"Landslide Research and Risk Reduction for Advancing Culture of Living with Natural Hazards"

Local Proceedings with Programme

29 May - 2 June 2017
Ljubljana, Slovenia

ICL

IPL UNESCO · ICL · ICSU · WFEO · UNU · WMO · UNISDR · FAO
A Programme of the ICL for ISDR
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Izvirni naslov: WLF4 Local Proceedings with Programme

Naslov: Lokalni zbornik 4. svetovnega foruma o zemeljskih plazovih s programom

Urednika: Matjaž Mikoš in Nejc Bezak

Izdajatelj: Fakuleteta za gradbeništvo in geodezijo Univerze v Ljubljani, Jamova cesta 2, 1000 Ljubljana

Oblikovanje in grafična priprava: Gašper Mrak

Dokumentacijska obdelava: Teja Koler Povh

Spletni naslov: https://www.wlf4.org

Naklada: 530 izvodov

Tisk: Birografika BORI d.o.o., Ljubljana

Cena publikacije: Publikacija je brezplačna

Izid: Ljubljana, maj 2017

The content of abstracts, photos and posters is the responsibility of authors.

CIP - Kataložni zapis o publikaciji

Narodna in univerzitetna knjižnica, Ljubljana

550.348.435(082)

WORLD Landslide Forum (4 ; 2017 ; Ljubljana)

Landslide research and risk reduction for advancing culture of living with natural hazards : WLF4 local proccedings with programme / 4th World Lanslide Forum, Ljubljana, Slovenia, May 29 - June 2, 2017 ; [urednika Matjaž Mikoš, Nejc Bezak]. - Ljubljana : Fakulteta za gradbeništvo in geodezijo, 2017

ISBN 978-961-6884-46-4

1. Gl. stv. nasl. 2. Mikoš, Matjaž

290267648

Table of Contents

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General Information

Location and conference address

Cankarjev dom, Cultural and Congress Centre

Prešernova 10, SI-1000 Ljubljana, Slovenia

Phone: +386 1 241 7100, Fax: +386 1 241 7296

Congress Secretariat

Mr. Gregor Rogač

Prešernova 10, SI-1000 Ljubljana, Slovenia

Phone: +386 1 24 17 145, Fax: +386 1 24 17 296, E-mail: gregor.rogac@cd-cc.si

Official language

The official language of the 4th World Landslide Forum is English.

Internet

Wireless internet connection is available in all halls of Cankarjev dom. The name of the network is **CD_GUEST**. No login or password is needed.

Photo contest

Each registered participant can vote for one photo in each category (best according to his/her opinion). Best 3 photos in each category will be awarded. Each registered participant will receive a voting poll in his/her conference bag. Photo contest is open until Friday, June 2 (12:00).

Coffee break and lunch

Coffee breaks are scheduled from 10:00 to 10:30 and 15:00 to 15:30 (in Foyer I).

Lunch breaks are scheduled from 12:00 to 13:30 (in Foyer I).

Registration and Information Desk

The Registration and Information Desk for the WLF4 will be located in Foyer II of Cankarjev dom as follows:

Monday, May 29	16.00 – 19.00
Tuesday, May 30	08.00 – 18.00
Wednesday, May 31	08.00 – 18.30
Thursday, June 1	08.00 – 19.00
Friday, June 2	08.00 – 16.30

Exhibitions

All exhibitions will be held in Foyer I (preddverje I).

Conference Identification Badge

A conference identification badge will be included in the conference material provided upon registration. There will be no admittance to the Scientific Sessions without the conference badge. Invitations to social events will be collected at the entrance.

Guidelines

ORALS

Authors are kindly asked to upload their presentation in the Speaker Centre located in the Foyer II next to the registration desk within 60 minutes before the actual time block of the session. Technical staff will make sure that your presentation will be downloaded on the computer in your specific session room. Please make sure that your computer presentation is fully operational before your talk. Only Power Point presentations, CDROM, USB Memory cards will be accepted. Version MS PowerPoint 2013 is recommended.

Each presentation should be 12 minutes talk followed by 3 minutes discussion.

POSTERS

Posters must be brought to the Forum by the presenting author and should not be mailed in advance. The required dimensions are 90 cm (width) by 120 cm (height). The general display time is from Tuesday, May 30 8:30 to Friday, June 2 13:30 (Foyer I). The boards for posters will be numerated – plelase, find and use your designated board.

Social Programme

Tuesday, May 30, 2017

18.00 – 20.00 Welcome Reception / Cankarjev dom – Grand reception hall

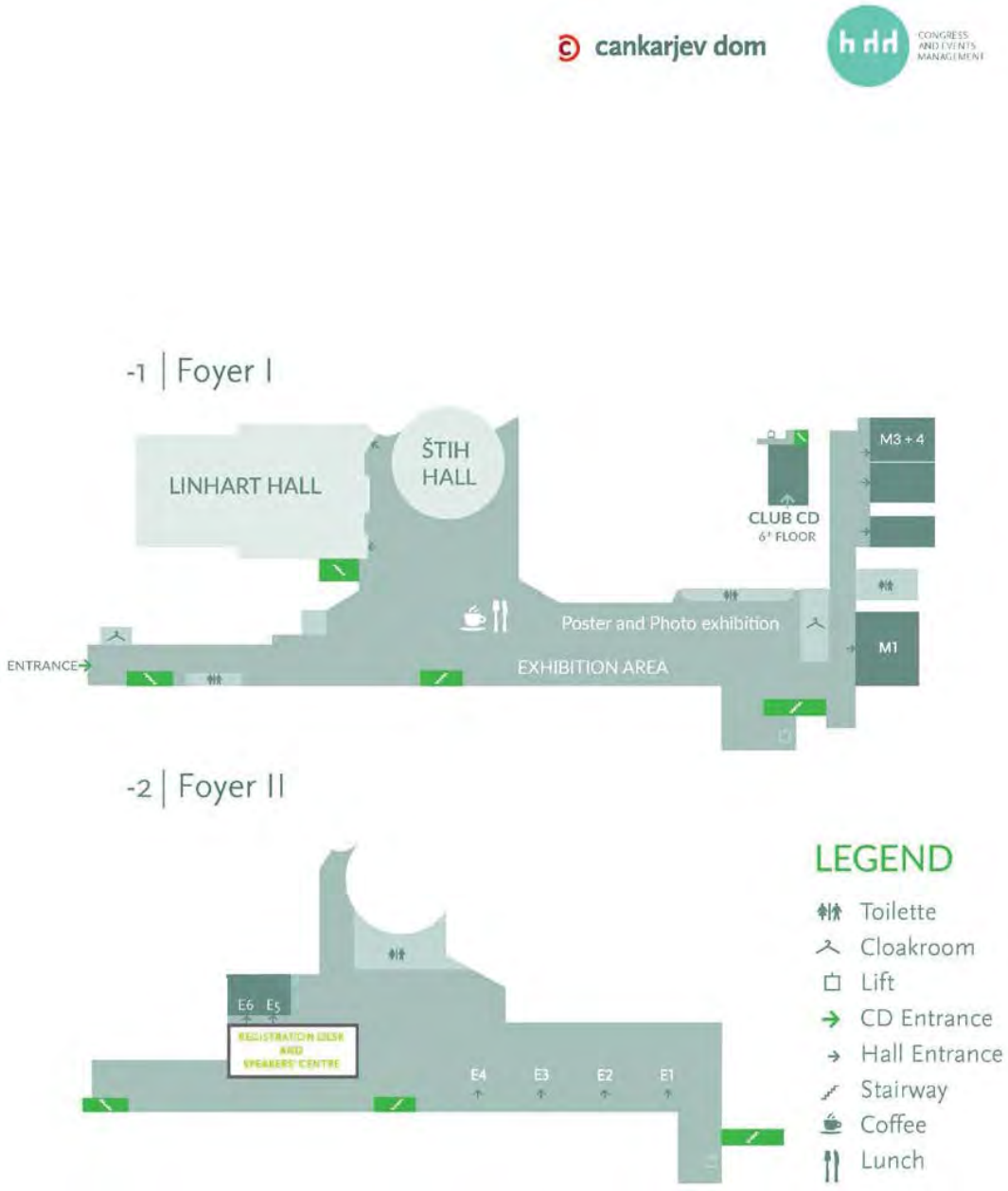
Wednesday, May 31, 2017

19.00 – 21.00 Forum Banquet / Ljubljana castle

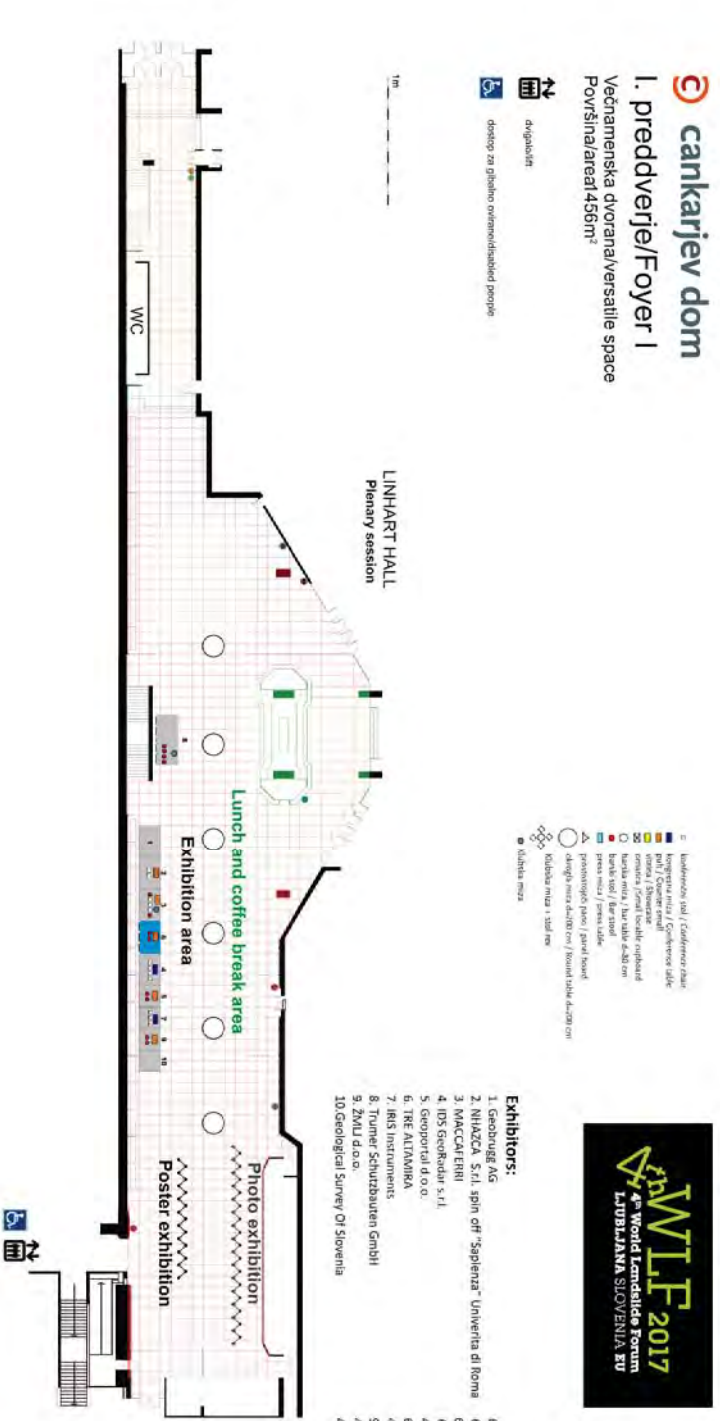
Bus transfer will be organized. Departure from Cankarjev dom, Erjavčeva Street, starting at 18.30 by bus, returning at 21.00.

Venue Floor Plan

Cankarjev dom General floor plan



WLF4 Technical Exhibition



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7. IRIS Instruments

8. Trumer Schutzbauten GmbH

9. ŽMLJ d.o.o.

10. Geological Survey of Slovenia

WLF4 Programme at a Glance

Monday, May 29 2017

- BOR and ICL-GPC meeting at University of Ljubljana main building (Kongresni trg 12, Ljubljana) (10:00-17:00) (at invitation only, separate programme available)
- Forum registration at Cankarjev dom (Prešernova cesta 10) (16:00-19:00)

Tuesday, May 30 2017

- Forum registration at Cankarjev dom (Prešernova cesta 10) (8:00-18:00)
- Opening Session (9:00-9:45) with opening/welcome addresses (Linhart Hall)
- Invited Forum Lectures "Understanding of Landslide Disaster Risk" (09:45-12:00) (Linhart Hall)
- Lunch Break (12:00-13:30)
- High-Level Panel Discussion "Strenghtening Intergovernmental Network and the International Programme on Landslides (IPL) for ISDR-ICL Sendai Partnerships 2015-2025 for global promotion of understanding and reducing landslide disaster risk" (13:30-15:45) (Linhart Hall)
- Recognition of ICL and IPL Activities (16:00-17:30) (Linhart Hall)
- Welcome Reception at Cankarjev dom for all WLF4 participants (18:00-20:00)

Wednesday, May 31 2017

Parallel Sessions

Wednesday, May 31	M1	M3/4	E1	E2	E3	Štih	Club CD
8:30-10:00	2.1	2.2	3.1	4.1	5.1	1.1	x
10:00-10:30	Coffee break						
10:30-12:00	2.1	2.2	3.1	4.1	5.1	1.1	x
12:00-13:30	Lunch break, Open session I (E1)						
13:30-15:00	2.1	2.2	3.1	4.2	5.1	x	Round Table
15:00-15:30	Coffee break						
15:30-17:00	2.1	2.2	3.1	4.2	5.2	x	WLF5 (16-18)
19:00-21:00	Forum Banquet						

Other activities

- Posters, Photo Exhibition, Forum Technical Exhibition
- Workshop "Management of Large-Scale Natural Disasters in Slovenia" (in Slovene only, no translation will be provided) (08:30-12:30) (Room E4)
- Open Session on "Resilience of communities exposed to landslide risk" (12:30-13:30) (Room E1)
- Round Table Discussion on the follow-up of the High-Level Panel Discussion and the implementation planning (13:30-15:30) (Club CD)
- Meeting "WLF5 Organising Committee" (16:00-18:00) (Club CD)

- Forum Banquet at Ljubljana Castle for all WLF4 participants (19:00-21:00) – bus transfer will be organized from Cankarjev dom and back

Thursday, June 1 2017

Parallel Sessions

Thursday, June 1	M1	M3/4	E1	E2	E3	Štih	Club CD
8:30-10:00	2.3	2.4	3.1	4.2	5.3	1.2	x
10:00-10:30	Coffee break						
10:30-12:00	2.3	2.4	3.1	4.2	5.3 & 5.4	1.2	x
12:00-13:30	Lunch break, Open session II (E1)						
13:30-15:00	2.3	2.4	3.1	4.3 & 4.4	5.4	1.2	x
15:00-15:30	Coffee break						
15:30-17:00	2.3	2.4	3.2	4.3	4.4 & 4.5	1.2	x
17:15-18:30	Student	x	3.3	x	x	x	x

Other activities

- Posters, Photo Exhibition, Forum Technical Exhibition
- Open Session organized and lead by FAO (12:15-13:30) (Room E1)
- Workshop "Geosynthetics for Slope Stabilization" organized by International Geosynthetics Society (13:30-17:00) (Room E4)
- Meeting "IAEG Commission on Landslide Nomenclature" (17:15-19:00) (Room E4)

Friday, June 2 2017

Parallel Sessions

Friday, June 2	M1	M3/4	E1	E2	E3	Štih	Club CD
8:30-10:00	2.4	2.4	3.3	4.3	1.3	x	Student
10:00-10:30	Coffee break						
10:30-12:00	2.4	2.4	3.3	4.5	1.3	x	Student
12:00-13:30	Lunch break, Open session III (Club CD)						
13:30-16:30	Round Table and Closing Ceremony (Club CD)						

Other activities

- Posters, Photo Exhibition, Forum Technical Exhibiton (only in the morning)
- Open Session on "Landslide risk management, an integrated approach in time" (12:30-13:30) (Club CD)

Saturday, June 3 2017

Post-study tour (Slovenia) – starting day of a 3 day technical tour

WLF4 Session List

Theme 1 – Sendai Partnerships 2015-2025 (Coordinator: Kyoji Sassa)

- Session 1.1 – Sendai Partnerships 2015-2025 (Invited papers from ICL-IPL)
- Session 1.2 – International Programme on Landslides (IPL) (Invited papers from ICL-IPL)
- Session 1.3 – Landslides and Society

Theme 2 – Advances in Landslide Science (Coordinator: Binod Tiwari)

- Session 2.1 – Landslide field recognition & identification: remote sensing techniques, field techniques
- Session 2.2 – Landslide investigation: field investigations, laboratory testing
- Session 2.3 – Landslide modeling: landslide mechanics and simulation models
- Session 2.4 – Landslide hazard, risk assessment & prediction: landslide inventories & susceptibility, hazard mapping methods, damage potential

Theme 3 – Advances in Landslide Technology (Coordinator: Željko Arbanas)

- Session 3.1 – Landslide monitoring and warning: monitoring techniques and technologies, early warning systems
- Session 3.2 – Landslide disasters and relief: case studies, emergency measures, first aid, civil protection measures
- Session 3.3 – Landslide mitigation, remediation and stabilization: landslide protection works, landslide stabilization and remediation, landslide non-structural measures

Theme 4 – Diversity of Landslide Forms (Coordinator: Nicola Casagli)

- Session 4.1 – Earthquake-induced landslides
- Session 4.2 – Rainfall-induced landslides
- Session 4.3 – Rapid landslides: debris flows, mudflows, rapid debris-slides
- Session 4.4 – Landslides in rocks and complex landslides: rock topples, rock falls, rock slides, complex landslides
- Session 4.5 – Landslides and other natural hazards: floods, droughts, wildfires, tsunamis, volcanoes

Theme 5 – Landslides in Different Environments (Coordinator: Vít Vilímek)

- Session 5.1 – Landslide interactions with the built environment
- Session 5.2 – Landslides in natural environment
- Session 5.3 – Landslides and water
- Session 5.4 – Landslides as environmental change proxies: looking at the past
- Student Session

WLF4 Detailed Programme

Monday, May 29, 2017

- BOR and ICL-GPC meeting at University of Ljubljana main building (Kongresni trg 12, Ljubljana) (10:00-17:00) (at invitation only)
- Forum registration at Forum venue (Cankarjev dom, Prešernova cesta 10) (16:00-19:00)

Tuesday, May 30, 2017

09:00-09:45

Room Linhart Hall: Opening Addresses/Speeches

- *Yueping Yin*, ICL President
- *Qunli Han*, UNESCO DG Representative
- *JH.E. Keiji Fukuda,* Ambassador of Japan in Slovenia
- *Matjaž Mikoš,* WLF4 Forum Chair

09:45-12:00

Room Linhart Hall: WLF4 Forum Lectures

Chair: *Peter Bobrowsky*, Geological Survey of Canada, ICL President-elect

Sálvano Briceño, Senior advisor of ICL, Former Director of UNISDR (2001-2011)

- Rupestrian world heritage sites: Instability investigation and sustainable mitigation by *Claudio Margottini* (Coordinator of the ICL successful thematic network, Italy)
- Rock fall occurrence and fragmentation by *Jordi Corominas* (2016 Varnes Medal Recipient, Spain)
- Glacial lake outburst floods by *Vít Vilimek* (Editor of 2016 thematic issue of Landslides, Czech Republic)
- Landslides and Society by *Irasema Alcántara-Ayala* (Convener of Session 1-3 Landslides and Society, Mexico)

Discussion for Understanding of Landslide Disaster Risk

12:00-13:30

Lunch

13:30-15:45

Room Linhart Hall: High-Level Panel Discussion

Video message from *Robert Glasser*, Special Representative of the Secretary-General for Disaster Risk Reduction and Head of The United Nations Office for Disaster Risk Reduction (UNISDR)

Chair: *Jakob Rhyner*, Vice rector of UNU

Moderator: *Kaoru Takara,* ICL Treasurer, Director of Disaster Prevention Research Institute, Kyoto University

Panelists:

Signatory organizations:

Kyoji Sassa, Executive Director of ICL: proposing and host organization

Qunli Han, Chair of IPL-Global Promotion Committee, Director of UNESCO Ecological and Earth Sciences

Andrey Kushlin, Deputy Director of the FAO Forestry Department

Alasdair Hainsworth, Chief of the WMO DRR Services Division

Irasema Alcantara-Ayala, on behalf of ICSU President, *Gordon McBean*

Roland Oberhänsli, Former President of IUGS

Alik Ismail-Zadeh, Secretary General of IUGG

Satoru Nishikawa, Former director, Disaster Preparedness and International Cooperation, Cabinet office of Japan

Paola Pagliara, Manager, National Centre for Forecasting and Surveillance for Hydrologic and Hydraulic Risk, Italian Civil Protection Department (DPC)

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Potential additional signatory organizations:

Miloš Bizjak, State Secretary, Ministry of Defence, Republic of Slovenia

Nguyen Linh Ngoc, Deputy Minister, Ministry of Natural Resources and Environment, Vietnam

Rudi Phadmanto, Deputy Minster, the Indonesian National Agency for Disaster Management

Shuaib Lwasa, Chair of the IRDR Science Committee

Luca Demicheli, Secretary General of EuroGeoSurveys

Experts/Advisers:

Sálvano Briceño, Senior advisor of ICL, Former Director of UNISDR (2001-2011)

Badaoui Rouhban, IPL Advisor, Former Director, Unit for Natural Disasters, UNESCO

15:45-16:00

Break

16:00-17:30

Room Linhart Hall: Recognition of ICL and IPL Activities

Chairs: *Qunli Han*, Chair of IPL-GPC, UNESCO; *Yueping Yin*, President of ICL

- Explanation of World Centers of Excellence (WCoEs), IPL Award for Success by IPL-GPC
- Recognition of WCoEs 2017-2020
- Certificates are awarded from by *Qunli Han*, Chair of IPL-GPC, UNESCO

Brief remarks by the head of each Centre and leader.

- Recognition of 2014-2017 IPL Award for Success (2 awards)
- Certificates are awarded by *Qunli Han*, Chair of IPL-GPC, UNESCO

Brief remarks by each of the recipients.

- Explanation of Varnes Medal and Best paper Award by BOR/ICL.
- Bestow the 2015 Varnes Medal to the recipient from ICL President.
- Bestow the 2016 Varnes Medal to the recipient from ICL President.
- Bestow the 2017 Varnes Medal to the recipient from ICL President.

A short talk by each recipient.

- Bestow the 2014 Best Paper Award to the recipient from ICL President.
- Bestow the 2015 Best paper Award to the recipient from ICL President.
- Bestow the 2016 Best paper Award to the recipient from ICL President.

A short talk by each recipient.

- Bestow the 2016 best reporter Award for the World Report on Landslides from ICL President.

18:00-20:00

Welcome Reception in Grand reception hall of Cankarjev dom

Welcome Address by Her Excellency Ms. *Irena Majcen*, the Minister of the Environment and Spatial Planning of the Republic of Slovenia

Wednesday, May 31, 2017

8:30-10:00

Session 1.1, Room Štih Hall, Convener(s): Qunli Han and Irasema Alcántara-Ayala

8:45-9:00 The Sendai Partnerships 2015-2025: Background and Content

Kyoji Sassa

9:00-9:15 International Consortium on Landslides (ICL)

Kyoji Sassa, Yueping Yin and Paolo Canuti

9:15-9:30 United Nations Educational, Scientific and Cultural Organization (UNESCO)

UNESCO's contribution to the implementation of UNISDR's global initiative and ICL

Giuseppe Arduino, Rouhban Badaoui, Soichiro Yasukawa, Alexandros Makarigakis, Irina Pavlo Shirai and Qunli Han

9:30-9:45 United Nations University (UNU)

United Nations University - Research and Policy Support for Environmental Risk Reduction

Jakob Rhyner

9:45-10:00 World Meteorological Organization (WMO)

Concerted International Efforts for Advancing Multi-Hazard Early Warning Systems

Jochen Luther, Alasdair Hainsworth, Xu Tang, John Harding, Jair Torres and Margherita Fanchiotti

Session 2.1, Room M1, Convener(s): Mateja Jemec Auflič and Binod Tiwari

8:30-8:45 Rock Avalanche Sedimentology—Recent Progress

Anja Dufresne

8:45-9:00 Determination of the Landslide Slip Surface Using Electrical Resistivity Tomography (ERT) Technique

A. Asriza, Supriyanto, T.H.W. Kristyanto, T.L. Indra, R. Syahputra and A.S. Tempessy

9:00-9:15 Rock Fall Characterization in Climbing Spots: The Case Study of the "Napoleonica" Tourist Route (Trieste, NE Italy)

Chiara Boccali, Sara Biolchi, Enrico Zavagno and Luca Zini

9:15-9:30 Combining Terrestrial and Waterborne Geophysical Surveys to Investigate the Internal Composition and Structure of a Very Slow-Moving Landslide Near Ashcroft, British Columbia, Canada

David Huntley, Peter Bobrowsky and Melvyn Best

9:30-9:45 Using Lidar DEM to Map Landslides: Škofjeloško Cerkljansko Hills, Slovenia

Erazem Dolžan and Mateja Jemec Auflič

9:45-10:00 Mapping Rapid-Moving Landslide with Satellite SAR Images: The Case of Montescaglioso (South Italy)

Federico Raspini, Andrea Ciampalini, Sara Del Conte, Luca Lombardi, Massimiliano Nocentini, Giovanni Gigli, Alessandro Ferretti and Nicola Casagli

Session 2.2, Room M3/4, Convener(s): Beena Ajmera and Ubydul Haque

8:30-8:45 *Increasing Fatal Landslides in Europe*

Ubydul Haque, Paula F. da Silva, Juneseok Lee, Susanne Benz, Mateja Jemec Auflič and Philipp

Blum

8:45-9:15 Landslides Triggered by Earthquakes from 1920 to 2015 (KEYNOTE LECTURE)

Binod Tiwari

9:15-9:30 The Application of ERT for the Geometrical Analysis of the Sebrango Landslide, (Cantabrian Range, Spain)

Alberto González-Díez, Mario Zarroca, Rogelio Linares, Viola Bruschi, Jaime Bonachea, José Ramón Díaz de Terán, Juan Remondo, Gema Fernández, Patricio Martínez, Javier Sánchez and S. Martin

9:30-9:45 Landslide Risk Analysis and Assessment for Urbanized Territories

Valentina Svalova

9:45-10:00 Slope Stability Hazard Assessment Using 3D Remote Sensing and Field Sketching Techniques Along Sohag-Red Sea-Cairo Highway, Egypt

Bosy A. El-Haddad, Ahmed M. Youssef, Abdel-Hamid El-Shater and Mohamed H. El-Khashab

Session 3.1, Room E1, Convener(s): Stefano Morelli and Timotej Verbovšek

8:30-8:45 Multisensor Landslide Monitoring as a Challenge for Early Warning: From Process Based to Statistic Based Approaches

Francesca Bozzano, Carlo Esposito, Andrea Fantini, Matteo Fiorucci, Salvatore Martino, Paolo Mazzanti, Alberto Prestininzi, Stefano Rivellino, Alfredo Rocca, and Gabriele Scarascia Mugnozza

8:45-9:00 Wireless Sensor Networks for Early Warning of Landslides: Experiences from a Decade Long Deployment

Maneesha Vinodini Ramesh, Divya Pullarkatt, T.H. Geethu, and P. Venkat Rangan

9:00-9:15 Design and Validation of Wireless Communication Architecture for Long Term Monitoring of Landslides

Sangeeth Kumar, P. Venkat Rangan, and Maneesha Vinodini Ramesh

9:15-9:30 Scalable, Secure, Fail Safe, and High Performance Architecture for Storage, Analysis, and Alerts in a Multi-site Landslide Monitoring System

Ramesh Guntha, Sangeeth Kumar, and Balaji Hariharan

9:30-9:45 A Self-adaptive Data Acquisition Technique and Its Application in Landslide Monitoring

Xing Zhu, Qiang Xu, Xing Qi, and Hanxiang Liu

9:45-10:00 Definition of a Fully Functional EWS Based on Rainfall Thresholds, the Case of Study of Tuscany Region

Ascanio Rosi, Samuele Segoni, Alessandro Battistini, Guglielmo Rossi, Filippo Catani, and Nicola Casagli

Session 4.1, Room E2, Convener(s): Gabriele Scarascia-Mugnozza and Wakai Akihiko

8:30-8:45 The Role of Simultaneous Impact of Exogenous and Endogenous Forces in Landslide Process Activation

Rustam Niyazov, and Bakhtiar Nurtaev

8:45-9:00 Local Terrain Relief: An Important Factor Influencing the Generation of Large Earthquake-Triggered Landslides

Xiaoli Chen, Hongliu Ran, Qing Zhou, and Bengang Zhou

9:00-9:15 Evaluation of Ground Shaking Characteristics in Residential Land Based on T/R Frequency Ratio of Microtremor

Yoshiya Hata, Fumihiro Minato, Takaaki Ikeda, Masayuki Yamada, Masaki Yamauchi, and Yutaro Okawa

9:15-9:30 Critical Displacement of Earthquake-Triggered Catastrophic Landslides

Che-Ming Yang, Chang-Hsuan Hsu, and Jia-Jyun Dong

9:30-9:45 Numerical Models of Unstable Slopes in Seismic Areas—Based on 3D Geomodels

Hans-Balder Havenith, Anne-Sophie Mreyen, Almaz Torgoev, and Mihai Micu

9:45-10:00 A Characteristic-Period Based Approach for Evaluating Earthquake-Induced Displacements of the Large Büyükçekmece Landslide (Turkey)

Salvatore Martino, Luca Lenti, and Celine Bourdeau

Session 5.1, Room E3, Convener(s): Mike Winter and Janusz Wasowski

8:30-8:45 Landslide Risk Assessment for the Built Environment in Sub-Saharan Africa

Peter Redshaw, Tom Dijkstra, Matthew Free, Colm Jordan, Anna Morley and Stuart Fraser

8:45-9:00 Rainfall-Induced Debris Flow Risk Reduction: A Strategic Approach

Mike G. Winter

9:00-9:15 RUPOK: An Online Landslide Risk Tool for Road Networks

Michal Bíl, Richard Andrášik, Jan Kubeček, Zuzana Křivánková and Rostislav Vodák

9:15-9:30 The Impact (Blight) on House Value Caused by Urban Landslides in England and Wales

William Disberry, Andy Gibson, Rob Inkpen, Malcolm Whitworth, Claire Dashwood and Mike Winter

9:30-9:45 Landslide Monitoring and Counteraction Technologies in Polish Lignite Opencast Mines

Zbigniew Bednarczyk

9:45-10:00 New Perspectives on Landslide Assessment for Spatial Planning in Austria

Arben Kociu, Leonhard Schwarz, Karl Hagen and Florian Rudolf-Miklau

10:30-12:00

Session 1.1, Room Štih Hall, Convener(s): Jakob Rhyner and Alik Ismail-Zadeh

10:30-10:45 International Council for Science (ICSU)

On the future challenges for the integration of science into international policy development for Landslide Disaster Risk Reduction

Irasema Alcántara-Ayala, Virginia Murray, Philip Daniels and Gordon McBean

10:45-11:00 International Union of Geological Sciences (IUGS)

Sendai – foreseeable but unpredictable geologic events – IUGS reactions

Roland Oberhänsli, Yujiro Ogawa and Marko Komac

11:00-11:15 International Union of Geodesy and Geophysics (IUGG)

Integrating Natural Hazard Science with Disaster Risk Reduction Policy

Alik Ismail-Zadeh

11:15-11:30 Cabinet Office, Government of Japan (CAO)

Sharing the Japanese Experience for International Cooperation-Mainstreaming Disaster

Reduction for Sustainable Development

Satoru Nishikawa on behalf of Setsuko Saya

11:30-11:45 Disaster Prevention Research Institute (DPRI), Kyoto University

Kaoru Takara

11:45-12:00 National Civil Protection Department, Italian Presidency of the Council of Ministers, Government of Italy

Understanding and Reducing Landslide Disaster Risk: Challenges and Opportunities for Italian Civil Protection

Pagliara Paola, Onori Roberta and Ambra Sorrenti

Session 2.1, Room M1, Convener(s): Mateja Jemec Auflič and Binod Tiwari

10:30-10:45 Multi-sensor a Priori PSI Visibility Map for Nationwide Landslide Detection in Austria

Filippo Vecchiotti, Dario Peduto and Tazio Strozzi

10:45-11:00 The Differential Slow Moving Dynamic of a Complex Landslide: Multi-sensor Monitoring

Gerardo Herrera, Juan Carlos García López-Davalillo, Jose Antonio Fernández-Merodo, Marta Béjar-Pizarro, Paolo Allasia, Piernicola Lollino, Giorgio Lollino, Fausto Guzzetti, Maria Inmaculada álvarez-Fernández, Andrea Manconi, Javier Duro, Ciscu Sánchez and Rubén Iglesias

11:00-11:15 Erosion Processes and Mass Movements in Sinkholes Assessed by Terrestrial Structure from Motion Photogrammetry

Helene Petschko, Jason Goetz, Max Böttner, Maximilian Firla and Sven Schmidt

11:15-11:30 Detection and Monitoring of Slow Landslides Using Sentinel-1 Multi-temporal Interferometry Products

Janusz Wasowski, Fabio Bovenga, Raffaele Nutricato, Davide Oscar Nitti and Maria Teresa Chiaradia

11:30-11:45 Method of Estimating Slope Movement Area Using DInSAR Analysis

Joko Kamiyama, Masaru Kunitomo, Masayuki Sakagami, Ikushi Hirata, Kazuo Yoshikawa and Daisuke Nishikawa

11:45-12:00 Studying a Landslide in Its Paroxysmal Phase; the Reactivation of the Sebrango Landslide (Spain), June 2013

A. González-Díez, V.M. Bruschi, J. Sánchez, J. Bonachea, J.R. Díaz de Terán, J. Remondo, G. Fernández, P. Martínez, M. Zarroca, R. Linares, V. Rodríguez, E. San Millán, A. Cendrero, S. Hoyos and S. Martin

Session 2.2, Room M3/4, Convener(s): Beena Ajmera and Fawu Wang

10:30-10:45 Integrated Geological-Geophysical Models of Unstable Slopes in Seismic Areas

Mreyen Anne-Sophie, Micu Mihai, Onaca Alexandru, Cerfontaine Philippe and Havenith Hans-Balder

10:45-11:00 Experimental Study of the Premonitory Factors for Internal Erosion and Piping Failure of Landslide Dams

Austin Chukwueloka-Udechukwu Okeke, Fawu Wang, Yohei Kuwada and Yasuhiro Mitani

11:00-11:15 Effect of Wetting-Drying Cycles on Shear Strength of the Clayey Soils in the Three Gorges Area

Baoping Wen, Hui Li and Boxun Ji

11:15-11:30 Pechgraben Landslide: Evaluation of Geophysical/Geotechnical Methods in Terms of

Remediation Support

David Ottowitz, Birgit Jochum, Stefan Pfeiler, Stefanie Gruber, Robert Supper and Jung-Ho Kim

11:30-11:45 Geological Assessment and Physical Model of Complex Landslides: Integration of Different Techniques

Davide Brambilla, Vladislav Ivov Ivanov, Laura Longoni, Diego Arosio and Monica Papini

11:45-12:00 Groundwater Flow Characterization Using Different Hydraulic Methods in Large and Deep Earth-Slide Rich in Clay

Francesco Ronchetti, Leonardo Piccinini, Manuela Deiana, Paolo Fabbri and Alessandro Corsini

Session 3.1, Room E1, Convener(s): Federico Raspini and Timotej Verbovšek

10:30-10:45 Prediction of Displacement Rates at an Active Landslide Using Joint Inversion of Multiple Time Series

Clara Lévy, Scarlett Gendrey, Séverine Bernardie, Marie-Aurélie Chanut, Aurélien Vallet, Laurent Dubois, and Jean-Paul Duranthon

10:45-11:00 Time-Prediction Method of the Onset of a Rainfall-Induced Landslide Based on the Monitoring of Shear Strain and Pore Pressure

Katsuo Sasahara

11:00-11:15 Improvement of Fukuzono's Model for Time Prediction of an Onset of a Rainfall-Induced Landslide

Naoki Iwata, Katsuo Sasahara, and Satoshi Watanabe

11:15-11:30 A Full-Scale Model Test for Predicting Collapse Time Using Displacement of Slope Surface During Slope Cutting Work

Nobutaka Hiraoka, Naotaka Kikkawa, Katsuo Sasahara, Kazuya Itoh, and Satoshi Tamate

11:30-11:45 Classification of Microseismic Activity in an Unstable Rock Cliff

Diego Arosio, Mauro Boccolari, Laura Longoni, Monica Papini, and Luigi Zanzi

11:45-12:00 Prediction of the Process of a Slowly Moving Loess Landslide by Electrical Resistivity Tomography

Sándor Szalai, Ernő Prácser, Kitti Szokoli, and ádám Tóth

Session 4.1, Room E2, Convener(s): Gabriele Scarascia-Mugnozza and Wakai Akihiko

10:30-10:45 Finite Element Simulation for Seismic Ground Response in Mountainous Areas in Nepal

Akihiko Wakai, Daisuke Higaki, Hiroshi Yagi, Go Sato, and Masahiro Chigira

10:45-11:00 Geophysical Investigation of the Landslide-Prone Slope Downstream from the Rogun Dam Construction Site (Tajikistan)

Torgoev Isakbek, Havenith Hans-Balder, Torgoev Almaz, Cerfontaine Philippe, and Ischuk Anatoly

11:00-11:15 Seismic-Induced Landslides: Lessons Learned from Recent Earthquakes in Spain

José Delgado, Martín J. Rodríguez-Peces, Francisco J. García-Tortosa, Jesús Garrido, Iván Martín, and Pedro Alfaro

11:15-11:30 Landslides Triggered by the Ms6.5 Ludian, China Earthquake of August 3, 2014

Kai-heng Hu, Xing-zhang Chen, Yong-gang Ge, Xing-yuan Jiang, and Yang-chun Wang

11:30-11:45 Earthquake-Induced Rockfalls Caused by 1998 Mw5.6 Earthquake in Krn Mountains (NW

Slovenia) and ESI 2007 Intensity Scale

Andrej Gosar

11:45-12:00 True 3D Kinematic Analysis for Slope Instability Assessment in the Siq of Petra (Jordan), from High Resolution TLS

Claudio Margottini, Daniele Spizzichino, Giovanni Gigli, Heinz Ruther, and Nicola Casagli

Session 5.1, Room E3, Convener(s): Mike Winter and Tom Dijkstra

10:30-10:45 Characterisation of Recent Debris Flow Activity at the Rest and Be Thankful, Scotland

Bradley Sparkes, Stuart Dunning, Michael Lim and Mike G. Winter

10:45-11:00 The Use of Morpho-Structural Domains for the Characterization of Deep-Seated Gravitational Slope Deformations in Valle d'Aosta

Daniele Giordan, Martina Cignetti and Davide Bertolo

11:00-11:15 Gediminas's Castle Hill (in Vilnius) Case: Slopes Failure Through Historical Times Until Present

Vidas Milkulėnas, Vytautas Minkevičius and Jonas Satkūnas

11:15-11:30 Design Criteria and Risk Management of New Construction in Landslide Areas: The Case of the Djendjen–El Eulma Highway (Algeria)

Mirko Vendramini, Attilio Eusebio, Fabrizio Peruzzo, Patrizia Vitale, Alessandro Fassone and Francesca Guazzotti

11:30-11:45 Numerical Analysis of a Potential Debris Flow Event on the Irazú Volcano, Costa Rica

Marina Pirulli and Rolando Mora

11:45-12:00 Landslides Impact Analysis Along the National Road 73C of Romania

Andreea Andra-Topârceanu, Mihai Mafteiu, Razvan Gheorghe, Mircea Andra-Topârceanu and Verga Mihaela

12:00-13:30

Lunch and Open Session I (12:30-13:30): Resilience of communities exposed to landslide risk (COST Initiative) (Room E1)

13:30-15:00

Round Table Discussion to promote the Sendai Partnerships

Room Club CD (13:30-15:30)

Objectives: The follow-up of the High-Level Panel Discussion and the implementation planning.

All participants will examine an action plan/road map/Addendum to the Partnerships to implement and further develop the Sendai Partnerships effectively contributing to SENDAI Framework for Disaster Risk Reduction. In the end of session, signing to the Sendai partnerships by new members may be organized.

Chairs: *Qunli Han*, *Kaoru Takara* and *Peter Bobrowsky*

Signatory organizations of the Sendai Partnerships and the additional Signatory organizations are invited to take part in this Round Table and discuss the promotion of SP 2015-2025.

Additional signatory organizations will be:

Branko Dervodel, Deputy Director General, Administration of the Republic of Slovenia for Civil Protection and Disaster Relief

Darko But, Director General of URSZR

Nguyen Linh Ngoc, Deputy Minister, Ministry of Natural Resources and Environment, Vietnam

Rudi Phadmanto, Deputy Minster, the Indonesian National Agency for Disaster Management

Shuaib Lwasa, Chair of the IRDR Science Committee

Luca Demicheli, Secretary General of EuroGeoSurveys

Session 2.1, Room M1, Convener(s): Limin Zhang and Tina Peternel

13:30-13:45 Landslide Diversity in the Rwenzori Mountains (Uganda)

Liesbet Jacobs, Olivier Dewitte, Clovis Kabaseke, François Kervyn, Jan Maes, Kewan Mertens, Adriano Nobile, John Sekajugo, Jean Poesen, Denis Samyn and Matthieu Kervyn

13:45-14:00 Multitemporal UAV Survey for Mass Movement Detection and Monitoring

Luca Tanteri, Guglielmo Rossi, Veronica Tofani, Pietro Vannocci, Sandro Moretti and Nicola Casagli

14:00-14:15 Landslide Inventory Map of Albania

Olgert Jaupaj, Mentor Lamaj, Hasan Kulici, Mimoza Jusufati, Edlira Plaku and Ilmi Gjeta

14:15-14:30 Comparing Landslide Mapping from DTM Satellite Derived Data and Field Based Studies of Loess Sediments in Western China

Philip Leopold, Wang Tao, Roland Perko, Gerhard Heiss, Martin Jung, Armin Oblin and Yongshuang Zhang

14:30-14:45 Multi-temporal Landslide Evaluation by Using UAV: Some Insights on Disaster Risk in Teziutlán, Puebla México

Ricardo J. Garnica- Peña and Irasema Alcántara-Ayala

14:45-15:00 Discussion

Session 2.2, Room M3/4, Convener(s): Beena Ajmera and Gen Furuya

13:30-13:45 Soil Characterization for Landslide Forecasting Models: A Case Study in the Northern Apennines (Central Italy)

Veronica Tofani, Gabriele Bicocchi, Guglielmo Rossi, Michele D'Ambrosio, Filippo Catani and Nicola Casagli

13:45-14:00 Groundwater Flow Behavior at Landslide Area in Crystalline Schist Mountains

Gen Furuya, Akira Suemine, Jun'ya Honda, Gonghui Wang and Mamoru Inoue

14:00-14:15 A Case Study of Deep-Seated Dukati Landslide, Vlore, Albania

Hasan Kuliçi, Mentor Lamaj, Zenel Hysa and Olgert Jaupaj

14:15-14:30 Kinematic Analysis of a Rock Slope at Strecno Castle (Slovakia) Based on the Processing of the Point Cloud Generated by UAV Photogrammetry

Vladimir Greif and Jan Vlcko

14:30-14:45 *Influences of Rheometer Size and the Grain Size on Rheological Parameters of Debris Flow*

Matej Maček, Jasna Smolar and Ana Petkovšek

14:45-15:00 *Discussion*

Session 3.1, Room E1, Convener(s): Željko Arbanas and Dario Peduto

13:30-13:45 The Pilot Construction of a Sensor-Based Landslide Early Warning System for Mitigating

Human Damages, Republic of Korea

Dongyeob Kim, Changwoo Lee, Choongshik Woo, Junpyo Seo, Minjeong Kang, and Hyunjung Kwon

13:45-14:00 An Early Warning System of Unstable Slopes by Multi-point MEMS Tilting Sensors and Water Contents

Wang Lin, Nishie Shunsaku, Uchimura Taro, Towhata Ikuo, Su Ling, and Tao Shangning

14:00-14:15 Early Warning of Long Channel and Post-controlled Debris-Flow Gully in Southwest China

Jian Huang

14:15-14:30 How Many Rainfall-Induced Landslides Are Detectable by a Regional Seismic Monitoring Network?

Andrea Manconi, Stefano Luigi Gariano, Velio Coviello, and Fausto Guzzetti

14:30-14:45 ANN Based Rainfall Prediction—A Tool for Developing a Landslide Early Warning System

S. Renuga Devi, P. Arulmozhivarman, and C. Venkatesh

14:45-15:00 Regional Landslide Early Warning Systems: Comparison of Warning Strategies by Means of a Case Study

Gaetano Pecoraro, Luca Piciullo, and Michele Calvello

Session 4.2, Room E2, Convener(s): Filippo Catani and Young-Suk Song

13:30-13:45 Analysis of the Predisposing Factors for Different Landslide Types Using the Generalized Additive Model

Carlotta Bartelletti, Roberto Giannecchini, Giacomo D'Amato Avanzi, Yuri Galanti, Michele Barsanti, Maria Giuseppina Persichillo, Massimiliano Bordoni, Claudia Meisina, Andrea Cevasco, and Jorge Pedro Galve Arnedo

13:45-14:00 Large-Scale Synoptic Weather Types and Precipitation Responsible for Landslides in Southern Norway

Graziella Devoli, Lisa Jørandli, Kolbjørn Engeland, and Lena M. Tallaksen

14:00-14:15 Definition of Rainfall Thresholds Triggering Landslides in Slovenia

Ascanio Rosi, Tina Peternel, Mateja Jemec-Auflič, Marko Komac, and Nicola Casagli

14:15-14:30 Analysis of the Impact of Precipitation on Landslide Activity Within the Erosive Slopes of River Valleys of the South of Ukraine

Galina Pedan, Olena Dragomyretska, and Oleksandr Dragomyretskyy

14:30-14:45 Drainage and Shear Velocity Dependent Shear Characteristics of Abandoned Imgi Mine Waste Materials in Ring Shear Tests

Sueng-Won Jeong, Sung-Sik Park, Hiroshi Fukuoka, Sang-Woo Ji, and Choon-Oh Lee

14:45-15:00 Landslide Monitoring and Management Challenge in Remote Papua New Guinea

Norbert Baczynski, and Neil Bar

Session 5.1, Room E3, Convener(s): Mike Winter and Janusz Wasowski

13:30-13:45 Evaluation of Building Damages Induced by Landslides in Volterra Area (Italy) Through Remote Sensing Techniques

Silvia Bianchini, Teresa Nolesini, Matteo Del Soldato and Nicola Casagli

13:45-14:00 The Resilience of Some Villages 36 Years After the Irpinia-Basilicata (Southern Italy) 1980 Earthquake

Sabina Porfido, Giuliana Alessio, Germana Gaudiosi, Rosa Nappi and Efisio Spiga

14:00-14:15 Urgent Need for Application of Integrated Landslide Risk Management Strategies for the Polog Region in R. of Macedonia

Igor Peshevski, Tina Peternel and Milorad Jovanovski

14:15-14:30 Comprehensive Overview of Historical and Actual Slope Movements in the Medieval Inhabited Citadel of Sighisoara

Andreea Andra-Topârceanu, Mihai Mafteiu, Mircea Andra-Topârceanu and Mihaela Verga

14:30-14:45 Analyze the Occurrence of Rainfall-Induced Landslides in a Participatory Way for Mid-Hills of Nepal Himalayas

Hari Prasad Pandey

14:45-15:00 Discussion

15:30-17:00

Session 2.1, Room M1, Convener(s): Jernej Jež and Mateja Jemec Auflič

15:30-15:45 Spatiotemporal Landslide Mapper for Large Areas Using Optical Satellite Time Series Data

Behling Robert and Sigrid Roessner

15:45-16:00 Integration of Multi-sensor A-DInSAR Data for Landslide Inventory Update

Roberta Bonì, Massimiliano Bordoni, Claudia Meisina, Alessio Colombo and Luca Lanteri

16:00-16:15 Sensor Data Integration for Landslide Monitoring—the LEMONADE Concept

Romy Schlögel, Benni Thiebes, Isabella Toschi, Thomas Zieher, Mehdi Darvishi and Christian Kofler

16:15-16:30 Mechanism of the Montescaglioso Landslide (Southern Italy) Inferred by Geological Survey and Remote Sensing

Francesca Bozzano, Paolo Caporossi, Carlo Esposito, Salvatore Martino, Paolo Mazzanti, Serena Moretto, Gabriele Scarascia Mugnozza and Antonio Michele Rizzo

16:30-16:45 Using the Intensity Values from Terrestrial Laser Scanner (TLS) for Determining Lithology of Flysch Rock Mass in Southwest Slovenia

Tina Živec, Andreja Anžur and Timotej Verbovšek

16:45-17:00 Combining Spectral and Morphometric Properties of Landslides for Separating Individual Landslides Based on Object-Oriented Method

Qigen Lin, Zhenhua Zou, Le Lin and Ying Wang

Session 2.2, Room M3/4, Convener(s): Beena Ajmera and Fawu Wang

15:30-15:45 Sediment Transport Along Earth Flows: Intermittent Cascade Effect Between Kinematic Zones

Luigi Guerriero, Lara Bertello, Nestor Cardozo, Matteo Berti, Gerardo Grelle and Paola Revellino

15:45-16:00 Landslide Investigation of a Residential Area in Göynüklü Village, Bursa (Turkey)

Tamer Topal; Muge Akin, Vedat Doyuran

16:00-16:15 High Performance Heterogeneous Data Storage System for High Frequency Sensor Data in a Landslide Laboratory

Guntha Ramesh, Hariharan Balaji and T. Hemalatha

16:15-16:30 Understanding Debris Flow Characteristics Using Flume Experiments

Sangjun Im, Song Eu and Dongyeob Kim

16:30-16:45 Slope Stability Investigation of Chandmari in Sikkim, Northeastern India

P. Thambidurai and Maneesha Vinodini Ramesh

16:45-17:00 H/V Technique for the Rapid Detection of Landslide Slip Surface(s): Assessment of the Optimized Measurements Spatial Distribution

Veronica Pazzi, Luca Tanteri, Gabriele Bicocchi, Andrea Caselli, Michele D'Ambrosio and Riccardo Fanti

Session 3.1, Room E1, Convener(s): Željko Arbanas and Dario Peduto

15:30-15:45 Hybrid Landslide Warning Model for Rainfall Triggered Shallow Landslides in Korean Mountain

Ananta Man Singh Pradhan, Hyo-Sub Kang, and Yun-Tae Kim

15:45-16:00 Sentinel-1 Data Analysis for Landslide Detection and Mapping: First Experiences in Italy and Spain

Anna Barra, Oriol Monserrat, Michele Crosetto, María Cuevas-Gonzalez, Núria Devanthéry, Guido Luzi, and Bruno Crippa

16:00-16:15 Testing Sentinel-1A Data in Landslide Monitoring: A Case Study from North-Eastern Italian Pre-Alps

Giulia Tessari; Mario Floris; Vladimiro Achilli; Massimo Fabris; Andrea Menin; Michele Monego

16:15-16:30 Innovative Landslide Change Detection Monitoring: Application of Space-Borne InSAR Techniques in the Thompson River Valley, British Columbia, Canada

David Huntley, Peter Bobrowsky, Francois Charbonneau, Jeffrey Journault, Renato Macciotta, and Michael Hendry

16:30-16:45 Remote Sensing Mapping and Monitoring of the Capriglio Landslide (Parma Province, Northern Italy)

Federica Bardi, Federico Raspini, William Frodella, Luca Lombardi, Massimiliano Nocentini, Giovanni Gigli, Stefano Morelli, Alessandro Corsini, and Nicola Casagli

16:45-17:00 Monitoring the Deep-Seated Landslides by Using ALOS/PALSAR Satellite Imagery in the Disaster Area of 2009 Typhoon Morakot, Taiwan

Rou-Fei Chen, Chen-Yang Lee, Hsiao-Yuan Yin, Hsiao-Yu Huang, Keng-Ping Cheng, and Ching-Weei Lin

Session 4.2, Room E2, Convener(s): Filippo Catani and Young-Suk Song

15:30-15:45 Deterministic and Probabilistic Rainfall Thresholds for Landslide Forecasting

Pasquale Versace, and Davide L. De Luca

15:45-16:00 Regional Rainfall Thresholds for Shallow and Deep-Seated Mass Movements Triggering in the South Eastern French Alps

Alexandre Remaître, and Jean-Philippe Malet

16:00-16:15 Explore on Hydro-Mechanical Threshold for Early Warning of Rainfall Induced Shallow Landslides

Zong-ji Yang, Jian-ping Qiao, Taro Uchimura, Lin Wang, Dong Huang, Xiao-qin Lei, and Li-li Shi

16:15-16:30 Influences of Rainfall on Shallow Slope Failures

Taworn Teerametatiparat, Avirut Chinkulkijniwat, and Somjai Yubonchit

16:30-16:45 Modelling Shallow Landslides Triggered by Rainfall in Tropical and Mountainous Basins

Edier Aristizábal, Hernán Martínez-Carvajal, and Edwin García-Aristizábal

16:45-17:00 Probabilistic Analysis of Shallow Landslide Susceptibility Using Physically Based Model and Fuzzy Point Estimate Method

Jung-Hyun Lee, Hyuck-Jin Park, and Jung-Yoon Jang

Session 5.2, Room E3, Convener(s): Jan Klimeš and Ying Guo

15:30-15:45 Multi-methodological Studies on the Large El Capulín Landslide in the State of Veracruz (Mexico)

Martina Wilde, Wendy V. Morales Barrera, Daniel Schwindt, Matthias Bücker, Berenice Solis, Birgit Terhorst and Sergio R. Rodríguez Elizarrarás

15:45-16:00 Cut Slope Icing Formation Mechanism and Its Influence on Slope Stability in Periglacial Area

Ying Guo, Wei Shan, Zhaoguang Hu and Hua Jiang

16:00-16:15 Climate Change Driving Greater Slope Instability in the Central Andes

Stella Maris Moreiras and Ivan Pablo Vergara Dal Pont

16:15-16:30 Understanding the Chandmari Landslides

Nirmala Vasudevan, Kaushik Ramanathan and Aadityan Sridharan

16:30-16:45 Activation of Cryogenic Earth Flows and Formation of Thermocirques on Central Yamal as a Result of Climate Fluctuations

Artem Khomutov, Marina Leibman, Yury Dvornikov, Anatoly Gubarkov, Damir Mullanurov and Rustam Khairullin

16:45-17:00 Landslide Investigations in the Northwest Section of the Lesser Khingan Range in China Using Combined HDR and GPR Methods

