderson and Holcombe (2013) including decision makers, response authorities, technical experts and stakeholders. Thus, 15 volunteer representatives from the geodetic company, a torrent maintenance company, the Municipality of Jesenice, the Administration for Civil Protection and Disaster Relief Slovenia (Branch Kranj), the Potoki agrarian community and local inhabitants from Koroška Bela as well as 5 experts from Geological Survey of Slovenia decided to participate in this working group (Jemec Auflič et al. 2017). The group was led by experts from GeoZS with the main aim to train its members in identifying and reporting landslides and topographic changes and to collaborate in fieldwork. To increase landslide risk awareness in the Koroška Bela community, which is threatened by the nearby Potoška planina landslide, members of the cooperative team applied four main working steps: (1) networking in terms of bringing together representatives from different sectors, backgrounds and disciplines—who otherwise would not necessarily meet—to jointly find solutions to the challenge; (2) participation in the selection of best prevention measures; (3) coordination in various tasks in local community and on the field and (4) informing the general public and national response authorities about the group activities and status of landslide risk in the community, since various and inconsistent information has been reported to the media and

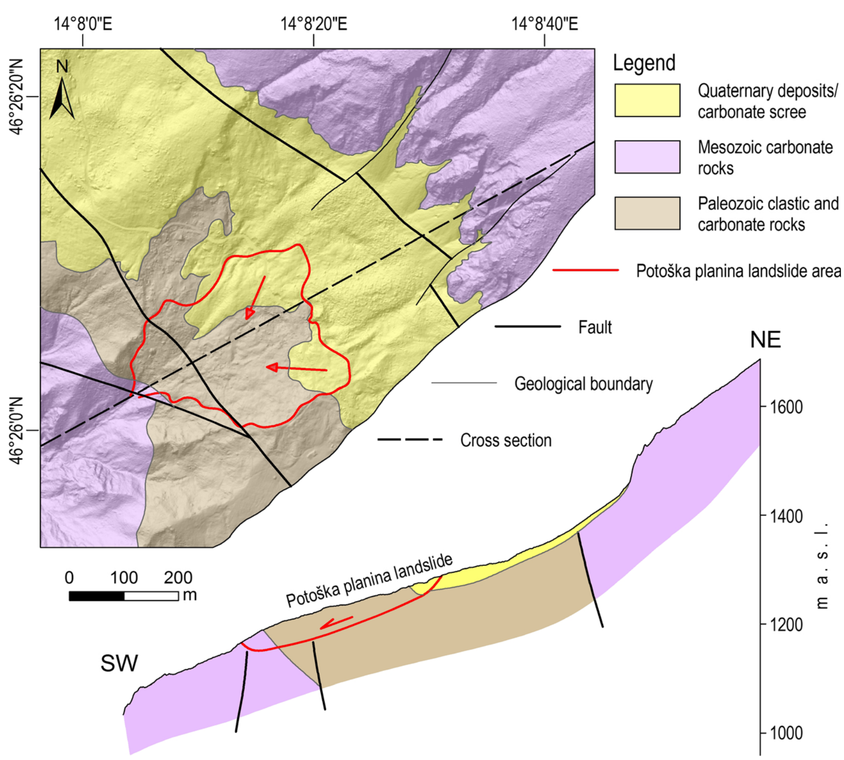

Fig. 2 Simplified geological settings of the Potoška planina landslide with the landslide section profile, both modified from Peternel et al. (2017a)

national response authorities. Before the cooperative team was established, the gathering of landslide data in Koroška Bela was not systematically conducted. Generally speaking, information on landslide activity has been provided primarily by GeoZS through different research projects (Jež et al. 2008; Komac et al. 2015; Peternel et al. 2017b).

Training sessions

In order to provide cooperative team members with the skills they need to better understand landslide risk, more than 20 indoor and outdoor training sessions were implemented with an emphasis on scientific knowledge transfer about natural risk mitigation methods and the use of various tools (Fig. 3). During the meetings, the specific objectives were set to (1) identify landslide area; (2) observe and monitor landslide features and changes; (3) record landslide changes using e-Tool; (4) install a monitoring system at the lower part of Potoška planina landslide to provide real-time monitoring data of surface movement patterns and immediate notification of landslide activity and landslide behaviour and (5) inform the public and responsible national authorities about the importance of prevention and such collaboration.

