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Editorial

Mountain Landslides: Monitoring, Modeling, and Mitigation

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Received: 20 August 2019; Accepted: 22 August 2019; Published: 23 August 2019

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Abstract: This editorial paper summarizes the contents of the papers included in the Special Issue "Mountain Landslides: Monitoring, Modeling, and Mitigation". The Special Issue provides an overview of methodological papers, as well as some innovative research carried out in the field and in the lab. Even if most papers adopted an integrated approach, sections representing the three research issues outlined in the title can be drawn: the first deals with monitoring, the second focuses on modeling, and the third is related to mitigation. Regardless of the section, the papers included in this special issue put forward methodological and practical implications that, more than likely, can stimulate further research efforts and support the stakeholders to gain better knowledge of landslide hazards in mountain environments, with an aim to tackle the urgent issue of sustainable development in times of global change that can affect landslide occurrences in mountain chains of the world.

Keywords: landslides; monitoring; modeling; mitigation

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1. Introduction

Since 2012, the journal *Geosciences* has promoted 14 published or forthcoming special issues dealing with natural hazards (in its Natural Hazards or Geophysics sections). In these special issues, together with other natural phenomena, more than 50 papers are related to slope instability processes. Nevertheless, so far this is the first special issue to be entirely focused on landslides.

The scientific and technological advancements of the last few decades have made monitoring, modeling, and mitigation (3Ms) increasingly important in this field. Never before have scientific and practitioner communities had access to such a large variety of powerful tools to monitor and model landslides at various scales. Nevertheless, a geoscientific understanding of slope processes is still crucial for an adequate interpretation of results provided by monitoring and modeling tools, and for their exploitation in the design of structural (i.e., engineering works) and non-structural (i.e., land-use planning and early warning) mitigation measures.

This special issue has collected 15 relevant papers regarding both innovative methods and/or case studies in which the 3Ms are implemented in a synergic manner and with a central geoscientific perspective for the solution of practical landslide risk management problems in different mountain chains of the world, including in Europe, Asia, and the Americas.

This volume provides an overview of methodological papers, as well as some innovative research carried out in the field and in the lab. Even if in most papers the 3Ms are adopted in an integrated approach, sections representing the three research issues outlined in the title can be drawn: the first deals with monitoring, the second focuses on modeling, and the third is related to mitigation.

2. Landslides Monitoring

The first section of the Special Issue concerns landslide monitoring, providing examples from Slovakia, Austria, Italy, and the USA.

Albano et al. [1] have investigated the contribution of earthquake-induced surface movements to the ground displacements detected through Interferometric Synthetic Aperture Radar (InSAR) data, after the Mw 3.9 Ischia earthquake on 21 August 2017. A permanent displacement approach, based on the limit equilibrium method, allowed for estimation of the spatial extent of the earthquake-induced landslides and the associated probability of failure.

Chudý et al. [2] processed, analyzed, and interpreted data from a large-scale landslide survey, data which were acquired through light detection and ranging (LiDAR) technology, remotely piloted aircraft system (RPAS), and close-range photogrammetry (CRP) using the *Structure-from-Motion* (SfM) method. Identification of micro-scale landforms in precise DEMs at large scales allow the monitoring and assessment of active parts of landslides that are invisible in digital terrain models at smaller scales.

Romeo et al. [3] illustrate an experimental application coupling new and low-cost photogrammetric techniques: Gigapixel and Structure-from-Motion (SfM). The stereographic analysis carried out on the preliminary 3D model, integrated with Ground Based Synthetic Aperture Radar Interferometry (GBInSAR) data, allowed the main fractures and discontinuities of an unstable rock mass to be obtained.

Segalini et al. [4] describe a field-based monitoring system including piezometers, manual inclinometers, and automatic modular underground monitoring system (MUMS) inclinometers. Thanks to displacement data recorded by the latter, it was possible to forecast a slope failure. Additionally, a numerical analysis was performed to better understand the mechanical behavior of the slope, back-analyze the monitored event, and to assess the stability conditions of the area.