Zhaoguang Hu, Ying Guo and Wei Shan

19:00-21:00

Forum Banquet at Ljubljana Castle for all WLF4 participants

Thursday, June 1, 2017

8:30-10:00

Session 1.2, Room Štih Hall, Convener(s): Giuseppe Arduino and Yueping Yin

8:30-8:45 International Programme on Landslides (IPL): Objectives, History and List of World Centres of Excellence and IPL Projects

Qunli Han, Kyoji Sassa, Feng Min Kan and Claudio Margottini

8:45-9:00 Landslide Dynamics: ISDR-ICL Landslide Interactive Teaching Tools (LITT)

Kyoji Sassa, Fausto Guzetti, Hiromitsu Yamagishi, Zeljko Arbabas, Nicola Casagli, Binod Tiwari, KoFei Liu, Alexander Strom, Mauri McSaveney, Khang Dang and Hendy Setiawan

9:00-9:15 Progress of the World Report on Landslides

Biljana Abolmasov, Teuku Faisal Fathani, KoFei Liu and Kyoji Sassa

9:15-9:30 UNESCO-KU-ICL UNITWIN Cooperation Programme for Landslides and Water-Related Disaster Risk Management

Kaoru Takara and Kyoji Sassa

9:30-9:45 Landslides: Journal of the International Consortium on Landslides

Kyoji Sassa and Željko Arbanas

Session 2.3, Room M1, Convener(s): Beena Ajmera and A. A. Virajh Dias

8:30-9:00 Stress Testing Framework for Managing Landslide Risks under Extreme Storms (KEYNOTE LECTURE)

Limin Zhang

9:00-9:15 Back-Analysis of an Artificially Triggered Landslide: A Case Study in Northern Italy

Alex Sanzeni, Tiziano Cancelli, Marco Peli, Stefano Barontini and Francesco Colleselli

9:15-9:30 Review on Types of Root Failures in Shallow Landslides

Ana Sofia Dias, Marianna Pirone and Gianfranco Urciuoli

9:30-9:45 Review on the Methods for Evaluation of Root Reinforcement in Shallow Landslides

Ana Sofia Dias, Marianna Pirone and Gianfranco Urciuoli

9:45-10:00 Factors Influencing Rainfall-Induced Slope Failures

Binod Tiwari, Beena Ajmera, Mohammed Khalid and Rosalie Chavez

Session 2.4, Room M3/4, Convener(s): Binod Tiwari and Snježana Mihalić Arbanas

8:30-8:45 An Overview of Recent Developments in Landslide Vulnerability Assessment-Presentation of a New Conceptual Framework

Aditi Singh, Shilpa Pal, Debi Prasanna Kanungo and Naveen Pareek

8:45-9:00 Distribution Characteristics of Mass Movements in the Upper Bhote Koshi Watershed Before and After the Gorkha Earthquake and Their Susceptibility Evaluation

Amar Deep Regmi, Cui Peng and Megh Raj Dhital

9:00-9:15 How to Improve the Accuracy of Landslide Susceptibility Maps Using PSInSAR Data

Andrea Ciampalini, Federico Raspini, Daniela Lagomarsino, Filippo Catani and Nicola Casagli

9:15-9:30 Comparing Patterns of Spatial Relationships for Susceptibility Prediction of Landslide

Occurrences

Andrea G. Fabbri, Angelo Cavallin, Antonio Patera, Laura Sangalli and Chang-Jo Chung

9:30-9:45 Integration of Geohazards into Urban and Land-Use Planning. Towards a Landslide Directive. The EuroGeoSurveys Questionnaire

Rosa María Mateos, Gerardo Herrera, Juan Carlos García-Davalillo, Gilles Grandjean, Eleftheria Poyiadji, Raluca Maftei, Tatiana-Constantina Filipciuc, Mateja Jemec Auflič, Jernej Jez, Laszlo Podolszki, Alessandro Trigila, Valerio Comerci, Hugo Raetzo, Arben Kociu, Maria Przyłucka, Marcin Kułak, Izabela Laskowicz, Michael Sheehy, Veronika Kopackova, Michaela Frei, Dirk Kuhn, John F. Dehls, Reginald L. Hermanns, Niki Koulermou, Colby A. Smith, Mats Engdahl, Pere Buxó Pagespetit, Marta González, Vanessa Banks, Claire Dashwood, Helen Reeves, Francesca Cigna, Pavel Liščák, Vidas Mikulėnas, Vedad Demir, Margus Raha, Lidia Quental, Daniel Oliveira, Ruben Dias and Cvjetko Sandić

9:45-10:00 A GIS-Based Landslide Hazard Mapping in the City of Constantine, Northeast Algeria

Hamid Bourenane, Mohamed Said Guettouche, Youcef Bouhadad and Massinissa Braham

Session 3.1, Room E1, Convener(s): Veronica Tofani and Martin Krkač

8:30-8:45 Study of an Active Landslide on A16 Highway (Italy): Modeling, Monitoring and Triggering Alarm

Andrea Carri, Clelia Grignaffini, Andrea Segalini, Giovanna Capparelli, Pasquale Versace, and Gennaro Spolverino

8:45-9:00 Experimental Landslide Monitoring Site of Poggio Baldi Landslide (Santa Sofia, N-Apennine, Italy)

Paolo Mazzanti, Francesca Bozzano, Alessandro Brunetti, Paolo Caporossi, Carlo Esposito, and Gabriele Scarascia Mugnozza

9:00-9:15 Prediction of the Kostanjek Landslide Movements Based on Monitoring Results Using Random Forests Technique

Martin Krkač, Snježana Mihalić Arbanas, Željko Arbanas, Sanja Bernat Gazibara, and Marin Sečanj

9:15-9:30 Remote 3D Mapping and GB-InSAR Monitoring of the Calatabiano Landslide (Southern Italy)

Teresa Nolesini, William Frodella, Luca Lombardi, Massimiliano Nocentini, Federica Bardi, Intrieri, Tommaso Carlà, Lorenzo Solari, Giulia Dotta, Federica Ferrigno, and Nicola Casagli

9:30-9:45 Monitoring Giant Landslide Detachment Planes in the Era of Big Data Analytics

Jan Blahůt, Matt Rowberry, Jan Balek, Jan Klimeš, Ivo Baroň, and Xavi Martí

9:45-10:00 Geophysical Model and Displacement of Active Landslide—An Example from Jastrzębia Góra Cliff (Northern Poland)

Mirosław Kamiński and Piotr Zientara

Session 4.2, Room E2, Convener(s): Pasquale Versace and Jean-Philippe Malet

8:30-8:45 Assessing Potential Effects of Climate Change on Rainfall-Induced Shallow Landslides in the Peloritani Mountains Area, Sicily

David J. Peres, and Antonino Cancelliere

8:45-9:00 Variations in Landslide Frequency Due to Climate Changes Through High Resolution Euro-CORDEX Ensemble

Guido Rianna, Alfredo Reder, Veronica Villani, and Paola Mercogliano

9:00-9:15 Potential Effects of Climate Changes on Landslide Activity in Different Geomorphological

Contexts

Guido Rianna, Luca Comegna, Stefano Luigi Gariano, Fausto Guzzetti, Paola Mercogliano, Luciano Picarelli, and Paolo Tommasi

9:15-9:30 Historical Patterns of Heavy Rainfall Event and Deep-Seated Rapid Landslide Occurrence in Japan: Insight for Effects of Climate Change on Landslide Occurrence

Taro Uchida, Wataru Sakurai, and Atsushi Okamoto

9:30-9:45 Geomorphologic and Structural Controls on Landslide Types in Nigeria

Ogbonnaya Igwe

9:45-10:00 Geomorphology and Susceptibility to Rainfall Triggered Landslides in Gudbrandsdalen Valley, Norway

Håkon Heyerdahl, and Øyvind A. Høydal

Session 5.3, Room E3, Convener(s): Vít Vilímek and Giovanna Capparelli

8:30-8:45 Quantifying the Performances of Simplified Physically Based Landslide Susceptibility Models: An Application Along the Salerno-Reggio Calabria Highway

Giuseppe Formetta, Giovanna Capparelli and Pasquale Versace

8:45-9:00 Assessing Landslide Dams Evolution: A Methodology Review

Carlo Tacconi Stefanelli, Samuele Segoni, Nicola Casagli and Filippo Catani

9:00-9:15 Inventory and Typology of Landslide-Dammed Lakes of the Cordillera Blanca (Peru)

Adam Emmer and Anna Juřicová

9:15-9:30 Recommending Rainfall Thresholds for Landslides in Sri Lanka

Udeni P. Nawagamuwa and Lasitha P. Perera

9:30-9:45 Downstream Geomorphic Response of the 2014 Mount Polley Tailings Dam Failure, British Columbia

Vanessa Cuervo, Leif Burge, Hawley Beaugrand, Megan Hendershot and Stephen G. Evans

9:45-10:00 Discussion

10:30-12:00

Session 1.2, Room Štih Hall, Convener(s): Binod Tiwari and Daisuke Higaki

10:15-10:30 Advanced Technologies for Landslides (WCoE 2014-2017, IPL-196, IPL-198)

Nicola Casagli, Veronica Tofani, Filippo Catani, Sandro Moretti, Riccardo Fanti and Giovanni Gigli

10:30-10:45 Mechanisms of Landslides and Creep in Over Consolidated Clays and Flysch (WCoE 2014-2017)

Matjaž Mikoš, Janko Logar, Matej Maček, Jošt Sodnik and Ana Petkovšek

10:45-11:00 Researches on Heavy-Rainfall-Induced and Hydraulic-Driven Geological Hazards in China (WCoE 2014-2017)

Yueping Yin, Yongqiang Xu and Wenpei Wang

11:00-11:15 Landslide Risk Reduction in Croatia: Scientific research in the framework of the WCoE 2014-2017, IPL-173, IPL-184, ICL ABN

Snježana Mihalić Arbanas, Željko Arbanas, Martin Krkač, Sanja Bernat Gazibara, Martina Vivoda Prodan, Petra Đomlija, Vedran Jagodnik, Sanja Dugonjić Jovančević, Marin Sečanj and Josip Peranić

11:15-11:30 Shape and mechanism of large-scale landslides in Japan: forecasting analysis from an inventory (WCoE 2014-2017)

Ogita, S., Sagara, W., Higaki, D. and Research Committee on Elucidating Mechanisms of Large-Scale Landslides

11:30-11:45 Retrospect and Prospect of Cold Regions Landslide Research (2012-2016) (WCoE 2014-2017, IPL-132, IPL-167, IPL-203, CRLN)

Wei Shan and Ying Guo

11:45-12:00 Large-scale rockslide inventories - from Kokomeren River Basin to the entire Central Asia region (WCoE 2014-2017, IPL-106-2)

Alexander Strom and Kanatbek Abdrakhmatov

Session 2.3, Room M1, Convener(s): Katsuo Sasahara and Beena Ajmera

10:30-10:45 Stability of Red-Clay Slopes Subjected to Different Durations of Rainfall

Kaixi Xue, Binod Tiwari, Beena Ajmera and Yanxiang Hu

10:45-11:00 A Smoothed Particle Hydrodynamics Study of an Experimental Debris Flow

Caitlin Chalk, Manuel Pastor, Duncan Borman, Andrew Sleigh, Jeff Peakall, William Murphy and Raul Fuentes

11:00-11:15 Simulation Model to Predict Landslide Speed Using Velocity-Dependent Viscous Damping

Eisaku Hamasaki, Hideaki Marui and Gen Furuya

11:15-11:30 The Effect of the Front Inclination on the Impact Forces Transmitted by Granular Flows to Rigid Structures

Francesca Ceccato, Paolo Simonini, Claudio di Prisco and Irene Redaelli

11:30-11:45 Understanding and Modelling a Highly Ductile 25+ Years Old Active-Passive Landslide at Ok Tedi Mine in Papua New Guinea

Neil Bar and Norbert Baczynski

11:45-12:00 Analysis and Mapping the Landslide Hazard in Bulgaria

Plamen Ivanov, Boyko Berov, Nikolai Dobrev, Radoslav Varbanov, Miroslav Krastanov and Georgi Frangov

Session 2.4, Room M3/4, Convener(s): Binod Tiwari and Snježana Mihalić Arbanas

10:30-10:45 Landslide Susceptibility Analysis in Arandu Area Shigar Valley, CKNP (Gilgit-Baltistan-Pakistan)

Chiara Calligaris, Shahina Tariq, Hawas Khan and Giorgio Poretti

10:45-11:00 Deep-Seated Landslide Mapping and Geomorphic Characteristic Using High Resolution DTM in Northern Taiwan

Ching-Fang Lee, Wei-Kai Huang, Chuen-Ming Huang and Chung-Chi Chi

11:00-11:15 Common Patterns Among Different Landslide Susceptibility Models of the Same Region

Chyi-Tyi Lee and Chih-Chung Chung

11:15-11:30 Creation of a National Landslide Domain Map to Aid Susceptibility Mapping in Great Britain

Claire Dashwood, Catherine Pennington, Emma Bee, Katy Freeborough and Tom Dijkstra

11:30-11:45 A New Statistical Approach for Landslide Susceptibility Assessment in the Urban Area of Napoli (Italy)

Francesco Carotenuto, Anna Claudia Angrisani, Akram Bakthiari, Maria Teresa Carratù, Diego

Di Martire, Giovanni Francesco Finicelli, Pasquale Raia and Domenico Calcaterra

11:45-12:00 Multifractal Analysis of Spatial and Temporal Distributions of Landslides in Colombia

Estefanía Muñoz, Germán Poveda, Andrés Ochoa and Humberto Caballero

Session 3.1, Room E1, Convener(s): Veronica Tofani and Miloš Marjanović

10:30-10:45 Statistical Analysis of Displacement Rate for Definition of EW Thresholds Applied to Two Case Studies

Stefano Alberti, Giovanni Battista Crosta, and Carlo Rivolta

10:45-11:00 Ground Based Wireless Instrumentation and Real Time Monitoring of Pakhi Landslide, Garhwal Himalayas, Uttarakhand (India)

Debi Prasanna Kanungo, Anil Kumar Maletha, Manali Singh, and Neelu Sharma

11:00-11:15 Terrestrial Radar Interferometry Monitoring During a Landslide Emergency 2016, Ghirone, Switzerland

Caduff Rafael, and Strozzi Tazio

11:15-11:30 Monitoring of the Stogovce Landslide Slope Movements with GEASENSE GNSS Probes, SW Slovenia

Timotej Verbovšek, Marko Kočevar, Igor Benko, Matej Maček, and Ana Petkovšek

11:30-11:45 DFOS Technology-Based Landslide Monitoring: The Majiagou Landslide Case Study (China)

Bin Shi, Hongtao Jiang, and Yijie Sun

11:45-12:00 Seismic Noise Measurements on Unstable Rock Blocks: The Case of Bismantova Rock Cliff

Diego Arosio, Alessandro Corsini, Riccardo Giusti, and Luigi Zanzi

Session 4.2, Room E2, Convener(s): Pasquale Versace and Jean-Philippe Malet

10:30-10:45 Overview of Rainfall Induced Landslide Events and Importance of Geotechnical Investigations in Nilgiris District of Tamil Nadu, India

V. Senthilkumar, S.S. Chandrasekaran, and V.B. Maji

10:45-11:00 Physically-Based Models for Estimating Rainfall Triggering Debris Flows in Campania (Southern Italy)

Pantaleone De Vita, Francesco Fusco, Elisabetta Napolitano, and Rita Tufano

11:00-11:15 Physical Modelling of the Rainfall Infiltration Processes in Pyroclastic Soil Responsible of Landslide Trigger

Giovanna Capparelli, Pasquale Versace, and Gennaro Spolverino

11:15-11:30 Role of Land Use in Landslide Initiation on Terraced Slopes: Inferences from Numerical Modelling

Luca Schilirò, Andrea Cevasco, Carlo Esposito, and Gabriele Scarascia Mugnozza

11:30-11:45 Heavy Rains and Flash Floods at Rocky Coast. The Costiera Amalfitana (Southern Italy)

Crescenzo Violante, Eliana Esposito, Giuseppe Tranfaglia, and Giovanni Braca

11:45-12:00 RFID-Aided Sediment Transport Monitoring—Laboratory and Preliminary Field Test Results

Vladislav Ivov Ivanov, Davide Brambilla, Laura Longoni, Diego Arosio, and Monica Papini

Session 5.3 and 5.4, Room E3, Convener(s): Vít Vilímek and Bjoern Kalsnes

10:30-10:45 Brahmaputra River Bank Failures—Causes and Impact on River Dynamics

Archana Sarkar

10:45-11:00 The Sediment Production and Transportation in a Mountainous Reservoir Watershed, Southern Taiwan

Chih Ming Tseng, Kuo Jen Chang and Paolo Tarolli

11:00-11:15 Integration of Geometrical Root System Approximations in Hydromechanical Slope Stability Modelling

Elmar Schmaltz, Rens Van Beek, Thom Bogaard, Stefan Steger and Thomas Glade

11:15-11:30 Patterns of Development of Abrasion-Landslide Processes on the North-West Coast of the Black Sea

Olena Dragomyretska, Galina Pedan and Oleksandr Dragomyretskyy

11:30-11:45 Rock-Avalanche Activity in W and S Norway Peaks After the Retreat of the Scandinavian Ice Sheet

Reginald L. Hermanns, Markus Schleier, Martina Böhme, Lars Harald Blikra, John Gosse, Susan Ivy-Ochs and Paula Hilger

11:45-12:00 The Role of Rainfall and Land Use/Cover Changes in Landslide Occurrence in Calabria, Southern Italy, in the 20th Century

Stefano Luigi Gariano, Olga Petrucci and Fausto Guzzetti

12:00-13:30

Lunch and Open Session II (12:30-13:30): Strengthening resilience of rural communities exposed to landslides and other natural hazards (Room E1)

13:30-15:00

Session 1.2, Room Štih Hall, Convener(s): Nicola Casagli and Faisal Fathani

13:30-13:45 Interventions for Promoting Knowledge, Innovations and landslide risk management practices within South and Southeast Asia (WCoE 2014-2017)

Peeranan Towashiraporn and N.M.S.I. Arambepola

13:45-14:00 Promoting a Global Standard for Community-based Landslide Early Warning System (WCoE 2014-2017, IPL-158, IPL-165)

Teuku Faisal Fathani, Dwikorita Karnawati and Wahyu Wilopo

14:00-14:15 Model Policy Frameworks, Standards and Guidelines on Landslide Disaster Reduction (WCoE 2014-2017)

A A Virajh Dias, Nimesha Katuwala, K L S Sahabandu and Nihal Rupasinghe

14:15-14:30 Landslide Hazard and Risk Management (WCoE 2014-2017)

Josef Stemberk, Vít Vilímek, Jan Klimeš, Jan Blahůt, Filip Hartvich and Jan Balek

14:30-14:45 Mitigation of landslide hazards in Ukraine under the guidance of ICL: 2009–2016 (IPL-153, IPL-191)

Oleksander Trofymchuk, Iurii Kaliukh, Silchenko Konstantin, Viktoriia Berchun, Taras Kaliukh and Iaroslav Berchun

14:45-15:00 The Croatian-Japanese SATREPS Joint Research Project on Landslides (IPL-161)

Željko Arbanas, Snježana Mihalić Arbanas, Kyoji Sassa, Hideaki Marui, Hiroshi Fukuoka, Martin Krkač, Martina Vivoda Prodan, Sanja Bernat Gazibara and Petra Đomlija

Session 2.3, Room M1, Convener(s): Beena Ajmera and Veronica Tofani

13:30-13:45 Stochastic Investigation of the Feasibility of Using Remotely Sensed Moisture Data for Rainfall Induced Landslide Hazard Assessment

Thilanki Dahigamuwa and Manjriker Gunaratne

13:45-14:00 Process Chain Modelling with r.avaflow: Lessons Learned for Multi-hazard Analysis

Martin Mergili, Jan-Thomas Fischer and Shiva P. Pudasaini

14:00-14:15 Parametric Analysis of Weathering Effect on Possible Reactivation of the Valići Landslide, Croatia

Martina Vivoda Prodan and Željko Arbanas

14:15-14:30 Modeling Debris Flows in Anomalous Basin-Fan Systems

Erika de Finis, Paola Gattinoni, Lorenzo Marchi and Laura Scesi

14:30-14:45 Investigation on the Hydraulic Parameters Affecting Shallow Landslide Triggering in a Pyroclastic Slope

Roberto Greco, Luca Comegna, Emilia Damiano and Andrea Guida

14:45-15:00 Discussion

Session 2.4, Room M3/4, Convener(s): Vladimir Greif and Binod Tiwari

13:30-13:45 Landslides Induced by the 2015 Gorkha Earthquake

Binod Tiwari, Beena Ajmera, Smriti Dhital and Nagendra Raj Sitoula

13:45-14:00 Analysis of Building Vulnerability to Slow-Moving Landslides via a-DInSAR and Damage Survey Data

Gianfranco Nicodemo, Dario Peduto, Settimio Ferlisi, Giovanni Gullà, Luigi Borrelli, Gianfranco Fornaro and Diego Reale

14:00-14:15 The SAMCO Web-Platform for Resilience Assessment in Mountainous Valleys Impacted by Landslide Risks

Gilles Grandjean, Loïc Thomas and Séverine Bernardie

14:15-14:30 Landslide Risk Analysis Incorporated to the Land-Use Legislation in Colombia

Guillermo ávila and María del Pilar Guzmán

14:30-14:45 Landslide Risk Evaluation in Central Provinces of Vietnam

Le Hong Luong, Toyohiko Miyagi, Phan Van Tien, Doan Huy Loi, Hamasaki Eisaku and Shinro Abe

14:45-15:00 Mechanisms for Secondary Slope Failure in Slope Having Failed

Kiminori Araiba and Shoji Doshida

Session 3.1, Room E1, Convener(s): Biljana Abolmasov and Michele Calvello

13:30-14:00 Remote Sensing Techniques in Landslide Mapping and Monitoring (KEYNOTE LECTURE)

Nicola Casagli

14:00-14:15 Hydrological Monitoring of Ash-Fall Pyroclastic Soil Mantled Slopes in Campania (Southern Italy)

Francesco Fusco and Pantaleone De Vita

14:15-14:30 Analysis of Hydro-meteorological Monitoring Data Collected in Different Contexts Prone to Shallow Landslides of the Oltrepò Pavese (Northern Italy)

Massimiliano Bordoni, Claudia Meisina, Roberto Valentino, Marco Bittelli, Silvia Chersich, Marco Musetti

14:30-14:45 Field Monitoring to Measure Deformation of a Mine Waste-Dump Slope

Young-Suk Song and Yong-Chan Cho

14:45-15:00 Monitoring Soil Movement Characteristics of an Area Subject to Land Creeping in the Republic of Korea

Min-Jeng Kang, Chang-Woo Lee, Choong-shik Woo, Dong-Yeob Kim, Jun-pyo Seo, Hyun-Jung Kwon, Jae-Hyeon Park, and Ki-Dae Kim

15:00-15:15 A New Landslide Early Warning Technology—Escorting for Life

Hui Yu, Nianzhi Yu, Yan Wang, Lei Yu, and Zhengsheng Yu

Session 4.3 and 4.4, Room E2, Convener(s): Paolo Frattini and Mauri McSaveney

13:30-13:45 Characterization and Modeling of a Debris Flow in a Dolomitic Basin: Results and Issues

Chiara Boccali, Romano Lapasin, Luca Zini, Chiara Calligaris, and Franco Cucchi

13:45-14:00 Debris Flow Hazard Assessment (Cave del Predil—NE Italy)

Chiara Calligaris, Glenda Nicola, Giacomo Casagrande, Luca Zini, and Franco Cucchi

14:00-14:15 Susceptibility to Sea Cliff Failures at Cala Rossa Bay in Favignana Island (Italy)

Roberto Iannucci, Salvatore Martino, Fabio Martorelli, Luca Falconi, and Vladimiro Verrubbi

14:15-14:30 Characteristics, Causes and Hazards of Large-Scale Debris Flows on June 23 at Haitong Watershed, Tibet, China

Ge Yonggang, Zou Qiang, Zhang Jianqiang, and Guo Xiaojun

14:30-14:45 Large-Scale Rockslope Deformations in Sogn Og Fjordane County (Norway)

Ivanna M. Penna, Martina Böhme, Reginald Hermanns, Trond Eiken, and John Dehls

14:45-15:00 Landslide Zoning Using the Principal Component Analysis on Monitoring Data: The Sauna Earth Slide—Earth Flow (Parma, Italy

Marco Mulas, Francesco Bonacini, Marcello Petitta, Francesco Ronchetti, Giovanni Truffelli, Michela Diena, and Alessandro Corsini

Session 5.4, Room E3, Convener(s): Vít Vilímek and Mario Parise

13:30-13:45 Geomorphology and Age of Large Rock Avalanches in Trentino (Italy): Castelpietra

Susan Ivy-Ochs, Silvana Martin, Paolo Campedel, Kristina Hippe, Christof Vockenhuber, Gabriele Carugati, Manuel Rigo, Daria Pasqual and Alfio Viganò

13:45-14:00 Coupled Slope Collapse—Cryogenic Processes in Deglaciated Valleys of the Aconcagua Region, Central Andes

Stella Maris Moreiras

14:00-14:15 Rock Avalanches in a Changing Landscape Following the Melt Down of the Scandinavian Ice Sheet, Norway

Markus Schleier, Reginald L. Hermanns and Joachim Rohn

14:15-14:30 Multi-Temporal Landslide Susceptibility Maps and Future Scenarios for Expected Land Cover Changes (Southern Apennines, Italy)

Luca Pisano, Veronica Zumpano, Žiga Malek, Mihai Micu, Carmen Maria Rosskopf and Mario Parise

14:30-15:00 Discussion

15:30-17:00

Session 1.2, Room Štih Hall, Convener(s): Alexandar Strom and Matjaž Mikoš

15:30-15:45 Development of a Hazard Evaluation Technique for Earthquake-Induced Landslides Based on an Analytic Hierarchy Process (AHP) (IPL-154)

Daisuke Higaki, Eisaku Hamasaki and Kazunori Hayashi

15:45-16:00 Technical Cooperation Project to Develop Landslide Risk Assessment Technology along Transport Arteries in Vietnam (IPL-175)

Dinh Van Tien, Nguyen Xuan Khang, Kyoji Sassa, Toyohiko Miyagi, Hirotaka Ochiai, Huynh Dang Vinh, Lam Huu Quang, Khang Dang and Shiho Asano

16:00-16:15 Study of slow moving landslide Umka near Belgrade, Serbia (IPL-181)

Biljana Abolmasov, Miloš Marjanović, Svetozar Milenković, Uroš Đurić, Branko Jelisavac and Marko Pejić

16:15-16:30 Influence of Post-Earthquake Rainfall on the Stability of Clay Slopes (IPL-192)

Binod Tiwari, Beena Ajmera and Duc Tran

16:30-16:45 Public Awareness and Education Programme for Landslides Management and Evaluation on Social Research Approach in Determining "Acceptable Risk" and "Tolerable Risk" in Landslide Risk Areas in Malaysia (IPL-194, IPL-207)

Ab. Rashid Ahmad, Ir. Zainal Arsad Md Amin, Ir. Dr. Che Hassandi Abdullah and Siti Zarina Ngajam

16:45-17:00 Geotechnical Site Characterization of Mud Eruption Disaster Area using CPTu for Risk Assessment and Mitigation Program (IPL-195)

Paulus P. Rahardjo, Adityaputera Wirawan and Andy Sugianto

17:00-17:15 Massive landsliding in Serbia following Cyclone Tamara in May 2014 (IPL-210)

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

17:15-17:30 Geohazard prevention in China

Guan Fengjun, presented by Yueping Yin

17:30-17:45 International Research Plan of Disaster Risk Reduction in Belt & Road Countries

Cui Peng, presented by Lijun Su

Session 2.3, Room M1, Convener(s): Kiminori Araiba and Beena Ajmera

15:30-15:45 Propagation Modeling and Inverse Analysis of a Landslide in Hong Kong

Sabatino Cuomo, Michele Calvello and Pooyan Ghasemi

15:45-16:00 Insights from LS-RAPID Modeling of Montaguto Earthflow (Italy)

Sabatino Cuomo, Vincenzo de Chiara, Sanja Dugonjić Jovančević, Martina Vivoda Prodan and Željko Arbanas

16:00-16:15 Numerical Modelling of Hydrological Parameters for an Enhanced Interpretation of ERT Monitoring Data

Stefan Hoyer, David Ottowitz, Birgit Jochum, Stefan Pfeiler, Robert Supper and Jung-Ho Kim

16:15-16:30 Preliminary Investigations and Numerical Simulations of a Landslide Reactivation

Željko Arbanas, Snježana Mihalić Arbanas, Martina Vivoda Prodan, Josip Peranić, Marin Sečanj, Sanja Bernat Gazibara and Martin Krkač

16:30-16:45 Analysis of Failure Mechanism of Slopes with a Horizontal Weak Intercalation Under Earthquakes

Zhenlin Chen and Nanqi Huang

16:45-17:00 Influence of Ice Content on the Run-Out of Rock-Ice Avalanches

Qingqing Yang, Zhiman Su, Zhihao Li and Hongwei Liu

Session 2.4, Room M3/4, Convener(s): Igor Peshevski and Snježana Mihalić Arbanas

15:30-15:45 Selecting the Most Appropriate Route for Tehran-Shomal Freeway (Northern Iran) Based on Landslide Susceptibility Mapping

Mohammad Madankan, Jafar Hassanpour and Akbar Cheshomi

15:45-16:00 Reservoir Landslides and Its Hazard Effects for the Hydropower Station: A Case Study

Jia-wen Zhou, Peng-yuan Lu and Yu-chuan Yang

16:00-16:15 Risk Assessment of Earthquake-Induced Landslides in Urban Zones

Johnny Alexander Vega and Cesar Augusto Hidalgo

16:15-16:30 The Role of ICGC on Urban and Territorial Planning: The Geological Hazard in Catalonia

Jordi Marturià, Marta Gonzalez, Jordi Pinyol, Marcel Barbera and Pere Buxó

16:30-16:45 Deterministic and Probabilistic Slope Stability Models Forecast Performance at 1:5000-Scale

Jorge P. Galve, Carlotta Bartelletti, Davide Notti, Francisca Fernández-Chacón, Michele Barsanti, José Miguel Azañón, Vicente Pérez-Peña, Roberto Giannecchini, Giacomo D'Amato Avanzi, Yuri Galanti, Francisco J. Lamas and Rosa María Mateos

16:45-17:00 Identification of Landslides as Debris Flow Sources Using a Multi-model Approach Based on a Field Survey—Koroška Bela, Slovenia

Jošt Sodnik, Špela Kumelj, Tina Peternel, Jernej Jež and Matej Maček

17:00-17:15 Rainfall-Induced Large-Scale Landslide Hazard Zonation in Taiwan

Yuan-Jung Tsai, Wen-Chi Lai, Teng-Chieh Hsu, Chjeng-Lun Shieh and Hsiao-Yu Huang

Session 3.2, Room E1, Convener(s): Biljana Abolmasov and Teuku Faisal Fathani

15:30-15:45 Landslide Disaster and Relief Activities: A Case Study of Urban Area of Doboj City

Cvjetko Sandić, Biljana Abolmasov, Miloš Marjanović, Petar Begović, and Boban Jolović

15:45-16:00 Landslide Risk Management in Uganda: A Multi-level Policy Approach

Jan Maes, Jean Poesen, Constanza Parra, Clovis Kabaseke, Bosco Bwambale, Kewan Mertens, Liesbet Jacobs, Olivier Dewitte, Liesbet Vranken, Astrid de Hontheim, and Matthieu Kervyn

16:00-16:15 RECALL Project: Toward Resilent European Communities Against Local Landslides

Mateja Jemec Auflič, Tina Peternel, Špela Kumelj, Jernej Jež, Blaž Milanič, Erazem Dolžan, and Giovanna Brunelli

16:15-16:30 Project BEWARE—Landslide Post-disaster Relief Activities for Local Communities in Serbia

Biljana Abolmasov, Dobrica Damjanović, Miloš Marjanović, Ranka Stanković, Velizar Nikolić, Sandra Nedeljković, and Žarko Petrović

16:30-16:45 BEWARE Multi-Device Web GIS Application for Landslides

Nikola Vulović, Olivera Kitanović, Ranka Stanković, Dalibor Vorkapić, and Ana Vulović

16:45-17:00 A Web-based Landslide Risk Mitigation Portal

Marco Uzielli, Jung Chan Choi, and Bjørn G. Kalsnes

Session 4.3, Room E2, Convener(s): Paolo Frattini and Mauri McSaveney

15:30-15:45 Impact Forces of a Supercritical Flow of a Shear Thinning Slurry Against an Obstacle
Michele Iervolino, Claudia Carotenuto, Corrado Gisonni, Mario Minale, and Andrea Vacca

15:45-16:00 Observation and Numerical Simulation of Debris Flow Induced by Deep-Seated Rapid Landslide
Taro Uchida, Yuki Nishiguchi, Naoki Matsumoto, Wataru Sakurai, and Atsushi Okamoto

16:00-16:15 Analysis on Debris Flow Non-rectilinear Motion—From Case Study to Hazard Zone Delimitation Discussion
Tingyeh Wu, and Su-Chin Chen

16:15-16:30 Frequency Difference of Debris Flows in Moxi Basin, Southwestern China
Yongbo Tie, Jintao Jiang, Zhi Song, Alena V. Kadetova, and Artem A. Rybchenko

16:30-16:45 Debris Flow Activity in Permafrost Regions in Austria During the 20th Century
Roland Kaitna, and Thomas Huber

16:45-17:00 Discussion

Sessions 4.4 and 4.5, Room E3, Convener(s): Mario Parise and Fawu Wang

15:30-15:45 A New Calculation Method to Flexural Toppling Failure of Anti-dipped Rock Slope
Su Lijun, Qu Xin, and Zhang Chonglei

15:45-16:00 Joint Modelling and Monitoring on Case Pennetta and Case Costa Active Landslides System Using Electrical Resistivity Tomography and Geotechnical Data
Andrea Quagliarini, Andrea Segalini, Alessandro Chelli, Roberto Francese, Massimo Giorgi, and Laura Spaggiari

16:00-16:15 Structural and Climatic Control of Mass Movements Along the Karakoram Highway
Sajid Ali, Sascha Schneiderwind, and Klaus Reicherter

16:15-16:30 The Influence of the Geological Model in the Stress-Strain Analysis of the 1963 Vajont Landslide
Paolo Paronuzzi, and Alberto Bolla

16:30-16:45 Numerical Simulation on Gentle Dip Slope Deformation Caused by River Erosion
Tien-Chien Chen, Feng-Long Chou, and Cheng Meng Hsieh

16:45-17:00 Mass Movement Processes of Quaternary Deposits in the Vipava Valley, SW Slovenia
Tomislav Popit, Jernej Jež, and Timotej Verbovšek

17:00-17:30 Debris Flow Generation in Burned Catchments (KEYNOTE LECTURE)
Mario Parise, and Susan H. Cannon

17:15-18:30

Session 3.3, Room E1, Convener(s): Sabatino Cuomo and Janko Logar

17:15.17:30 Collapse and Remediation of Vrhole Landslide
Saša Galuf and Vojkan Jovičić

17:30-17:45 Landslide Remediation Between Kvaternikova and Divoselska Street in Zagreb
Katarina Ravnjak, Goran Grget, Leo Matešić, and Marko Kaić

17:45-18:00 Landslide Stabilization in Building Practice: Methodology and Case Study from Autonomic Republic of Crimea

Oleksander Trofymchuk, Iurii Kaliukh, and Viktoriia Berchun

18:00-18:15 Monitoring and Assessment of Remedial Measures in Closed Open Cast Mine

Jan Zalesky and Kristyna Capova

18:15-18:30 DEM simulations of punch tests for the mechanical characterization of cortical meshes

Fabio Gabrieli, Antonio Pol, Klaus Thoeni, and Nicola Mazzon

Student Session, Room M1, Convener(s): Johannes Hübl and Paolo Frattini

17:15.17:30 Slope Mass Assessment of Road Cut Rock Slopes Along Karnprayag to Narainbagarh Highway in Garhwal Himalayas, India

Saroj Kumar Lenka, Soumya Darshan Panda, Debi Prasanna Kanungo and R. Anbalagan

17:30-17:45 Automatic Landslides Mapping in the Principal Component Domain

Kamila Pawłuszek and Andrzej Borkowski

17:45-18:00 A Check-Dam to Measure Debris Flow-Structure Interactions in the Gadria Torrent

Georgl Nagl and Johannes Hübl

18:00-18:15 Simulating the Formation Process of the Akatani Landslide Dam Induced by Rainfall in Kii Penins

Pham Van Tien, Kyoji Sassa, Kaoru Takara, Khang Dang, Le Hong Luong and Nguyen Duc Ha

18:15-18:30 Flat-slab subduction and crustal models for the seismically active Sierras Pampeanas region of Argentina

Sebastián Junquera Torrado, Stella Maris Moreiras and Sergio A. Sepúlveda

Friday, June 2, 2017

08:30-10:00

Session 1.3, Room E3, Convener(s): Irasema Alcántara-Ayala

8:30-8:45 Landslides and Society—A Foreword

Irasema Alcántara-Ayala

8:45-9:00 Landslide Societal Risk in Portugal in the Last 155 Years

Susana Pereira, José Luís Zêzere, and Ivânia Quaresma

9:00-9:15 Landslide Inventory Mapping in the Fourteen Northern Provinces of Vietnam: Achievements and Difficulties

Le Quoc Hung, Nguyen Thi Hai Van, Pham Van Son, Nguyen Hoang Ninh, Nguyen Tam, and Nguyen Thi Huyen

9:15-9:30 Geological Conservation Through Risk Mitigation and Public Awareness at the Siq of Petra, Jorda

Giorgia Cesaro, Giuseppe Delmonaco, Bilal Khrisat, and Sabrina Salis

9:30-9:45 Case Histories for the Investigation of Landslide Repair and Mitigation Measures in NW Germany

Annika Wohlers, Thomas Kreuzer and Bodo Damm

9:45-10:00 Surveying Perception of Landslide Risk Management Performance, a Case Study in Norway

Jessica Chiu and Unni Eidsvig

Session 2.4, Room M1, Convener(s): Binod Tiwari and Beena Ajmera

8:30-8:45 Landslide Hazard Scenarios Based on Both Past Landslides and Precipitation

Juan Remondo, Jaime Bonachea, Victoria Rivas, Javier Sánchez-Espeso, Viola Bruschi, Antonio Cendrero, José Ramón Díaz de Terán, Gema Fernández-Maroto, José Gómez-Arozamena, Alberto González-Díez and Carlos Sainz

8:45-9:00 Observation and Mapping of Complex Landslides Using Field Investigation and Remote Sensed Data

Kuo-Lung Wang, Yo-Ming Hsieh, Meei-Ling Lin, Jun-Tin Lin and Yi-Hsuan Lee

9:00-9:15 Generating Application-Orientated Susceptibility Maps for Shallow Landslides Understandable to the General Public

Leonhard Schwarz and Nils Tilch

9:15-9:30 Landslide Hazard and Risk Assessment Lanzhou, Province Gansu, China—Project Introduction and Outlook

Tingshan Tian, Dirk Balzer, Lichao Wang, Jewgenij Torizin, Liqin Wan, Xianglong Li, Liang, Ch Dirk Kuhn, Michael Fuchs, Thomas Lege and Bin Tong

AND

Landslide Susceptibility Assessment in rapidly devoloping area - Use Lanzhou as

an example

Bin Tong

9:30-9:45 Built-Up Area Exposure to Landslides and Related Social Impactsin Molise (Italy)

Luca Pisano, Veronica Zumpano, Vittoria Dragone and Mario Parise

9:45-10:00 Remarks on the Role of Landslide Inventories in the Statistical Methods Used for the Landslide Susceptibility Assessment

Maria Giuseppina Persichillo, Massimiliano Bordoni, Claudia Meisina, Carlotta Bartelletti,

Roberto Giannecchini, Giacomo D'Amato Avanzi, Yuri Galanti, Michele Barsanti, Andrea Cevasco, Pierluigi Brandolini and Jorge Pedro Galve

Session 2.4, Room M3/4, Convener(s): Snježana Mihalić Arbanas and Stefan Steger

8:30-8:45 Landslide Susceptibility Mapping at National Scale: A First Attempt for Austria

Pedro Lima, Stefan Steger, Thomas Glade, Nils Tilch, Leonhard Schwarz and Arben Kociu

8:45-9:00 Natural Hazards and Disaster Risk in One Belt One Road Corridors

Cui Peng, Amar Deep Regmi, Zou Qiang, Lei Yu, Chen Xiaoqing and Cheng Deqiang

9:00-9:15 Delineation of Endangered Areas in a Slowly Moving Landslide by the Pressure Probe Method

Sándor Szalai, Viktor Wesztergom and Kitti Szokoli

9:15-9:30 Identification and Mapping of Shallow Landslides in the City of Zagreb (Croatia) Using the LiDAR Terrain Model

Sanja Bernat Gazibara, Martin Krkač, Marin Sečanj and Snježana Mihalić Arbanas

9:30-9:45 Estimation of Landslides Activities Evolution Due to Land–Use and Climate Change in a Pyrenean Valley

Séverine Bernardie, Rosalie Vandromme, Apolline Mariotti, Thomas Houet, Marine Grémont, Gilles Grandjean and Yannick Thiery

9:45-10:00 The Difference in the Landslide Information by the Difference Between Geographical Features and Geological Conditions

Shoji Doshidan

Session 3.3, Room E1, Convener(s): Sabatino Cuomo and Janko Logar

8:30-8:45 Reliability of Shear Strength Parameters for a Safe Slope Design in Highly Jointed Rock Mass

Mutluhan Akın

8:45-9:00 A Subgrade Reaction Solution for Anchored Dowel Piles to Stabilize Landslides

Fei Cai

9:00-9:15 Modelling the Performance of a Reinforced Natural Slope in Niscemi (Italy)

Sabatino Cuomo, Lorenzo Frigo, and Lorenzo Ciorciari

9:15-9:30 Modelling the Propagation of Debris Avalanches in Presence of Obstacles

Sabatino Cuomo, Leonardo Cascini, Manuel Pastor, and Stefano Petrosino

9:30-9:45 High Geogrid-Reinforced Slopes as Flexible Solution for Problematic Steep Terrain: Trieben-Sunk Project, Austria

Oliver Detert and Pierpaolo Fantini

9:45-10:00 Inadvertent Engineered Activation of Utiku Landslide, New Zealand

Mauri J. McSaveney and Christopher I. Massey

Session 4.3, Room E2, Convener(s): Domenica Calcaterra and Oldrich Hungr

8:30-8:45 Statistical Methods for the Assessment of Rainfall Thresholds for Triggering Shallow Landslides: A Case Study

Yuri Galanti, Michele Barsanti, Roberto Giannecchini, Giacomo D'Amato Avanzi, and Gianni Benvenuto

8:45-9:00 Using Weather Radar Data (Rainfall and Lightning Flashes) for the Analysis of Debris Flows

Occurrence in Emilia-Romagna Apennines (Italy)

Giuseppe Ciccarese, Alessandro Corsini, Pier Paolo Alberoni, Miria Celano, and Anna Fornasiero

9:00-9:15 Monitoring of Debris Flows with an Improved System Setup at the Lattenbach Catchment, Austria

Johannes Hübl, Andreas Schimmel, and Richard Koschuch

9:15-9:30 Natural Hazard Analysis for a Small Alpine Catchment in the Nepalese Himalayas

Klaus Schraml, Christian Uhlir, and Johannes Hübl

9:30-9:45 Experimental Study of Fluidized Landslide

Hu Wei, Hicher Pierre-Yves, Qiang Xu, van Asch Theo, and Wang Gonghui

9:45-10:00 Discussion

Student Session, Room: Club CD, Convener(s): Matjaž Mikoš and Paolo Frattini

8:30-8:45 Stress-Strain Modelling to Investigate the Internal Damage of Rock Slopes with a Bi-Planar Failure

Alberto Bolla and Paolo Paronuzzi

8:45-9:00 Towards Decentralized Landslide Disaster Risk Governance in Uganda

Sowedi Masaba, N. David Mungai, Moses Isabirye and Haroonah Nsubuga

9:00-9:15 Geological Aspects of Landslides in Volcanic Rocks in a Geothermal Area (Kamojang Indonesia)

I. Putu Krishna Wijaya, Christian Zangel, Wolfgang Straka and Franz Ottner

9:15-9:30 Adaptive Learning Techniques for Landslide Forecasting and the Validation in a Real World Deplo

T. Hemalatha, Maneesha Vinodini Ramesh and Venkat P. Rangan

9:30-9:45 Influence of Mixture Composition in the Collapse of Soil Columns

Lorenzo Brezzi, Fabio Gabrieli, Simonetta Cola and Isabella Onofrio

9:45-10:00 New Thoughts for Impact Force Estimation on Flexible Barriers

Daoyuan Tan, Jianhua Yin, Jieqiong Qin and Zhuohui Zhu

10:30-12:00

Session 1.3, Room E3, Convener(s): Irasema Alcántara-Ayala

10:30-10:45 Landslide Hazards and Climate Change Adaptation of Transport Infrastructures in Germany

Martin Klose, Markus Auerbach, Carina Herrmann, Christine Kumerics, and Annegret Gratzki

10:45-11:00 Integration of Landslide Susceptibility Maps for Land Use Planning and Civil Protection Emergency Management

Sérgio C. Oliveira, José L. Zêzere, Clémence Guillard-Gonçalves, Ricardo A.C. Garcia, and Susana Pereira

11:00-11:15 Participatory Approach to Natural Hazard Education for Hydrological Risk Reduction

Giovanna Lucia Piangiamore, and Gemma Musacchio

11:15-11:30 More Room for Landslides

Klaudija Sapač, Nina Humar, Mitja Brilly and Andrej Kryžanowski

11:30-12:00 Discussion

Session 2.4, Room M1, Convener(s): Mario Parise and Snježana Mihalić Arbanas

10:30-10:45 Investigation and Assessment Plan at the Xinzhuang Potential Large-Scale Landslide in Southern Taiwan

Ming-Chien Chung, Chien-Hsin Chen, Chih-Hao Tan, Ching-Fang Lee and Wei-Kai Huang

10:45-11:00 Forecasting the Hydrogeological Hazard in the Anomalous Basin-Fan System of Sernio (Northern Italy)

De Finis Erika, Gattinoni Paola and Scesi Laur

11:00-11:15 Regional Landslide Susceptibility Analysis Following the 2015 Nepal Earthquake

Andrea Valagussa, Paolo Frattini, Giovanni B. Crosta, Elena Valbuzzi and Stefano Gambini

11:15-11:30 A Web-Based Inventory of Landslides Occurred in Italy in the Period 2012–2015

Elena Innocenzi, Luca Greggio, Paolo Frattini and Mattia de Amicis

11:30-11:45 Comparing the Performance of a Logistic Regression and a Random Forest Model in Landslide Susceptibility Assessments. the Case of Wuyaun Area

Haoyuan Hong, Paraskevas Tsangaratos, Ioanna Ilia, Wei Chen and Chong Xu

11:45-12:00 Landslide Susceptibility Mapping and Comparison Using Frequency Ratio and Analytical Hierarchy Process in Part of NH-58, Uttarakhand, India

Ramesh Veerappan, Ankur Negi and Anbazhagan Siddan

Session 2.4, Room M3/4, Convener(s): Biljana Abolmasov and Binod Tiwari

10:30-10:45 The Challenge of "Trivial Areas" in Statistical Landslide Susceptibility Modelling

Stefan Steger and Thomas Glade

10:45-11:00 A New Approach to Assess the Stability of Rock Slopes and Identify Impending Failure Conditions

Tommaso Carlà, Emanuele Intrieri, Paolo Farina and Nicola Casagli

11:00-11:15 Modern Map of Landslide Hazard for Sulukta Town and Its Agglomeration Area, South-West Mountainous Margins of the Fergana Basin

Abdybachaev Ulan, Moldobekov Bolot and Ormukov Cholponbek

11:15-11:30 Landslide Susceptibility Assessment by EPBM (Expert Physically Based Model): Strategy of Calibration in Complex Environment

Yannick Thiery, Rosalie Vandromme, Olivier Maquaire and Séverine Bernardie

11:30-11:45 Management of Landslides in Small Settlements in Slovenia

Bojana Božiček and Eva Koren

11:45-12:00 Tailings Dam Stability

Bjørn Kalsnes, Hans Petter Jostad, Farrokh Nadim, Audun Hauge, Angèle Dutra and Arnaldo Muxfeldt

Session 3.3, Room E1, Convener(s): Sabatino Cuomo and Janko Logar

10:30-10:45 Implementation of a Flexible Wire Net Dam for Controlling Debris Flow in a Small Mountain Torrent

Sangjun Im, Seungyoub Yi, and Song Eu

10:45-11:00 Synthetic Water Repellent Soils for Slope Stabilization

Shuang Zheng, Sérgio D.N. Lourenço, Peter J. Cleall, Stuart W. Millis, Angel K.Y. Ng, and Ting

Fong May Chui

11:00-11:15 Destructive Influence of Technogenic Factors and Precipitations on Landslide Support Structure

Georgi Frangov, Hristina Zayakova, and Stefan Frangov

11:15-11:30 Interaction of Landslide with Critical Infrastructure

Daniel Jirásko, Ivan Vaníček, and Martin Vaníček

11:30-11:45 The 10-Mile Slide and Response of a Retaining Wall to Its Continuous Deformation

Renato Macciotta, Tommaso Carlà, Michael Hendry, Trevor Evans, Tom Edwards, Paolo Farina, and Nicola Casagli

11:45-12:00 Flexible Barriers Composed of High-Strength Steel Nets, as a Solution to the Near Surface Slides

Corinna Wendeler, Volker Leonhardt, and Roberto Luis

Session 4.5, Room E2, Convener(s): Peter Bobrowsky and Silvia Bianchini

10:30-10:45 Insights into Deep-Seated Rockslides in Metamorphic Rock Masses: Lessons Learned from Field Surveys, In Situ Investigations and Numerical Modelling

Christian Zangerl, Thomas Strauhal, Christine Fey, Michael Holzmann, and Sebastian Perzlmaier

10:45-11:00 Flash Floods in the Rwenzori Mountains—Focus on the May 2013 Multi-Hazard Kilembe Event

Liesbet Jacobs, Jan Maes, Kewan Mertens, John Sekajugo, Wim Thiery, Nicole van Lipzig, Jean Poesen, Matthieu Kervyn, and Olivier Dewitte

11:00-11:15 Residual Slope Stability in Low Order Streams of Angangueo Mining Area (Michoacán, Mexico) After the 2010 Debris Flows

Stefano Morelli, Veronica Pazzi, Victor Hugo Garduño Monroy, and Nicola Casagli

11:15-11:30 Monitoring Eruption-Induced Mass-Wasting at Active Volcanoes: The Stromboli Case

Federico Di Traglia, Teresa Nolesini, and Nicola Casagli

11:30-11:45 Development of a Rockfall Risk Mitigation Plan in the Montserrat Massif (Central Catalonia, Spain)

Marc Janeras, Guillem Domènech, Judit Pons, Elisabet Prat, Ferran López, and Pere Buxó

11:45-12:00 Assessment of Rockslide Dam Scenarios at Catchment Scale in the Context of Cascading Hazards

Christian Kofler, Francesco Comiti, Bernhard Gems, Benni Thiebes, Stefan Schneiderbauer, and Romy Schlögel

Student Session, Room Club CD, Convener(s): Matjaž Mikoš and Paolo Frattini

10:30-10:45 Detail Study of the Aratozawa Large-scale Landslide in Miyagi Prefecture, Japan

Hendy Setiawan, Kyoji Sassa, Kaoru Takara and Hiroshi Fukuoka

10:45-11:00 Identification of Rock Fall Prone Areas on the Steep Slopes Above the Town of Omiš, Croatia

Marin Sečanj, Snježana Mihalić Arbanas, Branko Kordić, Martin Krkač and Sanja Bernat Gazibara

11:00-11:15 Automatic Detection of Sediment-Related Disasters Based on Seismic and Infrasound Signals

Andreas Schimmel and Johannes Hübl

11:15-11:30 Diversity of Materials in Landslide Bodies in the Vinodol Valley, Croatia

Sara Pajalić, Petra Đomlija, Vedran Jagodnik and Željko Arbanas

11:30-11:45 Small Flume Experiment on the Influence of Inflow Angle and Stream Gradient on Landslide-Triggered Debris Flow Sediment Movement

Hefryan Sukma Kharismalatri, Yoshiharu Ishikawa, Takashi Gomi, Katsushige Shiraki and Taeko Wakahara

11:45-12:00 Relative Landslide Risk Assessment for the City of Valjevo

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

12:00-13:30

Lunch and Open Session III (12:30-13:30): Landslide risk management, an integrated approach in time (Club CD)

13:30-15:00

Room Club CD: Round Table Discussion: Review of WLF4 and Forum development towards WLF5

Chairs: *Giuseppe Arduino and Peter Bobrowsky*

Panelists:

Matjaž Mikoš, Forum Chair

Kyoji Sassa, Coordinator for Theme 1 Sendai Partnerships 2015-2025

Binod Tiwari, Coordinator for Theme 2 Advances in Landslide Science

Željko Arbanas, Coordinator for Theme 3 Advances in Landslide Technology

Nicola Casagli, Coordinator for Theme 4 Diversity of Landslide Forms

Vít Vilímek, Coordinator for Theme 5 Landslides in Different Environments

Participants from SP Signatory organizations

Concluding remarks:

Qunli Han, Chair of IPL Global Promotion Committee

Yueping Yin, President of the International Consortium on Landslides

15:30-16:30

Room Club CD: WLF4 Closing Ceremony

- Speech by the new President of ICL (2018.1.1-2020.12.31), *Peter Bobrowsky*
- Announcement of the ICL-WLF4 Distinguished Student Award and awarded by ICL President *Yueping Yin*
- Announcement of the best photo in each category awarded by Forum Chair *Matjaž Mikoš*
- Introduction of new ICL officers by the New President (2018.1.1-2020.12.31), *Peter Bobrowsky*
- Certificates to leaders of New IPL Projects by *Qunli Han* of UNESCO, chair of IPL-GPC
- Certificates to new ICL members (2014-2017) by ICL President *Yueping Yin*
- Welcome to 5th WLF by *Kyoji Sassa*, WLF5 Forum Chair

WLF 4 side events

WLF5 Kyoto 2020 Organizing Committee Meeting 16:00-18:00 on 31 May 2017, Room: Club CD

Chairs: *Kyoji Sassa*, *Peter Bobrowsky* and *Kaoru Takara*

All landslide researchers from the WLF4 participants who are willing to join the WLF5 organizing committee and organize sessions in WLF5 are invited. We may discuss the process of organization of WLF5 required from May 2017 till November 2020.