Indoor trainings consisted of several different modules starting with theoretical background and definitions and terminology adapted from Varnes (1978) and Cruden and Varnes (1996). Indoor and outdoor training sessions were combined; classroom-type lectures were followed by the fieldwork that proved successful, in particular for majority of cooperative team members which were not familiar with the landslide topic.

Recording landslide changes using Prevention e-Tool

A user-friendly open-source web tool was used to serve the cooperative team in recording landslide changes. The tool was developed in the frame of RECALL project and can be assessed at: https://recallpreventionetool.linuxweb.eu/. The tool enables collecting data online, where data are automatically or manually transferred to the server, where one could convert online form data to PDF files. Through different tool components, the user can conduct registration, select a pilot area on a map, report the landslide changes, add field photography and submit the form. In order to facilitate landslide identifying, the GeoZS team selected seven locations (observation points) where landslide characteristics are more significant (Fig. 4a). At these observation points, different landslide elements and their geometry could be recognised and observed. With the Prevention e-Tool, the local cooperative team members may collect landslide changes either descriptively or numerically (e.g. Fig. 4b, c, refer to the five pairs of wooden stakes installed up to 40 cm into soil at observation point 1—Fig. 4a).

At the location of point 5, the 3D cameras were utilised for the real-time monitoring of the lower part of Potoška planina landslide where the Bela stream increases the possibility of mobilisation of the material into debris flow (Fig. 5). The local members of the cooperative team were responsible for camera performance and battery replacement, while the members from geodetic company provided cameras and software (Peterman 2018).

The questionnaire set up

For the evaluation of the operating efficiency of the cooperative team in understanding and recognising landslide occurrences in the hinterland of Koroška Bela settlement, the questionnaire was set up and circulated among members of the cooperative team. The questionnaire was organised into four different sections, as shown in Table 1. The first section was related to the general information of questionnaire respondents (organisation, location, contact person, e-mail), the second targeted to thinking and informing about hazard in the Koroška Bela (3 questions), the third aimed to the role of the cooperative team (3 questions) and the fourth addressed possible prevention measures to reduce hazard (5 questions).

Answers were collected from 15 different members of the cooperative team: five from local inhabitants, three from civil

Fig. 3 Cooperative team member activities. **a** Indoor teaching. **b** Outdoor training. **c** Presentation of achievements to the local community. **d** Presentation of planned small reinforcement works to the local authority