Xiong et al. [5] use repeated ALS surveys for evaluating the vertical detectability of multi-temporal ALS surveys in a typical mountain area. Global Navigation Satellite Systems (GNSS) and Terrestrial Laser Scanning (TLS) surveys were also performed for assessing the accuracy of ALS datasets. The accuracy of ALS varies from approximately one decimeter (~10 cm) to one foot (~30 cm) depending on the roughness of terrain surface and vegetation coverage (point density).

3. Landslides Modeling

In the second section of the Special Issue, which regards research on different modeling approaches, the contributing authors examine a wide range of instability processes in areas with different geological and geomorphological characteristics in a variety of climatic settings including Italy, China, and Slovenia. Instrumented physical models are also used to describe slope processes.

Bezak et al. [6] have presented the results of numerical simulations investigating the impact of a random sequence of debris flows on torrential fan formation. The results confirm that the random sequence of debris flow events have only minor effects on the fan formation (e.g., slope, maximum height), even when changing debris flow rheological properties in a wide range.

Calista et al. [7] investigate the role played by morphostructural setting, seismic, and meteorological factors in the onset of landslides in the piedmont of the Abruzzo Apennines. Through this integrated analysis, the triggering factors and the stability of the slope have been evaluated via numerical modeling, in pre- and post-landslide conditions.

Darban et al. [8] analyze the mechanical process of progressive failure in granular unsaturated sloping soils. The results of a couple of small-scale experiments on slopes reconstituted with unsaturated pyroclastic soils and subjected to continuous rainfall are presented.

Donati et al. [9] study the progressive accumulation of brittle damage that occurred prior to and during failure, by using a synthetic rock mass approach. After the mapping of brittle fractures, rock bridge failures, and major structures using terrestrial laser scanning, photogrammetry, and high-resolution photography, numerical analyses are conducted using the 2D and 3D codes.

Li et al. [10] investigate the behavior of a large landslide under river level fluctuations. A 2D numerical model is created and a series of fully coupled hydro-mechanical simulations have been conducted. Back analysis is also employed to calibrate the model against real field data. Results show that the model can appropriately simulate the long-term behavior of the landslide.

Olivares et al. [11] develop two complex models for pyroclastic soils which allow for correct simulation of the physical processes, such as saturation increase due to rainwater infiltration and mechanical degradation as far as undrained instability, which govern post-failure evolution. A framework to be used in defining a soil database, as well as for flowslide generation forecast to be used for implementation within EWSs, is proposed.

Tanaka et al. [12] investigate the influence of soil pipes and entrapped air on the build-up of pore water pressure by using bench-scale model experiments. The results indicate that although soil pipes can drain a certain amount of water from a soil layer, they can also increase the pore water pressure and destabilize slopes. Furthermore, entrapped air enhances this effect.

4. Landslides Mitigation

The third section of the special issue concerns landslide mitigation achieved thanks to the integration of monitoring and modeling, with examples from Italy and Ecuador.

Bossi and Marcato [13] provide an example application of a grey-box modeling approach, which is presented. Through landslide monitoring, it has been possible to define a model capable of linking the landslide displacements with the triggering factors and to predict them consistently; that model has then been used to evaluate the effect of countermeasure works.

Cola et al. [14] present a novel methodology for monitoring the strain and stress accumulated in the composite anchors with a distributed fiber optic sensing system, exploiting the optical frequency domain reflectometry (OFDR) technique. The system permits an evaluation of the axial force distribution in the anchor and the soil-anchor interface actions with a spatial resolution of up to some millimeters.

Morante et al. [15] perform geomechanical classifications to calculate stability value of a quarry slope, which has resulted in accordance with the high susceptibility to rockfall and low safety factor. Based on these results, the application of systematic bolt and shotcrete have been recommended to preserve a public area.

5. Conclusions

Regardless of the section, the papers included in this special issue put forward methodological and practical implications that, more than likely, can stimulate further research efforts and support the stakeholders to gain better knowledge of landslide hazard in mountain environments, with an aim to cope with the urgent issue of sustainable development in times of global changes that can affect landslide occurrences in mountain chains of the world.

Author Contributions: Authors have contributed equally to this work.

Funding: This research received no external funding.