MOP delavnica "Obvladovanje naravnih nesreč večjega obsega v Sloveniji" 08:30-12:30 on 31 May, 2017, Room: E4

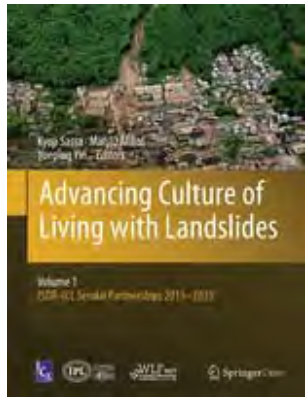
IGS Workshop "Geosynthetics for slope stabilization" 13:30-17:00 on 1 June, 2017, Room: E4

IAEG Commission 37 on Landslide Nomenclature 17:15-19:00 on 1 June, 2017, Room: E4

WLF4 Abstracts Proceedings

Details about the Volume number and Page number given for each abstract are taken from Springer books

Volume 1: ISDR-ICL Sendai Partnerships 2015–2025



Part I: ISDR-ICL Sendai Partnerships 2015–2025

larger wave crest than the wave trough while loose material shows a dam-break type behaviour with a LGW having a larger wave trough. A real case of SALGW is simulated by both models. The maximum LGW height predicted by the 2LCMFlow model which is closer to the physics is about 14% less than the equivalent value predicted by the LS3D model. On the other hand, the LS3D model, with the 4th order of accuracy of wave dispersion, simulates the LGW propagation stage more efficiently and with around 30% less runtime. Assessing the effects of the landslide initial submergence on the LGW characteristics shows that a semi-submerged, a submarine, and a subaerial landslide induce the largest wave crest, wave trough, and landslide runout distance, respectively. Combining different conceptual and mathematical models at the various stages of SALGWs initiation, propagation, transformations andrun-up can advance the current numerical practice, in this field, both from accuracy and computational efficiency point of views.

Rockfall Occurrence and Fragmentation, page 75

Jordi Corominas, Olga Mavrouli, and Roger Ruiz-Carulla

Abstract: Rockfalls are very rapid and damaging slope instability processes that affect mountainous regions, coastal cliffs and slope cuts. This contribution focuses on fragmental rockfalls in which the moving particles, particularly the largest ones, propagate following independent paths with little interaction among them.

The prediction of the occurrence and frequency of the rockfalls has benefited by the rapid development of the techniques for the detection and the remote acquisition of the rock mass surface features such as the 3D laser scanner and the digital photogrammetry. These techniques are also used to monitor the deformation experienced by the rock mass before failure. The quantitative analysis of the fragmental rockfalls is a useful approach to assess risk and for the design of both stabilization and protection measures. The analysis of rockfalls must consider not only the frequency and magnitude of the potential events but also the fragmentation of the detached rock mass. The latter is a crucial issue as it affects the number, size and the velocity of the individual rock blocks.

Several case studies of the application of the remote acquisition techniques for determining the size and frequency of rockfall events and their fragmentation are presented. The extrapolation of the magnitude-frequency relationships is discussed as well as the role of the geological factors for constraining the size of the largest detachable mass from a cliff. Finally, the performance of a fractal fragmentation model for rockfalls is also discussed.

International Consortium on Landslides (ICL)—The Proposing Organization of the ISDR-ICL Sendai Partnerships 2015–2025, page 99

Kyoji Sassa, Yueping Yin, and Paolo Canuti

Abstract: The International Consortium on Landslides (ICL) was founded in January 2002 during the UNESCO-Kyoto University Joint IGCP symposium “Landslide Risk Mitigation and Protection of Cultural and Natural Heritage”. It proposed and adopted the Letter of Intent in 2005 during the 2nd UN World Conference on Disaster Reduction, Kobe, Japan, adopted the Tokyo Action Plan in 2006, and the ISDR-ICL Sendai Partnerships 2015-2025 in 2015. This paper describes the history of ICL from preparation to present in a table of the chronology of events since 1987-present including the organization of ICL until 2020 when the Fifth World Landslide Forum will be held in Kyoto, Japan.

United Nations Office for Disaster Risk Reduction (UNISDR)—UNISDR’s Contribution to Science and Technology for Disaster Risk Reduction and the Role of the International Consortium on Landslides (ICL), page 109

Chadia Wannous and German Velasquez

Abstract: The Sendai Framework for Disaster Risk Reduction 2015-2030 was agreed at the Third UN World Conference on Disaster Risk Reduction in Sendai, Japan in March 2015 and endorsed by the UN General Assembly in June 2015. The goal of the Sendai Framework is to prevent new and reduce existing disaster risk.

UNISDR coordinates and ensures synergies among the disaster reduction activities of the United Nations system and regional organizations and stakeholders

The role of science and technology in providing the evidence and knowledge on risk features prominently in the Sendai Framework. Expanding the interface between science, technology and policy is therefore essential for effective disaster risk reduction. In January 2016, UNISDR hosted the Science and Technology Conference on the Implementation of the Sendai Framework. The main outcome of the conference was the launching of the Science and Technology Partnership and the endorsement of the science and technology roadmap that outlines expected outcomes, actions, and deliverables under each of the four priority actions of the Sendai Framework.

Over the last twenty years, the majority of disasters have been caused by floods, storms, heatwaves and other weather-related events. Most of these disasters can cause landslides, which in turn cause hundreds of billions of dollars in damage and hundreds of thousands of deaths and injuries each year

The International Consortium on Landslides (ICL) 2015–2025 and The Sendai Partnerships promotes global understanding and reduction of landslide disaster risk. They will contribute significantly to the implementation of the science and technology roadmap by providing practical solutions and tools, education and capacity building, and communication and public outreach to reduce landslides risks.

United Nations Educational, Scientific and Cultural Organization (UNESCO)—UNESCO's Contribution to the Implementation of UNISDR's Global Initiative and ICL, page 117

Giuseppe Arduino, Rouhban Badaoui, Soichiro Yasukawa, Alexandros Makarigakis, Irina Pavlova, Hiroaki Shirai, and Qunli Han

Abstract: UNESCO operates at the interface between natural and social sciences, education, culture and communication, playing a vital role in constructing a global culture of resilient communities. UNESCO assists countries to build their capacities in managing disaster and climate risk and with their ability to cope with disasters. The Organization provides a forum for governments to work together and it provides essential scientific and practical advice in disaster risk reduction. UNESCO's programmes in relation to the International Strategy for Disaster Reduction (ISDR) cut across all of its areas of competence (education, natural and social sciences, culture and communication). Working alone or in collaboration with both UN Agencies and other scientific entities, UNESCO has been a catalyst for international, inter-disciplinary cooperation in many aspects of disaster risk reduction and mitigation. Since the establishment of ICL in 2002, UNESCO has continuously supported ICL's activities as a part of its contributions to ISDR, namely the Hyogo and now Sendai Frameworks for action.

United Nations University (UNU)—The United Nations University: Research and Policy Support for Environmental Risk Reduction, page 123

Jakob Rhyner

Abstract: The United Nations University (UNU) was established in 1973 in Tokyo, Japan, as the academic arm of the United Nations. In its role as a think tank for the UN system it engages in policy-relevant research to generate science-based knowledge and solutions to urgent global challenges across a variety of comprehensive themes. UNU's research focuses on three broad thematic clusters: Peace and Governance, Global Development and Inclusion as well as Environment, Climate and Energy. In addition, research is complemented by important themes in science, technology and innovation. Research is carried out by a global network of institutes and programmes (see. Fig. 1), each with a specific thematic focus. This paper provides an overview of United Nations University, with particular attention to one of its institutes, namely the Institute for Environment and Human Security (UNU-EHS) in Bonn, Germany.

World Meteorological Organization (WMO)—Concerted International Efforts for Advancing Multi-hazard Early Warning Systems, page 129

Jochen Luther, Alasdair Hainsworth, Xu Tang, John Harding, Jair Torres, and Margherita Fanchiotti

Abstract: Recent international agreements such as the Sendai Framework for Disaster Risk Reduction 2015-2030, the 2030 Agenda for Sustainable Development and the Paris Agreement have all recognized the importance of developing and operationalising multi-hazard early warning systems that integrate the specificities of single-hazard early warning systems in a holistic, systematic and coordinated manner to promote synergies and maximize efficiency. While much progress has been made in recent years towards the advancement of knowledge and practice related to early warning systems worldwide, the lack of multi-disciplinary and transboundary cooperation among and across communities of scientists, decision-makers and practitioners continues to be a key challenge for the successful establishment and operation of these systems. To address this gap, major international and national organizations have collaborated to establish the International Network for Multi-Hazard Early Warning Systems (IN-MHEWS), with the aim of facilitating knowledge sharing and capacity development for multi-hazard early warning systems around the globe. This paper presents an overview of advances and challenges in promoting a multi-hazard and systematic approach to early warning, as well as the aim, objectives and expected contributions of this newly established Network.

International Council for Science (ICSU)—On Future Challenges for the Integration of Science into International Policy Development for Landslide Disaster Risk Reduction, page 143

Irasema Alcántara-Ayala, Virginia Murray, Philip Daniels, and Gordon McBean

Abstract: In 2015 four UN landmark agreements were developed: the Sendai Framework for Disaster Risk Reduction 2015-2030 (hereafter referred to as the Sendai Framework); the agenda related to Financing for Development; the Sustainable Development Goals and the Paris Agreement on Climate Change. These can be regarded as the main guiding documents to galvanise action to address the new or emerging global challenges.

The Science and Technology community are asked to support the implementation of the Sendai Framework, in order to prevent new and reduce existing disaster risk' by 'enhancing the scientific and technical work on disaster risk reduction and its

mobilization through the coordination of existing networks and scientific research institutions at all levels and all regions with the support of the UNISDR Scientific and Technical Advisory Group (STAG)' (UNISDR 2015a, Paragraph 25g).

Within the Sendai Framework agenda, the commitment of STAG and the Integrated Research on Disaster Risk Program (IRDR) is focusing the integration and collaboration between science, policy and practice. IRDR is a multi-disciplinary, all-hazards approach, supported by the International Council for Science (ICSU), the International Social Science Council (ISSC) and the United Nations Office for Disaster Risk Reduction (UNISDR), to strengthen capacity at global, regional and local levels to address hazards and generate science-based decisions on actions to reduce their impact (IRDR 2013).

Along the line of critical actions identified by STAG and IRDR, particular efforts are being undertaken by the International Consortium on Landslides (ICL) to understand the configuration of landslide disaster risk and reduce its impacts. ICSU, via IRDR, as one of the voluntary signatories of the International Strategy for Disaster Reduction–International Consortium on Landslides (ISDR-ICL) Sendai Partnerships 2015-2025 for Global Promotion of understanding and reducing landslide disaster risk, is committed to enhance such endeavours. In this paper, attention is drawn to identifying some of the main future challenges for the integration of science into local, national, regional and international policy development for Landslide Disaster Risk Reduction within the Sendai Framework.

Kenichi Tsukahara

Abstract: In the Sendai Framework, the importance of coordination mechanisms within and across sectors and with relevant stakeholders at all levels is stressed. Engineers are working for disaster risk management in the public sector, private sector, and community. Thus, the World Federation of Engineering Organizations (WFEO), which represents the engineering profession worldwide, should take an important role in achieving the goals of the Sendai Framework. This paper explains what WFEO and WFEO's committee on disaster risk management (CDRM) are, and activities of CDRM in achieving goals of the Sendai Framework.

Roland Oberhänsli, Yurijo Ogawa, and Marko Komac

Abstract: This paper gives an overview of the International Union of Geological Sciences (IUGS) activities that are related to the geologically related events – geohazards that pose risk to contemporary society. As geohazards are common events, IUGS has established an initiative with the aim to address the issue from a geological perspective and consequentially enable more holistic approach to the geohazds, including understanding processes, approaching them with the most effective solutions and educating public.

Alik Ismail-Zadeh

Abstract: Science-driven approaches to disaster risk reduction and management can help communities and governments become more resilient and reduce the human and economic impacts of disasters. The International Union of Geodesy and Geophysics (IUGG) promotes international scientific research and cooperation in natural hazards and disaster risks, and contributes to development of sound scientific knowledge on hazards, based on monitoring of physical phenomena and integrated observations, analysis, and modeling. IUGG makes scientific information available to people, and bridges advanced science with policymaking via international and intergovernmental programs. This report describes the union's major activities in the area of hazard and risk research and considers potential contribution of IUGG to the Sendai Partnerships. The contribution could include assessments of landslide hazards and risks; development of a scientific background to high-precision early warning systems for landslides; geophysical and geodetic monitoring of landslides; analysis and modeling of landslides and other rapid land movements; and relevant science education and capacity building.

Setsuko Saya

Abstract: The Disaster Management Bureau of the Cabinet Office of Japan has a mandate to coordinate policies and systems for all phases of disaster risk reduction in Japan. The bureau took a key role to host the the Third UN World Conference on Disaster Risk Reduction (WCDRR), which was held in Sendai City, Miyagi Prefecture, 14-18 March, 2015. Japan has suffered from various disasters, including earthquakes, volcanic eruptions, floods, landslides, tsunamis and others and took active roles in

international cooperation for disaster risk reduction at the World Conference on Natural Disaster Reduction in Yokohama, Japan in 1994, the World Conference on Disaster Reduction in Kobe, Japan in 2005 and the World Conference on Disaster Risk Reduction in Sendai, Japan in 2015. At the WCDRR in Sendai, Japan, the Government of Japan advocated the importance of "mainstreaming DRR (Disaster Risk Reduction)". The Cabinet office encouraged and supported the International Consortium on Landslides (ICL) to propose the ISDR-ICL Sendai Partnerships 2015-2025 as a voluntary commitment to the WCDRR.

Disaster Prevention Research Institute (DPRI), Kyoto University, page 179

Kaoru Takara

Abstract: This article describes an outline of the Disaster Prevention Research Institute (DPRI), which was established in Kyoto University in 1951, including its mission and objectives in terms of research, education and social contributions. Brief history of DPRI, as well as that of Research Centre on Landslides (RCL), is also given in relation with domestic and international activities such as the Natural Disaster Research Council (NDRC), designated COE programs, a Leading Graduate Schools Program (GSS), the International Decade for Natural Disaster Reduction (IDNDR), UNESCO-KU-ICL UNITWIN Program, UNESCO International Hydrological Program (IHP), Science and Technology Research Partnership for Sustainable Development (SATREPS) projects, Japan-ASEAN Science, Technology and Innovation Platform (JASTIP) and the Global Alliance of Disaster Research Institutes (GADRI).

Understanding and Reducing Landslide Disaster Risk: Challenges and Opportunities for Italian Civil Protection, page 185

Pagliara Paola, Onori Roberta, and Ambra Sorrenti

Abstract: This work provides an overview of the hydraulic and hydrogeological warning system, starting with a description of the tasks carried out by the Italian Civil Protection Department and in an Italian context. The Italian early warning system was put in place with the intent of following a specific approach, also confirmed by the Sendai Framework, that has shifted its focus towards Disaster Risk Management (DRM) as opposed to Disaster Management. The aim of the paper is to stress the challenge and the relevance of the approach to reducing landslide risk, which requires the involvement of many actors, including scientists and decision makers, as well as international, national, local, governmental, and non-governmental institutions, to find, develop and share new and best practices in the technical-scientific and regulation fields in order to make the necessary tools and instruments available to carry out the challenging tasks defined in the Sendai Framework toward real Disaster Risk Reduction.

Landslide Dynamics: ISDR-ICL Landslide Interactive Teaching Tools (LITT), page 193

Kyoji Sassa, Fausto Guzzetti, Hiromitsu Yamagishi, Željko Arbanas, Nicola Casagli, Binod Tiwari, Ko-Fei Liu, Alexander Strom, Mauri McSaveney, Eileen McSaveney, Khang Dang, and Hendy Setiawan

Abstract: The International Consortium on Landslides (ICL) and ICL supporting organizations jointly established the ISDR-ICL Sendai Partnerships 2015-2025 which is the voluntary commitment to the Sendai Framework for Disaster Risk Reduction 2015-2030. As the core activity of the Sendai Partnerships, ICL has created "Landslide Dynamics: ISDR-ICL Landslide Interactive Teaching Tools", which are always updated and continuously improved, based on responses from users and lessons during their application. This paper describes the aim, outline, the contents of Text tools, PPT tools for lectures and PDF tools including already published reference papers/reports, guidelines, etc. Core parts of two fundamentals of the Teaching Tools, namely 1. Landslide types: description, illustration and photos, and 2. Landslide Dynamics for Risk Assessment are introduced.

Progress of the World Report on Landslides, page 219

Biljana Abolmasov, Teuku Faisal Fathani, KoFei Liu, and Kyoji Sassa

Abstract: The IPL World Reports on Landslides (WRL) database is created as a cooperation platform for sharing landslide case studies and the best practice in the global landslide community. ICL and IPL wishes to promote and publish global landslide information using the ICL/IPL network for the ISDR-ICL Sendai Partnership 2015-2025 and the Sendai Framework for Disaster Risk Reduction 2015-2030 through WRL activities were assigned as one of priority action. World Report on Landslides data base contains 40 submitted reports on landslide cases over the world. The best rating reports are accessible for world-wide landslide community as open access data, as well as all basic reports. In this paper results of ICL/IPL World Report on Landslides Commeetee members and related activities from 2010 to 2016 are presented.

Part II: International Programme on Landslides (IPL)

Mechanisms of Landslides and Creep in Over-Consolidated Clays and Flysch (WCoE 2014–2017), page 279

Matjaž Mikoš, Janko Logar, Matej Maček, Jošt Sodnik, and Ana Petkovšek

Abstract: The Faculty of Civil and Geodetic Engineering of the University of Ljubljana (UL FGG), Slovenia, Europe, was voted in 2014 at the 3rd World Landslide Forum in Beijing, China to be one of the 15 new World Centres of Excellence (WCoE) in Landslide Disaster Reduction for the period 2014 to 2017. This successful nomination followed the period 2011-2014, in which UL FGG successfully fulfilled the role as one of the WCoEs for the second time. The title of the activities of the WCoE in this third term was slightly modified to be "Mechanisms of Landslides and Creep in Over-Consolidated Clays and Flysch".

We can divide the activities of the WCoE at UL FGG into international and national research activities. The international ones consisted of the ICL related activities with the main task of being the main organizer of this 4th World Landslide Forum 2017, international cooperation, European research activities, and bilateral cooperation. The national ones consisted of the national projects and the national research program "Water Science and Technology, and Geotechnics". In the paper, these activities of the WCoE at UL FGG are elaborated in more detail, with a comprehensive list of publications to show the dissemination and capacity building efforts.

Research on Heavy-Rainfall-Induced and Hydraulic-Driven Geological Hazards in China (WCoE 2014–2017), page 291

Yueping Yin, Yongqiang Xu, and Wenpei Wang

Abstract: China Geological Survey (CGS) is one of the 15 new World Centres of Excellence (WCoE) in Landslide Disaster Reduction for the period 2014 to 2017. The title of the activities of the WCoE has been "Scientific research for mitigation, preparedness and risk assessment of landslides" since 2008, due to the complex conditions for the occurrence of geohazards in China. The Center of Geohazards Emergency of Ministry of Land Resources, which is directly under CGS, is responsible for the emergency response to major geohazards nationwide, including survey and investigation, monitoring and warning, risk assessment, prevention, training, and information systems. In this paper, the important activities of CGS are elaborated. The research project entitled "Research Project on the Early Recognition and Warning on Heavy Rainfall-Induced and Hydraulic-Driven Geological Hazards in China" was conducted from 2011 to 2015. From 2015 to 2017, a new project on mechanisms and hazards patterns of hydraulic-driven landslides has been conducted by the Center of Geohazards Emergency, China Geological Survey.

Landslide Risk Reduction in Croatia: Scientific Research in the Framework of the WCoE 2014–2017, IPL-173, IPL-184, ICL ABN, page 301

Snježana Mihalić Arbanas, Željko Arbanas, Martin Krkač, Sanja Bernat Gazibara, Martina Vivoda Prodan, Petra Đomlija, Vedran Jagodnik, Sanja Dugonjić Jovančević, Marin Sečanj, Josip Peranić and Research Committee on Elucidating Mechanisms of Large-Scale Landslides

Abstract: In this paper scientific activities of the Croatian Landslide Group (CLG), World Centre of Excellence on Landslide Risk Reduction (WCoE) of the International Consortium on Landslide (ICL) for the period 2014-2017, are shortly described. The results of scientific research are presented through the fields of landslide science: landslide identification and mapping, landslide investigation and testing, landslide monitoring, landslide modelling and landslide stabilization and remediation. It is concluded that the resulting landslide inventory maps, regional empirical rainfall intensity-duration thresholds, kinematic landslide models and soil strength parameters, landslide movement prediction models, numerical models and simulations and behavior of geotechnical construction for landslide stabilization provide necessary information for landslide risk management in Croatia. Besides applied scientific research, the general objectives of ICL WCoE are achieved in the framework of two Croatian IPL Projects and regional ICL Adriatic-Balkan Network.

Shapes and Mechanisms of Large-Scale Landslides in Japan: Forecasting Analysis 800 from an Inventory (WCoE 2014–2017), page 317

S. Ogita, W. Sagara, and D. Higaki and Research Committee on Elucidating Mechanisms of Large-Scale Landslides

Abstract: Large-scale landslides with widths and lengths of 1 km or more have been reported in many parts of the world. Occurrences of large-scale landslides have recently tended to increase due to climate change and frequent seismic activity. To conduct research on proper measures for large-scale landslides, elucidation of the occurrence mechanism, for which there are as yet many unclear points, will be required in future. The Japan Landslide Society established a research committee that worked from 2011 to 2014 to elucidate the occurrence mechanisms of large-scale landslides. Analysis of examples of large-scale landslides collected from members of the research committee showed that a volume of moving body larger than 1×106 m3 and a maximum landslide thickness of more than 30 m are appropriate as the definition of a large-scale landslide. The shape of a large-scale landslide depends on the geology and age of the landslide site, and landslide activity and history affect the symmetry of the

shape of a landslide. This paper presents some results of the WCOE (2014-2017) project titled "Emergency response support system for large-scale landslide disasters" by the Japan Landslide Society.

Retrospective and Prospects for Cold Regions Landslide Research (2012–2016) (WCoE 2014–2017, IPL-132, IPL-167, IPL-203, CRLN), page 327

Wei Shan and Ying Guo

Abstract: For nearly 100 years, the average temperature of the global surface has showed a consistent warming trend. Climate change and extreme weather events causing landslides are rising, especially landslides in cold regions, and the topic has become a hot issue in landslide research. With the support of ICL and the Chinese government, based on highway construction projects in Heilongjiang Province (China), Prof. Shan and his group (Institute of Cold Regions Science and Engineering, North East Forestry University, China) conducted thematic studies focusing on environmental and engineering geology problems in cold regions in the context of climate change, such as IPL132, IPL167, and IPL203.These studies attracted the interest of international colleagues, then Chinese colleagues, together with researchers from Russia, Canada, Japan, Italy and Czech Republic, together organized the ICL-cold regions landslide network (ICL-CRLN). In ICL-CRLN researchers could exchange research information and results, and so promote the development of landslide research in cold regions. In 2014, IPL-GPC approved the establishment of IPL-WCoE: Research Center of Cold Regions Landslide, so landslide research in cold regions came into a new stage of development. This article is a summary and outlook of these activities.

Large-Scale Rockslide Inventories: From the Kokomeren River Basin to the Entire Central Asia Region (WCoE 2014–2017, IPL-106-2), page 341

Alexander Strom and Kanatbek Abdrakhmatov

Abstract: Large-scale bedrock landslides are among the most hazardous natural phenomena posing a threat to communities living in mountainous regions and in the river valleys there. Their study requires regular mapping of past features and compilation of uniform and representative inventories. This paper presents the main activities of the World Center of Excellence on Landslide Disaster Reduction of the Geodynamics Research Center – branch of JSC "Hydroproject Institute" (Moscow, Russia) and of the Kyrgyz Institute of Seismology (Bishkek, Kyrgyzstan). Their activities include compilation of a landslide inventory for the Kokomeren River Basin in Central Tien Shan, where the annual Kokomeren Summer School on Rockslides has been carried out since 2006, and of the uniform inventory of large-scale bedrock landslides (rockslides) for the entire Central Asia region, including the Djungaria, Tien Shan and Pamir mountain systems. Basic principles of rockslides identification and the structure of the database are described in brief.

Interventions for Promoting Knowledge, Innovations and Landslide Risk Management Practices Within South and Southeast Asia (WCoE 2014–2017), page 341

Peeranan Towashiraporn and N.M.S.I. Arambepola

Abstract: Asia is a dynamic nexus of economic and social change, with population growth, industrialisation and urbanisation playing a large part in shaping the exposure of communities to hydro-meteorological as well as geologic hazards. Among them, landslides have become most widespread and commonly observed events throughout South and Southeast Asia. Recent incidents triggered by South Asian monsoons affected by El Niño resulted in devastating landslides in many countries in Asia. Realizing the essential need for landslide risk reduction, the Asian Disaster Preparedness Center (ADPC) implements an umbrella program, namely the Asian Program for Regional Capacity Enhancement for Landslide Impact Mitigation (RECLAIM) to undertake various measures for landslide risk mitigation such as pilot demonstration projects, capacity building programs for the stakeholder institutions through regional and national level training courses, networking events for experience sharing.

This paper presents some of the needs and gaps in the region and initiatives undertaken by the Asian Disaster Preparedness Center (ADPC) through its programs to address them. In acknowledgement of the initiatives being undertaken for landslide disaster risk reduction in Asia, the International Consortium of Landslides (ICL) has recognized ADPC to be one of the World Centers of Excellence (WCoE).

Promoting a Global Standard for Community-Based Landslide Early Warning Systems (WCoE 2014–2017, IPL-158, IPL-165, page 357

Teuku Faisal Fathani, Dwikorita Karnawati, and Wahyu Wilopo

Abstract: The implementation of early warning systems is in line with the Sendai Framework for Disaster Risk Reduction (SFDRR) 2015-2030. One of the four priorities of the Sendai Framework for Action emphasizes the improvement of preparedness in response to a disaster by carrying out a simple, low-cost early warning system and improving its dissemination. A new proposal of a standard for community-based landslide early warning systems has been promoted to the International Organization for Standardization (ISO) by Universitas Gadjah Mada, in corporation with the Indonesian Standardization Agency and the Disaster Management Authority. The standard will serve to empower individuals and communities who are vulnerable to

landslides to act in sufficient time in appropriate ways to reduce the possibility of injuries, loss of life and damage to property and the environment. It is designed to encourage communities to play a much more active role in their own protection. The guidelines adopted the concept of people-centered early warning system by UNISDR (2006) and will be used by communities vulnerable to landslides, and by government agencies and non-governmental organizations at central, provincial, municipality/district, sub-district, and village levels. The recommendations include: (1) Risk assessment; (2) Dissemination and communication; (3) Formation of disaster preparedness and response teams; (4) Development of evacuation maps; (5) Development of standard operating procedures; (6) Monitoring, early warning, and evacuation drills; (7) Commitment of the local authority and community to maintain the system. The standard will be developed by ISO/TC 292 Security and resilience, with the participation of 43 countries in the committee's work and another 14 as observers. The basic concept of this global standard has been initiated since 2007 through the Asian Joint Research on Early Warning of Landslides proposed by International Consortium on Landslides (ICL) and Disaster Prevention Research Institute (DPRI) Kyoto University and funded by JST and implemented in Indonesia, China, Korea and Japan. This paper describes the achievements and the current activities of the World Centre of Excellence (WCoE) on Landslide Risk Reduction (2014-2017), IPL Project (IPL-158) "Development of community-based landslide early warning system", and IPL Project (IPL-165) "Development of community-based landslide hazard mapping for landslide risk reduction at the village scale in Java, Indonesia".

Model Policy Frameworks, Standards and Guidelines on Landslide Disaster Reduction (WCoE 2014–2017), page 365

A.A. Virajh Dias, Nimesha Katuwala, H.M.J.M.K. Herath, P.V.I.P. Perera, K.L.S. Sahabandu, and N. Rupasinghe

Abstract: The Central Engineering Consultancy Bureau (CECB) has been approved and designated as one of the "World Centres of Excellence on Landslide Disaster Reduction 2014-2017" under the theme of "Model Policy Frameworks, Standards, and Guidelines on Landslide Disaster Reduction" by the Global Promotion Committee of the International Consortium on Landslides (ICL) at the award ceremony of the World Landslide Forum 3 in Beijing, China. The above theme is divided into three thematic areas: first, Developing Conceptual Policy Frameworks to Understand the Causes, Effects and Mitigatory Measures of Landslide Occurrences, secondly to Implement Applicable Guidelines/Teaching Tools to Establish Essential Synergies in Landslide Disaster Phenomena, and thirdly to Originate Pertinent Standards for Humanitarian Activities in support of Effective Risk Reduction and Mitigations on Landslide Occurrences. The amalgamation of these three areas will originate a successive approach to developing a master plan for disaster risk reduction as a cost-effective investment in preventing future losses.

The proposal for WCoE submitted by CECB was mainly focused on continuing IPL research activities, building up global partnerships and regional networks and conducting national projects and awareness programmes on Landslide Risk Reduction. This paper illustrates the above activities in a more comprehensive and descriptive manner.

Landslide Hazard and Risk Management (WCoE 2014–2017), page 375

Josef Stemberk, Vít Vilímek, Jan Klimeš, Jan Blahůt, Filip Hartvich, and Jan Balek

Abstract: The World Centre of Excellence (WCoE) on Landslide Risk Reduction entitled "Landslide risk assessment and development guidelines for effective risk reduction" (2014 – 2017) was designed to contribute to the risk reduction effort formulated in the Sendai Partnership initiative. Several research activities were developed and their results were presented to a broad public through a series of articles, informative web pages and documentary movies. The research focused on improving landslide hazard assessment in a variety of natural environments, including deep-seated as well as shallow landslides. Landslide hazard assessment was applied practically through development projects in Ethiopia and Peru. Within the scope of the WCoE we proposed and conducted two projects of the International Program on Landslides (IPL). One of them is dedicated to compilation and analysis of glacial lake outburst floods (Database of glacial lake outburst floods (GLOFs) – project No. 179) at the global level. This potentially highly damaging natural phenomenon combines characteristics of floods and debris flows and often also involves landslides in the initiation process. The other IPL project focuses on the main challenges of landslide risk reduction in the Czech Republic (Challenges for landslide hazard and risk management in "low risk" regions, Czech Republic, IPL project No. 197), which is a country with abundant landslide-related knowledge and rather low annual occurrence frequencies. Despite that, landslides cause considerable damage and financial losses, which often could be prevented if the available hazard information were to be used.

Mitigation of Landslide Hazards in Ukraine Under the Guidance of ICL: 2009–2016 (IPL-153, IPL-191), page 381

Oleksander Trofymchuk, Iurii Kaliukh, Silchenko Konstantin, Viktoriia Berchun, Taras Kaliukh, and Iaroslav Berchun

Abstract: More than 90% of the territory of Ukraine has complex soil conditions. The number of landslides has increased by a factor of 1.3 in the last 15 years, and by a factor of about 3 over the last 30 years. Ukraine became a member of ICL only in 2009. The main task of Ukrainian division of ICL (UDICL) from 2009 to 2016 was and still is the implementation of the National Plan (the State Programme) on lanslide hazards mitigation. Because of a lack of governmental or any other support during the above

years, UDICL has managed to carry out only two projects and is working on one more on a voluntary base. Objectives of the first IPL project were to determine the slopes with a landslide hazard in the Kharkiv region of Ukraine; to develop a database containing the engineering-geological information relevant to descriptors of landslide sites; and to develop targeted GIS on landslides in the Kharkiv region. All the goals of the project were achieved. In 2012–2014 IPL 153 project was implemented: information about landslide protection structures and measures was collected and structured, prospects of their development in the Autonomous Republic of the Crimea of Ukraine (ARCU) were studied, and the target database was created. Since 2015 "Landslide hazard zonation using GIS", the IPL 191 project, is being realized. The main goal of the project was to develop an instrument for landslide hazard forecasting to minimize the impact of landslide activation on people and tangible objects for the Carpathian region of Ukraine. Two Ukrainian standards of construction objects monitoring and building in the landslide sensitive areas will be completed and put into effect in 2017–2018. UDICL plans a training programme concerning these building standards for more than 1000 designers from all the regions of Ukraine.

Development of a Hazard Evaluation Technique for Earthquake-Induced Landslides Based on an Analytic Hierarchy Process (AHP) (IPL-154), page 389

Daisuke Higaki, Eisaku Hamasaki, and Kazunori Hayashi

Abstract: In this study, we developed a hazard evaluation technique for earthquake-induced landslides that is based on topographical and geological factors extracted by an analytic hierarchy process (AHP). Several past earthquake cases that have caused multiple landslides in Japan were analyzed. With this method, through buffer movement analysis, we were able to obtain factor data on the respective sizes of terrain impacted by landslides and the magnitude of the landslides in the target area. In addition, we incorporated a method to provide predictive values for the evaluation through blunder probability analysis. The area distribution of the coherent landslides following the Mid-Niigata Prefecture Earthquake in 2004 corresponded well with the high-scoring areas derived by our evaluation model. This paper presents the results of the IPL project (IPL-154) titled "Development of a methodology for risk assessment of the earthquake-induced landslides".

The Croatian-Japanese SATREPS Joint Research Project on Landslides (IPL-161), page 397

Željko Arbanas, Snježana Mihalić Arbanas, Kyoji Sassa, Hideaki Marui, Hiroshi Fukuoka, Martin Krkač, Martina Vivoda Prodan, Sanja Bernat Gazibara, and Petra Đomlija

Abstract: The Croatian-Japanese joint research Science and Technology Research Partnership for Sustainable Development (SATREPS) project 'Risk Identification and Land-Use Planning for Disaster Mitigation of Landslides and Floods in Croatia' was performed from 2009 to 2014. Key objectives of the project were landslides and floods hazard analysis and the development of guidelines for use in urban planning. This project is also designated as on-going IPL project 161. The aims of the working groups dealing with landslides were to establish a methodology of comprehensive real time monitoring at two most important landslides in Croatia based on the results of previous investigations and new in situ and laboratory testing and behavior analysis; laboratory soil testing and numerical modelling of static and dynamic landslide behavior; development of landslide inventories using direct sensing and remote sensing techniques followed by the development of methodologies of landslide hazard analysis and zonation in three pilot areas in Croatia. In this paper we will present the most important achievements of working groups related to landslide studies at the project pilot areas: two in Primorsko-Goranska County (the Rječina River Basin and the Dubračina River Basin) and one in the City of Zagreb (a hilly area of Medvednica Mt.). The identification and mapping of existing landslides in the hilly area of Medvednica Mt., Dubračina River Basin and Rječina River Basin so as establishment and results of the monitoring systems installed on the Grohovo Landslide and the Kostanjek Landslide will be described.

Results of a Technical Cooperation Project to Develop Landslide Risk Assessment Technology Along Transport Arteries in Vietnam (IPL-175), page 413

Dinh Van Tien

Abstract: Like other South-East Asia countries, Vietnam is a country with mountainous terrain, complicated geological structure and high rainfall, and as a result, landslides occur regularly, with serious consequences for the mountain road networks in the rainy season. Due to economic difficulties and a lack of deep knowledge of the phenomena, activities to prevent and mitigate landslides are not effective. The SATREPS project of research cooperation between Japanese and Vietnamese researchers in the years 2011 to 2016 has not only helped Vietnam in the development of human resources, research equipment and development of a standard system of landslide investigation, monitoring, forecast and early warning, but has also contributed to disaster prevention and reduction in Vietnam in the future.

This project is considered as a success for a new landslide-training tool, in cooperation with Asia members of the International Consortium on Landslides (ICL), especially South-East Asia countries, for the mitigation of natural disasters.

Study of Slow Moving Landslide Umka Near Belgrade, Serbia (IPL-181), page 421

Biljana Abolmasov, Miloš Marjanović, Svetozar Milenković, Uroš Đurić, Branko Jelisavac, and Marko Pejić

Abstract: The IPL project No 181 titled "Study of slow moving landslide Umka near Belgrade" started in November 2012. The study area is located on the right bank of Sava River, 25 km south west of Belgrade, Serbia. The basic objective of the Project was to enable the analysis, correlation and synthesis of data obtained from various phases of investigation of Umka landslide after 35 years of research. Apart from this, the analysis of data from monitoring conducted during certain phases of research was compared with data from automated GNSS monitoring over the last six years, although during numerous investigations various research methods were used for research and monitoring. The project was focused on: analysis of previous detail site investigations and field instrumentation from 1990–2005, analysis of aerial photos and orthophoto images from 1957–2010, analysis of automated GNSS monitoring results from 2010 to end of the Project and analysis of precipitation and levels of the Sava River. Project beneficiaries are local community and local and regional authorities. In this paper we will present results of the proposed project targets performed by Project participants.

Influence of Post-Earthquake Rainfall on the Stability of Clay Slopes (IPL-192), page 431

Binod Tiwari, Beena Ajmera, and Duc Tran

Abstract: Rainfall and earthquakes are considered two of the major causes of landslides worldwide. These landslides cause billions of dollars in property damage and revenue losses, as well as the deaths of thousands of people each year. While researchers have been examining the effect of either rainfall or earthquakes on the deformation and stability of slopes, the combined effect of rainfall and earthquakes on deformation and slope stability has not been evaluated systematically. In this study, a series of model slopes were constructed in a Plexiglas container placed on top of a shake table. The model slopes were prepared to have different initial void ratios of 0.89, 1.0 and 1.2 and various slope inclinations of 30°, 40°, and 45°. These slopes were instrumented with accelerometers, tensiometers and inclinometers and subjected to a number of sinusoidal seismic motions with different seismic accelerations from 0.1 g to 0.3 g, with several frequencies ranging from 1 Hz to 3 Hz for various durations ranging from 10 cycles to 50 cycles of loading. Following the earthquake event, a rain simulator system was used to induce rainfall at intensities of either 18 mm/hour, 30 mm/hour or 60 mm/hour. The seepage velocity, spatial variation of suction and the deformation of the slopes were determined. The results obtained were compared to those obtained from similar slopes subjected to rainfall without an earthquake event. The study showed that the seismic shaking resulted in a reduction in the seepage velocity in the slope, which led to an increase in the factor of safety of the slope with time.

Public Awareness and Education Programme for Landslide Management and Evaluation Using a Social Research Approach to Determining "Acceptable Risk" and "Tolerable Risk" in Landslide Risk Areas in Malaysia (IPL-194, IPL-207), page 439

A. Rashid Ahmad, Zainal Arsad Md Amin, Che Hassandi Abdullah, and Siti Zarina Ngajam

Abstract: Although early records of landslides in Malaysia have existed since the beginning of the last century, national attention on landslides increased in earnest in the wake of the 1993 Highland Towers landslides. In 2003, an economically devastating rockslide in Bukit Lanjan led to the establishment of the Slope Engineering Branch (Cawangan Kejuruteraan Cerun – CKC). One of CKC's first achievements upon formation was to carry out a National Slope Master Plan study to reduce risks and losses from landslides. One of the studies explores and devises methods for assessing risk that combine traditional and risk-based approaches. It introduces a risk assessment-based approach that looks beyond the fulfilment of Factors of Safety; it evaluates a slope based on its risk or probability of slope failure occurrence and assesses the consequence or damage caused by the failure. Most significantly, it compares the derived risk assessment results with the acceptable risk level of the public and residents. In essence, it becomes a decision-making tool for slope planners and developers to determine whether to proceed with the construction of a new slope or how much mitigation work should be put into an existing failing slope. One of the study components, Public Awareness and Education, launched a national awareness and education campaign to get create awareness of landslide risks and mobilize various stakeholders in the public, private, civil society and community levels into taking proactive measures for mitigation and prevention. It culminated in a programing conveying four main key messages, which are "Learn, Monitor, Maintain and Report".

Geotechnical Site Characterization of a Mud Eruption Disaster Area Using CPTu for Risk Assessment and Mitigation (IPL-195), page 451

Paulus P. Rahardjo, Adityaputera Wirawan, and Andy Sugianto

Abstract: A mud eruption in East Java that occured on May 29, 2006 is well known worldwide. The mechanisms of the causes of the eruptions are still in debate, whether it was trigerred by gas well drilling or by pressurised fluid reactivated by the Jogjakarta earthquake of May 26, 2006. This debate is not the main issue in this report. Instead, this paper discusses mainly the results of CPTu tests recently conducted and mitigation and risk reduction.

The volume of the mud discharge is estimated at 5000 cubic meters. Dykes were constructed to contain the mud, which covered areas reaching 650 hectares (Sofyan 2015). The location of the disaster is in the middle of the town of Porong in the district of Sidoardjo, near Surabaya International airport, and mud has blocked the major arterial roads from north to south of East Java.

The soil condition of the site is deep soft clays which causes instability of the dykes. Some dyke failures occurred, endangering residential areas due to the flow of the mud (Rahardjo 2015). This paper describes the characterics of the soil conditions from a number of drillings and CPTu tests conducted by the authors for designing the replacement of the arterial road and for dyke reinforcement, and also in the middle of the mud. The paper discuss the geotechnical problems of land subsidence over large areas and differential settlement that cause damage to infrastructure, including roads, gas pipes, railways, bridges and buildings, and is of particular importance to the safety of the dykes. The mud has been discharged through the Porong River, and sedimentation is part of the problem.

Massive Landsliding in Serbia Following Cyclone Tamara in May 2014 (IPL-210), page 475

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.

Part III: Landslides and Society

Abstract: In Portugal, social impacts caused by landslides occurred in the period 1865-2015 are gathered in the DISASTER database. This database includes social consequences (fatalities, injuries, missing people, evacuated people and homeless people) caused by landslides documented in newspapers. The DISASTER database contains 291 damaging landslides that caused 238 fatalities. In this work we aim to: (i) analyse the spatio-temporal analysis of damaging landslides occurred in the last 155 years; (ii) analyse the frequency and the temporal evolution of fatal landslides; (iii) analyse the spatio-temporal distribution of landslide fatalities; (iv) identify the most deadly landside types; (v) verify gender tendencies in landslide mortality; and (vi) evaluate the individual and societal risk. Individual risk is evaluated computing mortality rates for landslides, which are calculated based on the annual average population and the annual average of fatalities. The societal risk is evaluated by plotting the annual frequency of landslide cases that generated fatalities. The results demonstrate the absence of any exponential growth in time of both landslide cases and landslide mortality in Portugal. The highest number of landslide cases and related mortalities occurred in the period of 1935-1969 in relation to very wet years. Most of landslide fatalities mainly occurred in the north of the Tagus valley where the geologic and geomorphologic conditions are more prone to landslides. The Lisbon area registered a mortality hotspot, which is explained by natural conditions combined with the high exposure of population to landslide risk. Falls and flows were responsible for the highest number of fatalities associated with landslides. Males were found to have the highest frequency of fatalities. In conclusion, the spatial patterns of landslide mortality can be related to the unequal distribution of predisposing conditions to landslides, changes in the land use and exposure and social vulnerability to landslide hazards.

Abstract: The State-Funded Landslide Project (SFLP) is a national program to systematically assess landslide susceptibility, hazard and risk for all of prone areas in Vietnam. Under this SFLP, in the first phase of SFLP (2012-2014), activities of landslide inventory mapping were implemented over the fourteen Northern mountainous provinces. As the achievements, 10,149 historic landslides were mapped by field surveys and 9,405 locations with landslide signs were interpreted from air-photos and analysis of 3D relief. Approximately 83% of the surveyed landslides locate in accessible areas, with small and medium dimensions and partly as a result of the slope cuts. About 76% of the interpreted landslides locate in inaccessible areas, and only 24% of the interpreted locate in accessible areas, of which 65% were found active landslides at the time of surveying, naturally occurred with large dimensions. However, the inventory exposes some major drawbacks: (1) The unavailability of multi-date air-photos; (2) The lack of human resources with enough experiences in image interpretation; (3) The difficulties of verifying the interpreted landslides, especially for the inaccessible sites; (4) Few or no sources of historic information due to the isolated sites or little memory of small or medium size events; (5) No updates developed by the surveyors after they finished their tasks. Those drawbacks can lead to the insufficiency of adequate data on the types, sizes and characteristics of the slope failures, especially the exact dates of occurrences. Despite of those difficulties, the achieved inventory database have been updated and then used as basic input for the susceptibility and hazard mapping as well as preliminary results of SFLP to inform the local authorities and communities about real situations of landslides in their areas.

Abstract: The Petra Archaeological Park (PAP), a World Heritage Site (WHS) since 1985, characterized by a spectacular geo-archaeological landscape, is also a fragile site facing a wide diversity of geological risks. Potential occurrence of rapid onset natural phenomena (landslides, flash floods, earthquakes) pose a major threat to the heritage as well as to the visitors. Since 2009, the UNESCO Office in Amman (UoA), in partnership with the Department of Antiquities of Jordan (DoAJ) and the Petra Archaeological Park (PAP) has, therefore, engaged in a long term strategy aimed at the prevention and mitigation of natural hazards at the site. In this framework, specific attention has been devoted to the case of the Petra Siq, a 1.2 km naturally formed gorge in the sandstone mountains serving as the only tourist entrance to the site, which is particularly at risk due to its narrow pathway, limited access points and recent active processes. Drawing on this approach, the UNESCO "Siq Stability" project has undertaken several steps to develop a strategy towards prevention and mitigation of instability phenomena at the Siq of Petra and, thus, further contribute to the management and conservation of the site. In the past years actions have been focussing on the

analysis of the stability conditions of the Siq slopes based on a comprehensive site documentation, the installation of an integrated monitoring system for the detection and control of deformation processes and the definition of mitigation measures against rock instability. The current phase of the project focuses on the following components: 1. Implementation of priority landslide mitigation interventions in the upper Siq plateau and on the Siq slopes to address immediate slope hazards in the short term; 2. Capacity development of the national authorities to address the management of landslide risk at the site and implement mitigation measures in coordination with international experts; 3. Awareness raising among different levels of stakeholders on the natural hazards occurring within the Petra Archaeological Park and specifically in the Siq. A strong focus has been placed on raising awareness among a broad set of stakeholders such as decision makers, governmental institutions, NGOs and UN agencies, professionals/researchers, site business beneficiaries, tour guides, children, local community. In fact, data gathered showed that awareness of natural risks preparedness and mitigation, mostly at the community level, can be the foundation for risk prevention in Petra. This study aims at demonstrating the essential role that risk identification, monitoring and awareness can play to address the challenges to which the Petra Archaeological Park is regularly exposed. Specific reference will be made to the role that stakeholders and local communities can play in the management of a geo-archaeological site, in particular in relation to disaster risk reduction. Main focus will be put on project activities undertaken, results achieved and suggestions for steps ahead, aiming to present a useful case study on the management of natural hazards applied to heritage sites leading to the conservation of a unique World Heritage property.

Case Histories for the Investigation of Landslide Repair and Mitigation Measures in NW Germany, page 521

Annika Wohlers, Thomas Kreuzer and Bodo Damm

Abstract: To understand the complex interactions between landslide risks, public and private risk awareness including land use practices and repair and mitigation measures in complete manner, case histories were developed and analyzed using the example of the highway network of the Lower Saxon Uplands, NW Germany. The case histories utilize datasets extracted from the German landslide database that includes valuable information of historical and current landslide impacts, elements at risk as well as land use practices and provide an overview of changes in social exposure and vulnerability to landslide hazards over the last 150 years. Most information within the database is gathered by means of archive studies from inventories of emergency agencies, state, press and web archives, company and department records as well as scientific and (geo)technical literature. Furthermore, the database contains data from various sources, including field surveys, climatic records, and satellite imagery. The database stores information related to landslide characteristics, dimensions and dynamics as well as data concerning the relationship of landslides to soil and lithologic properties, geomorphometry and climatic conditions. Beyond that, it includes information about land use effects, damage impacts and economic losses. For the developed case histories the recorded economic losses, maintenance, repair and mitigation costs were categorized and classified at representative landslide sites, according to relevant landslide types, processes, and damages, considering the usually applied repair and mitigation measures, geotechnical expertise and available resources. In a further step, the data of recent landslides are compared with historical and modern mitigation measures and are correlated with socioeconomic concepts. As a result, it is possible to identify some complex interactions between landslide hazard, hazard awareness and damage impact, including time lags, intensity thresholds, and even surprises. The case histories show that especially since the last 20 years public risk awareness raised due to an apparent increase in landslide frequency and magnitude at some sites. Before the 1990s landslide mitigation measures implemented low cost prevention measures such as the removal of loose rock and vegetation, rock blasting, catch barriers, and temporal or perpetual traffic lane closure. Recently there is a shift toward the implementation of expensive mitigation measures in order to minimize landslide occurrence. Local decision makers increasingly invest in expensive long-term stabilization projects like soil anchoring, rock nailing, and steel-reinforced concrete walls.

Surveying Perception of Landslide Risk Management Performance, a Case Study in Norway, page 529

Jessica Chiu and Unni Eidsvig

Abstract: The effectiveness of landslide risk management should be assessed to optimize the implementation of landslide risk mitigation measures. The Risk Management Index (RMI) of Cardona et al. (2004) provides useful procedures to holistically measure perceptions of risk management for natural hazards from selected actors. This paper uses Norway as a case study to present a modified RMI for surveying perceptions of landslide risk management at two time scenarios: 2015 (present) and 2050 (future), and for various administrative levels: national, county, and municipality. All survey respondents are practitioners in landslide risk management in Norway. The survey results are able to reflect some viewpoints of these experts on landslide risk management in Norway. Factors considered for assessing the future performance of landslide risk management by respondents are also studied to understand how respondents project their expectations. This paper also demonstrates how areas of improvement in landslide risk management in Norway can be identified based on the survey results. Due to limited responses, limited knowledge of respondents and the subjective nature of perceptions, the survey results are associated with uncertainties and should thus be used with care. Upon simplification of technical terms, the survey can be applied to survey public perceptions. The survey can also be regarded as a starting point for developing a common language/terminology for landslide risk management in Norway.

Abstract: This paper provides insights into a new landslide hazards project which is part of a national research program on safe and sustainable transport in Germany funded by the Federal Ministry of Transport and Digital Infrastructure (BMVI). Here we report on a work in progress and present selected results of a pilot study conducted prior to the launch of the research program in 2016. The main goal of the landslide hazards project is to assess the future landslide hazard potential for the federal transport system under the influence of climate change. A federal road-related pilot study with focus on developing an approach to this type of hazard assessment was a first step in this direction. The developed approach is based upon a Geographic Information System (GIS) as mapping tool to combine a landslide susceptibility map with spatial datasets of regional climate change projections. Here we present the basic framework of this approach only, and provide information on landslide activity and climate change. This information refers to findings from three example landslide sites in Germany. The purpose of this paper is to introduce these landslide projects of German transport research against the backdrop of the existing national strategy of climate change adaptation.

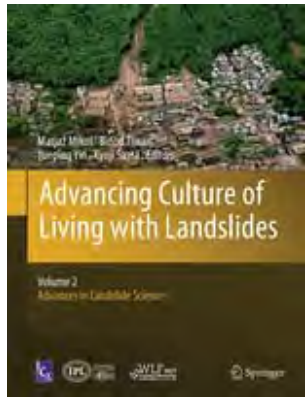
Abstract: Landslides are one of the most relevant geomorphological hazards in Portugal, by the high levels of people affected, destruction of assets and disruption of economic and social activities. Regarding the Portuguese territorial land use planning and emergency management, regulation, practice, prevention and risk management have been promoted in different ways. In Portugal, the areas susceptible to landslides are included in the 'National Ecological Reserve', which is a public utility restriction legal figure that rules the land use planning at the municipal level. In addition, the Municipal Emergency Plans include landslide susceptibility maps that are combined with the map of the exposed elements, allowing the assessment of exposure to landslides. This study is applied to the Loures municipality located to the north of Lisbon. In this municipality 621 landslides registered in a landslide inventory (rotational slides, deep-seated translational slides and shallow translational slides) that affected 1,469,577 m^2 (0.87 %) of the Loures territory. The final landslide susceptibility map shows that in Loures municipality 1,347 ha are associated to a Very high landslide susceptibility and 2,372 ha to High landslide susceptibility, which corresponds both to 22.1 % of the entire municipality, and constitutes the larger fraction of the National Ecological Reserve, related to landslides. These areas do not present geomorphological and geotechnical suitability for building structures or infrastructures. From the civil protection and emergency management point of views 34 classes of exposed elements were identified in the municipality, with point, linear and polygonal representations. The elements at risk located in the Very High or High landslide susceptibility classes were summarized and correspond to: high voltage poles; wind turbines; transmission/reception antennas; industrial areas; water tanks; silo; gas station/tank; service area; buildings of educational institutions; worship buildings; buildings of electricity facilities; regular buildings; gas pipeline; motorways; national roads; and municipal roads.

Abstract: Modern Society needs interactive public discussion to provide an effective way of focusing on hydrological hazards and their consequences. Embracing a holistic Earth system Science approach, we experiment since 2004 different stimulating educational/communicative model which emotionally involves the participants to raise awareness on the social dimension of the disaster hydrogeological risk reduction, pointing out that human behavior is the crucial factor in the degree of vulnerability and the likelihood of disasters taking place. The implementation of strategies for risk mitigation must include educational aspects, as well as economical and societal ones. Education is the bridge between knowledge and understanding and the key to raise risk perception. Children's involvement might trigger a chain reaction that reinforce and spread the culture of risk. No matter how heavy was the rain that hit our land in the past and recent seasons we still are not prepared. If on one hand we need to fight against worsening Global Warming that trigger extreme meteorological events, we should also work on sustainable land use and promote landscape preservation. Since science can work on improving knowledge of phenomena, technology can provide modern tool to reduce the impact of disasters, children and adults education is the flywheel to provide the change. We present here two cases selected among the wide range of educational activities that we have tested and on which more than 22.000 students and adults have participated within a period of 12 years. They include learn-by-playing, hands-on, emotional-learning activities, open questions seminars within several projects, learning paths, curiosity-driven approaches, special venues and science outreach.

Abstract: More room for landslide control means more space for potential landslide control out man made impacts that cause land slope instability, more space for torrent, more space for water and sediment storages, less impact on the slope stability and higher security for the peoples. We should change paradigm of space planning and development, especially in countries in

development under intensive urbanization. Since ancient times, and more intensively from the mid-19th century, land in the mountain region is developing for and the space belonging to land and water has been reduced. The surfaces 'taken' intended primarily for agriculture, traffic route and urban development. The middle of the 19th century saw the emergence of such regulation works on the Alpine mountains and, in the first half of the 20th century it spread worldwide. At the end of the 20th century, development spread over hazard areas, many torrents flowed in highly confined channels, and ground water recharges drop down, instability of land surface decrease and security for inhabitants decrease. This resulted in the changes reducing water resources of appropriate quality, reduce space for sediment deposit, increase erosion, affecting natural habitats, causing major flood damage, decreasing groundwater stock, and deteriorating water quality. The water regime integrates all events across space from landslides, debris flow and is manifested in river regime in low lands. This problem is partially covered by many UN and UNESCO documents and reports, such as: The United Nations World Water Development Report 2015 and Managing Water under Uncertainty and Risk. Proper actions are also suggested in the Ministerial Declaration from the 7th World Water Forum. The Ministerial Declaration first mentioned the significance of appropriate land management in relation to sustainable water management and planning. Contemporary societal development around the world is oriented at developing urban centres, and it is expected that by 2030, more than 60% of the world population will live in urban areas that enlarge on the nearby sloped areas with potential high damage. On other hands population in mountain regions drop down and especially agricultural activity move out. The needs for space drop down, but on other side needs for security on mountain urban areas and traffic route increase. We needs new paradigm in space planning and development close related to the real estate policy. The opportunity is release surface for landslide protection, and torrent or for water at all... There will be more space remove water from instability areas, for water flow and recharge of groundwater, more space for sediment transport and sediment deposition Errosin will lower, water storage increase and security of urbanised areas also increase. Some examples of good and bad practice will be presented.