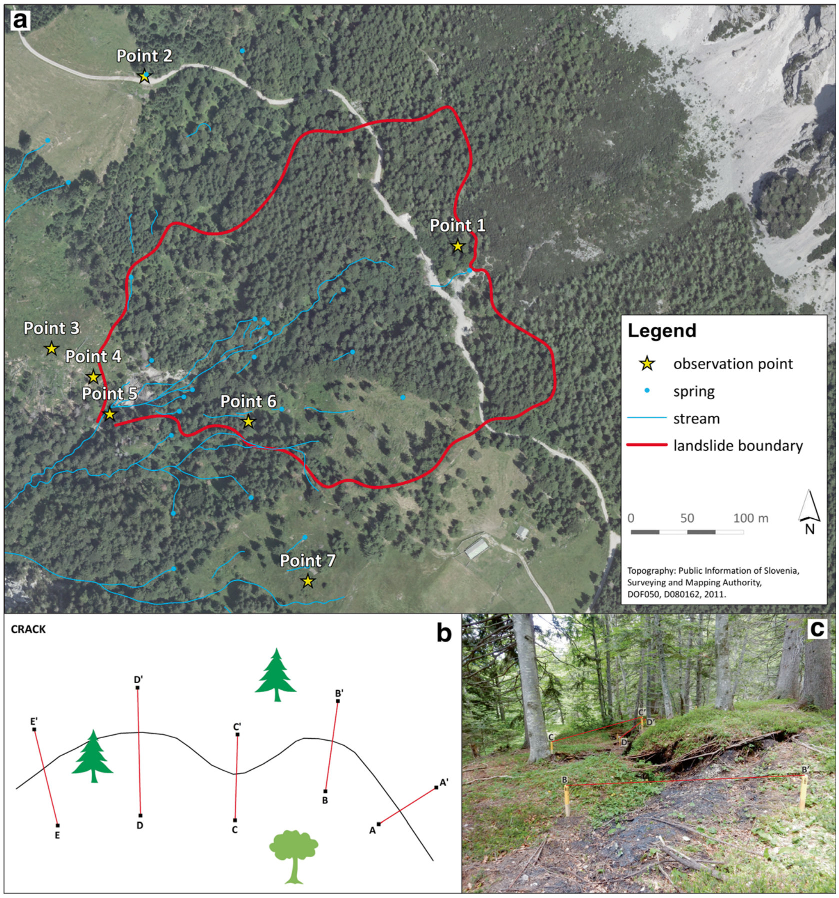

Fig. 4 **a** Locations of the seven observation points in the Potoška planina landslide. **b** Sketch map of five pairs of wooden stakes installed up to 40 cm into soil transversely to opened crack at observing point 1 (**b**, **c**) where cooperative team recorded distance using Prevention e-Tool. **c** Pairs of wooden stakes after installation to opened crack

Fig. 5 **a** Installation of 3D cameras at the observing point 5 at the lower part of landslide (Fig. 4a). **b** The view of the lower part of landslide from the point, where cameras were placed

Table 1 Overview of the questionnaire sections

Questionnaire sections	Concept	Responses
1 General information	Organization	
	Location	
	Contact person	
	Email	
2 Thinking and informing	What do you think about the landslide hazard?	I am very concerned.
		I think that the hazard is important.
		I am aware about hazard daily but I do not consider this to be essential.
		I don't consider this to be essential.
		I don't live in the hazard area.
		I don't know.
	How do you estimate the rate of landslide hazard?	Optional from very low to very high
	How was informing about the hazard before the cooperative team was established?	A little information was available.
		From experts in the field observation.
		Past research projects on the Potoška planina landslide.
3 Operating efficiency	How do you estimate knowledge transfer by GeoZS experts?	Excellent
		Ordinary
		Poor
	Were the methods used for understanding landslide processes effective enough for raising awareness of landslide risk?	Yes (Why?)
		No (Why?)
	Was the composition of the cooperative team competent enough to play an important element at raising awareness?	Yes (Why?)
		Partly (Why?)
		No (Why?)
4 Prevention measures	Continuation of the cooperative team activities	Claims on a scale of 1 = no effect to 5 = strong effect
	Greater role to the civil protection administration	Claims on a scale of 1 = no effect to 5 = strong effect
	Adherence of recommendation for construction	Claims on a scale of 1 = no effect to 5 = strong effect
	I feel safe, no need for additional measures	Claims on a scale of 1 = strongly disagree to 5 = strongly agree
	We can do nothing more	Claims on a scale of 1 = strongly disagree to 5 = strongly agree

protection, two from local authorities, two from the geodetic company and three from GeoZS experts.

Results and discussion

Landslide identification and observation

In the landslide classification system module, the activity, rate of movement, water content, material and type of landslide movements were shown in detail. The training of the cooperative team at the field to be able to recognise overall topography, main landslide elements and movement patterns was the core priority relating to understanding slope processes in the community.

In the 4-month period in 2016, the local members of the cooperative team recorded the distance between pairs of wooden stakes transversely to opened crack on point 1 (Fig. 4) six times. The measured data for each profile between pairs of wooden stakes do not vary significantly. A slightly larger movement was detected in the profile E-E′ and could be related to the lateral spreading of landslide (Peternel et al. 2017b). These results raise the question of the relevance and precision of the utilised method, because the measured movements are barely perceptible. In particular, the method pairs of wooden stakes were utilised only to show the cooperative team one of the possible ways for monitoring landslide features, as it was relatively easy to implement considering that millimetre accuracy cannot be expected, mostly due to the using of robust measuring tape. On the remaining six points (Fig. 4a), members of the cooperative team observed surface features on an active landslide: crown cracks, main scarp, head, slum blocks, areas of temporary or permanent water ponding, discharge of springs, degree of vegetation disturbance, changing of bare ground and the deformation of a local road. The 3D cameras at the location of point 5 (Figs. 4a and 5) produced a large number of photos, based on which the displacement vectors of the daily movements were calculated, ranging from one millimetre to several centimetres (Fig. 6). Although the observed and measured data should be considered informative due to the simplified methods, the primary purpose to get practice in recognition of landslide elements was achieved.