Acknowledgments: The authors wish to thank all the scientists that have contributed, with their valuable papers, to the success of the Special Issue "Mountain Landslides: Monitoring, Modeling, and Mitigation".

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Albano, M.; Saroli, M.; Montuori, A.; Bignami, C.; Tolomei, C.; Polcari, M.; Pezzo, G.; Moro, M.; Atzori, S.; Stramondo, S.; et al. The relationship between InSAR coseismic deformation and earthquake-induced landslides associated with the 2017 Mw 3.9 Ischia (Italy) earthquake. *Geosciences* **2018**, *8*, 303. [CrossRef]
2. Chudý, F.; Slámová, M.; Tomaštík, J.; Prokešová, R.; Mokroš, M. Identification of micro-scale landforms of landslides using precise digital elevation models. *Geosciences* **2019**, *9*, 117. [CrossRef]
3. Romeo, S.; Di Matteo, L.; Kieffer, D.; Tosi, G.; Stoppini, A.; Radicioni, F. The use of gigapixel photogrammetry for the understanding of landslide processes in Alpine Terrain. *Geosciences* **2019**, *9*, 99. [CrossRef]

4. Segalini, A.; Carri, A.; Valletta, A.; Martino, M. Innovative monitoring tools and early warning systems for risk management: A case study. *Geosciences* **2019**, *9*, 62. [CrossRef]
5. Xiong, L.; Wang, G.; Bao, Y.; Zhou, X.; Sun, X.; Zhao, R. Detectability of repeated airborne laser scanning for mountain landslide monitoring. *Geosciences* **2018**, *8*, 469. [CrossRef]
6. Bezak, N.; Sodnik, J.; Mikoš, M. Impact of a random sequence of debris flows on torrential fan formation. *Geosciences* **2019**, *9*, 64. [CrossRef]
7. Calista, M.; Miccadei, E.; Piacentini, T.; Sciarra, N. Morphostructural, meteorological and seismic factors controlling landslides in weak rocks: The case studies of Castelnuovo and Ponzano (North East Abruzzo, Central Italy). *Geosciences* **2019**, *9*, 122. [CrossRef]
8. Darban, R.; Damiano, E.; Minardo, A.; Olivares, L.; Picarelli, L.; Zeni, L. An experimental investigation on the progressive failure of unsaturated granular slopes. *Geosciences* **2019**, *9*, 63. [CrossRef]
9. Donati, D.; Stead, D.; Elmo, D.; Borgatti, L. A preliminary investigation on the role of brittle fracture in the kinematics of the 2014 San Leo landslide. *Geosciences* **2019**, *9*, 256. [CrossRef]
10. Li, X.; Zhao, C.; Hölter, R.; Datcheva, M.; Alimardani Lavasan, A. Modelling of a large landslide problem under water level fluctuation—model calibration and verification. *Geosciences* **2019**, *9*, 89. [CrossRef]
11. Olivares, L.; Damiano, E.; Netti, N.; De Cristofaro, M. Geotechnical properties of two pyroclastic deposits involved in catastrophic flowslides for implementation in early warning systems. *Geosciences* **2019**, *9*, 24. [CrossRef]
12. Tanaka, Y.; Uchida, T.; Nagai, H.; Todate, H. Bench-Scale experiments on effects of pipe flow and entrapped air in soil layer on hillslope landslides. *Geosciences* **2019**, *9*, 138. [CrossRef]
13. Bossi, G.; Marcato, G. Planning landslide countermeasure works through long term monitoring and grey box modelling. *Geosciences* **2019**, *9*, 185. [CrossRef]
14. Cola, S.; Schenato, L.; Brezzi, L.; Tchamaleu Pangop, F.; Palmieri, L.; Bisson, A. Composite anchors for slope stabilisation: Monitoring of their in-situ behaviour with optical fibre. *Geosciences* **2019**, *9*, 240. [CrossRef]
15. Morante, F.; Aguilar, M.; Ramírez, G.; Blanco, R.; Carrión, P.; Briones, J.; Berrezueta, E. Evaluation of slope stability considering the preservation of the general patrimonial cemetery of Guayaquil, Ecuador. *Geosciences* **2019**, *9*, 103. [CrossRef]