Volume 2: Advances in Landslide Science



Part I: Landslide Field Recognition and Identification: Remote Sensing Techniques and Field Techniques

Abstract: Many geotechnical works have been performed in recent years in Albania in regards to mass movements, from which was concluded that more than 50% of its area is in an unstable or already active state. In order to reduce the destructive potential of landslides and minimize the consequential losses the Albanian Geological Survey carried out a project, from 2010 to 2015, that was aimed at compiling a database on landslides to reduce the threat they pose. A landslide inventory database is defined as a collection of data that contains information on topics such as location, type, activity and physical properties of landslides in a region. Landslide inventories create a foundation for assessing landslide hazard and for risk reduction. The landslide inventory is the most comprehensive source of information on landslides and was compiled between January 2010 and December 2015 with a total of 3050 landslides documented using a combination of historical documents and archived data, aerial photography and Google Earth interpretations supported by field verifications. The landslides were mapped as a closed polygon on the basic geological and engineering mapps in ArcGIS on a 1:25 000 scale, and for all of them a landslide datasheet was prepared. Based on the Varnes classification the mass movements that have occurred in Albania are classified as either rockfalls or earth slides. They occurred over hilly-mountains regions, which are built by hardrocks-limestone, ultrabasic etc. (rockfalls) and weak rocks that are represented by molasses and flysch rocks (earthslides). Compiling landslide locations into the database allows landslides and rock-falls to be analyzed, so susceptibility and hazard maps can be created in the future.

Abstract: This paper proposes a multi-sensor a priori PSI visibility map for Austria in order to evaluate the feasibility of Differential SAR Interferometric (DInSAR) applications for landslide-affected slopes. For this purpose, the range index RI, introduced for the determination of areas in layover and foreshortening on both ascending and descending acquisition geometries, is computed and applied to the most diffuse X-C-L band SAR sensors. A new method is introduced to improve the accuracy of those products by fusing CORINE data with sharper European JRC forest map and Imperviousness Copernicus map. The results are tested with six different available PSI datasets over Austria. Then, a priori visibility map and a PSI density map are also derived for seven different satellites by combining the RI index and an enhanced CORINE land cover map. Finally, PSI velocity values, along the Line of Sight (VLos) and projected along the steepest slope direction (VSlope), are used in order to produce a landslide velocity map for the Austrian region of Vorarlberg.

Abstract: Indonesia is located between three tectonic plates which are actively interacting with each other. This condition has caused Indonesia to become vulnerable to the geological disaster, one of which is landslide. This condition is escalated by forming the critical area due to deforestation and overloading on the hillside, which triggers landslides and other geological

disasters. The most critical area for landslide is the highland with steep hillside; one of which is at Cianjur region, West Java. Looking at the critical potential of the geological disaster that could happen, especially the landslide, it is important to study the geometry and the depth of the slip surface of the landslide. In-situ geophysical techniques are able to measure physical parameters directly or indirectly (via satellite) linked with the lithological, hydrological and geotechnical characteristics of the terrains related to the land movement. Therefore, this research aims to determine slope stability analysis using geophysical method namely Electrical Resistivity Tomography (ERT). Data from 1-D and 2-D electrical resistivity tomography (ERT) showed that there is contrast resistivity value in the resistivity profile. It shows different kind of layers. The boundary between them plays a role as slip surface. The results show that there are two slip surfaces in research area; they are at the toe of the slope and at the top of the slope. They are the boundary between upper layer with higher resistivity value and lower layer which has lower resistivity. The upper layer is interpreted as clay soil and the lower one is interpreted as more porous soil. By determining slip surface using ERT, it can help to analyze the stability of the slope.

Combining Spectral and Morphometric Properties of Landslides for Separating Individual Landslides Based on Object-Oriented Method, page 61

Qigen Lin, Zhenhua Zou, Le Lin and Ying Wang

Abstract: Automatic detection of landslides using remote sensing images has been demonstrated to be an effective method in landslide inventory mapping. However, areas recognized as landslides using traditional methods may connect with each other and form a massive landslide, which is not conducive for accurate statistics on the number of individual landslides. Thus, this paper explored an object-oriented individual landslide separation method to solve this issue. The landslide areas were obtained by applying an object-oriented detection method on a SPOT-5 2.5m multispectral image and the field investigation. A sequence of processes including the multi-scale image segmentation, spectral characteristics difference analysis, morphometric properties for landslides selection was applied. Objects detected as landslides were subsequently separated into individual landslides. Comparison of model results indicates that the proposed method can divide the landslide areas into individuals better than just merging them directly. It is also relatively quick to use this method to separate individual landslides than to use visual interpretation. Therefore, the object-oriented individual landslides separation method proposed in this paper could be a good solution for rapid risk assessment of landslide disasters.

Sensor Data Integration for Landslide Monitoring—the LEMONADE Concept, page 71

Romy Schlögel, Benni Thiebes, Isabella Toschi, Thomas Zieher, Mehdi Darvishi and Christian Kofler

Abstract: The project LEMONADE (LandslidE MOnitoriNg And Data intEgration) aims to combine different techniques investigating their benefits and drawbacks. We present the different techniques used to monitor the active Corvara landslide located in the Italian Dolomites. Satellite remote sensing products allow covering the whole landslide providing 1D displacement measurements while proximal and terrestrial techniques can provide 3D information. In this paper, preliminary results considering each individual method applied are discussed and a first estimation of landslide displacements for the period considered is given.

Landslide Diversity in the Rwenzori Mountains (Uganda), page 79

Liesbet Jacobs, Olivier Dewitte, Clovis Kabaseke, François Kervyn, Jan Maes, Kewan Mertens, Adriano Nobile, John Sekajugo, Jean Poesen, Denis Samyn and Matthieu Kervyn

Abstract: In the Rwenzori Mountains, at the border between Uganda and the D.R. Congo, landslides frequently occur and cause fatalities and substantial damage to agricultural land and infrastructure. Up until recently, no information on the landslide characteristics, occurrence or spatial distribution was available. The use of archive inventories and field surveys however allowed identifying the key mass wasting processes in this region and their triggering and controlling factors. Here, we present the results of these multi-temporal archive and field inventories. The Rwenzori mountains are diverse in lithology, topography and land use patterns. This diversity in landslide controlling factors is also reflected in the types of landslides that occur in this 3,000 km² large region. The majority of the Rwenzori Mountains consists of steep slopes on gneiss, mica-schists and amphibolite lithologies. A dominance of shallow translational soil slides is observed in gneiss while the amphibolite is found not to be prone to such landslides. This is in sharp contrast to the lowlands, which are characterized by gentle slopes and a rift alluvium lithology. In contrast to what was expected, the largest landslide densities are found in these lowlands where large, deep-seated rotational soil slides with head scarps up to 30 m depth prevail. In both the lowlands and the uplands, slope gradients appears to be the main topographic predictor for the spatial occurrence of landslides. Finally, concerning landslide triggering events, in both the archive inventory and the field surveys, rainfall-triggered landslides are the most common but co-seismic slides were also observed.

Comparing Landslide Mapping from DTM Satellite Derived Data and Field Based Studies of Loess Sediments in Western China, page 87

Philip Leopold, Wang Tao, Roland Perko, Gerhard Heiss, Martin Jung, Armin Oblin and Yongshuang Zhang

Abstract: In course of an ongoing Chinese-Austrian scientific cooperation project a landslide susceptibility modeling was performed for a test area in Tianshui region / Gansu province in 2015. The test area consists of a Loess landscape that is strongly anthropogenic transformed by terraced agriculture and is interspersed by earthquake triggered landslides. For susceptibility modeling two landslide inventories were established. The first inventory was created by field investigation, where landslides were mapped directly in the field and digitized subsequently. For the second inventory, landslides were mapped from a 1 meter Digital Elevation Model (DEM) which was computed in course of the project from Pléiades stereoscopic satellite imagery. Based on the DEM, 562 landslide polygons and 1,173 landslide scarp points were mapped in an area of 237 km² in only one week working time (1 person). This is a quarter of the time that was necessary to map the same area in the field. The DEM-mapping was also solely accomplished from desk, making the mapping independent from weather conditions and other environmental influences and restrictions. Usually, additional field checks are performed for verification of the DEM-mapped landslides. Due to the remote location of the investigation area this was not possible within the project. Overall, the numbers of the two landslide inventories are very alike. The field based inventory includes 573 landslides; the DEM inventory counts 10 landslides less. However, the location and the coverage of the landslides differ between the two inventories. The DEM inventory overlaps only 68% of the field-mapped inventory but covers 25% more area all in all. We think that these differences are based on the technical restrictions of the applied methodologies, on varying spatial references in the base data of the field mapping, and on the consistent identification of landslides by DEM-mapping. One of the main results of the project was to demonstrate the applicability and the effectiveness of DEM-mapping in Loess sediments of Western China. In comparison to field mapping, the DEM-inventory is at least of equal quality as the field mapped inventory because of its consistency and completeness. Furthermore, the DEM-mapping is much more cost efficient, especially when it comes to mapping very large areas. A most complete landslide inventory of the investigation area is not only an essential input factor for a landslide susceptibility model. It can also serve as an indicator map for itself, based on the fact, that existing moved masses are much more likely to become reactivated compared to unmoved masses.

Mechanism of the Montescaglioso Landslide (Southern Italy) Inferred by Geological Survey and Remote Sensing, page 97

Francesca Bozzano, Paolo Caporossi, Carlo Esposito, Salvatore Martino, Paolo Mazzanti, Serena Moretto, Gabriele Scarascia Mugnozza and Antonio Michele Rizzo

Abstract: Montescaglioso is a village in the southern Italy (Matera, Basilicata region), located on a hill top, at about 300 m a.s.l., along the left bank of the Bradano River. On the Montescaglioso hill widely outcrop Plio-Pleistocene sedimentary deposits, strictly connected to the evolution of the Adriatic Foredeep and including from bottom to top: i) clays and silty clays belonging to the Argille Subappennine Formation, ii) conglomerates and silty sands belonging to the Irsina Conglomerate Formation. Several landslides already affected this area; the latest one occurred on 3rd December 2013 following a period of intense rainfalls and involved a section of the south-eastern slope of the hill about 500,000 m^2 wide. This landslide was recognized as a partial reactivation of an ancient landslide and involved about 3 million cubic meters of materials, mainly constituted of debris originated by previous landslides, clays and part of the Irsina Conglomerates. Detailed geomorphological, geological and geotechnical models of the area were reconstructed by means of field surveys and aerial photographs interpretation. Furthermore, detailed investigations based on Synthetic Aperture Radar images acquired by the COSMO-SkyMed constellation, referred to the time period between 2011-2015, were carried out. Specifically, the analyses of satellite SAR images allowed to characterize the deformational pattern of the area in the pre-failure, co-failure and post-failure phases. Both Differential InSAR analyses based on single interferograms and Advanced Differential InSAR analysis based on interferometric stacks were performed with the aim to detect the spatial-temporal deformational pattern of the area before and after the failure. Differently, sub-pixel cross-correlation based analysis on SAR amplitude tracking was performed to retrieve the co-failure displacement pattern (i.e. amount and vectors fields). The results achieved by the analyses of the COSMO-SkyMed SAR images, similar to those described in Raspini et al, (2015), allowed to retrieve interesting information about the landslide kinematics that can be summarized as follow: - the overall slope affected by the failure was characterized by spatially heterogeneous deformational features (ranging from null to 8 mm/year displacement values) before the failure; - the pre-failure deformational trend was not characterized by evident accelerations neither at long time scale (year/month), neither in the short time scale (e.g. 1 day before the failure); - displacements ranging from 6 to 25 m were reached during the December 2013 activation with a prevalent S-SW direction movement; - post-failure monitoring data show a deformational behaviour similar to the pre-failure one, but characterized by lower displacement values. Based on the above results, the main role played by geological setting in constraining the landslide mechanism and its complex kinematic was confirmed. The 2013 landslide can be, in fact, described as a complex, structurally constrained movement featured by three main distinct "blocks" with different direction of movement. Furthermore, the lack of pre-failure acceleration excludes that failure represented a tertiary stage of a creep process, thus confirming that the 2013 process is a re-activation of a past slope instability due to an episodically occurred trigger. To this aim, stress-strain numerical analysis would allow to back analyze the December 2013 re-activation event so providing mechanical constrains to the landslide mass and to its rheological behaviour.

Rock Fall Characterization in Climbing Spots: The Case Study of the "Napoleonica" Tourist Route (Trieste, NE Italy), page 107

Chiara Boccali, Sara Biolchi, Enrico Zavagno and Luca Zini

Abstract: In NE Italy, fast-moving landslides represent a significant threat both to the population and the built environment. In the eastern portion of the Italian Alps, rock falls are common and are often responsible for casualties or severe damage to infrastructure. This type of landslide is characterized by strong relief energy and is triggered by earthquakes or copious rainfall, which often exceeds 2000 mm/yr. To assess rock fall hazard using software analysis, field surveys are crucial to accurately recognize the source areas of falling rock phenomena, to quantify the volumes of unstable blocks and identify the possible block trajectories. The current work takes in detailed geological and geomorphological mapping, through the identification of dislodged blocks, fractures and fallen blocks on a much-frequented limestone cliff in the Trieste Karst used as a climbing spot. Moreover, a popular tourist path (the Napoleonica) lies at the foot of the climbing cliffs. In-depth traditional activities, such as field surveys and aerial photo analysis were undertaken, including morphometric and geomechanical characterization of the whole rock mass, in order to perform a first identification of the more hazardous sections of the Napoleonica. The field data were collected using UAV (Unmanned Aircraft Vehicle) images and videos and this innovative technique allow the reaching and study of difficult sites with excellent resolution and precision. The final output is a GIS-developed map, that will be the starting point for future 2D and 3D simulations, that will lead to the creation of a rock fall susceptibility evaluation of the whole area.

Rock Avalanche Sedimentology—Recent Progress, page 117

Anja Dufresne

Abstract: Since Yarnold and Lombard (1989) presented a systematic facies model for ancient rock avalanche deposits in dry climates, more landslide researchers have organized observations from one or more case studies into general sedimentological descriptions and facies models (references are provided in the main text). These recent advances show that rock avalanches are multi-facies deposits. Retention of source stratigraphy and a general three-part division of a coarse-grained, largely unfragmented upper part or carapace, a finer-grained body of diverse sedimentology, and a basal facies influenced by interactions with runout path materials are the most common observations. The greatest variation in the grain size distribution and comminution intensity occurs between the bouldery carapace and the matrix-supported interior, i.e. the body facies which constitutes the largest deposit volume. Most striking, but not surprising, is the highly heterogeneous nature of the body facies with a number of sub-facies and discontinuity layers, which must reflect highly heterogeneous states of stress within the deforming granular mass. These features within the body facies are the most important for studying those emplacement dynamics that are not affected by boundary conditions, such as runout path sediments. Where the base is exposed, a characteristic basal facies with substrate injections and/or a basal mixed zone and/or deformation features can be found, usually above a very sharp contact to the underlying, disrupted sediments. The overall commonalities of internal rock avalanche features indicate that some basic processes must act universally during their emplacement. The value of these sedimentological models and descriptions lies in contrasting universally valid features with those that are a function of unique geological, topographic, or structural settings, or which might suggest different/additional emplacement dynamics of a specific deposit.

Integration of Multi-sensor A-DInSAR Data for Landslide Inventory Update, page 133

Roberta Bonì, Massimiliano Bordoni, Claudia Meisina, Alessio Colombo and Luca Lanteri

Abstract: A systematic and reproducible methodology to analyze multi-sensors advanced,satellite radar differential interferometry (A-DInSAR) data for identifying ground motion, areas and for updating landsides inventories is proposed. We apply the methodology in a wide area of north-western Italy, corresponding to Piedmont region that is affected by different landslides. We use satellites images acquired, in ascending and descending acquisition geometry, by C-band (ERS ½ and ENVISAT, RADARSAT) and X-band (COSMO-SkyMed) sensors and processed using SqueeSARTM, PSInSARTM and

PSP-IfSAR techniques. Landslides characterized by linear and non-linear behaviour were recognized.

Spatiotemporal Landslide Mapper for Large Areas Using Optical Satellite Time Series Data, page 143

Behling Robert and Sigrid Roessner

Abstract: Worldwide, landslides cause thousands of fatalities and severe monetary losses every year. To predict and thus reduce the landslide risk in the future, a detailed knowledge is required about the spatiotemporal landslide occurrence and its relation to changing environmental conditions. The derivation of such spatiotemporal probabilities of landslide occurrence as an important prerequisite for probabilistic hazard and risk assessment requires landslide inventories to be as complete as possible in time and space. However, due to the lack of systematic assessments for many landslide-prone regions, such multi-temporal landslide inventories are often missing or are limited in spatiotemporal coverage. This study presents an approach for large area multi-temporal identification of landslides based on optical remote sensing time series data. It enables retrospective analysis of long-term landslide activity variations and monitoring of recently ongoing landslide occurrence. Thus, it has also the potential for rapid mapping of large areas in case of major landslide triggers. This wide applicability could be achieved because the approach

facilitates efficient processing of all common multispectral sensors. It comprises automated multi-sensor pre-processing and multi-temporal change detection methods enabling spatiotemporal identification of landslides in an object-based form. The change detection builds on the analysis of temporal trajectories, revealing landslide-specific footprints of surface cover changes over time mostly comprised by sudden vegetation cover destruction and longer-term revegetation rates as a consequence of landslide occurrence. In combination with DEM-derivatives the developed approach enables automated identification of landslides of different sizes, shapes, and in different stages of development (e.g. fresh occurrences and reactivations of existing landslides) under varying natural conditions. So far, the approach has been widely applied in Southern Kyrgyzstan for long-term retrospective analysis and for monitoring of ongoing landslide activity. The long-term analysis of a 2500 km² area between 1986 and 2015 based on 250 datasets acquired by seven multispectral sensors (Landsat-(E)TM, SPOT 1&5, IRS-1C (LISS3), ASTER and RapidEye) and resulted in the identification of 1583 landslides of sizes between 50 m² and 2.8 km². The analysis of their distribution revealed clear spatial and temporal patterns, with highest overall landslide rates in 2003 and 2004 exceeding the long-term annual average rate by more than five times. For monitoring of the recently ongoing landslide activity between 2009 and 2015, high spatial and temporal resolution RapidEye data were acquired in the frame of the RapidEye Science Archive (RESA) program for a 12000 km² region resulting in the identification of approx. 1000 slope failures. The combination of high spatial resolution (5 m) and frequent data acquisitions (up to several days/weeks) of the RapidEye data allowed for the systematic and nearly complete assessment of landslide occurrence also including small slope failures, which often represent precursors for subsequent larger and more hazardous landslides. Thus, the approach can be used for generating and maintaining up-to-date landslide inventories as well as for providing information in the context of early warning systems. The approach has also proven its applicability for automated analysis of landslide activity related to the devastating Nepal earthquakes in April/May 2015. It is planned to assess landslide activity several years after the earthquake trigger using the developed approach based on RapidEye and the newly available Sentinel-2 data. The globally available Sentinel-2 data form the basis for developing this approach into a globally applicable landslide mapper that will open up new opportunities for analyzing spatiotemporal landslide activity over large landslide-prone areas facilitating probabilistic landslide hazard and risk assessments world-wide.

Multitemporal UAV Survey for Mass Movement Detection and Monitoring, page 153

Luca Tanteri, Guglielmo Rossi, Veronica Tofani, Pietro Vannocci, Sandro Moretti and Nicola Casagli

Abstract: In the last decade, the combination between a rapid development of low cost and small Unmanned Aerial Vehicles (UAVs), improved battery technology and conventional sensors (Optical and LiDAR) in terms of cost and dimensions, lead to new opportunities in environmental remote-sensing and 3D surface modelling. The piloting ease and the mechanical simplicity are the main reasons for drone diffusion as a hobby and for professional use. To improve the existing multicopters, the Department of Earth Sciences of Florence (DST) has developed a new type of chassis structure that overcomes some critical issues of carrying scientific and heavy payload or long flight applications. Using the DST Drone, a long term monitoring campaign was performed in Ricasoli village, in the Upper Arno river Valley (Tuscany, Italy), to understand the possibility of this rising technology to characterize and to monitor landslides. In particular, the proposed technology was applied on a slope in the northern part of the village, recently affected by mass movements that are currently threatening some nearby dwellings. The RGB and multispectral imageries were analysed and combined using SfM (Structure from Motion) software, in order to obtain high resolution orthomosaics, highly detailed point clouds and 3D digital surface models (DSM). 3D surface reconstruction with optical sensors was carried out during multitemporal campaigns in order to define the entity of the volume variation in time. The photogrammetric surveys were performed in 5 different stages: (1) mission planning, (2) acquisition of ground control points with RTK-GPS, (3) flight and image acquisition, (4) image processing, (5) implementation in GIS environment. The available multi-temporal DSMs and point cloud data were compared using GIS and open-source cloud comparing software. The comparative analysis of the point clouds and the obtained DSMs, allowed a very accurate reconstruction and mapping of the detected landslides. Furthermore, based on each high-resolution DSM, multitemporal maps of some selected morphometrical and hydrological were extracted and compared using a change-detection approach. The collected data also allowed to precisely detect some slope portions prone to failure and to evaluate the area and volume of the involved masses as well as displacement rates. The high accuracy of the results of the drone survey proved the reliability of the proposed approach for mass movement monitoring. Furthermore, the drone survey has proven to be an easier and more cost- and time- effective approach with respect to other conventional techniques such as Laser Scanning. Thanks to these potentialities and to its repeatability, drone surveys became integral parts of the monitoring system in Ricasoli village.

Studying a Landslide in Its Paroxysmal Phase; the Reactivation of the Sebrango Landslide (Spain), June 2013, page 163

A. González-Díez, V.M. Bruschi, J. Sánchez, J. Bonachea, J.R. Díaz de Terán, J. Remondo, G. Fernández, P. Martínez, M. Zarroca, R. Linares, V. Rodríguez, E. San Millán, A. Cendrero, S. Hoyos and S. Martin

Abstract: This paper deals about the activities carried out during the emergency developed in Liébana region, (Cantabrian Range, Spain) by the reactivation of the Sebrango landslide, on June 2013, in that the two localities and a road were affected. The methodology employed in analysing an active event (paroxysmal phase), is described. The tasks carried out during the emergency stage have involved the supporting of all decision-making, understanding of the paroxysmal phase, displacement analysis and finally, some urgent stabilization actions. The main conclusions of this work can be grouped in two sets: during the emergency

phase the executive responsibility for the activities carried out corresponds to policy makers (the opinions of scientists are at the service of the authorities who make decisions); the most useful tools for the analysis of the landslide activity during paroxysmal phase are the traditional geological field methods combined with GPS measurements and images processed photogrammetrically. These tools enable a geomorphic analysis of the landslide features and give accurate information of the landslide activity. The drainage tasks done, in combination with the barrier made by the carboniferous olistoliths and cessation of precipitations led the progressive landslide slowdown.

Mapping Rapid-Moving Landslide with Satellite SAR Images: The Case of Montescaglioso (South Italy), page 171

Federico Raspini, Andrea Ciampalini, Sara Del Conte, Luca Lombardi, Massimiliano Nocentini, Giovanni Gigli, Alessandro Ferretti and Nicola Casagli

Abstract: Pre-event and event landslide deformations have been detected and measured for the landslide that occurred on December 3rd, 2013 on the south-western slope of the Montescaglioso village (Basilicata Region, Southern Italy). The event, triggered by 56 hours of continuous rainfalls, produced a ground displacement of several meters and created significant damages to buildings and local infrastructures. Ground displacements have been mapped through an integrated analysis based on a series of high resolution SAR (Synthetic Aperture Radar) images acquired by the Italian constellation of satellites COSMO-SkyMed. The purpose of this mapping activity was twofold: i) detect and record any pre-event deformation in and around the village of Montescaglioso, through the use of multi-image SAR interferometry, suitable for mapping slow deformation phenomena and ii) map and measure any surface changes produced by the 3rd December landslide, using amplitude-based method, suitable for mapping much faster displacements. SAR Interferometry, applied to images taken before the event, revealed a general pre-event movement, in the order of a few mm/yr, in the south-western slope of the Montescaglioso village, with highest velocities in the sector of the slope where the first movement of the landslide took place. Amplitude analysis allowed the retrieval of the three components of the landslide deformation field, with values exceeding 10 m for large sectors of the landslide area and local peaks of 20 m in its central and deposit areas. The synergistic exploitation of phase and amplitude of SAR images turned out to be a powerful tool for landslide investigation, allowing the detection of slow, precursory deformation patterns as well the retrieval of full 3D surface displacement fields caused by large, rapid-moving landslides.

Combining Terrestrial and Waterborne Geophysical Surveys to Investigate the Internal Composition and Structure of a Very Slow-Moving Landslide Near Ashcroft, British Columbia, Canada, page 179

David Huntley, Peter Bobrowsky and Melvyn Best

Abstract: Landslide hazards in the Thompson River valley, British Columbia adversely impact vital national railway infrastructure and operations, the environment, cultural heritage features, communities, public safety and the economy. Field investigations and monitoring of the very slow-moving Ripley Landslide indicates movement across the main body, with the greater displacement at the south end of the slide near a lock-block retaining wall separating Canadian National (CN) and Canadian Pacific (CPR) rail tracks. Knowledge of the internal composition and structure of the landslide as interpreted through surficial geology mapping and geophysical surveys provide contextual baseline data for interpreting monitoring results and understanding mass-wasting processes in the Thompson River transportation corridor. Bathymetry, electrical resistivity tomography, frequency-domain electromagnetic terrain conductivity, ground penetrating radar, seismic refraction, multi-spectral surface wave analyses, and borehole logging of natural gamma, conductivity and magnetic susceptibility all suggest a moderately high relief bedrock sub-surface overlain by a >20 m thick package of clay, silt, till diamicton and gravel containing groundwater. Planar physical sub-surface features revealed in geophysical profiles and logs include tabular bedding and terrain unit contacts. Profiles also show curvilinear-rectilinear features interpreted as sub-horizontal translational failure planes in clay-rich beds beneath the rail ballast and retaining wall at depths between 5 m and 15 m below the surface of the main landslide body. The landslide toe extends under the Thompson River where clay-rich sediments are confined to a >20 m deep bedrock basin. The upper clay beds are armoured from erosion by a lag deposit of modern fluvial boulders except along the west river bank where a deep trough has been carved by strong currents. High waterborne conductivity levels indicate discharge of groundwater with elevated total dissolved solids through the boulder lag. Fluvial incision of the submerged toe slope at the south end of the landslide is observed <50 m west of where critical railway infrastructure is at risk. Integrating data from surficial geology mapping and an array of geophysical techniques provided significantly more information than any one method on its own.

Using Lidar DEM to Map Landslides: Škofjeloško Cerkljansko Hills, Slovenia, page 191

Erazem Dolžan and Mateja Jemec Auflič

Abstract: Landslide inventory mapping in areas with dense vegetation is often difficult. Lidar offers a unique insight into topography of such areas. The ability to filter points belonging to vegetation and display a "bare Earth model" is invaluable in detecting topographic features indicative of landsliding and probably makes Lidar the most important tool for landslide inventory mapping in forested areas. Study area lies in Škofjeloško-Cerkljansko hills located in the western central part of Slovenia, northwest of Ljubljana and it occupies approximately 580 km^2. In terms of lithology, the area is composed largely of Mesozoic

carbonate rocks and Palaeozoic clastic rocks, ranging from quartz conglomerates to claystones that often govern the slope mass movement occurrence. Land cover is predominantly forest, partly also meadows. In recent years, intense short- and long-duration rainfall have triggered numerous shallow landslides and caused considerable economic losses in the study area. The area was mapped using a 1 m horizontal resolution DEM created from Lidar scanning data. Hillshades were created using sun orientations of 45°, 75°, 135°, 220° and 315° and sun angle of 45°. Different light orientations produced drastically different representations of the surface, so the area was examined in several orientations. In addition, a slope map, a surface roughness map and a Topographic Ruggedness Index (TRI) map were produced. In order to differentiate features produced by landsliding from man-made features, orthorectified aerial imagery was used. The data was processed and organised in a GIS environment, allowing for rapid visualisation and mapping. Landslides were mapped on the basis of distinct morphological characteristics, including head scarps, toe features, hummocky terrain, convex-concave features etc. Among those, head scarps were usually most prominent, but did not provide enough evidence to map landslides with certainty as there were many features visually similar to head scarps visible on hillshades. Only when head scarps were combined with other morphological characteristics a landslide was determined with any certainty. The area was examined by systematically panning over the area at scales of 1:10,000 and 1:5,000, while mapping was carried out at scales between 1:5,000 and 1:2,500. A certainty value between 1 and 5 was applied to every mapped feature. Overall, hillshades were found to be of most use, along with aerial imagery. To further aid determination, profiles were extracted from the DEM across suspect features. Various roughness analyses were found to reflect land cover more than features indicative of landsliding. Altogether 117 new landslides, rockfalls and areas of soil creep were mapped. The national landslide database for the area was also re-evaluated. Out of 492 landslide occurrences in the database, only 59 exhibited distinct morphology, visible on Lidar. The mapped landslides were further compared to PSInSAR data from the area. To validate new specified landslides field proofing was carried out looking for features such as ground cracks, water seepage, bent trees and damage to buildings. In general, landslides with a certainty value of 3 or higher were confirmed to exist, while lower certainty values usually meant that particular feature was not a landslide. Lidar mapping was confirmed to be of particular use when mapping areas of slow creep (identified mostly by hummocky terrain) and rockfall, while mapping actual landslides gave mixed results. Results revealed that inactive landslides would often display quite distinct morphology and would be impossible to separate from newer landslides presenting a higher hazard. Overall, using Lidar DEM to determine landslide sliding surface can give useful results in areas where other methods would be near impossible to carry out. Because of the inherent subjectivity of the method, it is vital that mapping is carried out by a knowledgeable, experienced and precise expert.

Using the Intensity Values from Terrestrial Laser Scanner (TLS) for Determining Lithology of Flysch Rock Mass in Southwest Slovenia, page 201

Tina Živec, Andreja Anžur and Timotej Verbovšek

Abstract: Heterogeneous rock mass, such as flysch is represented by individual lithological units with different geomechanical parameters. The heterogeneity of the rock mass affects its geotechnical behaviour, which causes difficulties in slope stability, as well as in underground construction. Development of modern ground-based remote sensing techniques, enables measurement and positioning of distant objects. Terrestrial Laser Scanner (TLS) has been in the past years successfully integrated in acquisition of geological features. In case of pulsed TLS, the scanner emits short pulsed beam of light and measures the time-of-flight from reflected object surface in order to compute the distance from objects. The resulted point cloud is georeferenced in the post-processing phase. Terrestrial Laser Scanner also records the intensity of reflectance, which depends on the properties of the scanned surface. Flysch rock mass can be followed in SW Slovenia, therefore a lithology profile in quarry Elerji was chosen to test the applicability of TLS in characterising the heterogeneous rock mass. The selected quarry wall was lithologically logged and scanned with TLS. Some samples along the profile have been collected for X-ray diffraction analysis of minerals. The analysis of point cloud included the examination of differences between intensity values for individual lithological units and determination of parameters, affecting the value. The resulted intensity intervals for sandstones and marlstones have been empirically tested on the same profile with relatively positive results. Findings and further analysis would help geologists determine the general engineering geological properties of flysch rock mass in the field, as well as geomechanical conditions for faster and more accurate decisions in providing support types in underground construction, defining slope stability and long-term solutions for stabilisation of rock wall.

Multi-temporal Landslide Evaluation by Using UAV: Some Insights on Disaster Risk in Teziutlán, Puebla México, page 209

Ricardo J. Garnica- Peña and Irasema Alcántara-Ayala

Abstract: This paper aimed at analyzing some insights related to landslide disaster risk at local scale in a mountain region of Mexico by using an Unmanned Aerial Vehicle (UAV). The developed methodology to produce UAV derived imagery is presented. Point cloud LiDAR, the Digital Surface Model (DSM) derivative, and the orthophoto generated have a resolution of 0.05 m. Moreover, an analysis of the growth of human settlements at local scale was carried out from 1942 to 2016, and related to landslide exposure. The latter resulted from a landslide susceptibility map produced with the DSM using the weight of evidence method. According to the results, at the present time the France vicinity (Teziutlán, Puebla) covers an area of 67.85 ha, although the inhabited surface is of 35.46 ha. In seven and a half decades, the size of the expansion of the dwellings was increased seven-fold. The 54% of total surface can be characterized as moderately or highly susceptible to landslides. Likewise, estimations

suggested that 52.27% (35.46 ha) of the total surface of the neighborhood is occupied by households; out of which, 18.74 ha, the equivalent of 50.81% of the total inhabited area is situated in the high and moderate landslide susceptibility zones.

The Differential Slow Moving Dynamic of a Complex Landslide: Multi-sensor Monitoring, page 219

Gerardo Herrera, Juan Carlos García López-Davalillo, Jose Antonio Fernández-Merodo, Marta Béjar-Pizarro, Paolo Allasia, Piernicola Lollino, Giorgio Lollino, Fausto Guzzetti, Maria Inmaculada álvarez-Fernández, Andrea Manconi, Javier Duro, Ciscu Sánchez and Rubén Iglesias

Abstract: Portalet landslide complex is located in the SW-facing slopes of an old glacial transfluence area at the border between Spain and France. The excavation in the summer of 2004 at the foot of the slides of a parking lot induced the development of a secondary failure in the lower part and accelerated the dynamic of the landslide complex. In this work we assess the advantages of combining multi-sensor monitoring techniques to measure the surficial and deeper displacement, rainfall and groundwater level evolution. As a result we are able to better understand the differential dynamic of this landslide complex and its governing mechanisms. Surficial displacements have been measured with differential GPS and InSAR in order to determine the spatial variability of the different slope movements. The installed automatic and continuous in situ monitoring devices, consisting of horizontal extensometers and the inclinometric robot (AIS), permitted to measure deep displacements of the pre-existing landslide, and the displacement in the transition zone between the recently induced landslide and the pre-existing one. Additionally the stress strain relationship of the moving mass along the hydric year was permitted to confirm the key role played not only by seasonal rainfall but also by snow melt.

Erosion Processes and Mass Movements in Sinkholes Assessed by Terrestrial Structure from Motion Photogrammetry, page 227

Helene Petschko, Jason Goetz, Max Böttner, Maximilian Firla and Sven Schmidt

Abstract: More than 9000 sinkholes have been documented by the Geological Survey of Thuringia in different lithological units of Thuringia of which many posed a serious threat on life, personal property and infrastructure. While it is clear that they are caused by hollows which formed due to solution processes within the local bedrock material, little is known about the surface processes and dynamics of erosion of the sinkhole visible above ground. The objective of this study was to analyze sinkhole surface dynamics over time with 3D models derived from terrestrial photos by structure from motion and multi-view 3D reconstruction. The sinkhole was surveyed by terrestrial photos on two days with a two months break. During each photo session 84 and 237 photos have been taken from all around the sinkhole. The photos were processed to 3D point clouds using Agisoft PhotoScan and compared using the software CloudCompare and the M3C2 plugin. The resulting point clouds show an area with significant change that covers about 26 % of the sinkhole. Toppling and a few erosion processes have successfully been detected with an observed change of up to 10 cm. Nevertheless, for future studies the study design has to be improved regarding the point cloud registration process, a longer observation duration and a quantitative evaluation of the quality of the individual point clouds is pending.

Method of Estimating Slope Movement Area Using DInSAR Analysis, page 237

Joko Kamiyama, Masaru Kunitomo, Masayuki Sakagami, Ikushi Hirata, Kazuo Yoshikawa and Daisuke Nishikawa

Abstract: For prevention / reduction of damage caused by large-scale sediment disaster, it is important to conduct field surveys and preventive measures by detecting the areas of minor slope movement as a sign of such sediment disaster at an early stage. As a technology for wide-area and routine monitoring of slope movement sites, Differential Interferometric SAR (DInSAR) analysis using L-band SAR satellite is effective in Japan. Because, analysis is possible with DInSAR even when there are few SAR images that meet the requirements such as the number of persistent scatteres or analytic pairs with good coherence as in mountain areas with thick vegetation in Japan. When interference fringes are detected by DInSAR analysis, the priority of field survey and countermeasures in the corresponding site will differ according to the magnitude of damage expected in case of slope movement. Accordingly, we studied a method of estimating the areas of slope movement representing a high possibility of landslide with interference fringes. This study compared actual slope movement area obtained from LiDAR data with the area estimated considering interference fringes and microtopography and evaluated the consistency between both areas by using accuracy rate, cover rate, and matching rate. We selected 10 cases mainly from the sites where slope movement was confirmed by the administrative organs for disaster prevention and the sites where interference fringes were detected by the DInSAR analysis so far conducted by the authors and occurrence of slope movement was confirmed through a field survey or GPS measurement. As areas for estimating slope movement, we set up a total of four patters - two patterns of the area of interference fringes according to the frequency of appearance when interference fringe was detected at two or more timings, one pattern of the area considering the surrounding microtopography, and one pattern of the area considering the whole slope. As the result, the possibility of actual slope movement is high in the area with a high frequency of appearance of interference fringes when such fringes are repeatedly detected. Also, actual slope movement area is larger than the area where the frequency of detection of interference fringes is high. It was found that the area of slope movement close to that of actual slope movement can be estimated by estimating as slope

movement area an area that is around the area with a high appearance frequency of interference fringe and has micro-topography shaped according to the estimated direction of slope movement.

Detection and Monitoring of Slow Landslides Using Sentinel-1 Multi-temporal Interferometry Products, page 249

Janusz Wasowski, Fabio Bovenga, Raffaele Nutricato, Davide Oscar Nitti and Maria Teresa Chiaradia

Abstract: Landslide investigations can now benefit from high quality information obtainable using multi-temporal interferometry (MTI) techniques (e.g., PSInSAR, SBAS) and images acquired by satellite synthetic aperture radars (SAR). MTI is only little affected by bad weather and can provide long-term (years), regular (weekly-monthly), precise (mm) measurements of ground displacements over large areas (thousands of km^2), with the possibility of exploiting the same series of radar images for regional to slope-scale investigations. Spatially dense measurements can be obtained (from hundreds to thousands data per km^2). Furthermore, by offering regular global-scale coverage, improved temporal resolution (from 12 to 6 days) and free imagery, the new radar satellite mission Sentinel-1 of the European Space Agency (ESA) can now guarantee wider and more efficient application of MTI to landslide investigations. In this work we demonstrate for the first time the excellent potential of MTI based on Sentinel-1 for the detection and monitoring of slope instabilities affecting small hilltop towns in the Apennine Mountains of southern Italy. The is done by comparing the MTI results based on Sentinel-1 images with those based on ENVISAT data (ESA satellite retired few years ago). The comparison shows that by using Sentinel-1 imagery a few times higher density of radar targets (measurement points) can be obtained. Thanks to this and more frequent measurement capability of Sentinel-1, landslide detection and monitoring can be more effective.

Part II: Landslide Investigation: Field Investigations and Laboratory Testing

Abstract: This paper presents a case study of slope failure in Vlora region Albania, The Dukati landslide is one of the largest and the most problematic slope movement along the Vlora - Himara -Saranda motorway in southern part of Albania. This landslide was triggered by heavy rainfall in February 2010. Geological structures (lithology, faults) and hydrologic conditions have played an important role in its initiation and further aggravation. After the landslide occurred, a research group from Albanian Geological Survey was carried out to investigate characteristic and reasons of the Dukati landslide. Coordinates of the crown of the landslide were recorded by GPS measurements. According to its characteristics, the Dukati Landslide can be defined as deep-seated complex landslide (Do Minh Duc , Nguyen Manh Hieu, Kyoji Sassa etc 2014). From the geological point of view the study area is composed by Cretaceous limestone that lie over flysch deposits of Torthonian. The sliding surface is typically on the contact of the limestone and flysch bedrock composed of interbedded clays and sandstones. The scarp of the landslide departs at an approximate elevation of 290-300 m; the horizontal travel distance of landslide is 525 m. The landslide has an estimate volume of about 1.8 million m^3 and 10 m depth. Samples for laboratory testing were taken from the flysch bedrock, the weathered zone and slope deposits, in order to provide specimens for the determination of their physical and geotechnical properties. The laboratory tests were performed according to the specifications of ASTM and grain size analysis was conducted by sieve methods. This landslide is very active. It has damaged and blocked a part of the motorway. The negative effects of the Dukati landslide are considerable, as the Vlora - Himara -Saranda motorway is an important road axis in southern Albania. Mitigation measures are given for this landslide.

Abstract: We will present a series of new integrated 3D models of landslide sites that were investigated in distinctive seismotectonic and climatic contexts: (1) along the Hockai Fault Zone in Belgium and (2) in the seismic region of Vrancea, Romania. Both sites are deep-seated failures located in more or less seismically active areas. In such areas, slope stability analyses have to take into account the possible contributions to ground failure. Our investigation methods had to be adapted to capture the deep structure as well as the physico-mechanical characteristics that influence the dynamic behaviour of the landslide body. Field surveys included electrical resistivity tomography profiles, seismic refraction profiles (analysed in terms of both seismic P-wave tomography and surface waves), ambient noise measurements to determine the soil resonance frequencies through H/V analysis, complemented by geological and geomorphic mapping. The H/V method, in particular, is more and more used for landslide investigations or sites marked by topographic relief (in addition to the more classical applications on flat sites). Results of data interpretation were compiled in 3D geological-geophysical models supported by high resolution remote sensing data of the ground surface. Data and results were not only analysed in parallel or successively; to ensure full integration of all inputs-outputs, some data fusion and geostatistical techniques were applied to establish closer links between them. Inside the 3D models, material boundaries were defined in terms of surfaces and volumes. Those were implemented in 2D and 3D numerical dynamic models (presented in a companion paper).

Abstract: Landslide is a natural process of the earth's surface, inevitably resulting from gravity with many triggering factors such as rainfalls, earthquakes, slope steepening, removal of vegetation, etc. The most frequent landslide-triggering mechanism is water from intense rainfall or human-based sources. The wide ranges of landslides and the complexity and variability of their interactions with the environment are the key points of a landslide investigation. The rate of the movement is the main factor of high property damages.

On 16th of March in 2006, a rapid landslide occurred in Göynüklü village in Bursa, Turkey. The properties were inevitably damaged after the failure. The triggering factors of the failure mechanism and the properties of the landslide were investigated to specify proper remedial measures at the site. The geotechnical investigations including surface and subsurface studies were performed to determine the extent of the landslide and its sliding surface accurately. Within the framework of the geotechnical investigations, the inclinometer measurements were also recorded after drilling boreholes. Besides, a number of trial pits were excavated for evaluating the shallow sliding surfaces. Samples taken from the boreholes and trial pits were tested in the laboratory to obtain the soil class and the distribution of the grain size of the soil layers as well. The field tests including the hydraulic effect on the soil layers were also resolved by means of in-situ permeability tests. Based on the data obtained, the characteristics and mechanism of the landslide were analyzed. The landslide occurred on a translational sliding surface in Neogene sediments including non-stratified sandstone-siltstone-claystone layers and a landfill site in a residential area. The shear strength characteristics of the sliding surface were calculated by back-analyses.

Pechgraben Landslide: Evaluation of Geophysical/Geotechnical Methods in Terms of Remediation Support, page 289

David Ottowitz, Birgit Jochum, Stefan Pfeiler, Stefanie Gruber, Robert Supper and Jung-Ho Kim

Abstract: Information from the application of geophysical and geotechnical methods are essential for decision makers to initiate appropriate emergency or remediation measures in case of a catastrophic landslide event. This paper summarizes all the applied measuring and monitoring methods that accompanied the catastrophic landslide event of Pechgraben (Upper Austria) in 2013 as well as the three years after the completion of major parts of the remediation work. Beside scientific aspects, the focus of the geophysical/geotechnical investigations was put on the support of decision makers. To improve the efficiency of the support for future similar landslide events, it is necessary to evaluate the applied methods in terms of their information content concerning the emergency and remediation strategy. We ended up with the conclusion that there are a few key methods providing essential information for decision makers during different time phases of the landslide event. However, for a detailed understanding of the landslide behavior and the ongoing subsurface processes, a combination of different methods is required.

Groundwater Flow Behavior at Landslide Area in Crystalline Schist Mountains, page 301

Gen Furuya, Akira Suemine, Jun'ya Honda, Gonghui Wang and Mamoru Inoue

Abstract: It is well known that in many cases the landslide movement is regulated by variation of groundwater. There are many cases the groundwater in landslide mass is shown as a water surface profile. However, it seems that actual groundwater flow exists as vein-like shape in a natural slope (e.g. Takeuchi, 1980; Furuya et al, 2006). It seems that such groundwater flow are controlled by internal structure of landslide mass. Therefore, detecting of location and behavior in groundwater flow are needed to evaluate detailed slope stability. In this study, we carried out one-meter depth ground temperature measurements and water-chemistry analyses in three landslide area (Shallow / debris flow type: Tobinosu area, generally type (deeper than former type): Zentoku area and Nishi-ikawa area), central Shikoku island, where located crystalline schist area, to clarify relationship between groundwater flow and landslide mass. Especially, we conducted additional measurement that continuous monitoring of ground temperature at the depth of one meter, borehole water level at the Nishi-ikawa landslide. These measurements, analyses, and continuous monitoring results were point out the groundwater flow was not simple shape form but spatially and temporarily various form. In the case of shallow / debris flow type, there are two types of flowing. One type was associated with the groundwater infiltrating from rainfall which has approximately the same temperature as the surrounding slope material and quickly discharges to the surface. The other type was a relatively long period flowing (storage) which rainfall was infiltrated in the mass and subsequent through a long path to the shallow layer. This type of groundwater temperature were shown value of deep layer (approximately isothermal layer). Furthermore, some groundwater were recognized flowing from outside if the geomorphological drainage basin. In the case of generally type, there were also groundwater flows were from deep layer into shallow layer. The results of continuous monitoring at the some ground temperature at the one meter depth measurement points at the Nishi-ikawa landslide, especially, showed that increasing of temperature during early heavy rain and significant decreasing of temperature during later in the summer season. The winter season was opposite phenomenon were monitored. The age of groundwater in two types of landslide after heavy rain were estimated not this event but a few years ago by analysis of environmental tracer. We estimated relationship of the continuous monitoring results between rainfall, borehole level, and ground temperature at the one meter depth in heavy rain of summer season, pointed out 1) phenomenon of increasing of ground temperature was caused by infiltration of rainfall, 2) decreasing of temperature was caused by increasing of groundwater level (borehole water level) from deep layer at least isothermal layer by concentrated flow through the vein-like shape flowing. These estimated results lead to the groundwater flows at the crystalline schist mountains were not simple behavior. It was important point when detailed consideration of movement mechanism and control measurement.

Groundwater Flow Characterization Using Different Hydraulic Methods in Large and Deep Earth-Slide Rich in Clay, page 309

Francesco Ronchetti, Leonardo Piccinini, Manuela Deiana, Paolo Fabbri and Alessandro Corsini

Abstract: Since 2013, different hydraulic tests have been conducted and replicated in a large earth slide characterized by a landslide body that is rich in clay, has a mean thickness of 30 meters, and is located in the Northern Apennines, Italy. All the tests were performed to estimate the hydrogeological properties of the landslide and to design future mitigation measures. To define the geometry of the sliding mass, the stratigraphy in more than 15 boreholes was analyzed. The boreholes were subsequently equipped with inclinometers and open standpipe piezometers. According to the stratigraphy, the landslide body is characterized by the presence of gravel layers in a clay-rich matrix. This study compares the results from the different techniques applied to 2 boreholes, 5 open standpipe piezometers and 1 well. The number of tests performed for each test type were 31 slug tests (ST), 4 falling head tests (FT), 5 low-flow pumping tests (PT), 1 point dilution (PD) test, and 2 aquifer tests (AT). Moreover, the test data was evaluated with different solutions. The ST data was evaluated with the Hvorslev and KGS solutions; the FT data was evaluated with the AGI and Hvorslev solutions; the PT data was evaluated with the Muskat solutions; the AT data was evaluated with the Theis, Cooper-Jacob, Neuman, Moench and Tartakosky-Neuman solutions; and the PD test data was evaluated with the classical solution where Darcy velocity is calculated as a function of the rate of dilution. The results show that hydraulic conductivity (K), storage (S) and specific storage (Ss) vary in the horizontal plane and with the depth (K ranges between 1.0E-5

and 1.0E-8 m/s; S ranges between 4.0E-3 and 5E-5; and Ss ranges between 1.0E-3 and 3.0E-3 1/m). The horizontal and vertical variability is correlated with the lithologic heterogeneity highlighted by the borehole stratigraphy. Moreover, all the hydraulic tests conducted on the landslide body give highly consistent results. Comparison of results derived from different methods show that they are comparable with each other and they differ by one order of magnitude only in a few cases.

H/V Technique for the Rapid Detection of Landslide Slip Surface(s): Assessment of the Optimized Measurements Spatial Distribution, page 335

Veronica Pazzi, Luca Tanteri, Gabriele Bicocchi, Andrea Caselli, Michele D'Ambrosio and Riccardo Fanti

Abstract: The investigation of landslides and slope deformation processes may require the integration of a wide range of data types, collected using different approaches, such as geomorphological, geotechnical and geophysical surveys. Among this latter category, seismic noise method can be used to detect and better understand the geometry of landslide slip surfaces. Indeed, a slip surface may generate evident contrasts in shear wave velocity due to changes in seismic impedance, generated by the different seismic velocity and density of materials at landslide boundaries. The H/V or Nakamura method allows to have a punctual information about the depth of the main impedance contrasts, thus, by performing a spatial interpolation of an adequate number of punctual depth measures, is possible to reliably estimate the depth and geometry of the slip surfaces with good accuracy. This study is focused on the relation between the number of the employed single-station seismic noise measurements and the goodness of the resulting, inferred, slip surface(s) for landslides. The final aim is to detect, if it exists, a threshold in the number of measurements beyond which the information obtained is redundant, since the variations in terms of morphology observed in the reconstructed impedance contrast surfaces become negligible. The proposed approach was validated at Castagnola Landslide (Liguria, Italy), where direct measures of the subsoil stratigraphy were available, then applied to another case study, i.e., the Roccalbegna Landslide (Tuscany, Italy), where no direct measurements, apart from those of the shallow layer geotechnical properties, were available. The experiments carried out are a proof-of-concept of the opportunities that this approach can offer.

The Application of ERT for the Geometrical Analysis of the Sebrango Landslide, (Cantabrian Range, Spain), page 349

Alberto González-Díez, Mario Zarroca, Rogelio Linares, Viola Bruschi, Jaime Bonachea, José Ramón Díaz de Terán, Juan Remondo, Gema Fernández, Patricio Martínez, Javier Sánchez and S. Martin

Abstract: Electrical resistivity tomography (ERT) was applied to the geometrical characterization of the Sebrango Landslide reactivation (Cantabrian Range, Spain), which threatened the villages of Sebrango and Los Llanos on June 2013. The Sebrango Landslide is a 1.2 km-long landslide that episodically affects a hillslope located at the northern margin of the Deva River, at the northern sector of the Liebana Syncline. ERT surveying offered the opportunity to investigate the unexposed geometry of the landslide just after finishing the 2013 paroxysmal stage, while other surveying techniques, as core logging, were ruled out for safety and local government regulation during the hazard emergency. The obtained resistivity images provided information on the thickness of the terrain involved by the landslide, on the location of the inner rupture surfaces, and on the groundwater flow pattern within the hillslope. The results suggest that the landslide involves a 40 - 60 m-thick mass of complex structure. The resistivity images show a profuse groundwater flow within the slid mass, especially in the header area affected by the 2013 reactivation. The images also show a preferential groundwater flow longitudinally to the axis of a secondary landslide lobe, at the eastern sector of the landslide body, pointing to this sector is that actually shows greater deformation, as opposed to the main lobe oriented NW-SE. The landslide geophysical model was constrained by a core logging and monitoring campaign conducted during the subsequent months. From a geomorphological perspective, our results suggest that the particular entrenchment dynamics of the Deva River is playing a key role as a preparatory landslide factor.

Understanding Debris Flow Characteristics Using Flume Experiments, page 357

Sangjun Im, Song Eu and Dongyeob Kim

Abstract: Confined or channelized debris flow is one of the most powerful processes for transporting solid materials along the mountain torrent. It is defined as a type of mass movement that involves water-charged, predominantly coarse materials flowing rapidly down along a steep confined, pre-existed channel. Development of debris flow is broadly characterized by initiation, transportation, and deposition, depending on channel gradient, and size and gradation of solid mixture. In order to design debris flow control structure, exact measurement of velocity and corresponding impact force are required. Therefore, debris flow flume has been designed in this study to experimentally examine the flow characteristics of debris flow. A 200 mm (W) x 300 mm (H) x 2,000 mm (L) flume has been used to conduct the experiments with a flume slope of 25, 30, 35, 40 degrees. Velocity of debris flow was estimated by image analysis of photographs, and runout length and width were measured using grids on deposition pan. Two types of debris mixture have defined, based on the portion of clay, sand, and gravel materials. Experiments showed that velocities of debris flow strongly related to flume slope, ranging 1.5 m/s to 2.5 m/s. Runout length and width were affected by the flume slope and debris flow composition

Slope Stability Investigation of Chandmari in Sikkim, Northeastern India, page 363

P. Thambidurai and Maneesha Vinodini Ramesh

Abstract: Landslides are very common in high altitude regions of the Himalayas. The Chandmari landslide is a recurrent landslide located in the Eastern part of Gangtok, Sikkim - a Northeastern state in India. Intense rainfall in the monsoon is the main triggering factor for landslides in this region. This paper enumerates the contributing parameter for rainfall induced landslides, viz., bedrock hydrogeology and geotechnical properties of soil and studies their impact on the same. A geophysical resistivity survey was carried out to identify the subsurface structure and to get an insight of the water saturation profile below the landslide surface. The result of the resistivity study showed high to moderate conducting zone in the lower elevations of the landslide site. This was contrary to what we measured at the higher elevations, which showed higher resistive zones. This anomaly was profound and revealed the existence of water saturated zones below the surface of landslide at these lower elevations. In addition, resistivity results revealed that the weak water saturated debris layer was parallel to the geological contact that favored movement. Results of geotechnical investigation for soil showed that an average maximum dry density was 1.8 kg/m^3 and average optimum moisture content was 31.84%. The results showed that the value of Coefficient of uniformity (Cu) was 6.4 and the value of Coefficient of curvature (Cc) was 0.894. The angle of internal friction and average cohesion values were calculated as 30.57° and 0.2 kPa respectively. A combined hydrological-slope study was performed using SLOPE/W software to understand the relationship of pore water in variations with the aforementioned soil parameters to determine the probability of a landslide occurrence. Finally, the identified conductive feature of the water saturated debris layer was correlated with the calculated slide mass using a slope stability model.