Evaluation of cooperative team

The questionnaire (Table 1) outcomes indicate a landslide hazard awareness rate of 80% for the cooperative team (Fig. 7a), while the estimated rate of hazard varies from high to very high according to Fig. 7b. Some 67% of respondents felt that the landslide researchers from the GeoZS interpreted the relevant landslide dynamics very precisely (Fig. 7c), and that the method of knowledge transfer, including the indoor and outdoor training sessions, proved to be a highly effective approach to raising awareness of landslide risk. On the question of the composition of the cooperative team, all respondents were satisfied with the scope and proficiency of the team (Fig. 7d), but missed the governmental institution covering the subject of the environmental. The last section of questions addressed prevention measures designed to reduce hazards, which could be rated on a scale of 1–5, with 1 meaning "no effect" and 5 "strong effect"—or "strongly agree" and "strongly disagree". The results are shown in Fig. 7e, f. Adherence to recommendations on the construction of new buildings is seen as having a very strong effect in reducing the level of hazard (80%), followed by the continued work of the cooperative team (67%) and a greater role for the civil protection administration (47%), as is shown in Fig. 7e. Referring to the question on safety related to prevention measures, almost 50% of responders feel safe enough, with no desire for additional prevention measures (Fig. 7f). They believe that regular field observations by experts are sufficient for safety in the community, but communication between local authority, government and civil administration office needs to be improved significantly. The remaining half of respondents thinks that additional prevention measures should be performed (e.g. early warning system). When asked about whether individuals or groups can do anything to reduce the level of hazard, 53% of responders answered that the cooperative team could contribute significantly toward reducing landslide risk (Fig. 7f).

Results of the questionnaire show that understanding of landslide risk among members of the cooperative team from Koroška Bela community is significantly better than before the group was established, which cannot be generalised to the entire community because only 10 respondents come from Koroška Bela. In addition, the combination of indoor and outdoor training offers theoretical and practical exercises on identifying landslides, and their characteristics, as well as monitoring methods. The members of the cooperative team are only concerned about the relative ignorance of national response authorities, who decided not to participate in the cooperative team despite the invitation. National authorities should engage with relevant stakeholders, volunteers, the community of practitioners, the public and private sectors and civil organisations, as well as with academia and scientific and research institutions, and work closely together to integrate disaster risk into their management practices (Sassa 2015). In the present case, the responsible national authority is missing, but the 2 years of work of the cooperative team have confirmed that it plays a decisive role in setting and implementing prevention measures. The establishment of the cooperative team as it was constituted endorses the guiding principles of the Sendai Framework, where it is stated that "it is necessary to empower local authorities and local communities to reduce disaster risk, including through resources, incentives and decision-making responsibilities". Similarly, the commitment of the local authority and multi-sectoral organisations in reducing landslide risk awareness has also proved effective in the case of Central Java (Fathani et al. 2016), the municipality of Teziutlán in Mexico (Alcántara-Ayala et al. 2018) and the Shihmen watershed in Taiwan (Chen and Wu 2016).

Conclusions

For the purpose of understanding the landslide dynamics as the default basis for landslide risk reduction, a learning by doing approach was implemented in the community of Koroška Bela. It turned out that such an approach can be very effective, as confirmed by the positive effects of the established cooperative team, composed of relevant groups of different sectors and proficiency. First, through indoor and outdoor training, the members were involved in observing of landslide elements and monitoring, which helped them in better understanding of landslides in general. Second, significant advantages of the cooperative team are its diversity in members' backgrounds and decision-making power. The fact that it includes local residents and the local authority enables experts not only to obtain additional information about the characteristics of the landslide and provides them with assistance in monitoring and observing the landslide itself but also to become a connection between the decision makers, while residents also obtain information on landslide-related activities taking place in the field. With two-way communication, it was possible to provide a more transparent functioning of the responsible national institutions and nurture trust among the local community in the performance of their tasks. By focusing on risk reduction on the local level, the cooperative team stands to benefit from dialoguing with the responsible national authorities in providing additional funding for the monitoring of landslides and the implementation of more effective landslide risk reduction measures. Through mutual cooperation and dialogue, steps toward more effective risk prevention can be taken, which is now particularly critical in local communities and is bound to become a focal point in the coming years—and all in parallel with the increasing scarcity of financial resources available at the local level. Third, effectiveness of the cooperative team's functioning is also shown in the extended research performed by Peternel et al. (2017a), which was financed by the responsible national authority after the presentation of RECALL outcomes and landslide hazard to the general public in Koroška Bela community (Jemec Auflič et al. 2017). Lastly, the cooperative team still exists, although some members are not active anymore, but the core members, such as the local authority, civil protection and geological experts assist, in landslide monitoring, developing appropriate risk mitigation strategies and disaster risk reduction measurements. Research institutions play a