High Performance Heterogeneous Data Storage System for High Frequency Sensor Data in a Landslide Laboratory, page 371

Guntha Ramesh, Hariharan Balaji and T. Hemalatha

Abstract: Wireless sensor networks can be deployed in landslide prone areas to monitor various geological and weather properties to detect a possible landslide and provide early warning for evacuation. Landslide lab is used to mirror geological conditions of target deployment site for the purposes of testing and perfecting the deployment locations of sensors and associated data models for accurate predictions under various simulated conditions. The landslide lab simulates the full cycle of landslide occurrence on a compact time window of few hours. Hence it's critical to capture sensor data at very high frequency, ranging from 100 samples to 1000 samples per second to understand all the minute changes to the geological properties leading to landslide occurrence. A typical test scenario using 16 sensors, sampling at 1000 samples per second, running for 8 hours would generate 460 million data points. A very finely tuned RDBMS system would take 25 hours to store this data at the rate of 5000 records/second at peak i/o rate and even NoSQL data store would not be able to efficiently retrieve this huge volumes of data. We prove that our system outperforms the NoSQL data store by an order of magnitude and the RDBMS data store by two orders of magnitudes in both storage and retrieval of the high frequency sensor data. In this paper we present the architecture, features and performance metrics of our high performance, scalable, and distributed heterogeneous system for data capturing, processing, and retrieval of high frequency sensor data.

Soil Characterization for Landslide Forecasting Models: A Case Study in the Northern Apennines (Central Italy), page 381

Veronica Tofani, Gabriele Bicocchi, Guglielmo Rossi, Michele D'Ambrosio, Filippo Catani and Nicola Casagli

Abstract: In this work we perform an assessment of the geotechnical and hydrological parameters affecting the occurrence of landslides. The aim of this study is to improve the reliability of the physically-based model HIRESSS (HIgh REsolution Slope Stability Simulator), for the forecasting of shallow landslides. The model and the soil characterization has been tested in northern Tuscany, in Italy, along the Apennine chain, an area that is historically affected by shallow landslides. In the area selected, the main geotechnical and hydrological parameters controlling the shear strength and permeability of soils have been determined by in situ measurements integrated by laboratory analyses. Around 60 survey points have been analyzed. The data obtained have been studied in order to assess the relationships existing among the different parameters and the bedrock lithology. Soil properties have been then statistically characterized and used to define the input parameters in the physical model, with the final aim of testing the ability of the model to predict shallow landslide occurrence in response of an intense meteoric precipitation. The rainfall event selected dates back to October 2010 when an intense precipitation affected the area, triggering around 50 reported shallow landslides. The geotechnical and hydrological data collected allowed to generate input map of parameters for the HIRESSS and the simulations showed substantial improvements in the results compared to the use of literature parameters.

identifying critical structural data sets delineating potentially unstable rock blocks, type of down fall movement and rock fall trajectories. This, along with detailed stability calculation of the critical rock blocks serves as powerful tool to recommend mitigation measures needed to secure the international road and the castle, as well.

Geological Assessment and Physical Model of Complex Landslides: Integration of Different Techniques, page 431

Davide Brambilla, Vladislav Ivov Ivanov, Laura Longoni, Diego Arosio and Monica Papini

Abstract: Complex landslides usually need to be investigated in depth in order to understand the geological setting that led to their formation and influenced their development. The origin of a landslide is strongly linked to the geological history of the area, which can be understood studying the slope, its structures and peculiarities. The knowledge of the landslide structure and history is the key point to understand potential future development and evolutions. Classical geological tools and campaigns can only give a partial insight into the inner slope structure, being limited to investigate surface evidences of underground structures. Integration of different survey techniques arises as a crucial point to improve knowledge and overcome traditional techniques' shortcomings. Here, the Torrioni di Rialba (Italy) case study is presented to underline the difficulties in the choice of the right landslide investigation techniques and the integration of data from surveys done in different times by various professionals. A vertical 135m-high rock cliff in Abbadia Lariana, Northern Italy, is suspected to be potentially unstable, although no information about the geological setting is available from previous studies. Although the landslide has not shown activity evidences in the last decades a possible collapse threatens a narrow corridor where the national road, rail road and gas pipe are running close together, menacing to disrupt any connection between the Valtellina valley and its 200.000 inhabitants and the rest of the country. The urge to better understand landslide causes led to start a broad campaign of surveys. Geological investigations were conducted to discover lithology of rocky outcrops and reconstruct the geological history of the slope so as to connect past events to the current setting. The geological knowledge then serves as a base for further surveys carried out to fill the gaps. Geophysical investigations, namely seismic tomography and several electrical surveys gave an insight in the inner slope structure and were calibrated drilling two boreholes on the slope. An accurate Lidar survey of the area as well as lake bathymetry near the landslide spot allowed for precise geometry assessment of the area to correctly locate information gathered by the various techniques and build interrelations between them. In this work, in addition to the obtained results, the weak and strong points of each choice is debated in order to highlight uncertainty in the decisional process, the risk of failure of each survey and to define good practice and caveats. The entire work, which took four years, due to economical and logistic limitations is critically reviewed and the better choices are underlined. Lastly, the physical model of the slope is presented, highlighting the integration of data from different sources and the few still existing doubts, discussing both how to tackle them, if possible, and how the landslide knowledge benefits from various surveying techniques.

Landslide Risk Analysis and Assessment for Urbanized Territories, page 439

Valentina Svalova

Abstract: Geological risk maps are the way and important step towards solving the problem of natural risk management. Due to the complexity and diversity of the problem the question of a combination of probabilistic and deterministic approaches and the use of expert estimates arises. Thus, the probability of the landslide process depends on the stability of the landslide slope, trigger mechanisms (precipitation, earthquakes), technological factors. Ideally, you first need to study the physical and mechanical sliding process in different conditions. But mechanics of landslide process is still not fully understood. Prediction of landslide event is not always possible. Even statistical frequency of activation of landslides for a particular area varies very widely. As an example let us consider the approach to the construction of the map of landslide risk in the territory of Moscow. Landslide processes in Moscow are well investigated. Landslides cover about 3% of the city, where there are 15 deep and a lot of small landslides. The maps of landslide hazard areas are constructed. Recently in Moscow there is a significant activation of landslide processes. Completed landslide measures significantly distort the natural pattern. But to assess the potential landslide hazard the height of the slope, the landslide body volume, mass velocity, rock properties, topography of the surrounding area, the range of possible promotion landslide masses, hydrogeological conditions, trigger mechanisms can be taken into account. Experienced landslide researchers are capable of giving highly accurate comparative assessment of landslide hazard for different slopes at Moscow area. Selection of taxons (special areas) varying degrees of landslide hazard in the city is completely solvable task. And gradation is possible as in the three degrees of danger (high, medium, low) as in five ones (very high, high, medium, low, not dangerous), depending on the detail of the task. The most expensive land and buildings in Moscow are located in the city center. There are also the oldest historic buildings, the most vulnerable to natural hazards. There are also the most expensive new ground and underground construction, subway lines, complex traffic and technical communications of high density. There is an increased density of population and the people in the daytime. We can assume that the closer to the center of Moscow, the greater the potential damage from possible landslide process. Hazardous industrial production brought to Moscow's periphery. But the protected zone of Moscow on the Vorobiovy Hills and in Kolomenskoye also have high inventory and cultural value, and the potential damage there is highly evaluated. So to a first approximation map of landslide risk in Moscow may be an overlay of landslide hazard maps and population density, building density, land prices, density of roads and infrastructure maps. Areas with the highest degree of landslide hazard and the highest damage are the areas of the highest landslide risk in the territory of Moscow. Methodology for risk evaluation and mapping is elaborated and suggested. On the basis of preliminary expert estimates,

it will be the areas in the vicinity of Moscow River and Yauza River, as well as in the areas of contrasting relief along riverbeds of paleorivers in the city center. These areas may be considered as "hot spots" on the risk map. And if in some of these points, the population density is not so high, the other components (cost of land, the historical importance of the object, the density of underground utilities and others) give a great contribution to the high risk assessment. The problem of geological risk management is seen as a series of events leading to risk reduction, including the organization of an integrated environmental monitoring system.

Effect of Wetting-Drying Cycles on Shear Strength of the Clayey Soils in the Three Gorges Area, page 447

Baoping Wen, Hui Li and Boxun Ji

Abstract: Slope along the water level fluctuation zone in the Three Gorges reservoir area of China is suffering from failure frequently. Shear strength reduction of the slope materials due to wetting-drying cycles along the water level fluctuation zone may be one of the major causes leading to slope failures there. In this study, shear strength of clayey soils derived from three kinds of highly weathered argillaceous rocks, which are the most susceptible to landsliding in the area, was experimentally investigated following different wetting-drying (W-D) cycles and with different initial water content. Test results reveal that shear strength and their parameters of the three clayey soils reduced significantly after experiencing W-D cycles regardless of their initial water content. Reduction in both shear strength and their parameters of the soils derived from highly weathered mudstone occurred significantly when W-D cycles were less than 9, while such reduction of the soil derived from highly weather marl linearly lowered with W-D cycles even when the cycles were up to 13 times. All the three kinds of clayey soils with lower initial water content had greater reduction in both shear strength and their parameters, and vice versa. It is further discussed that two effects: swelling and desiccation of clay size particles (mainly clay minerals) and slaking of rock fragments coarser than silt, which occur during W-D cycles, lead to reduction of shear strength and their parameters of the clayey soils. Difference in reduction degree of shear strength and their parameters among the soils should be related to their difference in abundance of clay fraction, percentage of active clay minerals and rock fragments prone to slaking.

Sediment Transport Along Earth Flows: Intermittent Cascade Effect Between Kinematic Zones, page 471

Luigi Guerriero, Lara Bertello, Nestor Cardozo, Matteo Berti, Gerardo Grelle and Paola Revellino

Abstract: We used GPS surveys, boreholes, seismic profiles and field observations to investigate the cross sectional geometry, kinematics and sediment discharge of the Mount Pizzuto earth flow in southern Italy. This earth flow is characterized by several kinematic zones, characterized by an area of stretching with normal faults upslope and an area of shortening with thrust faults downslope. Our results indicate that: i) during surging episodes, earth flow acceleration propagate from the head toward the toe with constant sediment discharge inducing a cascade effect between consecutive kinematic zones, ii) change in mechanical behavior of the material might occur due to the presence of a well-defined neck influencing movement propagation, iii) during ordinary movements, sediment discharge varies along the flow and the activity of kinematic zones seems to be independent from each other. Implications are that it is not correct to consider sediment discharge as constant but rather as a function of the earth flow activity.

Part III: Landslide Modeling: Landslide Mechanics and Simulation Models

Abstract: The Ok Tedi Mine is located in a rugged, mountainous region of the West-ern Province of Papua New Guinea that receives exceptionally high rainfall and is prone to seismic activity. Geologic and geotechnical conditions in the region are also complex and often unfavorable and contribute to slope in-stability and landslide activity. Very few suitable areas exist around the mine for the construction of infra-structure facilities. Most of the existing infrastructure is located on terraced areas developed by cut-and-fill earthworks. This paper describes the most recent efforts undertaken in attempt to model and understand a highly ductile active-passive landslide that has de-formed in the order of 30m on New York Ridge in the northern part of Ok Tedi Mine for over 25 years.

Abstract: Landslides are a major hazard causing large human losses worldwide. Thus, it is crucial to identify primary causes of deadly landslides and evaluate emerging landslide prediction efforts and public preparedness. However, there is currently only limited data available on the historical occurrence of fatal landslides. Hence, in the present study, European spatiotemporal distribution of fatal landslides are presented over the last twenty years (1995-2014). Spatial and temporal trends are evaluated in 476 locations. Relations between fatal landslides and population density were investigated. A total of 1370 deaths are recorded in this period resulting from 476 landslide events. High correlations were observed between high dense areas and fatal landslides locations. Most events occurred in mountainous regions. Significant increasing trends of fatal landslides are observed in various countries throughout Europe. Twenty eight (28) high risk clusters and excess risk locations were identified for future policy implementations. This study will contribute in saving human lives from killer landslides in near future.

Abstract: Landslide propagation modeling is important task in susceptibility and hazard analyses. Model reliability is typically assessed comparing the numerical results to field evidences. In the paper, the Smooth Particle Hydrodynamic (SPH) method and an inverse analysis procedure are used to calibrate the soil rheological parameters for a well-document case history of Honk Kong. The results obtained by the performed analysis are discussed to provide simple practical criteria to individuate the minimum amount of information required for a satisfactory rheology calibration.

Abstract: A major trigger for shallow slope failures is rainfall, whose infiltration results in a reduction in the factor of safety from an increase in pore water pressures, increases in the degree of saturation and reductions in the shear strength of the slope material. In this study, model slopes were prepared in a Plexiglas box from a clayey soil obtained from a housing development site at CSU Fullerton and used to examine the influence of the variations in the slope forming material properties and the applied rainfall. Specifically, model slopes were prepared to have four different relative compaction levels between 60% and 74% at an inclination of 40°. The slopes were instrumented with tensiometers and copper wires to evaluate the pore pressure response and deformation when 30 mm/hour of rainfall was applied using a rain simulator system. The variation of seepage velocity with rainfall duration, spatial distribution of suction and the deformation of the slope were recorded. The rainfall was stopped when complete saturation of the slope was obtained, as determined from visual inspection of the wetting front and the real-time tensiometer recordings. From the results obtained, increase in the initial void ratio and intensity of the rainfall resulted in an increase in the pore water pressure as well as the velocity of the wetting front. The study result was useful to obtain relationship between relative compaction, seepage velocity, and deformation characteristics of the slope.

Abstract: The influence of long duration rainfall on the stability and deformation characteristics of red-clay slopes in China was evaluated using GeoStudio 2012. The 15 m tall modeled slope with a slope inclination of approximately 37° was subjected to rainfall at an intensity of 6.25×10-3 m/hr for various durations. The durations examined in this study ranged between 1 day and 5 days. The pore water pressure and deformations resulting in the slope were evaluated using coupled and uncoupled analysis.

Specifically, in the coupled analyses, the combined influence of seepage and deformation on the pore pressure, development of strains and the slope stability were examined. On the other hand, in the uncoupled analyses, only the influence of seepage on the pore pressure, strain development and factor of safety was considered. The results obtained suggest that the rate of pore pressure development was most significantly influenced when four days of rainfall was applied to the slope. The slope was found to settle following short duration rainfall events. However, the slope would swell during the long duration rainfall events. In these events, the greatest swelling was observed at the head of the slope. Similar to the pore pressure response, the factor of safety behaved hysterically with larger magnitudes noted in the coupled analysis in comparison to the uncoupled analysis.

Back-Analysis of an Artificially Triggered Landslide: A Case Study in Northern Italy, page 541

Alex Sanzeni, Tiziano Cancelli, Marco Peli, Stefano Barontini and Francesco Colleselli

Abstract: The paper presents a case study of a landslide event, artificially triggered by an exceptional infiltration in an otherwise stable slope. The work aims at investigating the slope failure mechanism, within a simplified two-dimensional conceptual framework based on the formation of a perched water table. The landslide occurred in Northern Italy in April 2010 on a hillside with average slope angle between 36° and 37°. The event affected an area of about 200 m²; the slip surface was located approximately 1 m below the slope profile, in the uppermost layers of a predominantly coarse, well graded soil. The site was characterized by gathering existing information about the local climate, morphology, geology and hydrogeology. The geotechnical characterization was performed before authors' involvement and included bore-holes, in situ and classification laboratory tests. A series of numerical simulations were performed to backanalyse the event, using a commercial software. The hydrological model and the geotechnical model were uncoupled. The soil-water retention curves and the relative conductivity functions were estimated by means of the software ROSETTA, developed by the United States Department of Agriculture, which allows to infer the van Genuchten-Mualem model parameters known the soil texture and the matrix bulk density (experimentally determined from the soil samples taken on site). Values of the hydraulic conductivity at soil saturation were assumed according to the observed soil layering during the geotechnical investigation campaign. The artificial water infiltration and water content evolution were simulated with a two-dimensional finite element (FE) model of the unsaturated/saturated domain with appropriate infiltration boundary conditions. The slope stability analyses were conducted with classic limit equilibrium (LE) methods and performed at different time instants during the infiltration process, for tracking the temporal evolution of the slope safety factor and therefore to identify the crisis onset moment. The combined FE and LE numerical simulations showed the gradual formation of a perched water table which takes place during the infiltration process due to the physical and hydraulic properties of the uppermost soil layers. The formation of such localized pore pressure distribution results in the loss of the suction stabilizing effect and thus in the reduction of the safety factor. Although supported by a basic soil mechanical and hydraulic characterization, the numerical simulations allowed to perform a back-analysis which effectively captured the timing of the event and the location and depth of the slip surface along the slope. Also, due to the inherent stability of the hillside, the reconstructed intensity-duration function described infiltration events that are meaningfully intense if compared with other cases in the literature.

Numerical Modelling of Hydrological Parameters for an Enhanced Interpretation of ERT Monitoring Data, page 551

Stefan Hoyer, David Ottowitz, Birgit Jochum, Stefan Pfeiler, Robert Supper and Jung-Ho Kim

Abstract: Introduction: Since 2007, the Geological Survey of Austria runs a multi-parametric European landslide monitoring network, which is mainly based on Electrical Resistivity Tomography (ERT) monitoring in combination with other geotechnical parameters (displacement, precipitation, soil moisture,…). Hydrological interpretation of the collected ERT data is typically carried out qualitatively on a visual basis. The project LAMOND aims firstly at improving the observation, understanding and prediction of subsurface processes triggering landslides, based on an innovative, multi-parameter monitoring technology and the long-term observation of triggering events in different geological settings. The second part, the focus of this paper, is numerical modelling in combination with parameter estimation to build a basis for an enhanced hydrological interpretation of the ERT results. Furthermore, the project focuses on the handling of the social consequences of warning by developing new processes and methods for stakeholder involvement in the design of a warning system, ending up with recommendations for an end-user focused early warning system.

Data: ERT data is collected at five landslide sites, three of which located in Austria, one in Italy and one in France. The inversion of the collected ERT monitoring data is done using a 4-D inversion software developed by KIGAM (Kim et al., 2013) in close co-operation with the Geological Survey of Austria. The infiltration of rainwater is clearly visibly in the inversion results as declining electrical resistivity. The relation between electrical resistivity and water saturation is described by Archie's Law, for a conversion more parameters have to be evaluated and are a-priori unknown. Hence, a parameter estimation routine is employed.

Methodology: The process of parameter estimation consists of two iteratively repeated steps, the so-called forward and the reverse model. In this case the forward model is the Finite Element (FEM) solution of Richard's equation, the reverse model employs the Sparse Nonlinear Optimization solver (Gill et al., 2005) both implemented in the COMSOL Multiphysics modelling environment. The result of the forward model (water saturation) is compared to the ERT section (resistivity) using Archie's law, the variable model parameters are the porosity and the van Genuchten parameters describing the water retention of the vadose zone. Since also the Archie parameters - tortuosity as well as the cementation and the saturation exponents are a-priori unknown, another parameter estimation solving for these parameters is carried out.

Conclusions: The implementation of parameter estimation and finite element modelling makes the interpretation of ERT data quantifiable in terms of water saturation or soil moisture content, respectively. This is a crucial step towards closing the gap between field measurements (ERT monitoring) and a hydrological process model which can be the basis for definition of early warning levels on rainfall-induced landslides.

Process Chain Modelling with r.avaflow: Lessons Learned for Multi-hazard Analysis, page 565

Martin Mergili, Jan-Thomas Fischer and Shiva P. Pudasaini

Abstract: Multi-hazard configurations - including chains or interactions of landslide processes - have increasingly concerned scientists and practitioners in the last years. However, theoretical concepts have not yet fully evolved to effective modelling strategies suitable for anticipating the occurrence of particular multi-hazard events in space and time. The two-phase mass flow simulation tool r.avaflow would facilitate such a task. We employ r.avaflow along with a generic landscape including an initial landslide release mass, a reservoir, an erodible dam, a canyon with erodible bed and a horizontal plane in the foreland in order to analyze scenarios of process chains triggered by the release of the initial landslide. The analysis demonstrates that the simulation results are highly sensitive to changes in the initial conditions (release volumes), and the material parameters such as basal friction angle or entrainment coefficient. Minor parameter changes may lead to a complete change in the characteristics of the process chain due to threshold effects (dam overtopping) and strong positive feedbacks (entrainment of the dam and increased outflow). Since the parameters tested are often highly uncertain in real-world cases, we conclude that forward predictions of process chains are susceptible to failure unless (i) the system under investigation is well known; (ii) the parameter sets are derived from thorough back-calculations of well-documented events; and (iii) appropriate strategies to express the uncertainty of the results are applied. Whilst these criteria are relevant for all types of landslide processes, they are more important, but also more challenging to implement for process chains and other types of multi-hazard processes due to (i) their higher level of complexity; and (ii) their lower frequency (few reference cases).

A Smoothed Particle Hydrodynamics Study of an Experimental Debris Flow, page 573

Caitlin Chalk, Manuel Pastor, Duncan Borman, Andrew Sleigh, Jeff Peakall, William Murphy and Raul Fuentes

Abstract: A comparison between a physical model debris flow of a monodispersed sand and a numerical model is presented. The physical experiment consisted of the instantaneous release of a saturated sand mass via a lock gate in a 220 x 160 mm rectangular channel of length 1.75 m. The sand mass had a 20 % moisture content and was placed in the same position behind the lock gate before each experimental run. Additional water was added to the mass to keep the sand particles in suspension. The inclination of the flume was 31 degrees which meant that the sand reached runout velocities of 1 m/s, approximately. The free surface of the flow was monitored in order to compare the readings to a Smoothed Particle Hydrodynamics (SPH) numerical model where a frictional Mohr-Coulomb model was implemented. This model was that of Voellmy, including the turbulent Voellmy coefficient. The free surface of the experimental flow was predicted well by the numerical model, showing the ability of the SPH model to predict the run out behaviour of small scale debris flow experiments with physically viable rheological parameters. This validation of the model is essential for its use in predicting landslide behaviour in the field. The prediction of the behaviour of landslides in areas that are susceptible to them is a key step in reducing the damage that they cause.

Simulation Model to Predict Landslide Speed Using Velocity-Dependent Viscous Damping, page 579

Eisaku Hamasaki, Hideaki Marui and Gen Furuya

Abstract: Authors propose a simulation model using damper to predict the moving velocity(V) of the landslide before reaching 3rd creep stage. The landslide analyzed in this model is typical large scale slope movement which is more than 3 m thickness except small fall and collapse. The landslide is slow movement type, it is investigated daily or hourly using extensometer.

Saito model (1987) and Fukuzono model (1990) are well known as models to predict the final failure stage of landslide displacement by collecting data of displacement velocity.

Even if these models provide very useful result to know the time for final stage of the slope failure after 3rd creep stage, these models do not consider mechanical and physical state of landslide bodies. Even though another forces induced by such as rainfall, embankment and excavating are increasing, the effect of these increasing forces are not considered in the analysis using these models. In order to predict the landslide velocity, an effective simulation model which is based on kinematic equations is proposed using mass system model composed of damper. The damper is introduced to express a damping force, which effect into the opposite direction namely downward of the landslide, according to the velocity of landslide. We consider that this model can be named as "viscous damper model" or "dashpot damper model" in Maxwell creep model.

For stability analysis, the simple slope stability analysis method like Fellenius method is used. In the analysis, resistance force(R) and driving force(D) were calculated in each individual slice and summed up for all slices. Safety factor(Fs) is indicated as Fs=R/D. Then, the kinematic equations is shown as $m\alpha=F - A \cdot Cd \cdot V$. In the equation m is mass and α is acceleration of the landslide. After solving the kinematic equations, the formula "$V \approx F / A \cdot Cd$" is obtained. A is the area of the slip plane of the landslide. Cd is the viscosity coefficient of the damper, which effect on the slip surface of landslide. Furthermore it is finally

deduced by this method that downward forces(F) have close linear relationship to velocities(V). Therefore, velocities(V) of landslides increase in response to increasing downward forces(F). The analytical result using this technique to the Kostanjek landslide in Zagreb, Croatia clarified that this mass system model is effective to reproduce the variation of landslide velocity in response to the variation of groundwater level. Also, the landslide induced embankment along the Japanese highway road in 4th August 1986 during construction of the road was analyzed using this technique. The variation of moving velocity along reducing embankment is effectively reproduced by this damper method.

Influence of Ice Content on the Run-Out of Rock-Ice Avalanches, page 587

Qingqing Yang, Zhiman Su, Zhihao Li and Hongwei Liu

Abstract: Rock-ice avalanches in cold high mountain areas can have an extremely high mobility and an enormous destructive potential. As a result of a warming climate, these catastrophic rock-ice avalanches and rock-ice avalanche induced secondary disasters significantly increase and thus have attracted much attention from researchers. Ice is often subject to a critical role to enhance the mobility of rock-ice avalanches. However, the role of ice during the propagation process of rock-ice avalanches has not been systematically investigated and its influencing mechanism on the typically extremely long run-out of such events is poorly understood. In this paper, a series of small flume tests was carried out to simulate the propagation process of rock-ice avalanches and to quantify the influence of ice content on the run-out of such events. Experimental results show that ice particles were involved in the front mass of mixtures of rock and ice particles during their whole movement. The involved granular ice significantly enhanced the mobility of these mixtures. With excess granular ice, however, the run-out decreased because ice particles bonded together to be larger ones and were difficult to involve inside the mass of granular avalanches. This indicates that the mixing of ice and rock particles played an important role to enhance the mobility of rock-ice avalanches. The smaller size ratio of ice particles and rock particles, the easier ice particles entered into the mass of the mixtures, the farther the mixtures moved. This work contributes to a better understanding of the role of granular ice in enhancing the mobility of rock-ice avalanches.

The Effect of the Front Inclination on the Impact Forces Transmitted by Granular Flows to Rigid Structures, page 593

Francesca Ceccato, Paolo Simonini, Claudio di Prisco and Irene Redaelli

Abstract: The assessment of the damage of existing structures caused by flow landslides, as well as the design of sheltering structures, requires the evaluation of the forces arising during the impact. In particular, the peak force depends on several factors such as the impact velocity, the material bulk density, the flow thickness, and the material compressibility. The effect of the front shape on the force evolution has rarely been taken into account because it is experimentally very difficult to consider. The aim of this paper is to study numerically the impact process evaluating the effect of the material constitutive parameters and shape of the flow front. Large deformations of the granular material are simulated by employing a 3D numerical approach based on the Material Point Method (MPM). The granular material mechanical behavior is simulated by means of an elastic perfectly plastic model with a Mohr-Coulomb failure criterion. The soil mass is initially positioned in front of the wall with a prescribed uniform velocity and the evolution of the impact force is monitored. The results show that the front shape not only influences the peak pressure, but also the evolution of the impact force with time.

Modeling Debris Flows in Anomalous Basin-Fan Systems, page 601

Erika de Finis, Paola Gattinoni, Lorenzo Marchi and Laura Scesi

Abstract: The paper proposes a modeling analysis of debris flows in anomalous basin-fan systems. Previous studies pointed out that the main geo-hydrological hazard in anomalous basin-fan systems is really related to the occurrence of debris flows, favored by the presence of large amount of loose debris on high slopes, which also favor the predominance of the entrainment process in determining the magnitude of the events. Consequently, the pseudo-3D model RAMMS DEBRIS FLOW was used in order to simulate the debris flow dynamic in anomalous systems. At this aim, a back analysis was carried out on the debris flow that occurred in July 2013 in the Gadria catchment (Val Venosta, northern Italy). This event was characterized by a quite small source area located in the head zone of the basin, whereas the volume that reached the basin outlet was quite large, because of entrainment process. The frictional parameters were calibrated using the entrainment simulation, obtaining values more similar to the ones typical of rock avalanches than the values generally used for the simulation of debris flows.

Insights from LS-RAPID Modeling of Montaguto Earthflow (Italy), page 611

Sabatino Cuomo, Vincenzo de Chiara, Sanja Dugonjić Jovančević, Martina Vivoda Prodan and Željko Arbanas

Abstract: The paper deals with the numerical modeling of the Montaguto earthflow (Italy), as typical case of multi-stage flow-type landslide, formerly analyzed subdividing the whole process in subsequent stages. The paper proposed a unique simplified model including i) slope stability analysis to simulate the landslide initiation process due to pore pressure increase and ii) landslide dynamic analysis for propagation, volume enlargement by entrainment and energy dissipation due to frictional, non-

frictional and velocity dependent terms. The numerical results are capable to provide a substantial framework for interpreting the main kinematic and morphological features of the landslide.

Parametric Analysis of Weathering Effect on Possible Reactivation of the Valići Landslide, Croatia, page 621

Martina Vivoda Prodan and Željko Arbanas

Abstract: A landslide of approximately 500.000 m^3 occurred near the Valići Lake in outback of the City of Rijeka, Croatia, in February 2014 after long term period of heavy rainfall. The toe of the landslide reached the bank of the Valići Lake near the downstream located Valići Dam. The landslide is located on the west slope in the middle part of the Rječina River Valley which is an area susceptible to sliding with a lot of different types of mass movements recorded in the past and recent history. The Cretaceous and Paleogene limestone rock masses are located at the top of the slopes, while the Paleogene flysch rock mass is situated on the lower slopes and at the bottom of the valley. Flysch rock mass consists of silty marl, laminated silt to silty shale and fine-grained sandstones. Unlike carbonate rocks, a flysch rock mass is subjected to weathering which causes material disintegration, changing of geotechnical properties and shear strength degradation resulting in instability processes in flysch slope deposits. In this paper the influence of weathering on flysch rock mass and a new long term rainy period on the reactivation of Valići landslide is analysed. Numerical analysis are made using LS-Rapid simulation software which integrates the landslide initiation process by pore pressure increase, motion process and finally deposition stage. To obtain input parameters for numerical model, undrained ring shear and direct shear tests on the samples with different weathering grades taken from the Valići landslide were carried out. The results of numerical simulations demonstrate that raising of ground water level in the landslide body and weathering of the flysch rock mass on the sliding surface will have the main influence on possible landslide reactivation and further landslide development.

Review on Types of Root Failures in Shallow Landslides, page 633

Ana Sofia Dias, Marianna Pirone and Gianfranco Urciuoli

Abstract: Nowadays the interest of geotechnical engineers for green solutions is being developed and the use of vegetation as a reinforcement to improve slope stability is growing. The sliding surface of shallow landslides tends to not exceed 1.5-2 m depth, and as a consequence it can be crossed by roots that, in this case, work as a stabilizing measure. Therefore, the study of the soil-roots interaction is necessary to quantify the contribution of vegetation to the stability of shallow landslides. The goal of this paper is to provide an overview of the root failure mechanisms that can occur along the sliding surface and of the forces applied by roots, in order to evaluate the safety factor of a reinforced slope. Several prevailing stress states occur along a shallow landslide failure surface: tension stress at the slide crest, shear stresses along the base of the unstable soil layer and passive earth pressures at the slope toe. Some considerations are also made regarding acceptable simplifications, in terms of root geometry and soil-root friction strength, that are currently assumed in the literature.

Review on the Methods for Evaluation of Root Reinforcement in Shallow Landslides, page 641

Ana Sofia Dias, Marianna Pirone and Gianfranco Urciuoli

Abstract: Recently geotechnical engineers aim to adopt more environmental-friendly solutions (not harmful to the environment), therefore the interest on the use of vegetation as a measure to improve slope stability is increasing. The mechanical reinforcement due to roots against shallow landslides occur when the fibres intersect the shear surface, usually at depths lower than 2 m. In the literature, the presence of roots is often taken into account by modelling the soil as an equivalent composite material: 'the root-permeated soil', by including an additional cohesion term in the Mohr-Coulomb equation. The models used to estimate the root additional cohesion are presented in the first part of the paper. In some cases, root cohesion is calculated based on the resistant properties of the fibres and assuming an order for the progressive roots failure, either breaking, slipping out or buckling. On the other hand, some authors used structural models of the roots investigating not only the stresses in the roots, but also in the surrounding soil to obtain a better estimation of the root cohesion. In the second part of the paper, the calculation of the root reinforcement is used to assess the safety factor (SF) of the slope. Both Limit Equilibrium analyses (LE) and Finite Element Methods (FEM) are discussed, stressing the limitations of both the approaches.

Preliminary Investigations and Numerical Simulations of a Landslide Reactivation, page 649

Željko Arbanas, Snježana Mihalić Arbanas, Martina Vivoda Prodan, Josip Peranić, Marin Sečanj, Sanja Bernat Gazibara and Martin Krkač

Abstract: A large landslide occurred at the south-western slope of the Rječina River Valley in outback of the City of Rijeka, Croatia, on 13 February 2014 after long term period of heavy rain. The toe of the landslide reached the bank of the Valići Reservoir 250 m upstream of the Valići Dam. The landslide movements of approximately 12 to 15 m down the slope caused the complete damage of the local road over the landslide body. In the course of urgent measures, the preliminary surface observation was carried out immediately after sliding appearance enabled estimation of site condition, dimension of the landslide as well as

an assessment of a hazard and risk of further landslide movements and impact on reservoir and dam. The estimated dimension of landslide body are length of 350 m, width of 135 m and 20 to 30 m of soil deposits to the slip surface.

Landslide geometry was identified based on surface observation and mapping in combination with visual analyses of surface morphology of very high resolution digital elevation model. Very high resolution digital elevation model was derived from existing airborne LiDAR scanning data performed in March 2012. It was identified that the recent landslide is the reactivation of the dormant landslide which contours were clearly visible on LiDAR images. Borders of both dormant and reactivated landslides were confirmed by engineering geological mapping on the new topographic map. The reactivated landslide included only part of the dormant landslide area. Since a slip surface position was not identified by the field investigation, a numerical analysis of a slope using the strength reduction method was introduced to determine the shape of the zone of rupture which would be used in landslide simulation.

As a main hazard of further landslide movements, the filling of the Valići Reservoir, forming a landslide dam and overflow of the downstream located dam were identified. To determine possible scenarios those could be realized, numerical simulations of further landslide development were conducted using LS-Rapid simulation software. While the foot of the landslide is submerged in the reservoir, the magnitude of motion, run off sliding path and deposition of sliding mass significantly depend on the reservoir water level. The landslide simulations were conducted for four different reservoir water levels correspondent to full reservoir, overflow level, and two lower safety levels. In case of high reservoir water level correspondent to the dam overflow, the sliding mass would significantly fill the reservoir and cause the landslide dam, while the water level rising and landslide caused waves (tsunamis) would overflow the Valići Dam and cause significant damage downstream the Rječina River channel. Conducted numerical simulation results enabled a selection of relatively safe reservoir water level at which, in case of further landslide movements, no current harmful consequences would be realized but the reservoir filling by sliding mass would cause significant reduction of reservoir volume, disturbances in the Rječina River and Valići Reservoir flow regimes so as long term disruption of hydro power plant working.

Investigation on the Hydraulic Parameters Affecting Shallow Landslide Triggering in a Pyroclastic Slope, page 659

Roberto Greco, Luca Comegna, Emilia Damiano and Andrea Guida

Abstract: Large mountainous areas surrounding the city of Naples (southern Italy) are characterized by the presence of steep slopes covered with few meters of loose pyroclastic materials in unsaturated conditions lying upon a fractured limestone bedrock, the stability of which is ensured by the contribution to shear strength due to suction. Wetting of the soil cover during rainfall infiltration may cause the triggering of shallow landslides, sometimes developing in form of fast and destructive flows. In this preliminary study, a sensitivity analysis is carried out, aiming at quantifying the effects on the hydrological response of a slope to precipitations, of some factors, related either to the hydraulic properties of the soil cover or to the permeability of the soil bedrock interface. In particular, the sensitivity analysis refers to the slope of Cervinara, around 40 km northeast of Naples (Italy), covered by a pyroclastic deposit with an average thickness around 2.0 m, laying upon a fractured limestone bedrock, and characterized by an average slope angle of 40°. For the sake of simplicity, the analysis is carried out by means of a one-dimensional infiltration model, based on the Richards' equation written for a single homogeneous soil layer.

Analysis of Failure Mechanism of Slopes with a Horizontal Weak Intercalation Under Earthquakes, page 669

Zhenlin Chen and Nanqi Huang

Abstract: The wave theory was employed to analyze the dynamic response and deformation of layered rock slope under seismic loading in this study. According to the investigation of the wave theory, the wave propagation could be described by the distribution law of wave energy. The wave theory is seldom used to analyze the stability of a complicated slope because the computational cost is very high for studying the stability of the whole slope in practical engineering. In order to further develop the application of wave theory in studying the seismic dynamic response of slopes, the ray theory of seismic wave can be employed here. For decreasing the analysis difficult, the whole rock slope could be divided into different zones so that we can compute the dynamic response of the zone precisely which is affected obviously by seismic wave. The time-displacement functions of characteristic points in slope will be built for analyzing the layered rock slope deformation behavior. The energy density function was also employed to compute the dynamic deformation of the layered slope with a weak intercalation. Furthermore, the prophecy of potential danger zone and failure mechanism could be discussed carefully. The results obtained by energy analysis method are consistent with the results observed from the experiment. The proposed method could be helpful to reveal deformation behavior of complicated rock slopes under earthquakes.

Stochastic Investigation of the Feasibility of Using Remotely Sensed Moisture Data for Rainfall Induced Landslide Hazard Assessment, page 679

Thilanki Dahigamuwa and Manjriker Gunaratne

Abstract: The ability for timely evaluation of sudden increases in ground moisture levels would be a valuable tool in reliable assessment of rainfall triggered landslide risk. Surface soil moisture estimated based on satellite images would be vital in such evaluations. In this study, three alternative stochastic classification models, logistic regression, decision tree and bagged tree have been developed to identify locations of high landslide risk based on site attributes of geology, soil type, slope, land cover and the corresponding satellite based soil moisture estimates. As opposed to the commonly used validation set approach, in this work, cross validation was employed to improve the prediction accuracy of the models. It was seen that all three classification models provided reasonably accurate predictions. It is expected that the findings of this research would lay the groundwork for the future formulation of a timely, reliable and effective method for landslide hazard prediction.

Part IV: Landslide Hazard, Risk Assessment and Prediction: Landslide Inventories and Susceptibility, Hazard Mapping Methods and Damage Potential

Abstract: Reservoir landslide is a typical geological disaster in the hydropower reservoir, which poses a great threat to bank infrastructures and human lives. In this paper, one hydropower reservoir is taken as an example to study the distribution characteristics, formation mechanism and hazard effects of hydropower reservoir landslides. In this hydropower reservoir, different scales of landslides are distributed along the both banks of the reservoir. These landslides are formed in different time and related with the history of the reservoir water level variation. Most of the reservoir landslides are neared to the water surface line with small volume, and happened in the shallow deposits. Favorable geological conditions (steep slope, broken rock, widespread deposits and others) provide the susceptibility of the landslide, and the shocking of the 2008 Wenchuan earthquake and occasional rainfall provide some contributions for the reservoir landslides. Water fluctuation is the key triggering factor for the reservoir landslides, especially by the act of rapid drawdown of water level. These reservoir landslides pose several effects for the Hydropower Station, bank infrastructures and human lives, include uplift of the riverbed elevation and cause the decreasing of reservoir capacity, roadbed settlement and destroy of road and tunnel, threat for the human lives and properties, and others. For the hazard prevention of reservoir landslides, firstly, the traffic route should be changed and moved to higher elevations, and should be stay away from the reservoir bank; secondly, resident live near the reservoir bank can be relocated in advance, preferably not in the reservoir area; thirdly, to develop a reasonable operation scheme for the water level of reservoir, the large and frequent fluctuation of water level should be avoided, especially for the rapid drawdown of water level.

Abstract: Mechanically weak zones which may not visible from the surface and which may occur e.g. due to landslides can be detected and characterized by the newly developed Pressure Probe (Pre-P)method. On a high bank at Dunaszekcső, Hungary, the fracture system of the loess landslide area was investigated by large resolution applying this method and proved that: 1. cracks as small as 2-3 cm wide are detectable; 2. The fractures follow each other almost periodically; 3. On the side of the fractures towards the slump there are less fractured zones whose width correlates with the width of the given fracture. We also demonstrated that on the passive side of the clearly visible fracture: 1. There are also fractures along which future rock displacement is expected; 2. These fractures are at least as wide as the active side fractures; 3. The blocks there are about twice as wide as those on the active side. A block several meters wide is expected to fall before the main mass movement. The Pre-P method seems to be the most powerful tool to map the fracture system of such landslides because of its speed, simplicity of application, cost and interpretation. The Pre-P profiles and maps of the fracture system of a landslide enable to understand landslide evolution and delineate endangered areas earlier than by other methods.

Abstract: An evaluation method of large-scale landslide affecting area was proposed in this research. To setup the mitigation system, the defined of the affecting area is the most important work. The affecting area of landslide could divide into source, transporting, and deposition area. The source area, could be identify with the high solution DEM. The transportation and deposition area could be identified with the movement process of the landslide. In this research, three types could be defined for the transportation and deposition area, which are landslide type, debris flow type, and landslide dam type. The interpretation of three types are based on the volume, location, and the topography of the hill foot. There are two stages to quantity the affecting area of large-scale landslide. For the first stage, national wide work, the empirical method was used. From the area of source area, the volume, the movement distance could be evaluated. With the comparison between the movement distance and hill foot topography and interpretation process, the affecting area could be quantity quickly. The possible dangers village could be find out by the first stage result. For the high risk village, the numeral simulation method was applied as second stage. All the methods were verified with historical events.

Abstract: Anticipating the failure of unstable slopes is a topic of major concern in the field of landslide risk management. Arbitrary displacement or velocity thresholds are typically used to setup alarms representative of different risk levels. This is a difficult process, since experience showed that failure can occur over a wide range of values of these two parameters. Other approaches, such as the well-known inverse velocity method, aim at forecasting the time of failure; however predictions can be

characterized by a significant margin of error. It follows that determining when the failure of a slope is impending is still a great issue. It is therefore important to review monitoring data from past case studies and seek for recurrent correlations between specific variables in order to identify common slope behaviors in proximity of the instant of failure. The analysis of a database of rock slope failures at several coal mines is presented. For each event values of cumulative displacement and velocity measured 48 hours before failure, 24 hours before failure, 3 hours before failure and at failure instant were provided. A straightforward correlation was found between the average acceleration during the final 3 hours and the average acceleration during the final 24 hours before failure, regardless of the order of magnitude of the deformation. Comparable results were obtained considering data relative to 3/48 and 24/48 hours before failure. Consequently, impending failure conditions could be determined with suitable notice for future events of slope instability at the studied mine sites based on the relative intensity of the acceleration. Further development of the methodology requires that the presence of similar correlations in other databases of past slope failures is verified. The nature of the correlation may be influenced by factors such as geology, failure mechanism and mechanical properties of the rock mass.

Deterministic and Probabilistic Slope Stability Models Forecast Performance at 1:5000-Scale, page 741

Jorge P. Galve, Carlotta Bartelletti, Davide Notti, Francisca Fernández-Chacón, Michele Barsanti, José Miguel Azañón, Vicente Pérez-Peña, Roberto Giannecchini, Giacomo D'Amato Avanzi, Yuri Galanti, Francisco J. Lamas and Rosa María Mateos

Abstract: Deterministic methods are appropriate for analyzing specific slopes at site-scale where geotechnical parameters are better known. Probabilistic techniques provide better results than deterministic methods at regional scales (1:10,000-1:50,000). However, the performances of deterministic and probabilistic methods at large scales (e.g. 1:5,000-scale) are not well-known. We applied GIS-based deterministic (WEDGEFAIL, SAFETYFACTOR, SHALSTAB) and probabilistic (Likelihood ratio) methods to a mountain road of 14 km in the Alpujarras region (S Spain) to investigate the behavior of these models at detailed scales. The studied road stretch was affected by 111 landslides (7-8 landslides/km) during the 2009-2010 winter in a period of high precipitation. These landslides cut off the road in several points and disconnected the central region of Alpujarras from the main transport infrastructures. We delimited a small study area with only 4 km^2 restricted to the slopes that cross the road where we gathered as much data as possible. Our results show that deterministic methods have less prediction capability at ~1:5,000-scale than probabilistic methods and it seems that the needed effort to improve their results is not worthwhile. However, it must take into account that probabilistic methods need an inventory and they could not have been applied before the analyzed landslide event. As our results indicate, the deterministic methods, such as the SHALSTAB model, are reliable tools to make an evaluation of the stability of cut slopes in a roadway at project-scale.

GIS-Based Deterministic and Statistical Modelling of Rainfall-Induced Landslides: A Comparative Study, page 749

Carlotta Bartelletti, Jorge Pedro Galve Arnedo, Michele Barsanti, Roberto Giannecchini, Giacomo D'Amato Avanzi, Yuri Galanti, Andrea Cevasco, José Miguel Azañón and Rosa Maria Mateos

Abstract: Researches dealing with the forecast performance of rainfall-induced landslide susceptibility maps produced by both deterministic and statistical methods are abundant. However, comparisons between GIS-based deterministic and statistical/probabilistic modelling are less common. In this work we have compared the prediction capability of three different models: SHALSTAB, Likelihood ratio (LR) and Generalized Additive Models (GAM). These methods represent three different approaches for producing landslide susceptibility maps: (1) SHALSTAB is a deterministic model that integrates steady-state hydrological conditions of the slope with a infinite-slope limit equilibrium analysis. This model requires geotechnical parameters for producing the landslide susceptibility map, not always easy to extract at medium scales correctly (1:25,000-1:10,000). However, deterministic models are the unique alternative if previous landslide inventories are not available. (2) LR is a probabilistic method based on a mathematical approach that highlights the difference between the landslide conditioning factors of a portion of the study area containing landslides and the remainder. The higher the differences, the better is the prediction capability of the conditioning factors. This method considers the entire study area for computing the model and no high computational demands are required. (3) GAM is a statistical approach based on regression analyses. It is a semi-parametric extension of the linear regression technique that combines linear and non-linear relationships between predictor and response variables. As most of the statistical approaches, GAM uses a sample extracted from the study area to produce a model and usually needs higher computational time than the LR method. We assessed the predictive performance of the three methods through a 2-fold cross-validation technique and analyzing prediction rate curves (PRC). The above mentioned methods have already been extensively applied to landslide susceptibility modelling, but a comparison between them has not yet been performed. We tested the performance of the three methods in a small catchment of Northern Apennines (Pogliaschina, Vara Valley, Italy). This catchment (25 km^2 wide) was affected by an intense rainstorm that triggered at least 658 shallow landslides on 25 October 2011 that caused extensive damage in the study area and killed 7 people. Most of the landslides (>85%) was classified as complex translational debris slide-flows. Therefore, it is a priority to produce a reliable shallow landslide susceptibility model in the study area. With this purpose, we analysed the method showing the highest predictive performance for identifying the most landslide-prone areas in order to take the best mitigation actions and avoid further economic and human losses in the future.

Remarks on the Role of Landslide Inventories in the Statistical Methods Used for the Landslide Susceptibility Assessment, page 759

Maria Giuseppina Persichillo, Massimiliano Bordoni, Claudia Meisina, Carlotta Bartelletti, Roberto Giannecchini, Giacomo D'Amato Avanzi, Yuri Galanti, Michele Barsanti, Andrea Cevasco, Pierluigi Brandolini and Jorge Pedro Galve

Abstract: Landslide susceptibility assessment and mapping is a powerful tool able to represent coherent information about the spatial distribution of landslides in terms of initiation areas, on the basis of a set of relevant environmental characteristics. Among the procedures available in the landslide susceptibility assessment, the statistical methods are widely used. Many statistical techniques have been successfully developed and applied in the last decades, such as logistic regression, bivariate and multivariate models, probabilistic approaches and artificial neural networks. Such techniques allow to achieve a good prediction capability of the landslides spatial distribution using a relative small number of predisposing variables. But one aspect still remains poorly investigated: the role of the landslide inventory. Specifically, it is not yet well known if the predictive performance of statistical models can be influenced by the type of landslide inventory used and, more specifically, if it can be related to the adopted classification rules and the way in which it is implemented as a response variable. In this context, the main aim of this work was to evaluate the importance of the landslide inventory in the landslide susceptibility analysis. In particular, by the application of a non linear regression technique, namely the Generalized Additive Model (GAM), the use of different landslide inventories, available for the same areas, was investigated, evaluating their role as response variable, namely their influence in goodness and the accuracy of the model's predictive results.

Three catchment areas were analysed: the Versa catchment (Oltrepò Pavese, Southern Lombardy), the Vernazza catchment (Cinque Terre, Eastern Liguria) and the Pogliaschina catchment (Vara Valley, Eastern Liguria). The first area was involved in two different shallow landslide events, occurred in 2009 and 2013 respectively. The two different landslide inventories were used in GAM. Whereas, in the Vernazza and Pogliaschina catchments, only one landslide event, occurred on the 25 October 2011, was analysed. Despite this, two different inventories, based on two different methodologies of preparation, were used.

This approach preliminary allowed understanding and quantifying how the use of different landslide inventories of the same areas can affect the predictive performance of the model, identifying the possible causes of the observed differences in results.

This work provides a way to deeply investigate the role of the response variables in the landslides susceptibility assessment in order to understand the best choices to be adopted in the preparation of the landslide inventory, to improve the statistical model performance and to obtain more accurate and representative landslide susceptibility maps.

Deep-Seated Landslide Mapping and Geomorphic Characteristic Using High Resolution DTM in Northern Taiwan, page 767

Ching-Fang Lee, Wei-Kai Huang, Chuen-Ming Huang and Chung-Chi Chi

Abstract: Torrential rainfall and local geologic structure play principal roles in triggering deep-seated landslide around mountainous area. Typhoon Morakot (2009), the most destructive event occurred in 2009, battered southern Taiwan and caused severe casualties in Siaolin Village. For the purpose of reducing the damage resulted from geological disaster, this study adopted high resolution topographic data which extracted from airborne LiDAR scanning to map the recent and ancient deep-seated landslides in northern Taiwan. In this study, a visualization technique of sky-view factor was performed to generate quasi-3D relief image map by overlapping slope gradient, topographic openness, and multiple direction hill-shading maps, allowing us to interpret precisely the feature of landslide zonation. The study area covers an area of 5,502 km^2. The landslide micro-topography interpretation were presented with main scarp and landslide mass in polygon pattern, it shows more than 200 deep-seated landslides located on Hsuehshan Range, Tatun volcano group, and Western foothills in northern Taiwan. The spatial distribution of landslide relates highly to the regional strike of formation and local drainage pattern. Additionally, the detrimental geomorphic and geologic factors are extracted to evaluate the landslide evolution. For high scarp ratio slope, it usually represents the landform of ancient landslide characterized with apparent slope deformations. This work also explores the relationship between geomorphic evolutions of landslide and susceptibility. The paper describes expert mapping method combing with topography enhancement technique and provides competent authority to assess landslide magnitude and reduce disaster risk.

Modern Map of Landslide Hazard for Sulukta Town and Its Agglomeration Area, South-West Mountainous Margins of the Fergana Basin, page 779

Abdybachaev Ulan, Moldobekov Bolot and Ormukov Cholponbek

Abstract: The general plan of settlement always determines the development of munici-pal area in future, development of housing and communal services, transport sys-tems and industrial fund. This plan is based on the terms of zoning the urban area according to the state of knowledge of development and distribution of natural hazards. Knowledge of natural, including engineering and geological conditions and their spatial (and temporal) variability involves mapping and dividing the city territory into zones of different purposes. Main task of mapping of natural hazards is to identify dangerous exogenous processes, as well as their objective imagination on the map created by the study of literature and archive materials, preliminary decoding of optical satellite imagery and clarified or changed by field observations. All these data are summarized, and this generalization should

contain an assessment of conditions, which is one part of the system of planning, design, construction and exploitation, rational use of natural and technical geosystems. Having by now extensive literature, we nevertheless do not always find com-prehensive cartographic materials on the distribution of landslide masses which carrying immediate danger to urban infrastructure with the purpose of its visuali-zation and verification. In this study, the distribution of landslide masses in Sulyukty (Sulukta) town and its ag-glomeration area (Batken oblast, Kyrgyz Republic) had been investigated by means of remote sensing methods, field works and methods of GIS technology use. The studies identified the following: as the results of geo-reference (registration) of archive cartographic material, mapped landslide mass (scale 1: 100 000 for 1997), the accuracy range is 300 - 450 meters from their natural location. Also in the study area more than 150 landslides are revealed by decoding of optical im-ages of medium (MR) and high (HR) resolution. Totally 45 landslides are investi-gated and systemized which are located within town limits. From them 6 land-slides are direct threat to urban infrastructure and vulnerable communities. For the field surveyed landslide sites composed the technical passports including more than 50 parameters, such as exposure, geographic coordinates, morphometric parameters, typification of landslides, etc. According to the results of conducted works the modern map of landslide masses distribution for Sulyukty (Sulukta) town and its agglomeration area was developed. Modern map of hazards was simplified and designed for understanding and visualization for not experts in cartography field, and also collected materials can significantly assist the researcher in understanding the development of landslide processes in region. The product is submitted for official use to Municipality of Sulyukty (Sulukta) town. At the moment, we are working on issue of implementation of ob-tained and summarized data into interactive map of public access.

Ming-Chien Chung, Chien-Hsin Chen, Chih-Hao Tan, Ching-Fang Lee and Wei-Kai Huang

Abstract: A Central Geologic Survey investigation of large-scale landslides in the southern part of Taiwan identified a new, large-scale landslide in the Xinzhuang Village of Shanlin District, Kaohsiung City (ID: Kaohsiung-Shanlin-D021) which has the potential to influence the safety of residents. In order to reduce landslide hazard, this study assesses the potential for the landslide to fail. Field data, including the results of borehole sampling and laboratory experiments, is collected and analyzed and used to estimate the extent of the failure zone. We consider the effect of hydrogeological conditions, construct a conceptual model of subsurface conditions and analyze the stability of the landslide. After completing a comprehensive analysis of the Xinzhuang landslide, the landslide was divided into three potential failure masses (Zone 1, Zone 2 and Zone 3). Results of the analysis demonstrate that the safety factor of the Zone 3 is the lowest. Analysis results show that once precipitation causes the water table to near the bottom of the colluvium, the potential failure block may become unstable. Additionally, the impact of failure on the Xinzhuang Village is evaluated. If the Zone 3 potential sliding mass does mobilize, the main area affected by the deposit is the area southeast of Highway 29 (Sima road), Alley 106 and Alley 58. People living in this area are at risk of being buried by 1 to 20 meters of landslide debris. The methods applied in this study can be applied to other villages and used as a reference for the development of disaster prevention and evacuation planning.

Aditi Singh, Shilpa Pal, Debi Prasanna Kanungo and Naveen Pareek

Abstract: Landslides are one of the most destructive natural disasters, responsible for significant loss of life and livestock as well as damage to critical infrastructure, agricultural lands, housing and assets in mountainous regions. Despite all the recent technical progress towards landslide forecasting and mitigation, human activities are still affected by landslide disasters. Hence, assessment of landslide risk and vulnerability becomes an important aspect in all landslide studies. Vulnerability is a fundamental component in the evaluation of risk, and its estimation is essential in making a reasonable prediction of the landslide consequences. Most of the approaches applied for carrying out landslide risk assessment have inherent limitations. In most countries, there are no standard parameters and hence landslide risk assessment is still in its developing stage. The assessment of risk of communities prone to landslide is a topic that is gaining importance. In the field of landslide research, most of the studies have been focused on the landslide hazards maps. But, only a few studies have discussed on the risk and vulnerability aspects. This paper summarizes previous research on risk and vulnerability assessment and also discusses different methods suitable for estimating vulnerability of various elements to landslides. In addition, it proposes a conceptual framework for the assessment of landslide hazard and vulnerability, and mapping procedures for risk assessment.

Stefan Steger and Thomas Glade

Abstract: Landslide susceptibility maps are frequently produced by fitting multiple variable statistical models that generate a relationship between a binary response variable (presence and absence of past landslides) and a set of predisposing environmental factors. Within this study, we investigated the hypothesis that an inclusion of a high portion of "trivial areas" (e.g. flat areas) affects modelled relationships, quantitative validation results and the appearance of the final maps. This assumption was tested by systematically comparing logistic regression models that were based on data sets which ignored respectively included a high

portion of "trivial areas". Modelled relationships were evaluated by estimating odds ratios for all predictors. The Area under the Receiver Operating Characteristic Curve (AUROC) provided information on the prediction skill of each model. This performance measure was assessed by applying non-spatial and spatial partitioning techniques. Each analysis was additionally performed with artificial samples to confirm our observations. The results showed that the delineation of the study area affected modelled relationships and consequently the spatial pattern of landslide susceptibility maps as well. AUROC values confirmed that the apparent prediction skill of a model may increase whenever a high portion of easily classifiable areas (e.g. flat area) is included. Therefore we concluded that an interpretation of modelled relationships and prediction skills should always consider the spatial extent to which the respective statistical landslide susceptibility analysis was carried out. The apparent prediction performance of a geomorphic meaningless model can be enhanced by including a high portion of easily classifiable areas.

Landslides Induced by the 2015 Gorkha Earthquake, page 819

Binod Tiwari, Beena Ajmera, Smriti Dhital and Nagendra Raj Sitoula

Abstract: Over 25,000 people were injured and more than 9,000 people were left dead after the Mw 7.8 Gorkha Earthquake that struck Nepal on April 25, 2015. The earthquake also caused substantial damage to many buildings including several historical monuments. The largest of the more than 400 aftershocks occurred was a Mw 7.3 earthquake that occurred on May 12, 2015. Slope failures following this earthquake, its aftershocks as well as the monsoon season following the earthquake were a major concern. In this study, high resolution Google Earth images were used to develop a geospatial landslide database containing over 4,000 landslides following the 2015 Gorkha earthquake. Some of the landslides in this database were verified during the post-earthquake reconnaissance. The landslide database was, then, used to examine geological, topographical and seismological factors that controlled the co-seismic landslides triggered. The spatial distribution showed that the majority of the landslides occurred within the fault rupture area with the most of landslides between the epicenters of the main shock on April 25th and the major aftershock on May 12th. Furthermore, the Gorkha, Sindhupalanchowk and Dhanding districts contained the most number of landslides. A maximum number of landslides were observed in slopes with inclinations between 30° to 40° and had areas between 500 to 1000 m^2. According to the Varnes Landslides Classification System, 93% of the landslides observed were earth flows, while the remaining 7% were weathered rock flows. Most of the landslides (72% of all landslides documented) occurred in gneiss formations, followed by quartzite and slate formations. The relationship between the number of landslides and the peak ground acceleration was found to follow the power law and was dependent on the geological formation. De-aggregation of the landslide frequency and landslide concentration with the geological units as well as the landslide classification are provided in the paper.

The SAMCO Web-Platform for Resilience Assessment in Mountainous Valleys Impacted by Landslide Risks, page 829

Gilles Grandjean, Loïc Thomas and Séverine Bernardie

Abstract: The ANR-SAMCO project aims to develop a proactive resilience framework enhancing the overall resilience of societies on the impacts of mountain risks. The project aims to elaborate methodological tools to characterize and measure ecosystem and societal resilience from an operative perspective on three mountain representative case studies. To achieve this objective, the methodology is split in several points: (1) the definition of the potential impacts of global environmental changes (climate system, ecosystem e.g. land use, socio-economic system) on landslide hazards, (2) the analysis of these consequences in terms of vulnerability (e.g. changes in the location and characteristics of the impacted areas and level of their perturbation) and (3) the implementation of a methodology for quantitatively investigating and mapping indicators of mountain slope vulnerability exposed to several hazard types, and the development of a GIS-based demonstration platform available on the web. The strength and originality of the SAMCO project lies in the combination of different techniques, methodologies and models (multi-hazard assessment, risk evolution in time, vulnerability functional analysis, and governance strategies) that are implemented in a user-oriented web-platform, currently in development. We present the first results of this development task, architecture and functions of the web-tools, the case studies database showing the multi-hazard maps and the stakes at risks. Risk assessment over several area of interest in Alpine or Pyrenean valleys are still in progress, but the first analyses are presented for current and future periods for which climate change and land-use (economical, geographical and social aspects) scenarios are taken into account. This tool, dedicated to stakeholders, should be finally used to evaluate resilience of mountainous regions since multiple scenarios can be tested and compared.

Built-Up Area Exposure to Landslides and Related Social Impactsin Molise (Italy), page 837

Luca Pisano, Veronica Zumpano, Vittoria Dragone and Mario Parise

Abstract: Italy is historically affected by a number of natural hazards, which include landslides, floods, earthquakes, snow avalanches and sinkholes, all of them posing severe threats to the socio-economic development in large portions of the country. In central-southern Italy, Molise stands among the sectors most prone to landslide occurrence. The region is located in the northern part of the Southern Apennine Chain, where prolonged tectonic stress, combined with heterogeneity and high erodibility of outcropping rocks, strongly influence the geomorphology determining a widespread presence of mass movements. The most common phenomena are complex landslides, typically represented by slides evolving into earth flows or debris flows, with

subordinate other typologies such as composite and complex shallow landslides. Complex landslides affect with different degree of severity most of the towns and villages in Molise, causing frequent damage to infrastructures or houses. They also are at the origin of large public economic investments, due to continue expensive stabilization works for maintaining the functionality of the road network, or to repair civil building construction. These circumstances in many cases influence the life quality of the population in the area, with inevitable negative consequences on the social and economical development of the region. Aim of this study is to explore the relationships between the spatial distribution of landslides and the social environment in Molise, with a particular focus on the impact that landslides produce on the local population. We present an exposure analysis that considers the interaction of high susceptible areas with the built-up environment. This approach can be considered an intermediate step towards a complete analysis of the landslide risk, given the fact that at this stage the information required for a quantitative analysis are scarcely available with high accuracy. Furthermore, in order to estimate the impact of landslides on the population and the social environment, for each municipality of the region we compared the average level of landslide susceptibility with the Demographic Malaise State indicator (SMD). The SMD is a composite index that analyses the changes of growing/decreasing rates in the local population. In this way we attempt to achieve a better understanding of how the environment degradation (in terms of landslide occurrence and evolution) could promote out-migration from the affected areas. This study is a contribution to improve the knowledge of the relationships among landslide prone areas and social-economical effects in the Molise territory, which can be essential for the development of efficient strategies for landslide risk reduction.

Distribution Characteristics of Mass Movements in the Upper Bhote Koshi Watershed Before and After the Gorkha Earthquake and Their Susceptibility Evaluation, page 847

Amar Deep Regmi, Cui Peng and Megh Raj Dhital

Abstract: The 2015 Gorkha earthquake (Mw 7.8) triggered about 4,000 mass movements in the mountainous areas of Nepal. We investigated the mass movements in the upper Bhote Koshi river valley, which is one of the most severely affected regions in central Nepal. In that valley, there were about 775 landslips before the earthquake and about 1,360 new failures were initiated by the quake. The mass movement investigation was carried out based on detailed fieldwork and satellite image interpretation. These mass movements were classified into rock falls, rockslides, debris flows, colluvial slides and their distribution is strongly controlled by their position on the landscape. A majority of rock falls were located at higher elevations with very steep slopes consisting of hard rocks, such as quartzites, schists, and gneisses; rockslides occurred mainly on moderate to steep slopes; while most of the debris and colluvial slides developed on moderately steep slopes. Though a few large landslips were reactivated by the quake, most of such pre-earthquake landslides were insensitive to seismic shaking. The mass movements before the earthquake and those triggered by the earthquake were used for the preparation of landslide susceptibility maps of the region before and after the earthquake using GIS and an Evidential Belief Function model. Subsequently, the two susceptibility maps were combined to illustrate the locations of maximum landslide probability. The combined susceptibility map can be utilized for future land-use planning and infrastructural development in the region.

Estimation of Landslides Activities Evolution Due to Land–Use and Climate Change in a Pyrenean Valley, page 859

Séverine Bernardie, Rosalie Vandromme, Apolline Mariotti, Thomas Houet, Marine Grémont, Gilles Grandjean and Yannick Thiery

Abstract: Global changes would have impacts worldwide, but their effects should be even more exacerbated in areas particularly vulnerable. Mountainous areas are among these vulnerable territories. In order to estimate the capacity of such mountainous valleys to face global changes (climate, but also climate- and human- induced land-use changes), it is necessary to be able to evaluate the evolution of the different threats. The present work shows a methodology to evaluate the influences of both vegetation cover and climate on landslides activities over a whole valley until 2100, to propose adequate solutions for current and future forestry management. Firstly, the assessment of future land use is addressed through the construction of four prospective socio-economic scenarios up to 2040 and 2100, which are then spatially validated and modeled with LUCC models. Secondly, the climate change inputs of the project correspond to 2 scenarios of emission of greenhouse gases. The used simulations were performed with the GHG emissions scenarios RCP 4.5 and RCP 8.5. The impact of land use and climate change is then addressed through the use of these scenarios into hazards computations. For that we use a large-scale slope stability assessment tool ALICE which combines a mechanical stability model, a vegetation module which interfere with the first model, to take into account the effects of vegetation on the mechanical soil properties, and a hydrogeological model. The results demonstrate the influence of the forest on slope stability; the absence of the forest implies an increase of the probability of landslide occurrence, and at the contrary, the presence of forest has a local stability effect on the slope. The results also indicate some future evolution of the land use, leading to significant modifications of the stability of the slopes. Finally the climate change may have noteworthy impact on the occurrence of landslide with the increase of the water content of the soil when regarding future long periods; the results point out a reduction of the SF in a large part of the studied area. These changes are not uniform over the area, and are particularly significant for the worse scenario RCP 8.5.

Generating Application-Orientated Susceptibility Maps for Shallow Landslides Understandable to the General Public, page 869

Leonhard Schwarz and Nils Tilch

Abstract: Nowadays, landslide susceptibility maps generated by various statistical, deterministic or heuristic methods are widespread among the scientific community. In most cases, the content of these maps is ranked either in (numeric) susceptibility classes or in derived descriptive hazard classes. While landslide susceptibility experts can interpret the meaning of these classifications to a certain extent, for laymen or experts from other fields the classes are often of little practical use. But understanding and acceptance of susceptibility maps by the general public and other experts is of fundamental importance for putting hazard assessment into praxis. Hence to reach this goals, we are preparing susceptibility maps and their classifications for specific issues and for potential users. Furthermore, we also focus on communicating content and quality of the used maps clearly and traceably. The latter is ensured by adding detailed information to the map about the process the map is calculated for, the applied modelling method, the used landslide inventory, the map`s topic (e.g. susceptibility), the map`s uncertainty, the map`s maximum valid scale and raster resolution, the used geo-environmental factors and the allowed and forbidden fields of applications. The preparation of maps for specific issues and users as well as the communication of the content in an understandable way, is implemented by dealing with questions, which can be understood by general public. Answering these questions lead to application-oriented maps, based on scenarios of change of land use and change of precipitation amount. The maps were calculated for the well studied region of Gasen-Haslau in Styria/Austria (60 km^2), where a high-quality process dataset of 413 shallow landslides of the 2005-event is available. According to land use, susceptibility maps based on the two basic scenario maps "complete deforestation of the whole project area" and "complete afforestation of the whole project area" were calculated. The final application-oriented susceptibility maps displayed answers to many different questions like - Where should deforestation be avoided, because it would cause a dramatic increase of hazard potential? - Where should afforestation be performed, because it would turn high hazard potential into low hazard potential? - Which landslides could probably have been avoided, if deep-rooted trees had stabilised the slope? According to precipitation amount, susceptibility maps based on the two basic scenario maps "maximum 2005-event precipitation (170 mm) for the whole project area" and "minimum 2005-event precipitation (100 mm) for the whole project area" were calculated. The final application-oriented susceptibility maps displayed, beside others, answers to questions like - Where do we always find low / high hazard potential, no matter how high the precipitation amount has been (100m or 170mm)? - Where do we find areas of low hazard potential, but assuming the maximum precipitation amount of the 2005-event, the hazard potential would turn into high? So where did we have good luck in the 2005-event? As conclusion, we consider the proposed application-orientated susceptibility maps as good and meaningful tools to communicate hazard assessment in a non-academic and practical way, which could increase the interest and acceptance of our work in the general public, among stake-holders and other experts involved. Furthermore, for specific questions, these application-orientated maps could support experts of other fields (like spatial planning, communities, forestry) better in putting their work into practice than conventional susceptibility maps do.

A New Statistical Approach for Landslide Susceptibility Assessment in the Urban Area of Napoli (Italy), page 881

Francesco Carotenuto, Anna Claudia Angrisani, Akram Bakthiari, Maria Teresa Carratù, Diego Di Martire, Giovanni Francesco Finicelli, Pasquale Raia and Domenico Calcaterra

Abstract: The city of Napoli, Italy, is an interesting case study for landslide susceptibility assessment, due to its complex interactions between landslides and the anthropic fabric, as highlighted by its landslide geodatabase consisting in over 1300 events surveyed from 1850 to date. Despite the long history of slope instabilities, the urban evolution, often illegal, disregarded the high landslide propensity of the hillsides and occupied unsafe lands, exposing the population to a high level of risk.

A new methodology for landslide susceptibility assessment has been here carried out. Such approach is widely employed in ecology in order to implement prediction maps for species' occurrence probability, but for the first time it is applied in such focus. The methodology consists of different procedures named Species Distribution Modeling (SDM) which includes several statistical approaches (mainly Bayesian) to predict the occurrences of an event in unsampled locations. More than twenty years of experience on Phlegrean shallow landslides allowed to select as predisposing factors to instability: slope, aspect, lithology, land use, distance to streams, to roads and to rocky scarps,. Slope, aspect and distance to rocky scarps were extracted from a high resolution Digital Elevation Model (LiDAR data 1 m × 1 m grid cell); lithology and land use layers were obtained from corresponding maps produced by the municipality of Napoli; distance to streams and to roads were obtained from Regional Topographic Map. Morphological and geological layers were considered as predictors in a multinomial logistic regression via MaxEnt (Maximum Entropy) algorithm, where locations of detected events and modeled background points are used as response variables. In details, MaxEnt algorithm uses as prior distribution of predictors the one which assumes the lowest knowledge beyond the stated prior data (i.e. the one with the maximum entropy), thus minimizing any bias in the assumption of the parameter's importance. Spatial autocorrelation of predictors is also accounted for by fitting empirical semi-variogram via Regression Kriging and by modeling an additional latent covariate via Bayesian Gibbs Sampling (BUGS). Starting from the entire landslide geodatabase of the municipality of Napoli, three districts have been selected, respectively, Soccavo, Pianura and Arenella. Over them impends the Camaldoli Hill, which is the most prominent peak of the Phlegrean district (458 m a.s.l.), and it is the site where more than 300 landslides, of the 1300 events recorded at Napoli, occurred. The results were critically evaluated

using validation dataset (Receiver Operating Characteristic - ROC curves), by means of Sensitivity-Specificity graph where Area Under Curve (AUC) was estimated. Susceptibility map was then compared to the official map provided in the Hydro-geomorphological Setting Plan (HSP) redacted by the competent governmental agency (River Basin Authority) by means of a semi-statistical approach already in use by the research group.

The Role of ICGC on Urban and Territorial Planning: The Geological Hazard in Catalonia, page 891

Jordi Marturià, Marta Gonzalez, Jordi Pinyol, Marcel Barbera and Pere Buxó

Abstract: In this abstract the main working lines of the Geological and Cartographic Institute of Catalonia (ICGC) in the management of geological risk are described, especially in reference to the urban development planning and in compliance with the Catalan Urban Law (1/2005, 26 July 2005) and the functions specifically assigned by law with the creation of the IGC in 2005 (ICGC since December 2014). Based on these laws, the ICGC must issue a mandatory report on geological risk, prior to any urban change or planning. The aim is to preserve the urbanization and construction in geological risk areas for the safety and welfare of people, unless the works to be executed are foreseen as a prevention or mitigation of the risk. In legal terms, the ICGC report is mandatory but not binding. Ultimately, it is the Planning Commission who has the responsibility to issue informs and resolve planning procedures. The specific geological phenomenons studied are: slides, falls, hyper concentrated, debris flows, collapses, snow avalanches and earthquakes. The ICGC performs this task by means of: 1) The Geological Hazard Prevention Map of Catalonia 1:25.000 (MPRG25M). This map is designed as a multi hazard map. The map gives an overview of geological hazards identified in the territory. Therefore, the map identifies those sectors likely to develop potentially destructive events that can generate risk. The methods used to analyze hazards basically consist of geomorphological, spatial and statistical analysis. For its design a working scale is focused on territorial planning. 2) Studies for the Geological Identification of Hazards (EIRG). The purpose of the EIRG is a preliminary assessment of natural geologic hazard in urban, subject to urbanization, building or public concurrence areas. The study conclusions and recommendations determine if there are signs of geological processes that may lead to hazardous situations which could be avoided. They can establish the need for further zoning hazard studies at scale 1: 5000 or larger. The methodology is based on analysis of existing documentation, work field and analysis of susceptibility. These studies are applicable to the urban planning (scale 1: 5000 and larger). 3) The ICGC can act as a supervisor for studies or hazard mitigation works carried out by third parties.

Analysis of Building Vulnerability to Slow-Moving Landslides via a-DInSAR and Damage Survey Data, page 899

Gianfranco Nicodemo, Dario Peduto, Settimio Ferlisi, Giovanni Gullà, Luigi Borrelli, Gianfranco Fornaro and Diego Reale

Abstract: Slow-moving landslides systematically cause social, economic and environmental impacts all over the world. For this reason, studies aimed at analyzing the consequences on exposed facilities are of great interest for both the scientific and the technical community.

Among consequence models, "fragility curves" -first developed in the field of earthquake engineering- provide the conditional probability for every element at risk to be in, or exceed, a certain damage state under a phenomenon (or danger) of given intensity. Recently the fragility curves started to be used also for quantifying the expected damage of single buildings interacting with slow-moving landslides; their intensity, in concomitance of activation/reactivation stages, can be conveniently expressed in terms of differential settlements experienced by the building foundations (Mavrouli et al., 2014; Peduto et al., 2016). In this regard, the use of Synthetic Aperture Radar (SAR) data, processed via Advanced Differential SAR Interferometry (A-DInSAR), can be extremely useful in providing long-term ground/building displacement archives. Indeed, A-DInSAR is a well-established, non-invasive and non-destructive technique, cost-effective in terms of coverage and accuracy. This technology takes advantage from the availability of past and current generation SAR sensors that offer a wide range in terms of spatial resolution, coverage and revisiting times as well as of several processing algorithms.

In this paper the joint use of A-DInSAR and damage survey data is proposed to derive fragility curves for slow-moving landslide-affected buildings via empirical methods at detailed scale. For this purpose, the urban area of Verbicaro (Calabria region, southern Italy), where several slow-moving landslides of different typologies have been causing damages to structures and infrastructures for many years (Ferlisi et al., 2015), was selected. The combination of A-DInSAR data, provided by the processing of medium and high resolution SAR data acquired by the former ENVISAT and current Cosmo-Skymed missions, and the results of in-situ damage surveys allowed the preliminary investigation of the relationship between cause (differential settlement) and effect (damage). Then, A-DInSAR-derived differential settlements were used as an intensity parameter for the generation of empirical fragility curves. The latter, once further validated, can be valuably used for forecasting purposes; accordingly, they can facilitate local authorities in charge of the land-use planning in selecting areas suitable for urbanization as well as - provided that they are properly used - in addressing restoration and adaptation policies.

Landslide Susceptibility Analysis in Arandu Area Shigar Valley, CKNP (Gilgit-Baltistan- Pakistan), page 909

Chiara Calligaris, Shahina Tariq, Hawas Khan and Giorgio Poretti

Abstract: The Pakistani Gilgit-Baltistan are recognised as being one of the most beautiful and interesting places in the world due to the presence of the longest glaciers and the highest reliefs. This area remained remote and inaccessible before 1965, after which began the construction of the first roads (Karakoram Highway - KKH). In 1992, the Pakistani Government delegated the responsibility for initiating a preliminary survey to outline the borders of the Central Karakoram National Park (CKNP). These surveys resulted in the preliminary outline of the CKNP area (about 3.000 km^2), in which the major mountain massifs (as Mt. K2), watersheds, and glaciers were included. Since then, several proposals followed. With the aim of preserving this natural beauty for future generations as well as providing the CKNP of a Management Plan, a 5-year multidisciplinary project called SEED (Social, Economic, Environmental Development) started. One of the project's objectives was the analysis of the landslide geohazards aiming at the implementation of a landslide inventory and the realization of a susceptibility map. The Arandu village and its surroundings, which is part of Shigar valley, where the Chogolungma glacier is, was chosen as pilot area. During the summer survey had in 2012, part of the landslide-prone areas, previously identified through DEM analysis (derived from ASTER and Remote Sensing (RS) images) and GIS techniques were identified validating the obtained maps. The Analytical Hierarchy Process (AHP) was used to extract the factor weights in a pairwise comparison matrix. Frequency ratio (FR) method was adopted to drive each class weight. The Weighted linear combination was used in the end to determine the landslide susceptibility index value (LSI).

Landslide Susceptibility Assessment by EPBM (Expert Physically Based Model): Strategy of Calibration in Complex Environment, page 917

Yannick Thiery, Rosalie Vandromme, Olivier Maquaire and Séverine Bernardie

Abstract: Landslide hazard assessment (LHA) estimates the landslide probability occurrence in a territory within a reference period for a given intensity. It is deduced from information on: (i) The landslide susceptibility expressed as the potential initiation of phenomena based on the spatial correlation between landslide initiation areas observed in a territory, predisposing terrain factors (slope, land-use, surficial deposits, etc.), and the occurrence of triggering factors (rainfalls, earthquakes, etc.) for different slope failure. In this way, temporal triggering component is taking into account. (ii) The landslide intensity which integrates the mode of propagation depending of the mechanic laws governing runout area. Hence, LHA answers to three questions: where (location), when (timing) and at which intensity and magnitude (size, propagation and velocity) landslides occur. In order to answer to these questions, several approaches can be used with inventory-based methods (IBMs), knowledge-driven methods (KBMs), data-driven methods (DDMs) and physically based methods (PBMs). Among them, PBMs are based on the modelling of slope failure processes and generally combine hydrogeological model and slop stability model. The methods are applied for complex phenomena for a little site (i.e. for one event) or over large areas when landslides have simple geometry (for instance shallow translational landslides) and environmental conditions (geological, geomorphological, etc.) are homogeneous.

Thus, assessing landslide prone areas for different type of landslides with several geometries and for large areas with different environmental conditions is becoming a challenge for scientists in charge of landslide hazard and risk assessment. In other words and more specifically calibrate a PBM for large areas with complex geomorphology and landslides needs some specific strategies. The objective of this study is the application of a PBM (i.e. ALICE®: a distributed and coupled model of landslide hydrology and stability) for one area with (i) complex geomorphology, (ii) several type of surficial formations and (iii) different landslide types. In order to overcome the drawbacks enumerated above and take into account the complexity of the test site, a specific calibration taking into account: (i) the geometry of landslides (type and shape of rupture, size, thickness), (ii) the heterogeneity of geotechnical parameters, (iii) the triggering factor (i.e. water table) is performed. The study site is located in the Ubaye valley known for its instability phenomena occurring either at the surficial deposit-bedrock interface or through several geological formations. The strategy allows (i) identifying the parameters the most important to calibrate the model for each type of phenomenon; (ii) obtaining landslide susceptibility map taking into account the different geometry of landslides and their own triggering factors.

Selecting the Most Appropriate Route for Tehran-Shomal Freeway (Northern Iran) Based on Landslide Susceptibility Mapping, page 927

Mohammad Madankan, Jafar Hassanpour and Akbar Cheshomi

Abstract: The second lot of Tehran-Shomal freeway with approximately length of 22 km is on the development phase to select the suitable rout in central part of Alborz Mountain, northern Iran. There are three main proposed routs for construction of this freeway. According to the geological condition of the area, landslide hazard assessment is one of the main effective factors in rout selecting. So, in this paper we want to prepare an applicable landslide susceptibility map for the study area. For this purpose, at first, nine factors of slope angle, aspect, altitude, lithology, roads proximity, fault proximity, vegetation cover, precipitation and drainage density were recognized as major factors in occurrence of landslide in the study area. Then, the analytical hierarchy process (AHP), the frequency ratio (FR) and weight of evidence (WOE) methods were applied for landslide susceptibility mapping. A landslide inventory map applied to operation of two FR and WOE methods as well as validation of created landslide

susceptibility maps. Finally, three landslide susceptibility maps were created using three mentioned method in the GIS environment. These maps were evaluated and validated using the landslide index (Li) and success rate carve (SRC). Results show that the two methods of FR and WOE, with the same SRC value of 80 %, present a slightly better model fitting compared to the AHP method with the success rate of 77.2 %.

Common Patterns Among Different Landslide Susceptibility Models of the Same Region, page 937

Chyi-Tyi Lee and Chih-Chung Chung

Abstract: Four rain-event landslide inventories and one combined-event dataset for the mountainous terrain around the Choswei river catchment area in central Taiwan were selected for studies. A total of five event-based landslide susceptibility analyses were completed, and one multi-temporal landslide inventory was used to carry out regular landslide susceptibility analysis. The basic susceptibility of each model was compared and a common pattern of susceptibility was found among them. The results indicate that there is a common pattern of landslide susceptibility in a given region regardless of which event is used to build the susceptibility model. Also, the basic susceptibility is similar in pattern to the susceptibility model built based upon the multi-temporal landslide inventory of that region.

Landslide Susceptibility Mapping at National Scale: A First Attempt for Austria, page 943

Pedro Lima, Stefan Steger, Thomas Glade, Nils Tilch, Leonhard Schwarz and Arben Kociu

Abstract: Numerous publications that addressing landslide susceptibility were published over the past decades, also due to an increasing demand of spatial information regarding potentially endangered areas. However, studies that provide an overview on landslide susceptibility at national scale are still scarce. This research presents a first attempt to generate a national scale landslide susceptibility map for Austria based on statistical techniques. Binary logistic regression has been applied to delineate susceptible areas using three different predictor sets. The initial predictor set relates to topographic variables only (model A), and was gradually expanded with the factors geology (model B) and land cover (model C). The Area Under the Receiver Operating Characteristic Curve (AUROC) was used to validate the predictions by means of a k-fold cross-validation. The obtained acceptable prediction performances (mean AUROC of model A: 0.76, B: 0.81 and C: 0.82) suggest a relatively high predictive performance of all models. However, during this study, several limitations of the conducted analysis (e.g. limited landslide data, bias propagation, overoptimistic performance estimates) became evident. The main drawbacks and further steps towards a more reliable representation of landslide susceptibility at national scale are discussed.

Risk Assessment of Earthquake-Induced Landslides in Urban Zones, page 953

Johnny Alexander Vega and Cesar Augusto Hidalgo

Abstract: At present, natural disasters are having a greater impact on population and infrastructure. Excessive exposure and vulnerability of the elements at risk in urban zones and an increase in frequency and severity of natural and anthropogenic phenomena that trigger disasters are the principal causes. Colombia is located in the northwestern corner of South America; around 35% of the people are located in the Andean region, a complex mountain range that crosses the country from south to north which has significant seismic activity. In these kinds of regions where urban residential areas coincide with mountainous terrains, the risk is higher for people and its infrastructure. Due to various social and economic factors, the city of Medellin has grown rapidly with accelerated and unplanned occupation processes. This has resulted in inadequate practices in urbanization and construction techniques on hillsides. These inadequate practices increase building and infrastructure vulnerability levels. Insufficient investment in preventive measures to reduce the fragility of existing buildings are factors causing greater vulnerability in a city where the constructed area already reaches around 75 km^2. In this paper, a quantitative risk assessment of earthquake-induced landslides based on physical and probabilistic models through a GIS application is proposed. The study zone is located in the eastern side of the city of Medellin, one of the most disaster-prone areas in the city. The model implemented is able to quantify the risk caused by landslide in an area of the city considering different values of horizontal ground acceleration, and also an analysis of the costs arising from damage to the urban infrastructure under different scenarios and structural conditions. With this kind of cost analysis it is possible to determine the amount of investment required to reduce to an acceptable level of safety the risk of urban infrastructure exposed to a disastrous event.

How to Improve the Accuracy of Landslide Susceptibility Maps Using PSInSAR Data, page 965

Andrea Ciampalini, Federico Raspini, Daniela Lagomarsino, Filippo Catani and Nicola Casagli

Abstract: Landslide susceptibility maps (LSM) are frequently used by local authorities for land-use management and planning activities. They are valuable tools used by decision makers for urban and infrastructural plans and for civil protection purposes. False negative and false positive errors can affect the accuracy of a LSM, decreasing the reliability of this useful product. False negative errors are usually the worst in terms of social and economic losses because they are related to a misclassification of areas at risk. In this paper we present a new methodology aimed at improve the accuracy of the LSMs using measurement points (PS, Permanent Scatterers and DS, Distributed Scatterers) retrieved through the multi-interferometric SqueeSAR technique. The

proposed approach uses two different TerraSAR-X datasets acquired in ascending and descending geometry. PS/DS velocity are re-projected along the steepest slope direction. The integration between the LSM and the ground deformation velocity maps was performed by using an empirical contingency matrix, which takes into account the average Vslope module and the susceptibility degree obtained by using the Random Forests algorithm for an area located within Messina Province (Sicily, Italy). Results highlight that 33.37 km^2 have been updated. The combination among SqueeSAR data and the LSM improves the reliability in predicting slow moving landslide which, especially, affect urbanized areas. The use of this procedure can be easily applied in different areas where multi-interferometric datasets are available. The proposed approach will help civil protection and decision making authorities to use reliable landslide susceptibility maps, correcting part of the errors of the original LSM.

Creation of a National Landslide Domain Map to Aid Susceptibility Mapping in Great Britain, page 973

Claire Dashwood, Catherine Pennington, Emma Bee, Katy Freeborough and Tom Dijkstra

Abstract: The need to develop a national map that characterises landslides across Great Britain has long been recognised by the British Geological Survey (BGS) as part of its strategic role providing hazard information to a range of stakeholders. The series of hierarchical landslide domains represents areas of similar meteorological, climatic, physiographic and geological characteristics which have shaped the style of landsliding that has taken place and in some instances is still on-going. Initially developed to underpin current research into how different types of landslides and terrains will be affected by precipitation, the map will further assist continuing development of a national landslide susceptibility map with conditioning factors tailored to a specific domain. The distribution of landsliding in Great Britain is not uniform. It reflects a complex range of lithologies, both superficial and bedrock, and geomorphological processes active under a range of climatic conditions. The domain map captures landslides across a range of unstable slopes including very large ancient, relict landslides formed under very different climate conditions and small, modern translational failures. One of the starting points for creation of the domain map was the National Landslide Database, a resource containing over 17,000 landslide event records gathered from reports, maps journals and more recently social media. Although analysis of this usually reflected the nature of landsliding within a specific domain, expert knowledge was also needed to supplement information contained within the database. If the database was the sole resource used for the South Wales Coalfield, the area would have been characterised as a shallow translational landslide domain, the result of extensive mapping surveys. In contrast the presence of large scale landslides known to directly impact on infrastructure is clearly more significant. Targeted data collection to supplement the National Landslide Database is being planned in relatively data-poor domains. Further research is on-going to refine the current national landslide susceptibility map, GeoSure, by weighting specific factors within a domain, in order to assess more readily the types of landsliding that are likely to occur regionally. Development of process-specific models is also on-going which will be used to assess the potential for landslides of that type in the relevant domains, for instance debris flows in the Scottish Highlands. This paper considers not only the role of land systems mapping at a national scale to create a Landslide Domain Map utilising a national landslide inventory, but also the techniques used to define the spatial extent and characteristics of landslides within each domain, as well as their applications to a range of applied research objectives.

Landslide Hazard Scenarios Based on Both Past Landslides and Precipitation, page 981

Juan Remondo, Jaime Bonachea, Victoria Rivas, Javier Sánchez-Espeso, Viola Bruschi, Antonio Cendrero, José Ramón Díaz de Terán, Gema Fernández-Maroto, José Gómez-Arozamena, Alberto González-Díez and Carlos Sainz

Abstract: The goal of this contribution is to develop a set of methods and techniques for modelling landslide hazard, in order to obtain better predictions and, therefore, to reduce the risk associated to this type of process, one of the natural processes that cause more damage in the world. The research has been carried out on the basis of data obtained in north-western Guipuzcoa (Spain), an area intensely affected by shallow landslides and debris flows. Hazard predictions, as any hypothesis on the future behavior of the processes, must be based on several assumptions materialized in what is commonly termed scenarios. In order to propose more realistic future hazard scenarios, two different approaches have been applied: on the one hand, by extrapolating the trends observed from recent past landslide activity and, on the other hand and indirectly, from the empirical analyses between landslides and their main trigger, precipitation. In this sense, it was necessary to get long time series of landslide occurrences, through which sound future frequency could be estimated and relationships between landslides and their triggering factors established. The landslide inventory includes 20 time intervals ranging from the 50s of last century to the present and has been obtained by analyzing photographic images from different dates. Rainfall records of several weather stations, within the study area, have been analyzed, making it possible to establish quite significant correlations between landslides and precipitation intensity-duration. According to rainfall quantity, duration and intensity, as well as landslide activity, six multiple occurrence regional landslide events (MORLE), regarding rainfall extreme events, have been identified and characterized. Different hazard scenarios have been proposed, utilizing estimates on future landslide frequency and rainfall return periods. Although they have different meanings, as a whole they provide a sound basis for hazard assessment and mapping. Finally, on the basis of both types of scenarios different quantitative hazard models have been obtained and to some extend validated. Landslide hazard uncertainty has been also analyzed and limitations to establish scenarios have been highlighted and discussed, particularly rainfall-landslide relationships. Hazard models have been obtained by means of a two-step procedure, starting with the production of a susceptibility model that then is converted into a hazard model, utilizing the hazard scenarios developed. Susceptibility models

have been based on statistical relationships between recent past landslides and a set of conditioning parameters related to instability. Improved hazard predictions thus obtained will help to reduce future economic losses due to landslides and to produce better land management plans, where damage caused by landsliding is minimized.

Management of Landslides in Small Settlements in Slovenia, page 989

Bojana Božičeк and Eva Koren

Abstract: Landslides are globally one of the most common natural hazards in Slovenia and have not been sufficiently addressed systematically. In SE Slovenia (municipality of Brežice), shallow landslide hazards have to be assessed at dispersed settlements each year. They cause considerable economic damage and affect many people. They occur due to a range of triggering factors, mostly human. This paper focuses on the prevention and management of shallow landslides in this municipality. In thus article we show that, among the triggering factors, those of a human origin are the most commonly responsible for the occurrence of shallow landslides. Based on knowledge of the terrain and experience with landslides, a stability map of the municipality of Brežice has been made, pointing out areas with high hazards of shallow landslides. We propose that, for better management of shallow landslides in dispersed settlements, there is a need for a multidisciplinary approach (geological, geomechanical, hydrogeological and hydrological), sustainable water management, better education and awareness of the relevant human factors on the long term.

The Difference in the Landslide Information by the Difference Between Geographical Features and Geological Conditions, page 999

Shoji Doshidan

Abstract: Landslide information, such as the number of landslide occurred by an event and the type of landslide (a deep-seated landslide, a shallow landslide, a debris flow, etc.) are important information for disaster prevention. Because the risk and the damage area change greatly with the number and the type of landslide. To guess the number and the type of landslide in the future decrease the risk and damage. In this research, I investigated and studied the landslide disasters which occurred in the typhoon No.12 disaster in 2011 and the northern Kyusyu-island heavy rain disaster, in Japan. The result compared with the disasters, area of landslide is larger and number of landslide is fewer in the deep-seated landslide area. In the shallow landslide area, the slope is steeper and the drainage network is more developed. And shallow landslide area mainly consists of volcanic rocks, on the other side deep-seated landslide mainly consists of sedimentary rocks and metamorphic rocks. In deep-seated landslide area, the precipitation type is long-time rain, and in the shallow landslide area is short-time heavy rain. It is surmised that the landslide information are subject to strong influence by geographical features and geological conditions. Therefore, it is important to read and analyze the past landslide disaster hysteresis from geographical feature and geological condition for specifying the landslide information.

Observation and Mapping of Complex Landslides Using Field Investigation and Remote Sensed Data, page 1007

Kuo-Lung Wang, Yo-Ming Hsieh, Meei-Ling Lin, Jun-Tin Lin and Yi-Hsuan Lee

Abstract: Landslide is always not hazard until mankind development in highly potential area. The study not only tries to map deep seated landslide but also monitoring before the initiation of landslide. Study area in central Taiwan is selected and the geological condition is slate. Major direction of bedding in this area is northeast and the dip ranges from 30-75 degree to southeast. Several deep seated landslides were discovered in the same side of bedding from rainfall events. Several methods such as DEM observation, optical image identification, DInSAR, and monitoring instrumentations are adopted in this study. Landslides in study area are easy to observed from DEM observation and previous traditional elevation survey. However, the activity of landslides should be carefully taken into consideration. Thus SAR data utilization is adopted in this case. DInSAR and SBAS sar analysis are used in this research and ALOS/PALSAR from 2006 to 2010 is adopted. DInSAR analysis shows that landslide is possible mapped but the error is not easy to reduce. The error is possibly form several conditions such as vegetation, clouds, vapor, etc. To conquer the problem, time series analysis, SBAS, is adopted in this research. The result of SBAS in this area shows that large deep seated landslides are easy mapped and the accuracy of vertical displacement is reasonable. Moreover, a landslide area is selected to verify landslide activity in study area. Mems accelerometer is designed to monitor both static and dynamic behavior of this study area. Several events have been observed not only from rainfall but also from earthquake.

Landslide Hazard and Risk Assessment Lanzhou, Province Gansu, China—Project Introduction and Outlook, page 1027

Tingshan Tian, Dirk Balzer, Lichao Wang, Jewgenij Torizin, Liqin Wan, Xianglong Li, Liang, Chen, Ang Li, Dirk Kuhn, Michael Fuchs, Thomas Lege and Bin Tong

Abstract: The project "Landslide Hazard and Risk Assessment Lanzhou, Province Gansu, People's Republic of China" (LHARA) is a joint cooperation project between the Federal Institute for Geosciences and Natural Resources of the Federal

Republic of Germany (BGR), China Geological Survey (CGS) and China Institute of Geo-Environment Monitoring (CIGEM). Within a multi-phase approach LHARA will focus on landslide hazard and risk assessment for the surroundings of Lanzhou City, the rapidly developing capital of Gansu Province. The project will pursue practical approaches and facilitate the integration of scientific findings into the daily work of local authorities for geological hazard prevention and management, ultimately leading to improved planning criteria and mitigation measures for the affected area. The long term goals are intended to be achieved by multiple upcoming project phases. The major tasks of the first phase of two years duration are addressed to following issues: "Applicability of statistical models for landslide susceptibility and hazard assessment under rapidly developing environmental conditions" and "GIS-aided physically-based models for slope failures in loess area considering different triggers". Both goals will be accompanied by development of handy tools based on Open Source solutions. In this paper, the framework of the project and current status quo are introduced, and an outlook for the upcoming activities is given.

Regional Landslide Susceptibility Analysis Following the 2015 Nepal Earthquake, page 1035

Andrea Valagussa, Paolo Frattini, Giovanni B. Crosta, Elena Valbuzzi and Stefano Gambini

Abstract: A magnitude 7.8 earthquake struck Nepal on April 25, 2015 triggering several thousands of landslides and causing widespread damages to mountain villages and the evacuation of thousands of people. This contribution describes landslide susceptibility analysis performed in the Dhading (1885 km^2), Sindhupalchok (2488 km^2), Rasuwa (1522 km^2) and Nuwakot (1194 km^2) districts. Three landslide inventories have been prepared covering most of the area affected by coseismic landslides in Nepal. The first one is a coseismic and post-seismic landslide inventory based on multi-temporal images (Google Earth, Google Crisis maps, Bing maps), and helicopter-based video. The inventory includes more than 15,000 landslides. The second one is a pre-event shallow landslide inventory showing landslides already active before the occurrence of the earthquake. This inventory includes more than 2,500 events. For these two inventories, the most abundant landslide types are debris flows, shallow translational slides, and rockfalls. The third inventory includes almost 20,000 deep-seated landslides, mostly rock avalanches, slumps, rockslides and deep-seated gravitational slope deformations (DSGSD). Starting from these inventories, a multivariate statistical analysis of geo-environmental variables with respect to landslide occurrence was performed, aimed at recognizing the most significant controlling factors, such as lithology, slope gradient, and the presence of older deep-seated landslides. This analysis was complemented by field activities carried out in October 2015. During the survey, local knowledge has been systematically exploited through interviews with local people that have experienced the earthquake and the coseismic landslides. This helped us to recognize fractures and active deformations and to reconstruct a correct chronicle of landslide events.

Comparing the Performance of a Logistic Regression and a Random Forest Model in Landslide Susceptibility Assessments. the Case of Wuyaun Area, China, page 1043

Haoyuan Hong, Paraskevas Tsangaratos, Ioanna Ilia, Wei Chen and Chong Xu

Abstract: The main objective of the present study was to apply two methods for the construction of a landslide susceptibility map in the Wuyuan area of China and to compare their results by performing a linear regression analysis. Logistic Regression and Random Forest were utilized, while the coefficient of multiple determinations R2 and a p-value from linear regression analysis and Analysis of Variance were estimated. A database of 510 sites classified into non-landslide and landslide areas was separated into a training dataset (70%) and a validation dataset (30%). The identification of the areas was established by analyzing airborne imagery, extensive field investigation and the examination of previous research studies. Thirteen landslide variables were analyzed, namely: lithology, soil, slope, aspect, altitude, topographic wetness index, stream power index, stream transport index, plan curvature, profile curvature, distance to roads, distance to rivers and distance to faults. Each landslide susceptibility map was reclassified by applying the Geometric Interval classification technique into five classes, namely: very low susceptibility, low susceptibility, moderate susceptibility, high susceptibility, and very high susceptibility. The comparison and validation of the outcomes of each model were achieved using statistical evaluation measures, the receiving operating characteristic and the area under the success and predictive rate curves. The presence of linear correlation among the two models was estimated by performing a simple linear regression analysis. The computation process was carried out using RStudio an integrated development environment for R language and ArcGIS 10.1 for compiling the data and producing the landslide susceptibility maps. From the outcomes of the Logistic Regression analysis it was induced that the variables stream power index, stream transport index, distance to rivers and distance to faults affect the LR function positively, while the highest b coefficient is allocated to distance to faults and stream power index, which was 0.7167 and 0.6980, respectively. The rest of the variables have a negative effect on the landslide occurrence as they have negative b coefficients. From the estimation of the mean decrease in Gini coefficient performed during the application of Random Forest and the mean decrease in accuracy the most important variable is aspect followed by the distance to fault, topographic wetness index and slope. The most accurate model was Random Forest which identified correctly 98.32% of the instances during the training phase, followed by the Logistic Regression 87.43%. The same pattern of accuracy was calculated during the validation phase, in which the Random Forest achieved a classification accuracy of 85.52%, while the Logistic Regression model achieved an accuracy of 80.92%. The area under the success and predictive curve for the Random Forest was calculated to be 0.9805 and 0.9324 respectively, while the Logistic Regression model showed as slightly lower predictive performance, 0.9372 and 0.8903 respectively. Concerning the produced from the Random Forest model landslide susceptibility map, the very high susceptibility class was estimated to occupy the 18.70% of the total research area, while the relative landslide density for the high and very high landslide susceptibility class was estimated to be

77.82%. Respectively, for the Logistic Regression model, the very high susceptibility class was estimated to occupy the 20.82% of the total research area, while the relative landslide density for the high and very high landslide susceptibility class was estimated to be 43.06%. Regarding the linear regression analysis it revealed that a strong evidence of linear relationship between the two models exist, having a p-value less than 0.0001 at a 95% confidence level and an R2 value estimated to be 0.6993. The R2 value indicates that 69.93% of the variability in the Logistic Regression model can be explained by variation in the Random Forest model.

Forecasting the Hydrogeological Hazard in the Anomalous Basin-Fan System of Sernio (Northern Italy), page 1051

De Finis Erika, Gattinoni Paola and Scesi Laur

Abstract: The paper deals with the analysis of the present day hydrogeological hazard in the anomalous basin-fan system of Sernio (Sondrio District, Northern Italy). This system is characterised by a very high ratio between the fan and basin area (equal to 1.5), and it was therefore identified as anomalous. Previous studies pointed out that its genesis can be related to the collapse of a sector of a deep-seated gravitational slope deformation. The collapse, having an estimated volume of some hundreds of Mm^3 and occurred after the last glacial maximum period, developed as a rock avalanche. Because of a flow confinement during the runout, it created a fan shaped deposit in the main valley (namely Valtellina), which temporarily interrupted the Adda River. Afterwards the river excavated a new river bed in the distal zone of the fan: nowadays a high step of about 50 m can be detected in the floodplain profile of the valley. In present days, the main hydrogeological hazard in this anomalous basin-fan system is related to the occurrence of debris flows, favoured by the following conditions: the large amount of debris, the high slope both in the basin and in the fan area, the lack of an organised hydraulic network. In the present study, the pseudo 3D model RAMMS DEBRIS FLOW (a numerical code describing the runout of a debris flow as a continuum based on the Voellmy-Salm rheology) was used in order to forecast the hydrogeological hazard in the Sernio area. At this aim, the frictional parameters were chosen to consider the entrainment phenomena typical of this basin, based on the results obtained in a previous study through the back analysis on a similar anomalous system, namely the Gadria system (Val Venosta, northern Italy). The source areas of the Sernio basin were identified based on the in situ surveys: they are mainly located in the head zone of the basin and they are generally small. As no monitoring data were available for site-specific calibration, the simulation was carried out with a stochastic approach, considering a probability distribution of the friction parameters, and therefore obtaining a probability distribution of the runout susceptibility, as well as of the flow height. Numerical results pointed out the influence of entrainment in the hydrogeological hazard, especially with reference to the runout distance and the extension of the depositional area, which reaches the urban area on the fan.

Landslide Risk Analysis Incorporated to the Land-Use Legislation in Colombia, page 1061

Guillermo ávila and María del Pilar Guzmán

Abstract: Recent National legislation in Colombia includes a new law known as Risk Management Law (Law Number 1523 of 2012), created for the regulation of land-planning and land-use, taking into account that many of the natural disasters occurred in Country have been related to unappropriated use of the territory. Under this legislation, quantitative risk evaluation for landslides, floods and earthquakes is required before approval of any new project, and if necessary, special mitigation actions have to be taken to approve the viability of the project. This major change in the political for land-use implies a big challenge in many aspects, but in particular in the methodologies that should be used for different working scales. Special efforts have been focus on developing methodological guides to unify terminology, to specify the basic information required, the types of analysis for the different steps (hazard, vulnerability and risk), the unified classification of risk zones, etc. This article reviews the general aspects of the risk legislation, applied in particular to landslide risk analysis and makes a special consideration on its benefits but also on the difficulties for the practical application.

Integration of Geohazards into Urban and Land-Use Planning. Towards a Landslide Directive. The EuroGeoSurveys Questionnaire, page 1067

Rosa María Mateos, Gerardo Herrera, Juan Carlos García-Davalillo, Gilles Grandjean, Eleftheria Poyiadji, Raluca Maftei, Tatiana-Constantina Filipciuc, Mateja Jemec Auflič, Jernej Jez, Laszlo Podolszki, Alessandro Trigila, Valerio Comerci, Hugo Raetzo, Arben Kociu, Maria Przyłucka, Marcin Kułak, Izabela Laskowicz, Michael Sheehy, Veronika Kopackova, Michaela Frei, Dirk Kuhn, John F. Dehls, Reginald L. Hermanns, Niki Koulermou, Colby A. Smith, Mats Engdahl, Pere Buxó Pagespetit, Marta González, Vanessa Banks, Claire Dashwood, Helen Reeves, Francesca Cigna, Pavel Liščák, Vidas Mikulėnas, Vedad Demir, Margus Raha, Lidia Quental, Daniel Oliveira, Ruben Dias and Cvjetko Sandić

Abstract: Exposure to hazards is expected to increase in Europe, due to rapid population growth in urban areas and the escalation of urbanization throughout many countries. In the framework of the Geological Surveys of Europe (EGS), the Earth Observation and Geohazards Expert Group (EOEG) has carried out a survey regarding how natural hazards, in particular geological hazards, are integrated into urban and land-use planning Among natural hazards, geological hazards or geohazards

evaluated were those related to earthquakes, volcanoes, floods, mass movements (e.g., landslides, rockfalls, debris avalanches), karst hazards, compressible soils, and tsunami. 17 European countries and 5 regions have participated in the survey revealing heterogeneous policies across national borders. 17% of the countries have not yet any legal measures to build geohazards into urban and land-use plans and half of the participant countries have no official methodological guides to create geohazard maps. Additionally, there is a lack of knowledge about real social impacts of geohazards in many of the countries, although they have a significant impact in their national economies. This overview stresses the need for a common legislative framework and homogenization of the national legislations, including the guidelines which adopt the principles applicable to the geohazards management and explain the process to be followed in the production of hazard documentation. This is especially relevant in case of landslide and subsidence hazards. Although those are the most widespread geohazards in Europe, there are no common guidelines and practices as defined on the assessment and management of flood risk (Directive 2007/60/EC). Based on their expertise EOEG/EGS can lead the actions to draw up these guidelines and thus promote the interaction among stakeholders.

Multifractal Analysis of Spatial and Temporal Distributions of Landslides in Colombia, page 1073

Estefanía Muñoz, Germán Poveda, Andrés Ochoa and Humberto Caballero

Abstract: Landslides are among the most frequent disasters and cause significant economic and human losses in the world. Colombia, located in the northwestern corner of South America, has high rainfall and steep slopes with deep weathering soil profiles, providing favorable conditions to landslides occurrence. Fractal theory is a tool used to describe scale-invariant phenomena, such as the spatial and temporal distribution of landslides. In this paper we used the historical landslide inventory published in the Mass Movement Information System (SIMMA) by the Colombian Geological Survey to study diverse fractal and multifractal properties of the spatiotemporal behavior of landslides. To that aim, the inventory was classified according to land cover, geology, geomorphology, water table depth and eco-hydroclimatological and geographical regions of Colombia. The box-counting method was used to estimate the multifractal spectra of the spatial and temporal distribution of landslides, and it was found that in most cases, landslides have spatial and temporal distribution with high multifractality. We concluded that the spatial and temporal distribution of landslides depends on land cover types, geology, geomorphology, water table depth and geographic region, as the shape of the generalized fractal dimension and the width of the multifractal spectrum are sensible to these variables. Multifractal characteristics allow us to conclude that strongest landslide distributions are related to agricultural and artificial areas, occurring over a Quaternary period geology, medium slopes and tectonic depressions, and shallow water tables.

Landslide Susceptibility Mapping and Comparison Using Frequency Ratio and Analytical Hierarchy Process in Part of NH-58, Uttarakhand, India, page 1081

Ramesh Veerappan, Ankur Negi and Anbazhagan Siddan

Abstract: In Himalayas, National Highway 58 (NH-58) is one of the important and the major lifelines, which is very badly affected by frequent landslide occurrences particularly during the monsoons and cause recurring problems to pilgrims and local people. In the present research, the 52 Km stretch ghat road in part of NH-58 was chosen for the landslide susceptibility zonation (LSZ) mapping using frequency ratio (FR) and analytical hierarchy process (AHP) models and through integrated remote sensing and geographical information systems (GIS) techniques. The landslide inventory details were mapped out using high resolution satellite image, the data collected from secondary sources and field investigation. There are 11 landslide influencing parameters were considered for the analyses. LSZ maps were generated by calculating relationship between the landslide influencing factors with training landslide data in the case of FR model but for AHP model pair-wise comparison were made to derive the weights and final score. The LSZ map prepared using FR and AHP models and classified into five different susceptibility zones. The LSZ maps were compared and validated with validation landslide dataset using Area Under Curve (AUC) method. The AUC value of FR model is 0.8157 showing better prediction accuracy than the AHP model (AUC value is 0.6780).

Identification and Mapping of Shallow Landslides in the City of Zagreb (Croatia) Using the LiDAR–Based Terrain Model, page 1093

Sanja Bernat Gazibara, Martin Krkač, Marin Sečanj and Snježana Mihalić Arbanas

Abstract: Landslides in the hilly zone of Medvednica Mt. were identified visually using LiDAR DTM with a spatial resolution of 15×15 cm. Acquisition of the LiDAR data was performed in December 2013, following an extreme precipitation period that resulted in numerous landslides. Topographic derivative datasets for interpreting landslide morphology were computed from the LiDAR DTM: hillshade maps, degree of slope, contour lines, curvature, and surface roughness. Visual interpretation of LiDAR DTM derivatives was taken for the pilot area of 21 km^2, which represents 12% of the hilly area in Zagreb City. This resulted in a landslide inventory map, indicating the contours of 676 landslides. Seventy-five percent of the landslide bodies showed a size between 159 and 2,018 m^2. The area of the smallest identified landslide in the test area is 43 m^2. The majority of mapped landslides are located in a forested area. Each mapped landslide was assigned a level of confidence based on the LiDAR characteristics and it could be concluded that the LiDAR-based terrain model is a valuable tool for preparation of landslide inventories in heavily vegetated regions such as the hilly area of Medvednica Mt. The analysis of morphological properties of the landslides will be implemented to perform a semi-automated landslide mapping in the entire hilly area of the City of Zagreb (total area is 180 km^2).