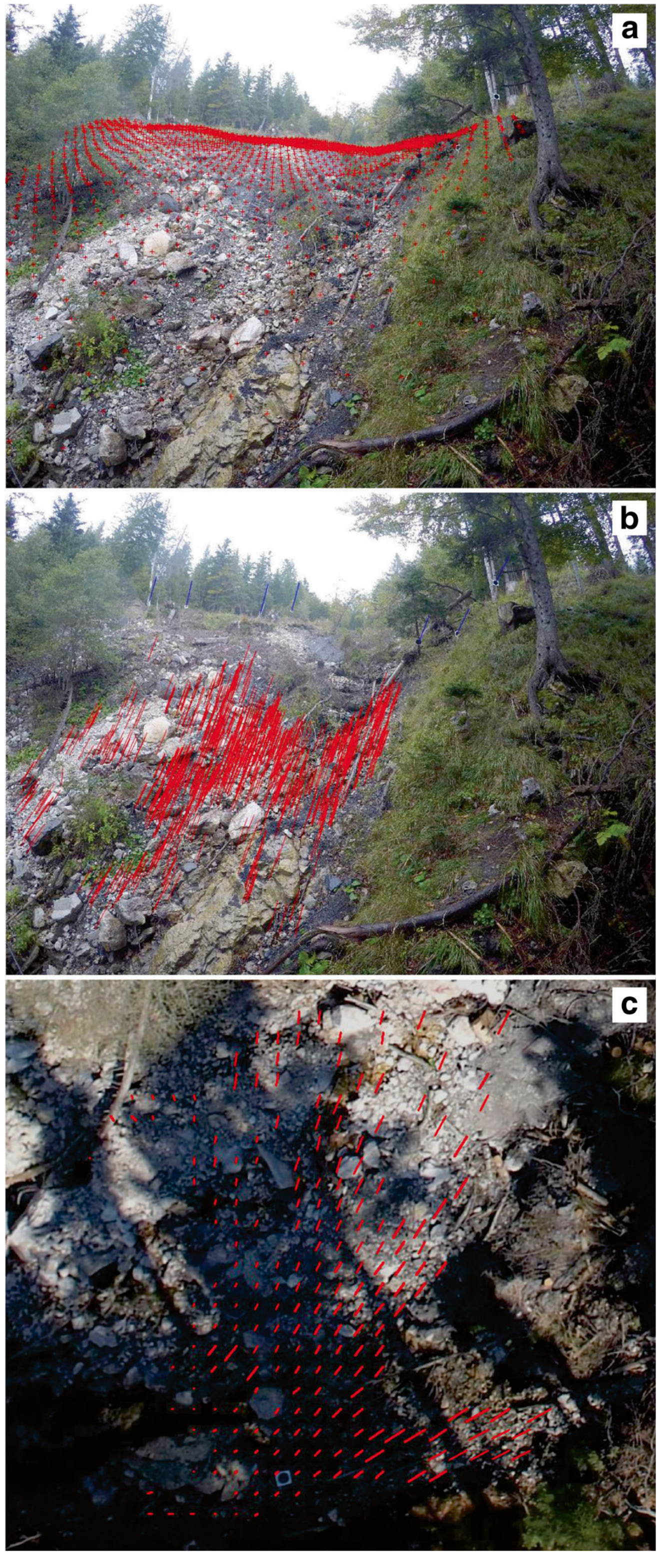

Fig. 6 **a** Digital terrain model projected on camera view (Peterman 2018). **b** 2D displacements of signalised targets (blue) and 2D displacement points of interest on landslide (red), all the displacements are exaggerated by factor of 20 (Peterman 2018). **c** 3D regular grid of landslide displacements displayed over orthophoto map (Peterman 2018)