Abstract: The purpose of this research is to prepare and compare the landslide hazard maps (LHMs) of the Constantine city, by applying frequency ratio (FR), logistic regression (LR) and weights of evidence (WOE) methods used in a framework of the Geographical Information System (GIS). Firstly, a landslide inventory map has been prepared based on the interpretation of aerial photographs, high resolution satellite images, fieldwork and available literature. Secondly, eight landslide-conditioning factors such as lithology, slope, exposure, rainfall, land use, distance to drainage, distance to road and distance to fault have been considered to establish LHMs using the FR, LR, and WOE models in GIS. For verification, the obtained LHMs have been validated comparing the LHMs with the known landslide locations using the receiver operating characteristics curves (ROC). The validated results indicate that the FR method provides more accurate prediction (86.59 %) of LHMs than the WOE (82.38 %) and LR (70.45 %) models. On the other hand, the obtained results showed that all the used models in this study provided a good accuracy in predicting landslide hazard in Constantine city. The established maps can be used as useful tools for risk prevention and landuse planning in the Constantine region.

Abstract: Mapping the landslides is one of the main activities in the overall spectrum of geological hazards and geological risk. Landslides form the most serious part of the geological hazard in Bulgaria after the earthquakes. They are widespread in the all country's territory. All known landslide types of internationally accepted classification of Varnes (1978) are represented there. The main attention is paid to the level of activity and the territorial scope of landslides according to the criteria involved in the National Programme for Landslide Prevention of Bulgaria (2014) aimed at prioritizing landslides depending on the level of activity and the risk they carry. Thus 5 degrees of landslide hazard are accepted. Hazards and vulnerabilities are considered to be weighed, i.e. they can be assessed in advance in terms of what will be the weight of the probability of landslide hazard of the research area and what will be the results (vulnerability) due to its occurrence. The vulnerability is represented by indicators of GDP per capita and density of population. The intensity of the hazard can be very low, low, medium, high and very high, which correspond respectively to classes from I to V. The third stage is the determining factor of landslide hazard. This stage is determined by the intensity of the landslide hazard for the study area. It is obtained according to the district class of intensity for landslide hazard. The results express the weighted average hazard. They are obtained through a combination of the weight of the landslide hazard and its intensity that is accepted for the zone concerned. The weights for landslide hazard and its ratios derived from the potential intensity are multiplied to obtain individually weighted hazard score.

Abstract: The landslide as a debris flow source identification is an important but often complex step in debris flow hazard assessment. Landslides are an important source of debris flows and this paper presents a multi-model approach of identification. The village of Koroška Bela in NW Slovenia has a history of debris flows and active landslides in the watershed of the Bela torrent, which presents a sediment source for potential debris flows in the future. Two models were applied for landslide identification in the watershed. A detailed field survey was carried out for model results validation. A GIS-based landslide susceptibility model was applied to identify areas susceptible to landslides and the LS Rapid triggering model was applied also to identify landslides and simulate the triggering phase. The study results show good agreement of the field survey and the models, particularly considering the completely different origin of both models and their development. These results show the possibility of applying numerical models to identify landslide sources and encourage their implementation in debris flow hazard assessment. But as with all models, a high level of expert knowledge and users' experience is required to get useful, and what is more, reliable results.

Abstract: Landslides in Italy are extremely frequent and cause a high number of casualties and damage to structures and infrastructures. A landslides database has been developed through the Google Alert's service from January 2012 to December 2015. In total, 10947 notifications have been received, read and analyzed, allowing to create an inventory of 1054 landslide events occurred in Italy in the studied period. For each landslide, the main event location, the number of people and the damages to structure have been inserted into a relational database together with information about following facts. In addition, a large number of information related to events occurred before the studied period have been inserted into the database. Starting from this inventory, we studied the spatial and temporal distribution of landslide events in Italy, and the relationship with geo-environmental factors, in order to recognize the most significant controlling factors, such as lithology, land use, slope gradient and aspect. As a conclusion, we found that Google Alert is a valuable tool for the study of landslide events, even if the resulting

inventory is not complete in remote inhabited areas. Moreover, in order to became a useful tool for landslide risk analysis, the web sources need to be integrated with more technical information existing in other databases.

Comparing Patterns of Spatial Relationships for Susceptibility Prediction of Landslide Occurrences, page 1137

Andrea G. Fabbri, Angelo Cavallin, Antonio Patera, Laura Sangalli and Chang-Jo Chung

Abstract: This contribution proposes a cautious way of constructing the susceptibility classes obtained from favourability modeling of landslide occurrences. It is based on the ranks of the numerical values obtained by the modelling. Such ranks can be displayed in the form of histograms, cumulative curves, and prediction patterns resembling maps. A number of models have been proposed and in this contribution the following will be compared in terms of their respective rankings for equal area classes: fuzzy set function, empirical likelihood ratio, linear and logistic regression, and Bayesian prediction function. The analyses performed and contrasted exemplify a generalized methodology for comparing predictions that should allow evaluating prediction patterns from any model. Unfortunately, many applications in the scientific literature use methods of characterizing prediction quality that make comparison hard or impossible. A database from a study area in the Mountain Community of Tirano in Valtellina, Lombardy Region, northern Italy, is used to illustrate how the results of the different models and strategies of analysis show the relevance of the properties of the database over those of the models.

Landslide Risk Evaluation in Central Provinces of Vietnam, page 1147

Le Hong Luong, Toyohiko Miyagi, Phan Van Tien, Doan Huy Loi, Hamasaki Eisaku and Shinro Abe

Abstract: In central provinces of Vietnam, landslides are hazardous phenomena that occur frequently, destroying human life, damaging structures, infrastructure and adversely affecting living conditions. Assessing landslide risks (probability of landslide re-occurrence) poses a difficult challenge for all Vietnamese scientists and civil managers. For risk evaluation, we applied Japan Landslide Society's Inspection sheet to study area with 261 landslide units were chosen for evaluation and developed 6 sheets of risk map. But this sheet shows geomorphological factors only, it does not mention geologic structures and weathering. The study area has a varied geologic composition with many stratigraphic unit and strata, original rocks have been found from Precambrian to Quaternary. Fieldwork shows that geologic conditions (such as geology age, bedrock lithology, bedrock structure, level of weathering) must play an important role in landslide occurrences in Vietnam. The authors propose and presume a new integrated inspection sheet that will combine two components: the first is geomorphology (as mentioned in the Japan Landslide Society's Inspection sheet); the second is geology. With this component, it is also classified into large, medium and small categories, similar to the Japan Landslide Society's Inspection sheet. A standard score system was created for the new integrated inspection sheet. Five landslide locations were trial application. Results present few differences when applying Japan Landslide Society's Inspection sheet and new integrated inspection sheet. The new inspection sheet is the initial stage of development, presenting some limitations and should be discussed much more.

Natural Hazards and Disaster Risk in One Belt One Road Corridors, page 1157

Cui Peng, Amar Deep Regmi, Zou Qiang, Lei Yu, Chen Xiaoqing and Cheng Deqiang

Abstract: This paper is to analyze geohazards along Belt and Road Initiative, which connects more than 60 countries of Asia, Europe and Africa. The countries in the BRC suffer from different types of geohazards. In this paper, we have shown different types of geohazards, including their trend of occurrence, and the trend of loss. Besides, we have given some cases of mega disasters in BRC where thousands of people lost their lives and billions of dollars of property was damaged. In order to reduce the effect of disasters, proper disaster risk assessment and management have to be done. This paper gives the procedure for risk assessment both in regional and local scale with some case studies from BRC. These methods can be applied in other parts of BRC as well.

Mechanisms for Secondary Slope Failure in Slope Having Failed, page 1169

Kiminori Araiba and Shoji Doshida

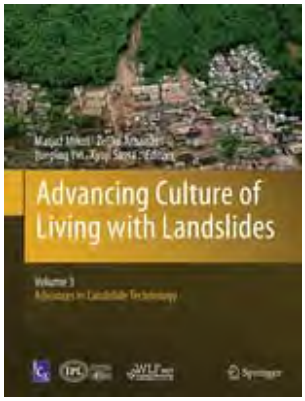
Abstract: We investigated the site where a rescuer was killed by debris flow during his activity on the deposit of prior debris flow and clarified the process of two debris flows; the first one is considered due to rapid surface flow coincident/just after the heavy rainfall and the second one is done to shallow slope failure induced by infiltrated and migrated groundwater. We gathered information of seventeen cases in which a secondary landslide occurred in the slope where the first landslide had occurred a few hours to a few days prior. The trigger of the first landslide are rainfall, earthquake and unknown. The mechanisms by which the secondary landslides had not taken place at the time of the first one was discussed and classified into three: loss of strength of material, change in force acting on the slope and time dependent characteristics of material. Geotechnical characteristics and conditions in which these mechanisms are possible to make an already-failed slope to fail again are discussed.

Tailings Dam Stability, page 1177

Bjørn Kalsnes, Hans Petter Jostad, Farrokh Nadim, Audun Hauge, Angèle Dutra and Arnaldo Muxfeldt

Abstract: Tailings are waste materials from mining operations, which need to be disposed of and safely stored. They are commonly transported as slurry in pipes to the storage facility and surface impoundments through spigots. Different types of tailings dam construction and disposal method include tailings dams designed as water retention dams, and dams built using the upstream method, downstream method or centreline method. Several examples of recent taillings dam failures involved dams constructed by the upstream method, where the new embankments are founded on tailings, causing the dam to become progressively more dangerous as its height increases. From back-calculation of historical failures, two distinct failure mechanisms seem to be dominant. The first mechanism is related to the development of progressive failure in a weak soil layer in the dam foundation. The second dominant failure mechanism is related to static or dynamic liquefaction of loose tailings material at a critical state. Static or dynamic liquefaction of loose tailings may occur at a critical condition, where a rapid (undrained) small increase in the shear strain results in a large increase in pore pressure, reduced effective stresses and a dramatic reduction of shear strength. Typical for these types of failures is that they occur rapidly with no warning. There is often no sign of increased displacement rates or pore pressure increase in the days prior to dam failure. Failure is often initiated by a local instability at a critical location, where redistribution of stresses due to reduced shear strength upon further deformations rapidly develops into a global failure mechanism without any additional load actions.

Volume 3: Advances in Landslide Technology



Part I: Landslide Monitoring and Warning

Multisensor Landslide Monitoring as a Challenge for Early Warning: From Process Based to Statistic Based Approaches, page 33

Francesca Bozzano, Carlo Esposito, Andrea Fantini, Matteo Fiorucci, Salvatore Martino, Paolo Mazzanti, Alberto Prestininzi, Stefano Rivellino, Alfredo Rocca, and Gabriele Scarascia Mugnozza

Abstract: In the last decades several approaches have been proposed accounting for early warning systems to manage of the real time risks due to fast slope failures where important infrastructures (e.g. roads, highways, railways or historic buildings) are the main exposed elements. Challenge of these approaches is to forecast the slope evolution, thus providing alert levels suitable for managing infrastructures in order to mitigate the landslide risk and reduce the "response" time for interventions. Three possible strategies can be depicted in this regard: an observation-based approach (OBA), a semi-empirical approach (SEA) and a statistical-based one (SA). The first one (OBA) is focused on searching objective co-relations among predisposing and triggering factors and induced effects. This approach is based on well constrained engineering-geological and evolutionary models, thus needing for several site specific information about the analyzed slope. This approach has the great advantage to allow for long term prediction and for the temporal calibration of the model, thus easily accounting also for changes in the boundary conditions. The second approach (SEA) is based on simplified rheological models and their time-by-time calibration based on long term monitoring time series. This approach does not need for detailed information about the slope, but only for a good dataset of monitoring data. It may allow for the temporal prediction of the slope failure, but it fails for slope processes affected by relevant temporal changes of the controlling and triggering factors. The third approach (SA) adopts statistically based cross co-relations among different parameters to point out trend anomalies of continuously recorded parameters as well as scatters of cumulative values. The SA needs huge datasets to be managed in very short time by (semi)automatic data-flow-to-data-processing analyses, accounting for early warning strategies. The recent development of several contact and remote monitoring technologies, as well as the development of cloud-systems for dataset storage and the increasing capabilities of processors, are making the application of the above described approaches more and more effective and the application of SA strategy more feasible. Feasibility, simplicity and low costs are key points for appreciating the SA strategy; nonetheless, specific research should be devoted in evaluating its efficiency respect to the observation-based and semi-empirical approaches. Main criteria for a suitability evaluation are represented by: i) delay-time from occurrence/data flow/data processing/alert detection; ii) number of true vs. false positives/negatives; iii) how to turn the alert detection into intervention strategies/procedures. At this aim, some experiments are being performed at different scales in the framework of technical applications, consulting activities and research projects managed by the Research Centre for the Geological Risk (CERI) of the University of Rome "Sapienza". These experiments are experiencing different kind of sensors including interferometers, optical cams connected to Artificial Intelligence systems, extensometers, distancemeter, rock-thermometers, for detecting changes in rock properties and detecting stress-strain changes, as well as pluviometers, anemometers, hygrometers, air-thermometers, micro- or nano- accelerometers and piezometers for detecting possible triggers. The results obtained up to now encourage improving the SA, based on data clouding, and testing them more extensively, at a national scale, by selecting test sites for experiencing their suitability for intervention strategies/procedures. These test sites will be selected along railways or roadways (in co-operation with the responsible National Agencies) where man-cut trenches could predispose to rock slides or falls that involve the infrastructures, in order to experience the suitability of SA vs OBA approaches for early warning in the framework of lifelines management.

Wireless Sensor Networks for Early Warning of Landslides: Experiences from a Decade Long Deployment, page 41

Maneesha Vinodini Ramesh, Divya Pullarkatt, T.H. Geethu, and P. Venkat Rangan

Abstract: Landslides are the third largest disasters worldwide. In order to save innocent lives and property damage, a system for understanding, assessment and early warning of the landslides is highly necessary. In this work, we have designed and developed an integrated wireless sensor network system for real-time monitoring and early warning of landslides. This paper will discuss the detailed requirements and design criteria considered in the design and development of the Intelligent Wireless Probe (IWP), to capture the relevant landslide triggering parameters. The network of IWPs is used to derive the local or regional contribution of geological, hydrological, and meteorological factors towards the initiation of a potentially imminent landslide. This heterogeneous sensor system provides the capability for gathering real-time context aware data to understand the dynamic variability in landslide risk. The data from these systems are continuously transmitted to our control center for real-time data analysis to derive the possibility of an imminent landslide. Based on the knowledge discovery from these analyses a three level warning system was developed to issue real-time landslide warnings. We have deployed the complete system in Western Ghats and North Eastern Himalayas in India. The system in Munnar has proven its validity by delivering real time warnings to the community in 2009, 2011, and 2013 and continues to monitor landslides even today for the tenth year in a row. The results from the experimentation shows this system has contributed in enhancing the reliability of landslide warning, reduced false alarm rate, and provides the capability to issue warnings in local, slope and regional levels. After the success of this work, Government of India has adopted the system nationally as a result of which we have carried out a second deployment in the North Eastern Himalayas.

Design and Validation of Wireless Communication Architecture for Long Term Monitoring of Landslides, page 51

Sangeeth Kumar, P. Venkat Rangan, and Maneesha Vinodini Ramesh

Abstract: Landslide prone areas are mostly in remote regions, with very limited network connectivity. Hence it is very challenging to develop a continuous monitoring system, which can deliver early warning of landslides. For developing most appropriate communication architecture we need to consider the following factors that could deliver long term monitoring and real-time early warning of landslides. The factors are: (1) frequency of data collection from spatially distributed heterogeneous sensors based on their impact on the landslide initiation (2) acceptable tolerance limit of latency for each type of data packet arrival, (3) adaptive bandwidth requirement for efficient data transfer with respect to balance energy in each wireless sensor nodes, (4) adaptive routing of the data based on the propagation, terrain and climatic effects, (5) remote maintenance using node level reconfiguration and network level reconfiguration (6) secured real time data transfer (7) scalable to multi-site deployments etc. In this work, considering all the above factors we have developed a context aware heterogeneous communication architecture. We have deployed the proposed communication architecture in two landslide prone areas, where one of the architecture is functional for the last ten years. This architecture has supported in collecting real time data from more than 150 geophysical sensors in adaptive frequency rate, remote configuring the sensor sampling rate, remotely triggering new software updates, providing prioritised service delivery based on the landslide alert level, data dissemination based on the warning levels etc. We have also designed and developed a Lightweight Management Framework (LMF) for this real-time, 24/7 operational, heterogeneous network. This LMF provides the ability to incorporate different heterogeneous networks such as 802.15.4, 802.11b/g/n, VSAT, GPRS, GSM, Internet and also proprietary wireless sensor network and hardware architectures. It also handles various network failures, data corruption, packet loss, and congestion problems. In this paper, we will discuss the performance evaluation and validation results of this architecture for achieving real-time monitoring and warning of landslides.

Scalable, Secure, Fail Safe, and High Performance Architecture for Storage, Analysis, and Alerts in a Multi-site Landslide Monitoring System, page 61

Ramesh Guntha, Sangeeth Kumar, and Balaji Hariharan

Abstract: Wireless sensor networks can be deployed in landslide prone areas to monitor various geological and weather properties to detect a possible landslide and provide early warning to local public for evacuation. Implementing and managing a system for capturing sensor data from the deployment sites and transferring to the central database for storage, analysis, retrieval and prediction is an endeavor riddled with both natural and technical challenges. The usual remoteness of the landslide prone areas result in power restrictions, bandwidth constraints and frequent connectivity issues. As the sensors and systems are exposed to constant natural elements, they are prone to frequent failures and calibration issues. Our high performance, scalable, robust, and secure system; featuring multi-site landslide data capture, replication, storage, monitoring, and processing functionalities, surmounts all these challenges effectively. The scalability and performance is achieved by real-time streaming of compressed data, in-memory processing, bulk storage, and retrieval through partitioned tables. The security is achieved through authenticating and encrypting streamed data and keeping only minimal raw data on site. The fail-safety is achieved through automated reconnection, and persisting and cross-tracking data at each processing step. Finally the high performance in analysis and alerts are achieved by series of hierarchical and temporal aggregate tables. In this paper we present the architecture and features of our

landslide data system along with the performance testing statistics and related analysis. We demonstrate that our system is capable of handling data from 100 sites, each having 1000 sensors and sending data once a minute using a single cloud server.

Abstract: With aim to deal with a continuously environmental change that may be unknown at design-time, we have proposed a novel self-adaptive data acquisition method for slope instability monitoring. The developed device can automatically adjust its data output rate from very low frequency to high one to capture the high-speed process when the physical variable sensed is dramatically changing. Such technique has the potential to reduce the energy consumption, bandwidth resources and data transmission burden in some practical energy conservation monitoring applications. A preliminary application of the proposed method was successfully carried out in one slope monitoring engineering in China. Application results indicate that the suggested solution can save much more energy consumed, while maintaining the data quality of crucial information.

Abstract: With vast territory, large latitude and longitude span, and complex geographical conditions, China is often subjected to various types of landslides that present unique characteristics in their forming and evolving. China suffers a lot from a great variety of geological disasters, which usually incur severe damages. As a developing country, China strongly relies on its natural resources in economic and social development. However, large-scale economic construction and resource exploitation have induced numerous landslides, making China one of the worst countries in the whole world that lie under the great damage caused by different kinds of landslides. Landslide is a major threat to the safety of people's lives and property. The focus of landslide prevention has always been the identification of the precursor of the occurrence of landslide as well as the early warning of its occurrence towards people in the disaster area. Building on traditional landslide monitoring and early warning methods, this paper presents a set of new and effective technology. The new technology has three advantages: efficiency, cost-effective, and easy to operate. It is an effective alternative, supplement and upgrade of the traditional method, able to function with greater efficiency, speed and flexibility. Equipped with this new technology, messages concerning the upcoming landslide could be delivered to people in the first place. Meanwhile, warnings could be sent to the emergency centers across the landslide areas automatically through the synchronization within the system. In this way, people are better informed, enabling them to take the initiative to cope with the disaster before it strikes. Moreover, casualties due to delayed informing of disaster could be avoided, and losses arising in the hazard could be reduced to the minimum. Thus, it is paramount to apply and promote this new landslide early warning technology.

Abstract: This work focuses on the development of FLAME (Forecasting Landslides induced by Acceleration Meteorological Events) that analyze of the relationship between displacements and precipitations using a statistical approach in order to predict the surface displacement at active landslide. FLAME is an Impulse Response model (IR) that simulates the changes in landslide velocity by computing a transfer function between the input signal (e.g. rainfall or recharge) and the output signal (e.g. displacement). This model has been applied to forecast the displacement rates at Séchilienne (French Alps). The FLAME model is enhanced by achieving the calibration using joint inversion of multiple time series data. We consider that the displacements at two different sensors are explained by the same long-term response of the system to ground water level variations. The parameters describing the long-term response of the system are therefore identical for all sensors. The joint inversion process allows decreasing the ratio between the number of parameters to be inverted and the volume of data and is thus more statically steady. The results indicate that the models are able to reproduce the displacement pattern in general to moderate kinetic regime but not extreme kinetic regime. Our results do not give clear evidence of an improvement of the models performance with joint inversion of multiple time series of data. The reasons which could explain these inconclusive results are discussed in the paper.

Abstract: It is important to simulate the shear deformation of a slope under rainfall to predict the onset of rainfall-induced landslides. Monitoring of deformation and soil-water characteristics in a sandy slope model under artificial rainfall was conducted to establish a prediction method for shear deformation of the slope due to rainfall infiltration and the onset of a rainfall-induced landslide. A hyperbolic relationship between the shear strain and the pore pressure at the same depth was identified from the

analysis of the monitored data. A time-prediction method of the shear strain in the slope was established based on the relation as follows. Regression analyses of the shear strain—the pore pressure relationship at any given time before the failure of the slope—and the time—the pore pressure relationship at the same time—were conducted first. Combining both equations produced an equation for the relationship between the time and the shear strain. The equation simulated the time variation of shear strain in the slope relatively well. Then, an equation for the relationship between the time and the inverse of the shear strain velocity was derived by differentiating the equation for the relationship between the time and the shear strain. This time-prediction method predicts the failure time relatively well, especially at deeper soil layers in the slope when the shear deformation proceeds with the smooth increase of positive pore pressure. The shear strain cannot follow rapid jumping up of the pore pressure. The results showed that the procedure described above could be applicable for the prediction of the time variation of shear deformation and the failure time of the slope.

Improvement of Fukuzono's Model for Time Prediction of an Onset of a Rainfall-Induced Landslide, page 103

Naoki Iwata, Katsuo Sasahara, and Satoshi Watanabe

Abstract: Time-prediction methods based on the monitoring of the displacement of a slope are effective for the prevention of sediment-related disaster. Several models are proposed to predict a failure time of slope based on the creep theory of soil, which describes accelerating surface displacement before slope failure. Fukuzono showed that the logarithm of the velocity of the surface displacement is proportional to the logarithm of the acceleration of the surface displacement and proposed the method for predicting a failure time by the extrapolation of the curve plotted an inverse of velocity of the surface displacement against time. His method can be only applied to the duration when the surface displacement accelerates. Fukuzono's method has been widely adopted for practice because of its simplicity. However, the actual displacement of the slope is complicated due to the change in the rainfall intensity and the inhomogeneity of surface layer, and it is not easy to specify the duration when the surface displacement accelerates. Therefore, time-prediction based on Fukuzono's method could be successful in some cases, it could not succeed in other cases in which the surface displacement might be not only accelerating but also decelerating. In this study, we predicted a failure time of the sandy model slope under artificial rainfall with a constant rainfall condition by three methods based on Fukuzono's model, and compared the prediction accuracy of each method and examined applicability. Generally, the curve which expresses the relationship of an inverse of the velocity of the surface displacement to time becomes convex or concave. However, we assumed the relationship is linear because we could not predict a shape of curve previously. The failure time was predicted from the intercept and the slope of the line calculated by following methods: (1) calculating from two monitoring data at different times, (2) extrapolating the straight line by least squares method using the previous monitoring data, (3) making the relationship between the velocity and the acceleration of the surface displacement by least square method using the previous monitoring data. Even if the artificial model slope might be under ideal condition, the inverse of the velocity of the surface displacement doesn't always show monotonic decrease with the increase of the elapsed time due to the fluctuation. As a result, the predicted failure time by method (1) and (2) varied widely, while that by method (3) could predict the failure time with high accuracy and had less variations. The good result of method (3) was caused by only using the data when the acceleration of the surface displacement was positive for the prediction. It indicates that the prediction using all monitoring data makes decrease in an accuracy of the prediction and the accuracy of the prediction improves if the period when acceleration of the surface displacement increased continually could be extracted. Therefore, we extracted the period when acceleration of the surface displacement increased continually and predicted the failure time by method (1) and (2). From these results, the accuracy of the prediction improved and the dispersion of the result of the prediction decreased. It reveals that the prediction only using the data of the period when acceleration of the surface displacement is positive leads to improvement of the precision. Moreover, the accuracy of the prediction improves by using regression analyses such as the least squares method to be able to reduce the influence of fluctuation of velocity of the surface displacement.

A Full-Scale Model Test for Predicting Collapse Time Using Displacement of Slope Surface During Slope Cutting Work, page 111

Nobutaka Hiraoka, Naotaka Kikkawa, Katsuo Sasahara, Kazuya Itoh, and Satoshi Tamate

Abstract: It is important to predict an onset of slope failures or rock falls for the occupational safety because about 15 to 20 workers were killed by these every year in Japan. Around a half of them were suffered from slope failure during slope-cutting works. In this research, in order to predict a time of slope failure, a full-scale model slope was used and its behaviour was monitored during slope-cutting. The dimension of the slope was initially 30degrees in angle and 3.5m in height. In slope-cutting, it was excavated at 60degrees in different height by the power shovel for 1st to 3rd stages and was also cut at 75degrees and 90degrees in the height of 2m from the bottom for 4th and 5th stages, respectively. A small area of the slope collapsed in 5th stage. Thereafter, its colluvial soil was removed in 3 more stages (6th to 8th stages) and then the whole slope failed after the 8th stage. From its experimental results, the collapse of slope was classified into 2 types: the collapse occurred during excavation and that after excavation. The latter has higher risk than the former because workers keep off slope during excavation, but they approach a slope after excavation. It is more significant to evaluate whether a slope is stable or not after excavation. The displacements at the surface of slope showed the creep fracture behavior after excavation, which were measured by displacement transducers. In order to predict the time of collapse, we applied Fukuzono's equations to the data of surface displacements. The

equations were proposed by Fukuzono (1985). The surface displacements rapidly increased with elapsed time and then the relationship between displacements and elapsed time included an exponential function just before collapsed. Therefore, the logarithmic relationship between the acceleration of the displacement and the velocity of the displacement showed linear and its relationship was approximated as an equation by least-square method and then its equation was expressed by only 2 original parameters. The prediction time of collapse was obtained by time integral of this equation. Thus, we validated that the time of slope failure could be predicted by the displacements of slope surface obtained.

Classification of Microseismic Activity in an Unstable Rock Cliff, page 123

Diego Arosio, Mauro Boccolari, Laura Longoni, Monica Papini, and Luigi Zanzi

Abstract: We installed a microseismic monitoring network on a 300m high unstable rock face threatening the city of Lecco, in Northern Italy. The network is active since February 2013 and consists of 5 electromagnetic velocimeters, two of which are deployed in boreholes, two temperature sensors in air and in a shallow fracture, and a rain gauge. Regarding the detection of microseismic events, we decided to set the triggering algorithm in order to tolerate false alarms, and, as a consequence, the network has collected several thousands of events so far. Hence, it is necessary to develop an automatic processing scheme able to discard all the recorded events that are not related to the instability of the rock slope. According to the outcomes of previous studies presented in the scientific literature and to careful analysis of the collected data, we first focused on manual classification of recorded signals according to two main classes: a first one grouping events related to the stability conditions of the slope (referred to as MS and local events), and a second one clustering all disturbances (referred to as spikes, mixed event and unclassified noise). Then, we attempted to develop a classification routine in order to cluster possibly all the signals manually classified as MS events, and at the same time having few false positives. The development of classification algorithm involved analysis of parameters in both time and frequency domains, also supported by spectrograms and Radon transform computations, correlation with meteorological datasets, polarization assessment of the 3-component recordings along with principal component analysis. The algorithm we developed has proved to have a satisfactory success rate. We are now focusing on the last step of the microseismic monitoring activity that involves the localization of events related to the instability of the slope.

Prediction of the Process of a Slowly Moving Loess Landslide by Electrical Resistivity Tomography, page 131

Sándor Szalai, Ernő Prácser, Kitti Szokoli, and ádám Tóth

Abstract: A slowly moving loess landslide along the River Danube in South Hungary was studied using Electrical Resistivity Tomography (ERT). The aim of the research was to determine the fracture system of the study site. It seems to be the only possibility to get information about the landslide and its further evolution due to the homogeneous composition of the loess. The mass movement was expected to occur in the direction of the identified crack openings. The applicability of the ERT technique for such a supposedly dense fracture system was studied by numerical modelling and the results have been verified in the field. It was shown that it is especially important to carry out the field measurements following dry periods; otherwise the interpretation may become extremely difficult if not impossible. The dip of the fractures could not be observed and they could not be explored deeply. It was possible to map their surface projection to get the desired information about the structure of the landslide. Fracture zones could be especially well localized enabling the prediction of the positions of future rupture surfaces and thus also the delineation of the endangered zone. Although the area outside of the one that already subsided is not endangered yet, the area which has already started to move is going to break into two. Parts of the about 5 m wide blocks at the front of the landslide may fall or slide down anytime. The area below the buildings was assumed to move as one unit. Most of our predictions have been verified by the mass movements which occurred about one and half years after the measurements. The ERT method proved to be a good tool to characterize the fracture system of such a landslide area, enabling the prediction of future rupture surfaces and also delineation of the endangered area. Its use is therefore highly recommended to monitor landslides.

The Pilot Construction of a Sensor-Based Landslide Early Warning System for Mitigating Human Damages, Republic of Korea, page 139

Dongyeob Kim, Changwoo Lee, Choongshik Woo, Junpyo Seo, Minjeong Kang, and Hyunjung Kwon

Abstract: A sensor-based landslide early warning system in landslide highly-prone site of urban areas as a part of integrated prevention system for sediment-related disasters was suggested. The system mainly consisted of sensors, network system, and monitoring system and it had been partly revised for the improvement of its effectiveness through three-year test-bed monitoring. The magnitude of sediment disaster (SDM) considering physical scale of the disaster and damage level was introduced for deciding the appropriate location of the system installation. The case study for Yongin-si, Republic of Korea, showed the 44 of total 1,013 debris flow-hazard watersheds were estimated as the first level of SDM, the most risky area, and one of the 44 watersheds was finally selected as the system location through field investigations. In the selected 10 ha watershed, pilot construction of the system was conduct as a first step of its field application. It was hoped that the suggested system can effectively mitigate human damage by sediment-related disasters through sending landslide early warning information to residents at a landslide highly risky area directly.

Sentinel-1 Data Analysis for Landslide Detection and Mapping: First Experiences in Italy and Spain, page 201

Anna Barra, Oriol Monserrat, Michele Crosetto, María Cuevas-Gonzalez, Núria Devanthéry, Guido Luzi, and Bruno Crippa

Abstract: One of the key inputs to landslide susceptibility and hazard analyses is provided by a precise inventory map, including the information of landslide activity. In the last decade the satellite SAR Interferometry has been demonstrated to be a powerful tool for landslide mapping and monitoring. However, until now, the systematic use of the technique has been strongly limited by different aspects like the image availability, the revisit time and the loss of coherence. In this context, the Sentinel-1 constellation provides interesting characteristics for landslide mapping and monitoring: the wavelength (55.5 mm) and the short temporal baseline (6 days when Sentiel-1B data will be available). The latter one is expected to be a key feature for increasing coherence and for defining monitoring and updating plans. However, the exploitation of these high coherent data for landslide purposes is not straightforward and demands of new tools and methods to properly discriminate the real displacements. The aim of this work is to show which are, according to the authors experience, the main pros and cons of landslides mapping and monitoring with Sentinel-1 data. These conclusions are based on the analysis over three different test sites with different characteristics from the SAR view point: the Canarias Islands (Spain), the Molise region (Italy) and the Toscana region (Italy). The Canarias Islands test site shows a good example of how Sentinel-1 can systematically provide deformation maps over wide areas and with a very high sampling density. The Molise region application shows how the short temporal revisit time of Sentinel-1 allows the detection and monitoring of landslides also over agricultural areas. In particular, for this test site, are shown some examples of detection and update of active landslide phenomena. Finally, in the third example, the Toscana area, we show another example of difficult scenario, where the high temporal sampling has allowed the detection of some landslide phenomena. However, this test site is also a good example to show one of the main problems to be solved when applying short temporal baseline interferometry in rural environments: false deformation trends related to soil changes.

Testing Sentinel-1A Data in Landslide Monitoring: A Case Study from North-Eastern Italian Pre-Alps, page 209

Giulia Tessari; Mario Floris; Vladimiro Achilli; Massimo Fabris; Andrea Menin; Michele Monego

Abstract: The main aim of this study is to test the effectiveness of Sentinel-1A Synthetic Aperture Radar (SAR) data in monitoring scarcely urbanized slopes affected by slow-moving instabilities. To this end, geological and geomorphological surveys were carried out, satellite SAR data were processed and a GPS network system was installed. The study area, named Rovegliana, is located in the North-Eastern sector of the Italian pre-Alps. Rovegliana slopes are covered by eluvial, colluvial and landslide debris deposits which are mainly affected by superficial phenomena such as creep and soil slips. In situ surveys and Advanced Differential SAR Interferometry (A-DInSAR) processing of ERS, ENVISAT and COSMO Sky-MED SAR data pointed out that the instabilities are active with constant velocities up to 10 mm/year. Only the central and eastern sectors of the area were subjected to an acceleration after an exceptional rainfall event occurred in November 2010. GPS monitoring started in October 2015 and has been implemented through four campaigns made up of high precision geodetic measures of possible soil deformations of 22 vertices of a Global Navigation Satellite System (GNSS) static network. These vertices have been connected by a network to obtain a robust system. Comparing results from historical interferometric data, GPS measurements and interferometry processing of Sentinel SAR data acquired in the period 2015-2016, make it possible to verify if Sentinel data, characterized by short revisiting time, can be used as useful tool to define the spatio-temporal evolution of the recorded instabilities, overcoming the limits of applying interferometric techniques caused by temporal decorrelation due to the presence of vegetation cover, increasing the possibility to obtain significant information about landslide dynamics from SAR data. Moreover, we expect that the high number of planned acquisitions will improve the accuracy of deformation measurements.

Innovative Landslide Change Detection Monitoring: Application of Space-Borne InSAR Techniques in the Thompson River Valley, British Columbia, Canada, page 219

David Huntley, Peter Bobrowsky, Francois Charbonneau, Jeffrey Journault, Renato Macciotta, and Michael Hendry

Abstract: In this paper we present the first results from Coherent Points Analyses and Differential Stacking of RADARSAT-2 InSAR persistent scatterer interferograms covering a portion of the Thompson River valley, south of Ashcroft in British Columbia Canada. Surface displacements amounting to less than 5 cm/yr are detected on landslides that are crossed by national railway infrastructure (train tracks and lock-block retaining wall). Our study shows that many landslides in the Thompson River valley have zones of displacement that are more active than others. For the portions of the North Slide, South Slide and Barnard Slide, processes contributing to displacement include: erosion of unconsolidated sediment by surface run-off and gullying, wind-driven deflation and deposition, and anthropogenic activities including temporary storage of composting agricultural materials and aggregate deposits. It is unclear whether a landslide component can be resolved within the InSAR data acquired between 2013 and 2016. In contrast, over this observation period both the Ripley Landslide and Red Hill Slide show marked variations in displacement rates related to seasonal changes in river stage and groundwater level, and sliding of coherent blocks of sediment. InSAR techniques effectively capture the surface movement detected by GPS stations, ground-based LiDAR, borehole

piezometers and fibre optic installations at the Ripley Landslide test site. This successful application of Coherent Points Analysis and Differential Stacking of persistent scatterer interferograms suggests both techniques are suitable for monitoring unstable terrain in other remote settings where infrastructure, natural resources, the environment, local communities and public safety are at risk.

Remote Sensing Mapping and Monitoring of the Capriglio Landslide (Parma Province, Northern Italy), page 231

Federica Bardi, Federico Raspini, William Frodella, Luca Lombardi, Massimiliano Nocentini, Giovanni Gigli, Stefano Morelli, Alessandro Corsini, and Nicola Casagli

Abstract: In the spring of 2013, the Parma Province (Northern Italy) was affected by a large number of landslides, as a result of heavy and persistent rainfall occurred between January and April. This resulted in the triggering of about 1400 mapped landslides, which caused severe damages. In particular, on April 6th 2013, a large landslide activated in Tizzano Val Parma municipality. It stretches from an altitude of 980 m to about 630 m a.s.l., covering an area of 0.92 km^2 with a total length of 3600 m. It is constituted by two main adjacent enlarging bodies with a roto-translational kinematics, channelizing downstream the Bardea Creek, forming an earth flow. The landslide crown area destroyed a 450 m-long sector of a provincial roadway, and its retrogression tendency put at risk the Capriglio and Pianestolla villages, located in the upper watershed area of the Bardea river. Moreover, the advancing toe threatened the Antria bridge, representing the "Massese" provincial roadway transect over the Bardea Creek. This work describes the main results of the landslide mapping and monitoring activities, conducted after the landslide trigger. With the aim of supporting local authorities in the hazard assessment and risk management, an integrated analysis of various remote sensing data was developed, in order to generate a multi-temporal mapping of the landslide, whose velocity reached values of several tens of meters per day in the first month, and several meters per day from early May to mid-July 2013. Satellite and aerial post-event images were analyzed, together with the results of field surveys, to accurately map the landslide extension and evolution. Moreover, on May 2013, a GB-InSAR (Ground Based Interferometric Synthetic Aperture Radar) monitoring campaign was started in order to assess displacements of the whole landslide area and to support early warning activities. The GB-InSAR acquired until December 2013.

Monitoring the Deep-Seated Landslides by Using ALOS/PALSAR Satellite Imagery in the Disaster Area of 2009 Typhoon Morakot, Taiwan, page 239

Rou-Fei Chen, Chen-Yang Lee, Hsiao-Yuan Yin, Hsiao-Yu Huang, Keng-Ping Cheng, and Ching-Weei Lin

Abstract: After the catastrophic Xiaolin landslide that caused 450 casualties during 2009 Typhoon Morakot, how to identify potential sites of large scale landslides and evaluate their activity become an important issue for landslide hazard mitigation of the island. In the past few years, Central Geological Survey has identified 56 sites of potential large scale landsides with important protected targets including village, reservoirs, roads or bridges in the disaster area of typhoon Morakot. To better understand the activity of these potential large scale landslide, Temporarily Coherent Points InSAR (TCP-InSAR) is used to estimate the surface deformation rate of 56 sites with protected target in this study. The TCP-InSAR analysis is based on ALOS/PALSAR images acquired during Dec. 2006 and Mar. 2011. The annual displacement rates are derived from images taken in the period of 2006-2009, 2009-2011, and 2006-2011, separtly. To understand the deformation induced by the Typhoon Morakot, tradition D-InSAR is also performed in this study. To validate the performance of TCP-InSAR, the retrieved TCP-InSAR measurements in Lushan area are compared with GPS observations from Taiwan GPS Network. The results indicate that the TCP measurements are in good agreement with GPS observation, indicating the effectiveness of the TCP-InSAR approach. The standard deviation of TCP measurement in Lushan area is estimated about 7-8 mm by comparison the TCP data with GPS observatuon. According to TCP measurements, four type of potential large scale landslides are classified. 14 sites are classified as type A which represents that the identified moving area is the same as potential landslide area. Within these sites, 11 sites show the annual displacement rate increasers after Typhoon Morakot, and the annual displacent rate decreases in 1 site. 18 sites are classified as type B which represent the identifid sliding area can be divived into serval parts. Within these sites, 10 sites show the annual displacement rate increasers after Typhoon Morakot, and the annual displacent rate decreases in 7 site. 10 sites are classified as type C which represent the toe of identified landslide already failure. Within these sites, 7 sites show the annual displacement rate increasers after Typhoon Morakot, and the annual displacent rate decreases in 2 site. 14 site is classified as type D which represents the TCP measuments are not enough to recognize the active moving part of the landslide.

Study of an Active Landslide on A16 Highway (Italy): Modeling, Monitoring and Triggering Alarm, page 249

Andrea Carri, Clelia Grignaffini, Andrea Segalini, Giovanna Capparelli, Pasquale Versace, and Gennaro Spolverino

Abstract: The aim of this paper is to present the preliminary results of a study carried out on an active landslide which insists on the A16 (E842) Highway Lacedonia-Candela , between Campania and Puglia region (South Italy). The area lies at the foot of a large gravitational mass, classified as "deposit of ancient landslide" where a system of landslides, with different types and activity

states, are present. It is characterized by the widespread presence of clayey sequences that affect the stability of the slopes looming over the highway. The site has been instrumented with a series of automated sensors, both innovative and traditional, which monitor different physical entities. In particular, slope monitoring has been carried out by: * geotechnical investigations (including in-situ testing, subsurface sampling and laboratory testing) traditional piezometer and inclinometer sensors and n.2 MUMS chain composed by 25 MEMS based sensors, 5 high precision electrolytic sensors, a piezometer and a barometer; * hydrological investigations (tensiometers and Time Domain Reflectometry - TDR). * meteorological investigation (rainfall, humidity, speed and direction of wind, temperature and solar radiation). All instruments are located on both sides of the highway, upstream and downstream. Furthermore, a topographical survey with a drone was done in order to know precisely the geometry of the slope. Once the geotechnical and hydraulic parameters were collected, a finite element numerical model (SUSHI-Simulation for Saturated Unsaturated Hillslope Instability) of the whole slope was set up and a series of back analysis were carried out comparing the model results with those obtained from the monitoring database. Through these back analyses the choice of the geotechnical parameter was refined and validated. Different physical entities and results are shown into a unique representation, in comparison with the developed model and the geological and geotechnical information. Following the trends of data, the weekly/monthly average displacements and the possible causes (heavy rainfall, raising of the water table), it is possible to study the mechanical behavior of the landslide and establish preliminary warning thresholds, which have to be verified in future. The large number of acquisitions permits to use a statistical approach in order to identify a good reliability and increase the confidence on the final results. The obtained knowledge permits to automate all the processing procedure and control the situation on the highway in near real time.

Experimental Landslide Monitoring Site of Poggio Baldi Landslide (Santa Sofia, N-Apennine, Italy), page 259

Paolo Mazzanti, Francesca Bozzano, Alessandro Brunetti, Paolo Caporossi, Carlo Esposito, and Gabriele Scarascia Mugnozza

Abstract: On 19th March 2010, a 4 million m^3 landslide was re-activated in Poggio Baldi. The landslide severely damaged some private houses, a regional road and dammed the Bidente River. The landslide can be classified as a complex movement started as a rotational slide and then evolved into an earthflow. The 2010 event was a re-activation of an ancient landslide, whose previous catastrophic activation is dated back to March 1914. Starting from 2010, the landslide has been monitored by permanent inclinometers, piezometers and extensometers. Then, from 2015 an Experimental Landslide Monitoring Site has been developed mainly for research purposes and several multi-temporal surveys have been performed by using different remote sensing techniques, such as Terrestrial Laser Scanning (TLS), Global Positioning System (GPS), Unmanned Aerial Vehicles (UAV) Photogrammetry, Digital Image Correlation (DIC), Terrestrial Interferometric SAR (TInSAR). The Experimental Landslide Monitoring site demonstrated to be a great opportunity for both research and training purposes, as well as a place where monitoring instrument can be tested and calibrated.

Prediction of the Kostanjek Landslide Movements Based on Monitoring Results Using Random Forests Technique, page 267

Martin Krkač, Snježana Mihalić Arbanas, Željko Arbanas, Sanja Bernat Gazibara, and Marin Sečanj

Abstract: Prediction of landslide movements with practical application for landslide risk mitigation is a challenge for scientists. This study presents a methodology for prediction of landslide movements using random forests, a machine learning algorithm based on regression trees. The prediction method was established based on a time series data gathered by two years of monitoring on landslide movement, groundwater level and precipitation by the Kostanjek landslide monitoring system and nearby meteorological stations in Zagreb (Croatia). Because of complex relations between precipitations and groundwater levels, the process of landslide movement prediction is divided into two separate models: (1) model for prediction of groundwater levels from precipitation data; and (2) model for prediction of landslide movements from groundwater level data. In a groundwater level prediction model, 75 parameters were used as predictors, calculated from precipitation and evapotranspiration data. In the landslide movement prediction model, 10 parameters calculated from groundwater level data were used as predictors. Model validation was performed through the prediction of groundwater levels and prediction of landslide movements for the periods from 10 to 90 days. The validation results show the capability of the model to predict the evolution of daily displacements, from predicted variations of groundwater levels, for the period up to 30 days.

Remote 3D Mapping and GB-InSAR Monitoring of the Calatabiano Landslide (Southern Italy), page 277

Teresa Nolesini, William Frodella, Luca Lombardi, Massimiliano Nocentini, Federica Bardi, Emanauele Intrieri, Tommaso Carlà, Lorenzo Solari, Giulia Dotta, Federica Ferrigno, and Nicola Casagli

Abstract: Landslides represent one of the most frequent geo-hazard, not only causing a serious threat to human lives, but also determining socio-economic losses, countable in billions of Euros and expressed in terms of damage to property, infrastructures and environmental degradation. Recent events show a significant increase in the number of disasters with natural and/or technological causes, which could have potentially serious consequences for Critical Infrastructures (CI). Where these infrastructures tend to fail or to be destroyed, the resulting cascade effect (chain of accidents) could lead to catastrophic damage

and affect people, the environment and the economy. In the field of landslide detection, mapping, monitoring and management, the availability of advanced remote sensing technologies, which allow systematic and easily updatable acquisitions of data, may enhance the implementation of near real time monitoring activity and the production of landslide maps, optimizing field work. This work aims at presenting an example of the advantages given by the combined use of advanced remote sensing techniques, such as Ground-Based Interferometric Synthetic Aperture Radar (GB-InSAR), Terrestrial Laser Scanning (TLS) and Infrared Thermography (IRT), in order to monitor and map the Calatabiano landslide, located in the Catania Province (Sicily Island, Southern Italy). The landslide occurred on October 24th 2015, after a period of heavy rainfall, causing the rupture of a water pipeline transect of the aqueduct supplying water to the city of Messina. As a consequence of this event a considerable lack in water resources occurred for a large number of the city inhabitants. A provisional by-pass, consisting of three 350 m long pipes passing through the landslide area, was implemented in order to restore the city water supplies during the emergency management phase. In this framework an integrated monitoring network was implemented, in order to assess the residual risk by analyzing the landslide geomorphological and kinematic features, and to support the early warning procedures needed to ensure the safety of the personnel involved in the by-pass realization and the long term landslide stabilization works. The intrinsic characteristics of the abovementioned techniques, such as the capability of: i) producing near-real time displacement maps without physical access to the analysed area; ii) observing the investigated scenario 24 hours per day and in all-weather conditions; iii) generating high-resolution images, especially for local scale phenomena analysis; iv) providing high versatility and transportability; represent consistent advantages with respect to the traditional methods. The preliminary monitoring results and a 3D landslide mapping have shown its effectiveness during the emergency and the post emergency management phase.

Statistical Analysis of Displacement Rate for Definition of EW Thresholds Applied to Two Case Studies, page 285

Stefano Alberti, Giovanni Battista Crosta, and Carlo Rivolta

Abstract: Large rockslides are characterized by complex spatial and temporal evolution, in addition to non-linear displacement trends and the significant effects of seasonal or occasional events on their behaviour. The displacement rate and the landslide evolution are intensely influenced by many factors like lithology, structural and hydrological settings, other than meteorological and climatic factors (e.g. snowmelt and rainfall). The relationship among these factors is evidently non-linear and site specific for each sector within the main landslide mass. Different Early Warning domains (EWD), characterized by different velocity regimes (slow to fast domains) and with different sensitivity to external perturbations (e.g. snowmelt and rainfall), have been identified in previous studies at the two sites. In this work, total displacement and displacement rate time series are extracted from Ground-based Interferometric synthetic aperture radar (GB-InSAR) surveys, monitoring of optical targets by total stations, a GPS network and multi-parametric borehole probes and from DEM difference (calculated by various algorithms) derived from terrestrial laser scanner surveys. The Mont de La Saxe rockslide (ca. 8 x 10^6 m^3) is located in the Upper Aosta Valley (Crosta et al., 2014), and it has been intensely monitored since 2009 by the Valle D'Aosta Geological Survey and have been subdivided into 5 EWD. The Ruinon landslide (ca. 15 x 106 to 20 x 10^6 m^3) is located in the Upper Valtellina (Lombardy region) and monitoring data are available starting since 2006 (provided by ARPA Lombardia) and subdivided into 8 EWD (Crosta et al., 2016). Both sites are located within an alpine deep-seated rock slope deformation characterized by dissimilar displacement velocity, from centimetres to meters per year, and which have undergone exceptional accelerations during specific events. We experiment the use of normal probability plots for the analysis of displacement rate data of each point belonging to different landslide sectors and recorded during almost ten years of monitoring. These analyses allow us to define: (i) values with a specific probability value expressed in terms of percentiles; (ii) values for which a specific change in behaviour is observed which could be associated to a specific type of triggering event (e.g. rainfall intensity, duration or amount; snowmelt amount). These values could be used to support the choice of threshold values for the management of Early Warning System, by considering also the minimization of false alarms. The analyses have been performed using data averaged with different time intervals so to study the effects of noise on the threshold values. Analyses of false alarm triggered by the choice of different threshold values (i.e. different percentiles) have been implemented and analysed. Finally, cross-correlation has been used to discriminate the different areas. This could represent an innovative approach to define velocity thresholds of Early Warning system and to analyse quantitative data derived from remote sensing monitoring and field surveys, by linking them to both spatial and temporal changes.

Ground Based Wireless Instrumentation and Real Time Monitoring of Pakhi Landslide, Garhwal Himalayas, Uttarakhand (India), page 293

Debi Prasanna Kanungo, Anil Kumar Maletha, Manali Singh, and Neelu Sharma

Abstract: Despite our increasing knowledge on the subject, the damage tolls due to landslides are on rise during monsoon in Indian Himalayan terrain. Therefore, the installation of a real-time monitoring system is often a cost-effective risk mitigation measure. A Landslide Observatory with wireless instrumentation for real time monitoring of ground deformation and hydrologic parameters has been established at Pakhi Landslide in Garhwal Himalayas, India. The measurement sensors include in-place inclinometers (IPI), piezometers, wire-line extensometers and an automatic weather station (AWS). The real time data is being monitored to establish warning thresholds. The annual cumulative rainfall during 2015 was 1388mm with cumulative monsoon period (June to September 2015) rainfall of 825mm. At the crown of landslide beyond main scarp, there is negligible displacement being the stable part. Within the main body of the landslide, it could be inferred that the colluvium, greatly

weathered bedrock and their interface experience somehow greater extent of movement at different depths in comparison to the interface between greatly weathered bedrock and unweathered bedrock. A correlation between higher intensity rainfall events and displacement pattern across the inclinometer sensors is also witnessed. However, these inferences can only be established with further data analysis of later periods.

Abstract: In early spring 2016 an exceptionally high rock-fall activity in a slope above the Village of Ghirone, Blenio-Valley Ticino, Switzerland was observed. Constant rock-fall activity was induced by toppling movement of the very thin-layered metamorphic rock. At this time, there was no information on the actual extent and the deformation rates of the landslide instability. Due to the rock-fall and failure related risk, no instrumentation on-site was possible. Local authorities then decided setting up a monitoring campaign using terrestrial radar interferometry that does not need installations in the target area.

A campaign was started in the morning of 22 March 2016. Shortly after the beginning of the measurements, the extent of the active area could be determined, showing a total affected area of 5,300 m2. The displacement velocity was in the range of 0.02-0.05 m/h, showing an increasing trend. Using inverse velocity extrapolations, a failure forecast could be done pointing to a potential failure event in the late afternoon of the same day. At 16:45 UTC+1 a major part of the slope failed. It was only 1/3 of the expected volume. Landslide activity continued and a second major failure was recorded in the night. The emergency campaign ended on 24 March 2016 after the deformation was decreasing to a level without imminent threat to the village. A refined post-processing of the radar data showed that the simplified real-time processing approach was suitable for the situation. Additionally, information on the 2d direction of the landslide movement could be obtained using intensity image pixel tracking technique. Finally, maps of volume differences could be created using the interferometric baseline, showing a difference of 33,900 m3 between 22 March and a later campaign performed on 12 April 2016.

Abstract: Landslide Stogovce had been triggered by an extreme precipitation event in September 2010, and destroyed a local road. Measurements in inclinometers along the newly constructed road have indicated movements in 2011 and 2016. GEASENSE GNSS probes, which were installed on the landslide body below the new road, have also measured movements in range of several cm/month in the 2012-mid 2015 period, with cumulative movement of 45 cm in this period. Depth to the slip surface was from 13 m to 25 m, and groundwater occurs in most of the boreholes, approximately half meter above the slip surface. The displaced material has been also detected by the calculation of surface difference in GIS, from the 2010 and 2014 lidar DEMs. The displaced material is composed mostly of debris of fractured Upper Triassic limestone and dolomite and weathered flysch, and due to its measured movements, is still capable of being transformed into a debris flow.

Abstract: The newly developed distributed fiber optic sensing technology (DFOS) offers a number of attractive advantages over conventional monitoring methods, such as better integration capability, higher accuracy and long-term stability, which are very suitable for the acquisition of multi-field information in slope. In this paper, the fields in slope are defined and proposed based on the engineering geological characteristics of slope. The fundamental principles of some typical DFOS technologies were introduced, and the details about the DFOS based monitoring system for the acquisition of multi-fields information, including stress, temperature, seepage and deformation were described as well. In the end, a field study was conducted to investigate the effectiveness of the DFOS based system for monitoring the Majiagou landslide near Three Gorges reservoir. In order to acquire the deformation, temperature and seepage information deep inside the slope mass, six boreholes were set up at different altitudes to install the DFOS based inclinometers, osmotic pressure gauge, moisture meter and other optical fiber sensors. To understand the stress characteristics of stress field, the stress optical fiber and earth pressure gauge were installed inside the anti-sliding pile. The monitoring system successfully achieve distributed acquiring the multi-fields information during the landslide evolution process. The locations with abnormal deformation could be accurately identified that corresponds to the potential sliding surfaces.

Abstract: In this work, we tested the use of passive seismic for the characterization of potentially unstable rock blocks in the Pietra di Bismantova site, a wide slab of calcareous sandstone located in the Northern Apennines of Italy. Ambient vibrations recordings with broad-band 3-component seismometers were carried out on potentially unstable areas such as 5 rock blocks and 1

rock column located close to the top of the 100m-high cliff. The rock blocks are also monitored by means of crackmeters. Seismic noise recordings were processed with a standard sequence and noise spectra and spectral ratios have been evaluated. Preliminary results are promising since in some cases a significant frequency peak can be observed, indicating resonance effects due to the vibration of the rock pillars. In addition, for the most favorable case, noise polarization analysis presents vibration direction values at given frequency in a limited angle range, reasonably corresponding to the direction of maximum displacement. Future investigations could address additional noise measurements and their correlation with the crackmeter datasets in order to understand possible relationship between change in resonance frequency or signal polarization and crackmeter hysteresis path. Moreover, new ambient noise surveys could be planned as a pilot investigation campaign, with the aim of designing extensometer monitoring network tuned on the most critical situations.