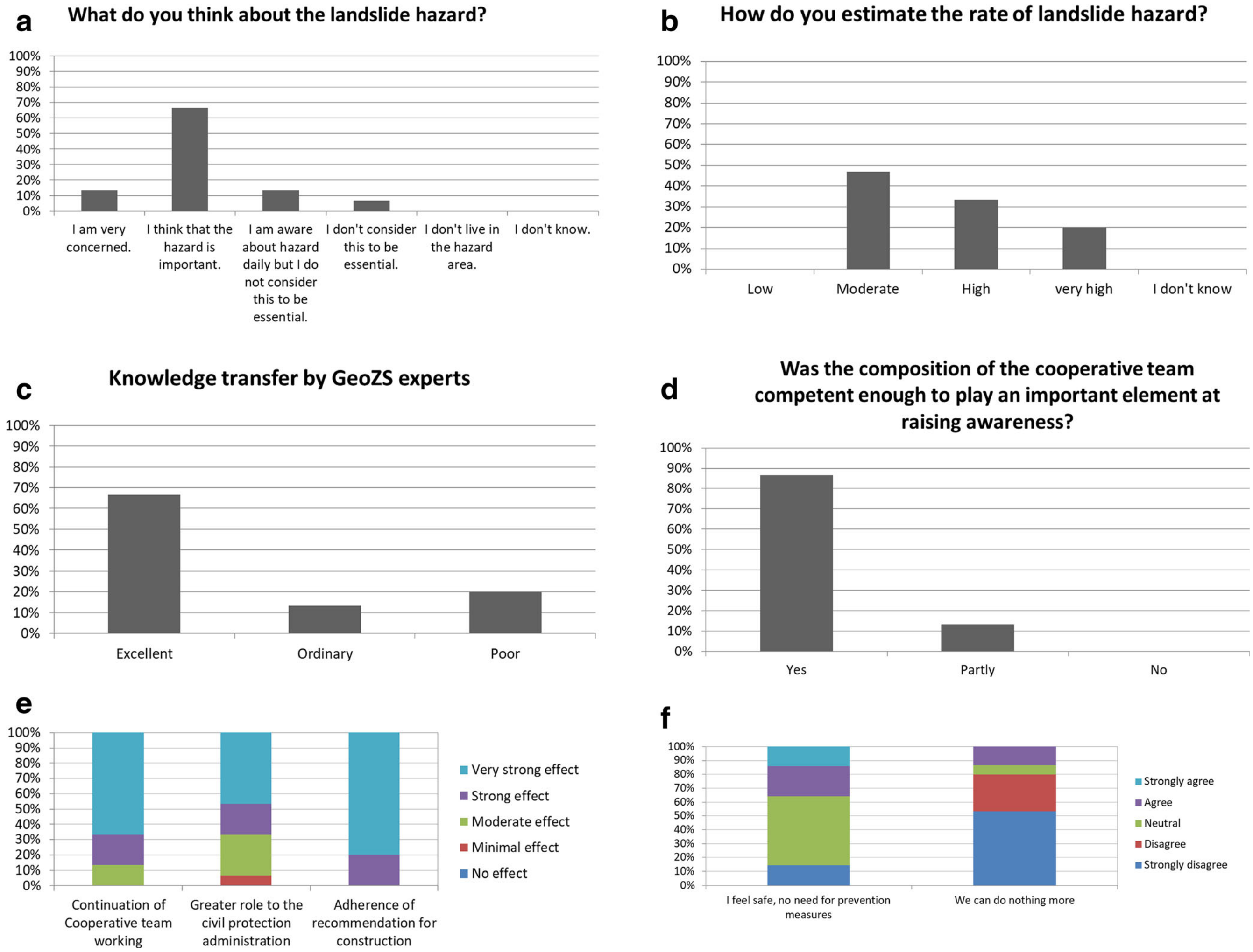

Fig. 7 The questionnaire answers. **a** and **b** Thinking and informing. **c** and **d** Operating efficiency. **e** Prevention measures to reduce hazards. **f** Landslide risk perception

particularly important role in landslide risk reduction, but are not always considered during the course of developing landslide prevention plans. However, there is at least one drawback of a cooperative team: the relatively small number of its members (20). Only 10 members are from the local community, which means only very few people received training. Thus, delivering opinions about raising awareness of landslide risk in the Koroška Bela community is still an open question and could be one of the future priorities of the cooperative team, as well as dialogue follow-up.

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