Monitoring Giant Landslide Detachment Planes in the Era of Big Data Analytics, page 333

Jan Blahůt, Matt Rowberry, Jan Balek, Jan Klimeš, Ivo Baroň, and Xavi Martí

Abstract: A small mesh of sensors which monitor movements across detachment planes of the giant San Andres Landslide on the northeastern lobe of El Hierro in the Canary Islands was established in 2013. In this paper we present the results obtained over a two year period spanning from October 2013 to October 2015. Our results demonstrate that the detachment planes are affected by sinistral strike slip displacements and subsidence of the depleted mass of the landslide. While these general trends are consistent the movements recorded at particular monitoring points differ in detail as one site is characterised by progressive strike slip and dip slip trends while another is characterised by movement pulses and reversals in the sense of movement. These findings contrast markedly with suggestions that the giant landslide is inactive and demonstrate that its reactivation is a possibility which cannot be dismissed categorically. Big data analytics have been used to identify interdependence between the recorded movements and a range of climatic and geophysical variables such as seismic data, tidal data, and geomagnetic data. We have found that the recorded movements correlate only weakly or moderately with climatic and seismic parameters but strongly to the horizontal and vertical intensity of the magnetic field. These findings are rather unexpected and we emphasise that special care must be taken in pushing the conclusions of a purely numerical analysis. The advantages of adopting a big data mindset led us to make significant improvements to the instrumental infrastructure in early 2016. These incremental improvements to the small mesh of sensors are driven partly by our desire to understand the kinematic behaviour of landslide itself and partly by our desire to explore the potential of big data analytics in geoscientific research.

Geophysical Model and Displacement of Active Landslide—An Example from Jastrzębia Góra Cliff (Northern Poland), page 341

Mirosław Kamiński and Piotr Zientara

Abstract: Digital photogrammetric analysis and electrical resistivity tomography (ERT) techniques were used to identify the structure of landslides and determine its dynamics in Jastrzębia Góra cliff (northern Poland). Two photogrammetric high-resolution models were generated from airborne laser scanning data and compared. The first model came in 2010 while another from 2013. This way, the displacement of the surface of the landslide was analyzed. The differences between the grids points of digital elevation models were used for determination of vertical movements and calculated the volume of displaced rock masses. The differences were visualized as a shaded relief map. Digital model derived from airborne laser scanning can determine the precise extent of landslides, slope and slope primary and secondary data provides many landslides morphometry. The advantage of this method is the ability to filter data and therefore to eliminate the vegetation. Interpretation of relief on the digital elevation model can efficiently speed up field work and thus reduce the cost of research. In order to identify the geological structure of the cliff, and landslides structure we used geophysical method of electrical resistivity tomography. For this purpose, they made five geophysical profiles on the landslide. To detect the sliding surface and estimate the thickness of the sliding material, several transversal and longitudinal ERT profiles were collected. The resistivity images of subsurface obtained from ERT data and supported by stratigraphic and lithological data from boreholes were integrated with the information from the DEMs. As a result geological structure of the landslide was examined and the depth of the slip zone was determined.

Hydrological Monitoring of Ash-Fall Pyroclastic Soil Mantled Slopes in Campania (Southern Italy), page 349

Francesco Fusco and Pantaleone De Vita

Abstract: Ash-fall pyroclastic deposits that mantle mountain slopes around the Mount Somma-Vesuvius (Campania, southern Italy) are frequently involved in debris flows under high-intensity and prolonged rainfall, thus representing a principal geohazard for settlements located alongside the footslope areas. In such a geomorphological framework, to understand temporal and spatial hydrological dynamics occurring into ash-fall pyroclastic soil coverings is a key factor for assessing and modelling landslide hazard as well as to set a reliable early warning system. Along with this research focus, since 2011 field monitoring activities were carried out in a test area of the Sarno Mountains to assess hillslope hydrological processes that predispose and lead to slope instability. The analysis of pressure head time series, recorded along four hydrological years (Jan. 2011 - Dec. 2014) in the whole thickness of the ash-fall pyroclastic soil cover, showed a composite variability, from the daily to the seasonal time scales, related to rainfall patterns and evapotranspiration regime as well as to unsaturated flow dynamics. Unsaturated conditions were always

observed with pressure head values ranging at the annual scale from about -0.6 m to, and beyond, -20 m. Such a marked hydrological dynamics of the ash-fall pyroclastic soil covers demonstrates the relevant role of antecedent hydrological conditions in predisposing landslide triggering under a single rainfall event. Therefore, results obtained by the proposed approach can be conceived as a fundamental basis to understand hydrological processes at slope scale, to set and calibrate hydrological numerical and slope stability models for estimating rainfall thresholds triggering slope instabilities as well as to assess inherent landslide hazard.

Analysis of Hydro-meteorological Monitoring Data Collected in Different Contexts Prone to Shallow Landslides of the Oltrepò Pavese (Northern Italy), page 357

Massimiliano Bordoni, Claudia Meisina, Roberto Valentino, Marco Bittelli, Silvia Chersich, Marco Musetti, and Maria Giuseppina Persichillo

Abstract: Rainfall-induced shallow landslides are widespread in different geological, geomorphological and environmental contexts of the entire world. Besides the limited volume of soil mobilized by these phenomena, they can provoke serious damages to cultivations, infrastructures and buildings due to their high speed of development and their high density in small areas.

Their triggering is strictly linked with the response of a usually unsaturated soil to intense rainfalls. For this reason, a continuous monitoring of unsaturated soil hydrological properties related to rainfall conditions is needed to understand the effects of hydrological parameters on landslides triggering and slope safety factor. This work presents the results of the continuous monitoring of two slopes of the Oltrepò Pavese (northern Apennines, north-western Italy), representative of different contexts usually affected by shallow landsliding. The main aims of this work were: i) to identify the main soil hydrological behaviors, highlighting the differences in the two selected sites; ii) to assess the impact of water content, pore pressure and hydrological hysteresis on safety factors of the two slopes; iii) to recognize the triggering mechanism of shallow landslides in both the contexts. The first station is located in Scuropasso catchment (north-eastern Oltrepò Pavese), in a steep slope with sandy silt soils in correspondence of the Oltrepò Pavese area with the highest shallow landslides density. The second one is located in Ardivestra catchment (central Oltrepò Pavese), in a low-medium gradient slope with silty clay soils affected by several shallow failures in the years 2009-2014. The two stations integrate field devices for the measurement of the main soil hydrological parameters (water content, pore water pressure, water electrical conductivity), at different depths in the soil profile, with sensors for measuring meteorological variables (rainfall, air temperature, air humidity, net solar radiation, wind speed and direction). The monitoring period has started in March 2012 for the station of Scuropasso catchment, while it has started in November 2015 for the station of Ardivestra catchment. The test-site slopes were characterized by a multidisciplinary point of view, determining the pedological profile and properties, the geotechnical parameters, the mineralogy and the hydrological properties. This research allowed for identifying the main soil hydrological behaviors of the two monitored settings. In particular, the different hydrological responses of the two test-sites to rainfall events of similar amount and intensity were recognized. In the same way, the responses to long drying periods were evaluated. These analyses allowed also for the assessment of the main shallow landslides triggering mechanisms of the two contexts. All these data provided a fundamental basis for: i) correctly modeling the time of failures through safety factor calculation based on water content or pore water pressure, neglecting or not hydrological hysteresis; ii) future application of the best methodologies for basin-scale and regional-scale shallow landslides susceptibility and hazard assessments.

Field Monitoring to Measure Deformation of a Mine Waste-Dump Slope, page 365

Young-Suk Song and Yong-Chan Cho

Abstract: This study surveyed and investigated the deformation of the coal waste depot slope and the natural ground slope under the waste depot at Dogye village in Samcheock city, Gangwon Province, Korea. Multiple sets of south-north tension cracks were observed at the crest of the coal waste depot slope. The size of these cracks was greater than 100 m in length, and the resulting drop head averaged 1.0-1.5 m. To investigate the behaviors of the waste depot slope and the natural slope under the waste depot, wire sensors and a rain gauge were installed at the crest of the waste depot slope, and inclinometers were installed in the natural slope of the ground under the waste depot. According to the monitoring results, the deformation at the crest of the waste depot slope steadily increased and then converged over time due to the effect of the infiltration of rain into the ground after rainfall. In addition, the horizontal deformation of the natural slope under the waste depot was affected by the accumulated precipitation. The basis of this effect is that the rate of increase of the maximum horizontal deformation tends to show increasing or convergent behavior according to the precipitation.

Monitoring Soil Movement Characteristics of an Area Subject to Land Creeping in the Republic of Korea, page 371

Min-Jeng Kang, Chang-Woo Lee, Choong-shik Woo, Dong-Yeob Kim, Jun-pyo Seo, Hyun-Jung Kwon, Jae-Hyeon Park, and Ki-Dae Kim

Abstract: Land creeping in mountainous regions is a phenomenon describing sediment blocks to move downwards very slowly through a slip surface due to its geographical or geological characteristics. In Republic of Korea, there was few case of land

creeping reported, but recently it often is reported because of anthropogenic impacts such as land use changes and constructions in forest sectors. The objective of the current study was to report on monitoring results of a land creeping case in Republic of Korea. The study site was located in Hadong-gun, Gyeonsangnam-do, southern part of Republic of Korea. The land creeping of 2.6 ha area was located on 200 to 300 m a.m.s.l. and on anorthosite of bedrock. The dominant tree species was oak trees (Quercus mongolica) in above story and bamboo trees (phyllostachys bambusoides) in underground story. Although the land creeping event was officially reported in April 2015, it appeared to start moving in late 1990s when a reservoir for agricultural use was constructed adjacent to the area. The overflows of the reservoirs by the land creeping can cause secondary damages to downstream resident areas. Soil bulk density, particle size distribution, porosity and hardness have been periodically measured as soil physical properties of the study site. These soil factors can be used as indirect index for vegetation restoration. As a result, there were no significant differences of investigated factors except for soil hardness. Forward plans to focus on monitoring the hardness of the soil. Several 2 sets of poles were installed for monitoring on the size of two tension cracks. The length, width, and depth of tension cracks just varied through monthly measurements from July to December, 2015, but did not tend to increase or decrease. Therefore, we re-arranged and installed poles around the main scar of the land creeping in April, 2016. Now filed survey for identifying detailed geological and geographical characteristics in the area is being carried out, then specific monitoring instruments such as extensometer, groundwater level meter, ground inclinometer and so on will be installed for precise measurement from the result of the field survey.

Part II: Landslide Monitoring and Early Warning Systems for Landslide Occurrence Prediction

Abstract: Landslides are the one of the most common hazard in the territory of Bosnia and Herzegovina. Despite this fact, urban area of Doboj City did not threatened frequently in the past from landsliding. In the mid of May 2014, heavy rainfall between 250 and 300 mm triggered flood and activated numerous landslides in the area of Doboj City. In the frame of EU recovery program the Study of flood and landslide risk assessment for urban area of Doboj was conducted. The landslide inventory, landslide susceptibility and relative risk assessment for housing sector were done as a support for local communities for better preparedness in the future. The landslide susceptibility map for urban area of Doboj City in scale 1:5000 has provided useful information for Master Plan and related urban planning documents. Several non-structural and structural measures were proposed as a result of situation analysis and recovery needs. In this paper post landslides disaster and relief activities in the area of Doboj City, Bosnia and Herzegovina are presented.

Abstract: While landslides constitute a major risk in Uganda, this geomorphological hazard has been largely neglected by national and local authorities in West Uganda. Nowadays, disaster risk management is emerging in Uganda. Monitoring the on-going efforts is therefore crucial in this region. We identify the actors involved in landslide risk management in West Uganda and examine their roles and interactions by investigating both policy and practice. This paper describes a qualitative multi-policy level approach, based on extensive field work and literature on systems analysis and scalar politics. The results show that in theory, landslide risk management in this region consists of a well-structured National Policy (2010), including the establishment of horizontally structured platforms at different administrative levels and a focus on pre-disaster mitigation activities. In practice, however, the implementation is insufficient, as most platforms at local level remain dysfunctional or only meet after a disaster occurred. The dominant arena for landslide risk management remains at national level, despite the promotion of decentralisation, and the focus remains on post-disaster emergency measures, such as providing relief. At local level, bottom-up landslide risk reduction efforts are made that are disconnected from the national policy, scattered and done haphazardly. Thus, discrepancies exist between policy and practice regarding landslide risk management in West Uganda but efforts are moving gradually towards disaster risk reduction.

Abstract: This paper focuses on the RECALL project, co-funded by the European Civil Protection Financial Instrument, ongoing from May 2015 to April 2017. The project involves 5 partners from 5 different European countries, working together to design and implement smart, community-based solutions supporting local authorities in better planning and implementing landslide and disaster prevention measures in their territories. RECALL operative part is composed of 4 main tasks. The first step deals with a detailed analysis of the state of the art of reinforcement measures, state of maintenance, priorities of investments in 4 European pilot areas (Slovenia, Italy, Croatia and Greece). Thorough on-site visits in each pilot area allow project technicians to assess the status of the landslide source areas, the latest processes, developments and movement indications, to inspect the transport paths of the material from the source areas to the areas under risk, including existing precaution measures and to map in particular situations such as the potential isolation of small villages in case of destruction of (the only) access road. The second step is the organization and training of special cooperatives teams composed by civil protection personnel and citizens that will cooperate with the local authorities in the monitoring and prevention of landslides risk, in each pilot area. This activity is carried out in parallel with the development of 2 innovative, specific IT tools, aimed at providing support to the local territorial authorities and cooperative teams in their actions regarding the landslides: (1) The e-prevention tool (the third step): a web-based tool supporting the cooperative teams in collecting and providing monitoring data, information and other relevant inputs to the local authorities in charge of territorial protection and disaster prevention, through shared vocabularies, formats and protocols; (2) The e-budget tool (the fourth step): a decision support system that will, taking into consideration data coming from the e-prevention tool and other inputs, support territorial entities in preparing the most effective and efficient strategic financial plan for landslide risk prevention, given a precise available budget. During the project, both the cooperative teams and the developed tools are directly involved in an extensive Pilot Test phase, aimed at validating and refining the proposed solutions, but also ensuring immediate and direct benefits for the involved territories. During the pilot phase, the cooperative teams will collect, by means of the e-prevention tool, a relevant amount of data and information about territory characteristics and risks levels and provide them to the competent territorial authority (project partners). In addition, they will also be directly involved in application of the

reinforcement measures, in case of simple and low-cost works to be done, in order to assure prompt responses to ordinary territorial degradation caused by natural events (time passing, weather, and material deterioration), decreasing the risk of disasters and contributing to decrease of damage and costs in case of one. Altogether project activities aim towards: (1) increased capacity of territorial entities in managing the available resources (financial and human); (2) increased capacity of territorial entities in assessing prevention measures' level of priority; (3) increased involvement of local communities in risk prevention measures and strategies; (4) increased capacity of local communities to develop adaptation strategies to climate changes; (5) increased integration of disaster prevention in economic and financial decisions and strategies, and (6) increased knowledge in landslide prevention measures and further contribution to the efforts done so far at international level.

Abstract: The project - on harmonization of landslide data and training of municipalities for its monitoring, nicknamed BEWARE (BEyond landslide aWAREness) was implemented by the Geological Survey of Serbia, and the University of Belgrade Faculty of Mining and Geology. The Project partners were UNDP Office in Serbia, Ministry of Mining and Energy and Government Office for Reconstruction and Flood Relief of the Republic of Serbia. Project was funded by People of Japan. Overall aim of BEWARE project was to standardize post-event landslide database and closely involve local community of 27 municipalities affected by May 2014 flooding and landslides episode in Serbia, and prepare them to cope with catastrophic events in the future. In this paper we are presenting main BEWARE project activities and results implemented on local communities in Serbia after May 2014 event

Abstract: In this paper we present BEWARE multi-device web GIS application that provides management of geospatial and attribute landslides data. Software solution is in use from July 2015. and it was continuously and successfully used for collecting field data for the project "The Harmonization of Landslide Data and training of municipalities for its monitoring: BEWARE (BEyond landslide aWAREness". It consists of several components, two mobile applications for data collection on the field, both on-line and in off-line mode, using android devices, web GIS application for field data and web analytical tool for comprehensive statistics. The offline mode is necessary because the most of landslide are located in the areas where is not possible to connect to the Internet. Mobile application provides integration of thematic layers in the form of tile package, with field work data, as well data synchronization with GIS web portal on server geodatabase. The BEWARE is a platform for interactive landslide event reporting, analyzing and unifying landslide data and multimedia management. Development of multi-functional application was initiated in order to facilitate and improve the landslides geodatabase use and avoid building-up in areas where there is an apparent high risk of landslides. Mobile applications are available for public use and can be downloaded from http://geoliss.mre.gov.rs/beware/?lang=sr, while web GIS application is available for public browse and search. Apart from authorized users from Faculty of Mining and Geology, Geological survey and employees of Ministry of Mining and Energy of Serbia, system is used by municipalities. who can record the occurrence of landslides as early notification for further inspection. The user friendly forms contain the combined inputs with the broad use of domain control, grouped in several parts: general and process data; morphological, hydrological and hydrogeological characteristics; geological structure data, detailed description of the geometry and other characteristics of the occurrence. Web form enable also data about area's affected by the process of instability use, vulnerability assessment, recommendations for measures to be taken, and additional notes. It is possible to take several photos for each landslide and automatically connect them with landslide. The paper form is also available on next link http://geoliss.mre.gov.rs/beware/webform/paperform, because some users find easier to fill classical paper form and later via web form populate geodatabase. When field word is finished, data uploaded and supervisor verifies data, they are visible and available on the web GIS portal. Central part of web portal contains interactive map with landslides as points and polygons. Map also contains several ArcGIS base layers, and several web map service layers such as the municipalities boundaries, AHP maps, hydrological phenomena and so on. Application enable search of landslides, with browse of detailed information and photo gallery for selected landslide. SWOT analysis and different statistical results are available for landslides within selected municipality. Development and use of this application, provided quick collection more than 2000 landslide within 5 months, starting from July 2015, as well as storing and analyzing collected data.

Abstract: The mitigation of landslide risk to human-valued physical and non-physical assets is a fundamental component in the disaster risk management cycle. The reduction of risk can be pursued through the selection, planning and implementation of suitable mitigation measures and/or actions. The selection of the most appropriate mitigation measures is a complex process which depends on both the characteristics of the expected landslide event and the potential impacts on the physical, economic, environmental, cultural and societal human-valued assets. Each risk mitigation effort is thus markedly case- and site-specific. A

web-based portal is in course of development within the Norwegian research project Klima2050. The project is aimed at reducing the risks associated with climate changes and enhanced precipitation and flood water exposure within the built environment. The portal implements the analytic hierarchy process (AHP) for the purpose of selecting the most appropriate landslide risk mitigation measures based on user inputs and dynamic expert scoring of an extensive set of candidate mitigation measures. This paper outlines the conceptual standpoints and the present and foreseeable future structure of the portal.

Part III: Landslide Monitoring and Early Warning Systems at Regional Level

Abstract: Shear strength parameters of a slope mass are of utmost concern in stability analyses. However, due to sampling difficulties, it is quite challenging to retrieve precise design parameters particularly for the slopes excavated in heavily jointed rock masses. As a matter of fact, a rough estimation of shear strength may lead to slope failures causing catastrophic events. In this paper, a repeating slope failure in highly jointed and deformed metamorphic rock mass threatening the safety of a large-scale reinforced concrete water storage tank in western Turkey is evaluated considering the reliability of shear strength parameters. On site, a series of slope stabilization works were carried out to protect the stability of existing water storage tank on the upper level. Slope stabilization by retaining pile wall failed to stop the failure at first as a consequence of poor structural design and improper assignment of shear strength parameters. Final slope stability was achieved after the placement of a permanent granular buttress. Back analyses using linear Mohr- Coulomb and non-linear Hoek-Brown failure criterion were executed to reveal the shear strength parameters of the chaotic rock mass. The maximum normal stress acting on the sliding surface was found to be around 130 kPa. Non-linear back analyses proposed a GSI value of 21 indicating a blocky and highly disturbed material. High shear strength parameters were found for the highly fractured rock mass after back analysis by the linear Mohr-Coulomb failure criterion. Eventually, it is noteworthy to mention that the shear strength parameters of a failure surface in heavily jointed rock mass are normal stress-dependent and well defined by the non-linear failure criterion.

Abstract: This paper reports a subgrade reaction solution for anchored piles used to stabilize landslides of which the sliding layer moves with a lateral displacement decreasing linearly with depth. The developed subgrade reaction solution can deal with the case in which pile segments in both sliding and stable layers are intermediate and flexible but not rigid, and also calculate the pile response under the additional resistance required to stabilize the landslide. The proposed subgrade reaction solution calculate the response of anchored piles with no iteration. The conventional solution can be obtained from the developed subgrade reaction solution for the case in which the movement of the sliding layer is uniform with depth. Calculation of the example described in Guidelines for Design of Landslide Control Steel Pipe Piles (JLS 2003) shows same pile response can be obtained by the proposed subgrade reaction solution and the conventional subgrade reaction solution in which an iteration process is necessary to obtain the results.

Abstract: Natural slopes may be marginally stable due anthropogenic excavations (Cuomo et al., 2013a, 2013b) and/or in relation to rainfall and climate actions (Cascini et al., 2010). Unsaturated soil conditions often exist in Mediterranean sites, thus making the performance of the slopes dependent on season effects related to the initial conditions of pore water pressures areas and time-dependent conductivity of soil. This is also the case for engineered slopes, and the paper analyses a case study of Southern Italy, where a slope about to an historical centre was improved through a reshaping of the slope ground surface and the introduction of both coarse-grained material and geosynthetics (Cuomo et al., 2013a, 2014). An advanced seepage analysis is performed through a FEM (Finite Element Method) model, which is well suited either for complex slope configurations or for unsaturated soils subjected to short heavy rainfall and transient pore water pressures. The latter ones are then used in standard slope limit equilibrium analyses. The results of both seepage and stability analyses provide a model for the response of the engineered levee against heavy hydraulic boundary conditions related to rainfall, also taking into account different initial conditions related to the season. On the other hand, numerical modeling provides a global framework for a performance-based selection and design of control and remedial works

Abstract: Landslide propagation modelling is an important issue in engineering-based procedures for susceptibility and hazard analysis. The paper deals with debris avalanches, which develop along open slopes with nearly constant inclination and may propagate over large distances. In particular, the paper investigates the effect of different combinations of artificial obstacles on landslide run-out, deposition heights and thicknesses of soil eroded along the landslide path. Among the several numerical techniques available to this purpose, Smooth Particle Hydrodynamic (SPH) is used since it is a convenient tool for reasonable computational times and accurate description of the main kinematic quantities such as heights and velocities of the mobilised volumes. A frictional rheological model is used, and also the role of time-space variable pore water pressures is considered. The

numerical results are discussed to individuate the changes induced by obstacles in landslide dynamics and to discuss the feasibility of such typology of intervention in steep slopes.

High Geogrid-Reinforced Slopes as Flexible Solution for Problematic Steep Terrain: Trieben-Sunk Project, Austria, page 495

Oliver Detert and Pierpaolo Fantini

Abstract: A large-scale construction project was implemented between June 2006 and September 2008 to reroute the B114 mountainside link road between Trieben and Sunk in Austria. In addition to comprehensive drainage and anchorage measures, the works included the extensive use of extra-steep, geosynthetic-reinforced slope structures to build the route and stabilize critical slip-prone slopes. This paper presents a technically expedient and practically feasible solution for the use of geosynthetic-reinforced retaining structures on projects subject to extremely difficult geotechnical and topographical conditions. Following a description of the geotechnical situation and associated problems, the procedure for dimensioning the geogrid-reinforced structures and practical aspects of the site operations are outlined, explained and discussed.

Implementation of a Flexible Wire Net Dam for Controlling Debris Flow in a Small Mountain Torrent, page 503

Sangjun Im, Seungyoub Yi, and Song Eu

Abstract: Debris flow is recognized as a major natural hazard in torrent landscape over the world. Various types of control structures have been employed to capture debris flow in mountain torrents of Korea. In this study, a revised wire net dam was newly designed and implemented to retain debris flow on a small, steep mountain torrent. The dam consists of a flexible net panel, wire anchors and supporting rods to dissipate the energy of debris flow. A 500 mm x 500 mm wire panel was designed to endure the impacts of debris sediments, regarding the characteristics of streambed materials on upstream torrents. The plane stresses induced by debris impacts are uniformly distributed over the panel and subjected to the wire anchors installed in river banks. The anchors are specially designed to absorb the kinetic energy of sediment movement. Supporting rods are anchored into streambed and keep the wire panels against sediment-induced force. Designed dam was implemented in average slope of 35 degree torrent of Mt Gwanak in Seoul. The dam has a 15 m bottom width and 3 m height. Design load was estimated from the size and density of stony debris materials placed in upstream torrents. A 95-percentile diameter of sediment materials (D95) is 0.5 m in size. Maximum force acting on wire net was estimated to be 14.81 kN/m for design purpose. The flexible wire net dam has well-designed and installed in a site for preventing debris flow movement. The dam can be constructed without disturbing the stream environment and with ease, so it has environmental benefit and safety performance by reducing dangerous works for construction.

Flexible Barriers Composed of High-Strength Steel Nets, as a Solution to the Near Surface Slides, page 513

Corinna Wendeler, Volker Leonhardt, and Roberto Luis

Abstract: On steep slopes, a number of different gravity driven hazards (shallow landslide, rockfall, snow slides) threaten the safety of people and infrastructures. Saturated layers of soil can form shallow landslides, which can trigger spontaneously and flow at relatively high speeds of up to 10 m/s (35 km/h). If a shallow landslide flows into a river channel, this can spark a debris flow. Depending on the flow speed and volume of the displaced material, shallow landslides can have a destructive impact, disrupting traffic routes and causing major damage to buildings. The climate as a risk factor with an expected increase in heavy rainfall in lower case alpine regions and more frequent winter storms, coupled with the fact that the snow line is moving ever higher, in the future the environment will contain more water to potentially trigger shallow landslides. Meteorologists are predicting that the likelihood of extreme rainfall events will also rise across the world (global climate change). Suitable protective measures are designed to secure roads and rail lines against shallow landslides. Exposed buildings must also be protected against these near surface landslips. The conventional protective measures consist in erecting structures to divert the landslide -dams or reinforced mountainside walls- requires a huge amount of constructing work. Particularly in steep terrain alongside roads and rail lines, measures like this can only be taken in certain circumstances. Flexible shallow landslide barriers have been proven to retain mixtures of water and solids, such as mudslides and shallow landslides, even in the event of multiple impacts. The barriers can be installed with a low outlay of material and man hours, greatly reducing costs and construction time. Combined shallow landslide and rockfall hazards are a common situation for unstable slopes: the steep flanks of landslide slopes are often sources of rockfalls. Moreover, the erosive action of a shallow landslide can remove soil and vegetation cover down to the underlying bedrock, exposing further potential for rockfall events. In this contribution we also discuss the challenges in designing protection measures that can cope with both shallow landslides and rockfalls, each one characterized by different load cases. Shallow landslides impact with spreading pressures that load gradually, while rockfalls impact punctually with high velocities. We discuss the findings of number of full scale experiments investigating different load case; a finite element simulation software FARO used in the design of flexible wire protection systems will be presented.

Synthetic Water Repellent Soils for Slope Stabilization, page 523

Shuang Zheng, Sérgio D.N. Lourenço, Peter J. Cleall, Stuart W. Millis, Angel K.Y. Ng, and Ting Fong May Chui

Abstract: Water repellent soils, or non-wettable soils, are described to have delayed wetting of soil surface and water infiltration, and have been studied by soil scientists and agriculturists for decades. Soil water repellency induced by wildfire is believed to be a major trigger of post-fire debris flows, by changing the hydrological characteristics of the slopes, the rainfall infiltration is delayed, leading to the increased surface runoff and eventual soil mass movement. On the other hand, the potential applications of water repellent soils in the field of slope engineering have also been recognized recently. Due to their ability to inhibit water infiltration while remaining gas permeable, water repellent soils are considered to be promising fill materials and impermeable barriers. Soil water repellency is widely observed to occur in nature because of wildfire and organic matter, while in the laboratory, it can be induced by coating the soil particles with low surface energy substances such as silane compounds. An advantage of synthetic water repellent soils is that the level of water repellency is adjustable (from very wettable to extremely water repellent), and therefore the rate of infiltration can be controlled in various scenarios. Since intense rainfall and subsequent infiltration significantly contribute to fill and natural slope failures, water repellent soils have proved to be effective in hindering the infiltration and generation of excess pore pressure and therefore could increase the overall factor of safety during rainstorms. Landfill cover is another potential application of water repellent soils.

Destructive Influence of Technogenic Factors and Precipitations on Landslide Support Structure, page 529

Georgi Frangov, Hristina Zayakova, and Stefan Frangov

Abstract: The investigated landslide occurred after mass excavation at the toe of the slope due to construction of an aqua park and heavy rainfall in November 2014. The induced slope instability affected the only road linking the village of Gorni Voden with the town of Asenovgrad. Immediately after the landslide occurrence an engineering-geological site investigation had been carried out. It was followed by proposal for remediation measures. The landslide has an elongated shape with a maximum width of up to 60 m, length 140 m and area of approximately 8000 m^2. The volume is above 20 000 m^3. The damaged length of the road was 35 m. The investigation established the geological composition of the slope, key elements of the landslide, its mechanism, physical and engineering properties of the soil and the groundwater conditions. The reinforcement design consists of anchored pile retaining wall and drainage system. Due to the delay in construction, during the following warm and rainy winter the landslide increased its area more than two times. Subsequently, after the anchored pile retaining walls were constructed, the builder of the new aqua park made a new deep excavation downslope from the reconstructed road section. This excavation destabilized the landslide once again leading to cracks formation on the slope and increasing the depth of the sliding surface. The landslide body has been saturated through the open cracks by the following rainfall, soil consistency has been changed and the shear strength has decreased. The landslide process has progressed upwards and the new sliding surface reached the anchored pile retaining wall and compromised it locally. This paper discusses the remediation design proposed after the landslide occurrence, its implementation and the factors influencing the consequent structural damages on retaining wall due to loss of overall stability.

Collapse and Remediation of Vrhole Landslide, page 537

Saša Galuf and Vojkan Jovičić

Abstract: The first signs of instability of a 20m high cut, which was executed during the construction of Ljubljana - Maribor motorway in the nighties, were observed in 2010. On the bottom of the cut, next to the shoulder of the motorway, there was distinguished ground heaving while some 2m deep cracks appeared on the body of the sliding mass. Approximately 100m wide landslide was formed endangering the traffic on the motorway. A comprehensive site investigation was carried out in 2011, which included measurement of movements and the installation of the set of piezometers and inclinometers. Based on the contemporaneous state of the landslide and the results of site investigation the design of the remediation was carried out. The design, which comprised a 100m long pile wall and deep drainage, was never applied in practice. During the night in the spring in 2013 the landslide collapsed and the debris covered all three lanes of the motorway in Ljubljana direction. Fortunately, the maintenance services were quickly informed and the motorway was immediately closed so that there was no material or human loss resulting from the landslide. The new design of the remedial measures, which conformed to the newly developed boundary conditions, was carried out in 2014. The new design comprised deep drainage and the gravity wall, so that the landslide was fully stabilized during the same year. Geological conditions, the ground model, causes of instability and remedial measures are presented in the paper.

Interaction of Landslide with Critical Infrastructure, page 545

Daniel Jirásko, Ivan Vaníček, and Martin Vaníček

Abstract: The interaction of natural hazards, namely landslides, with critical infrastructure is still very actual problem especially from the new demands on such transport infrastructure. Paper describes very sensitive example of such interaction, as new constructed motorway D8 from Prague to Dresden is passing the area with old tertiary volcanic activity, generally prone to landslides. At the end of excavation for motorway lanes - in two different levels - large landslide occurred immediately after for

this area extremely heavy rainfalls at the beginning of June 2013. The evaluation of landslide reasons, proposed remediation measures are therefore described in details, allowing to guarantee full operation of this motorway at the end of 2016.

The 10-Mile Slide and Response of a Retaining Wall to Its Continuous Deformation, page 553

Renato Macciotta, Tommaso Carlà, Michael Hendry, Trevor Evans, Tom Edwards, Paolo Farina, and Nicola Casagli

Abstract: The 10-mile Slide has a volume of about 750 000 m^3 and is sliding on a through-going shear surface at velocities up to 10 mm/day. Its importance is associated with the location of a highway and a railway line within its boundaries. Risks posed to the railway were managed through monitoring and running patrols in front of trains, and a pile retaining wall was installed immediately downslope from the tracks to prevent deformations caused by loosening of materials associated with the slope deformations and delay the retrogression of the landslide. Displacement measurements of the piles have monitored the response of the wall as the landslide retrogressed upslope from the railway track. This paper presents a brief description of the 10-mile Slide geologic context, its kinematics, mechanism, and evolution followed by a presentation of measured response of the retaining wall as the landside retrogressed.

Inadvertent Engineered Activation of Utiku Landslide, New Zealand, page 563

Mauri J. McSaveney and Christopher I. Massey

Abstract: New Zealand's North Island Main Trunk railway and State Highway 1 cross the Utiku landslide in central North Island. When we began a research project on slow-moving blockslides, we assumed that Utiku landslide was typical of over a thousand other blockslides in the Neogene sedimentary rocks. Its relationship with a national transport corridor enabled intensive engineering geological investigation. It became obvious near the close of our study, that the landslide's activity through the 1960s to the 1970s was an extreme anomaly in the geological record, and coincided with intensive engineering work on both the road and rail. By then, we knew that Utiku landslide was very sensitive to changes in environmental conditions. This led us to examine the sequence of engineering work on the landslide. Utiku landslide initiated prehistorically by erosion by Hautapu River, when incision intercepted a weak clay seam. Further incision in recent decades released the rock mass further down-dip, allowing lateral propagation of the landslide. Hautapu River joins Rangitikei River 100 m downstream of the landslide toe. The bed of Rangitikei River downstream of the junction is a source of gravel for construction and maintenance of the transport corridor. The Rangitikei River bed has been lowered, leading to loss of gravel from the bed of Hautapu River, which is now a bedrock channel. This accounts for the recent landslide propagation, and raised the question of where the gravel was being used. The railway crosses Utiku landslide on an embankment. As the rails move with the landslide, the offsets are realigned and the railway is re-leveled using the gravel. The railway has always crossed Utiku landslide on an embankment, so the head of Utiku landslide has carried some surcharge since before 1904, but the surcharge has increased each time the railway has been re-leveled. A most extensive repair was shortly after 1960. State Highway 1 also crosses Utiku landslide; its realignment in the 1960s involved cuts to the north and south of the landslide and fill was placed on the landslide. The total surcharge may now add about 10% to the landslide mass. Engineering work on Utiku landslide has loaded the head and unloaded the toe of a landslide that is very sensitive to environmental changes; the predictable consequences continue to affect the transport corridor.

Landslide Remediation Between Kvaternikova and Divoselska Street in Zagreb, page 569

Katarina Ravnjak, Goran Grget, Leo Matešić, and Marko Kaić

Abstract: On the slope between Kvaternikova and Divoselska street in Zagreb landslides have been activated after heavy snowfall in mid-January 2013 that threaten surrounding residential buildings and water, gas and sewage infrastructure in Kvaternikova Street. According to residents whose houses were threatened by landslides first cracks on slope surface were noticed in the summer of 2012 after a long dry period. Unfavorable weather conditions in 2013, snow melting and rain caused the progression of sliding and on the landslide surface it created loosened soil material with high water content. Accessing the landslide with heavier machinery was not possible and in accordance with such a situation on the site and the available technology emergency measures were implemented that included the drain trenches and driven wooden piles from local wood. Implemented emergency measures prevented the collapse of road, sewage, gas and water supply as well as sliding and launching larger landslide mass. In the next phase detailed design were made in which remediation of the entire landslide was planned. For the purposes of the design for landslide remediation insight into the existing geological maps and earlier investigation works was made and geotechnical investigation works were conducted. Based on the research, soil layering, soil classification and properties, groundwater level and the causes of sliding with its mechanisms and depth were determined. The wider surrounding area of described landslide in Kvaternikova street is located in the zone of unstable and conditionally unstable slopes on which they are registered active landslides, old landslides, marks of old landslides, creeping of slope surface and damages on constructions and roads. According to the existing geological maps (Geoexpert, 1979, HGI, 2007) and investigation works in 2006 (Geokon-Zagreb, IGH) the location history indicates slopes instabilities in the last 40 years. That is why most of the slope is covered with colluvium. The main natural cause for slope instability at the investigated location is stratigraphical order of geological units, because boundary between two different Pliocene soil layers is driven out to the surface at relatively steep slope below Kvaternikova street (slope inclination is 20-35°) and landslides are mostly initiated by human interventions (house

construction, sewage discharge on the slope, uncontrolled soil dumping) and / or by very bad weather conditions (rain, snow). Final landslide remediation measures included the construction of retaining wall with strand anchors and foundation on piles along the road, shifting soil masses on the slope, gabion wall in the lower part of the slope, construction of drain trenches and planting vegetation. In order to control performance of landslide remediation and record side effects that require additional remedial measures, monitoring was carried out. In this article are presented all the phases of the landslide remediation in chronological order from the investigation works, emergency remedial measures, detailed design documents, construction phase and monitoring.

Landslide Stabilization in Building Practice: Methodology and Case Study from Autonomic Republic of Crimea, page 587

Oleksander Trofymchuk, Iurii Kaliukh, and Viktoriia Berchun

Abstract: Within the framework of the IPL Project № 153" Landslide protection structures and their development in the Autonomous Republic of the Crimea, Ukraine (ARCU)" the information about landslide protection structures and measures, prospects of their development in the ARCU was collected and structured; the target data base was created. In specific Crimean conditions driven piles are not used, as a rule, due to general spread of soils with high content of rock and hard rock inclusions presented by argillites and siltstones with sandstone layers. Bored piles have been widely used since 1968 on the Crimean landslide slopes. They allow successful fixation of landslides with the thickness of 15-20 m. One of the most efficient solutions for landslide protection is the retaining constructions based on the short underground piles (SUP). They are shortened bored piles, immersed below the slide surface on the calculated value and output above it at a distance providing overlapping of slipping soils. In the process of experimental work there appeared the need to choose the optimal testing mode. In summary, the above results of IPL Project № 153 were used for design structure № 1 in Gurzuf town and landslide protection structures № 2 in Koreiz town of landslide protection structures based on SUP's technology. The seismicity of the construction sites is 8 points due to Medvedev-Sponheuer-Karnik seismic scale (MSK-64). At present all the building structures are commissioned in ARCU of Ukraine.

Monitoring and Assessment of Remedial Measures in Closed Open Cast Mine, page 587

Jan Zalesky and Kristyna Capova

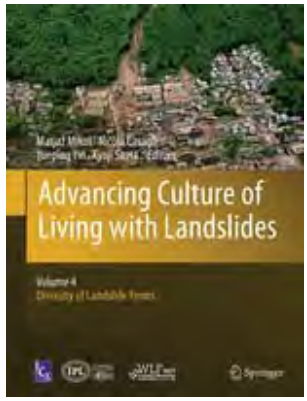
Abstract: The excavated open cast mine Chabarovice, particularly the part of it with local name Rabenov, has been investigated and monitored by the Czech Technical University since 1998 because of problems connected with different types of instabilities. Complicated geotechnical conditions, extreme heterogeneity and artesian ground water of the origin site together with the conditions modified by open cast mining were the main reasons of land sliding. Stability analyses made by the Department of Geotechnics were focused on final slopes of the mine together with the supporting waste dump and they were based on analyses of 3-D deformation monitoring in instrumented boreholes and pore water pressure sensing. The Department has contributed to development of several types of remedial measures as drainage works, re-shaping, stabilizing embankment assessment, discontinuous anchored pile wall. The group of experts of the Department was asked to provide risk analysis of the final version of the design of the measures of the last but not stable Rabenov part of the mine. The results of the monitoring with results of analyses will be presented in the paper. Development of displacements on the site demonstrated partly different behavior than expected at the design stage and it approved concerns stated in our risk analysis. These events are described and discussed in the paper. There were successfully tested different applications of fiber optics deformation monitoring developed in before research and development projects, there. Continuous high resolution fiber optic monitoring system was modified for a new research focused on a group of churches in eastern Bohemia.

DEM simulations of punch tests for the mechanical characterization of cortical meshes

Fabio Gabrieli, Antonio Pol, Klaus Thoeni, and Nicola Mazzon

Abstract: In this work, a plain steel wire double-twisted hexagonal mesh is modeled with the discrete element method for the evaluation of its mechanical behavior. In the current model, the wires are replaced with long-range interaction forces between nodes of the mesh. The implemented force-displacement curves for the basic elements, i.e. single wires and double-twists, are derived from laboratory tensile tests. The mechanical behavior of the considered mesh is investigated through laboratory punch tests. The results of these numerical tests permitted to highlight two subsequent phases linked to the geometric distortion of hexagons and to the tensile properties of the materials respectively. An anisotropic stress-strain distribution was also observed, which reveals a preferential direction of tensile forces in the mesh panel.

Volume 4: Diversity of Landslide Forms



Part I: Earthquake-Induced Landslides

Rustam Niyazov, and Bakhtiar Nurtaev

Abstract: Landslides, as any geological phenomena, formed due to simultaneous action of exogenous and endogenous forces. We consider simultaneous formation in the different areas of large landslides caused by the influence of these forces as a trigger effect. The nature of this connection, it is not only change of tectonic stress field, the intensity of the force and the direction of their influence varies in space and time, but at the same time the impact of climatic factors, the movement of groundwater, as well as the value of the natural frequency spectra of fluctuations in landslide-prone slopes. In this paper we consider the natural frequency of landslide-prone slopes by comparison with the maximum spectral frequency of long-acting low-frequency oscillations of Hindu Kush earthquakes that caused major landslides in 2015 and spring 2016. Interesting events took place in 2015 and the spring of 2016, when atmospheric precipitations was low, and frequent strong Hindu Kush earthquake created intense seismic situation. As a result from March 11 to April 6, 2015 during the Hindu Kush earthquakes with M=4,4-5,3, H = 173-196 km, with a duration of 90-110sec and predominant frequency 2.5-3 5 Hz - in the southern part of the Republic of Uzbekistan at a distance of 350-400 km from the epicenter in 6 sites have occurred landslides with volume 1.0-5.0 million m^3. From January to March 15, 2016 in the Hindu Kush occurred 37 earthquakes with M = 4-5,7. As a result of Hindu Kush earthquake January 18 with M = 5.0, H = 180 km, duration of vibrations 130 and maximal frequency of 2.9 Hz it was formed landslide with volume 1.8 mln m^3. All landslides are characterized by a one-time simultaneous displacement, occurred at a frequency of earthquakes vibrations 2.5-3.5 Hz. We suppose that they have been caused by resonant vibrations in these sites, because at a frequency of oscillations 0,16-0,35 Hz with higher amplitudes of vibrations the landslides were not occurred. They were formed in slightly moist sand and clay soils, where the width is greater than the length of displacement of soils occurred at deep slightly watered slip surface. As a result, it is formed smooth, 18-32 m high wall, landslide mass covered with numerous cracks, with length from 40 to 60 m and amplitude of 1.0-2.5 m, and characterized by closed system. Most often they are of triangular shape with the extension of top or bottom part.

Xiaoli Chen, Hongliu Ran, Qing Zhou, and Bengang Zhou

Abstract: Compared with ordinary scale landslides, landslides with a large scale of volume or plane area like deep-seated landslides and rock avalanches can cause more serious damages. The study of the factors controlling large earthquake-induced landslides by the 2008 Ms8.0 Wenchuan Earthquake demonstrated that this kind of large and deep slope failures could be specifically tied to some particular geologic settings after analyzing their distribution characteristics and its big earthquake magnitude was an important factor. However, observations show some exceptions. For example, the 3 August 2014 Ludian, Yinnan, China Mw6.1 (Ms6.5) earthquake, though of a moderate intensity, has caused lots of landslides. Among them, there are 18 large landslides (landslide with plane area ≥50000 m^2) and the biggest one is the Honshiyan landslide, which created a 120m high, 1.0×107 m^3 dam. The damage caused by this earthquake surpassed some events of M = 7 or greater due to the serious landslides disaster. Base on the distribution features of coseismic landslides caused by the Ludian earthquake, this paper analyses the statistics relationship between the local terrain relief condition and large landslides occurrences in the seismic area. It is shown that the areas with high local relief are prone to generate the large landslides. To further address this issue, 2D limit

A Characteristic-Period Based Approach for Evaluating Earthquake-Induced Displacements of the Large Büyükçekmece Landslide (Turkey), page 59

Salvatore Martino, Luca Lenti, and Celine Bourdeau

Abstract: The Büyükçekmece landslide is located in Turkey, W of Istanbul, about 15 km northward form the North Anatolian Fault Zone (NAFZ) and involves upper Oligocene to lower Miocene deposits, consisting of silty clays, tuffs and sands. No earthquake-induced re-activations are testified so far but due to the high seismicity of the area (struck by the 17th August 1999 Mw 7.4 Kocaeli and by the 12th November Mw 7.2 Düzce earthquakes) it was selected as the case-study in the framework of the European project "MARSite - Marmara Supersite: new directions in seismic hazard assessment through focused Earth observation in the Marmara Supersite". Due to the existence of several secondary scarps, the original geological setting of the sedimentary deposits is significantly modified as many counter-slope-tilted landslide sub-masses can be identified in the landslide mass. Earthquake-induced displacements of the landslide were evaluated through a characteristic-period based (CPB) approach. To this aim, a stress-strain dynamic numerical modelling was carried out using several seismic inputs with Arias intensity (AI) values ranging from 1 and 0.01 m/s and characteristic periods, Tm, ranging from 0.3 to 16.5 s. Depending on the landslide dimensions (thickness and length), characteristic periods for thicknesses (Ts) and lengths (Tl), were computed to define the corresponding ratios over Tm. The obtained results indicate that the effective characteristic period of the landslide (Tl*) corresponds to the length of a single sub-mass, and not to the total length of the landslide. Moreover, for the lowest AI values the maximum earthquake-induced displacements correspond to Tm values close to resonance period of the landslide mass. Moreover, for higher AI values, such a 2D interaction between landslide mass and seismic waves is much more evident.

Finite Element Simulation for Seismic Ground Response in Mountainous Areas in Nepal, page 67

Akihiko Wakai, Daisuke Higaki, Hiroshi Yagi, Go Sato, and Masahiro Chigira

Abstract: In this study, dynamic elasto-plastic finite element method is applied to simulate seismic ground response in mountainous districts in Nepal, which aims to reevaluate the earthquake-induced landslides occurred at the time of The 2015 Nepal Gorkha Earthquake. In the analysis, nonlinear material properties of the ground as well as 3D topography, geological conditions and input motion are taken into account appropriately. Those factors strongly influence the dynamic amplification effects relevant to slope failures. Throughout the comparisons of the results between the calculated one and observed facts in local areas, it can be concluded that the proposed numerical method has a sufficient ability to predict the phenomena and can be possibly utilized for predicting overall distribution of earthquake-induced landslide which would be helpful for developing landslide susceptibility maps in mountainous areas in Nepal.

Geophysical Investigation of the Landslide-Prone Slope Downstream from the Rogun Dam Construction Site (Tajikistan), page 75

Torgoev Isakbek, Havenith Hans-Balder, Torgoev Almaz, Cerfontaine Philippe, and Ischuk Anatoly

Abstract: The dam under construction on Vakhsh River for the Rogun Hydropower Plant (HPP) in Tajikistan, with a planned height of 335 m, would become the tallest dam in the World. The secure construction and later operation of the dam located in a seismically active region in Central Asia strongly depend on the long-term stability of the steep slopes in the vicinity of the dam and near the future lake that would have a volume of 13 billion m^3. Therefore, World Bank and Rogun HPP experts asked for the completion of engineering geological studies applied to a landslide developing on the right-bank slope downstream from the dam, which might affect the security of the entire Rogun HPP project. In order to assess the risk of failure of this slope we carried out sophisticated geophysical and geotechnical investigations on the site in 2015. Those provided the necessary inputs for the dynamic numerical modelling of slope deformation completed later on. The geophysical investigations included electrical resistivity and seismic refraction profiles, ambient noise measurements and earthquake recordings (over a short period of time). Geotechnical works included the drilling of two hundred meter deep boreholes; cores were extracted over the whole depth and used for geotechnical tests in the laboratory. Electrical and seismic data were processed in terms of 2D tomographic sections, ambient noise measurements provided information on the resonance frequency and thus on the thickness of weakened surface materials; seismological recordings revealed the local seismic amplification potential. All data were compiled both within 2D GIS platforms and 3D geological models. On the basis of these models, we completed extensive slope stability calculations (in 2D) considering variable groundwater pressures and different seismic inputs (with involved amplification effects). This paper presents an overview of all input data and dynamic numerical modelling results obtained for the landslide prone slope. Those indicate that the landslide mass has a volume of 2 to 5 Mio. m^3. This mass could be destabilised under extreme adverse conditions, either entirely or partly, notably if we consider the combination of a strong earthquake impact reaching on the site (on hardrock) an acceleration of more than 0.3 g and of very wet climatic conditions leading to full saturation of the surficial soil and rock layers. If we consider the hypothesis of a landslide mass with a volume of more than 4 Mio. m^3 that becomes unstable, then the sliding mass might reach the valley floor and, thus, could form a 20 m high dam (or more), which might cause problems to the outflow from the spillways located immediately upstream.

Seismic-Induced Landslides: Lessons Learned from Recent Earthquakes in Spain, page 111

José Delgado, Martín J. Rodríguez-Peces, Francisco J. García-Tortosa, Jesús Garrido, Iván Martín, and Pedro Alfaro

Abstract: On February 23, 2015, an earthquake of magnitude Mw 4.7 (Imax = V, scale EMS) struck the center of the Spain, triggering dozens of instabilities in taluses and natural slopes of an area characterized by low relief. These instabilities were characterized by: 1) very small size, most of them with volumes lower than 1 m^3, and 2) to occur in rock masses affected by multiple discontinuities, which pre-defined blocks that fell down during the shaking. The inventory of instabilities of this earthquake has shown that most of the instabilities occurred on the slopes of the road network, although the larger instabilities were observed in natural slopes. The comparative analysis of this inventory with those made for other recent earthquakes occurred in the SE of Spain (1999, 2002, 2005 and 2011), all of them of similar magnitude Mw (between 4.7 and 5.1), allow to recognize that the vast majority of instabilities induced by these earthquakes were rock/soil falls, being other typologies of landslides very rare. In all cases, the size of instabilities triggered were small, usually with volumes of 1 m^3 or less, reaching the larger volumes up to 500-1000 m^3. Data available from these events point out that large landslides, as known in relation with historical earthquakes in Spain, cannot be induced by moderate to low magnitude earthquakes. Besides, slope morphology seems to control the location of induced instabilities. Thus, when the terrain is steep, as in the area affected by the earthquake in Lorca (2011, Mw 5.1), most of instabilities occur in natural slopes and affect the upper part of slopes. As the relief is less rugged, natural slopes instabilities are progressively less frequent until the extreme case of the 2015 event, when instabilities were located mostly on slopes of the road network.

Landslides Triggered by the Ms6.5 Ludian, China Earthquake of August 3, 2014, page 119

Kai-heng Hu, Xing-zhang Chen, Yong-gang Ge, Xing-yuan Jiang, and Yang-chun Wang

Abstract: Ludian Earthquake (Ms6.5, Mw6.1) on August 3, 2014 has induced many new slope failures, and resulted in more than 600 deaths and significant property losses. The seismogenic fault is a left-lateral strike-slip hidden fault, an extension of NW-SE Baogunao-Xiaohe Fault. 235 landslides induced by the earthquake have been interpreted by field investigation and remote sensing. The high-susceptibility ranges of different effective factors to the landslides are examined by the index of the ratio of occurrence probabilities. Unlike other earthquake events such as the Wenchuan earthquake in 2008, most of the landslides are located in the footwall, and their spatial arrangement is controlled by the NE oriented main fault of Zhaotong-Ludian, not by the NW seismogenic fault. Four large-scale landslides very closed to the seismogenic fault are described in details. The sliding direction of the four landslides is influenced strongly by the fault properties and the aspect of free face, and there are two principal directions for the large landslides.

Earthquake-Induced Rockfalls Caused by 1998 Mw5.6 Earthquake in Krn Mountains (NW Slovenia) and ESI 2007 Intensity Scale, page 131

Andrej Gosar

Abstract: The 12 April 1998 Mw5.6 Krn Mountains earthquake with a maximum intensity of VII-VIII on the EMS-98 scale caused extensive environmental effects in the Julian Alps. The application of intensity scales based mainly on damage to buildings was limited in the epicentral area, because it is a high mountain area and thus very sparsely populated. On the other hand the effects on the natural environment were prominent and widespread. These facts and the introduction of a new Environmental Seismic Intensity scale (ESI 2007) motivated a research aimed to evaluate the applicability of ESI 2007 to this event. All environmental effects were described, classified and evaluated by a field survey, analysis of aerial images and analysis of macroseismic questionnaires. These effects include rockfalls, landslides, secondary ground cracks and hydrogeological effects. It was realized that only rockfalls (78 were registered) are widespread enough to be used for intensity assessment, together with the total size of affected area, which is around 180 km^2. Rockfalls were classified into five categories according to their volume. The volumes of the two largest rockfalls were quantitatively assessed by comparison of Digital Elevation Models to be 15x106 m^3 and 3x106 m^3. Distribution of very large, large and medium size rockfalls has clearly defined an elliptical zone, elongated parallel to the strike of the seismogenic fault, for which the intensity VII-VIII was assessed. This isoseismal line was compared to the tentative EMS-98 isoseism derived from damage-related macroseismic data. The VII-VIII EMS-98 isoseism was defined by four points alone, but a similar elongated shape was obtained. This isoseism is larger than the corresponding ESI 2007 isoseism, but its size is strongly controlled by a single intensity point lying quite far from others, at the location where local amplification is likely. The ESI 2007 scale has proved to be an effective tool for intensity assessment in sparsely populated mountain regions not only for very strong, but for moderate earthquakes as well.

Part II: Rainfall-Induced Landslides

Abstract: The frequency of heavy rainfalls has increased during the last decades, so that the world scientific communities are still dealing with this concern. Extreme meteorological events increasingly affect many parts of Italy inducing damage and human losses due to landslides. This is quite normal because about three-quarters of the Italian territory include hilly and mountainous areas, which are typical landslide-prone areas. Although the recent improvement of the meteorological forecasting techniques often allows to predict early extreme weather phenomena, the general lack of detailed geological and geomorphological investigations in many territories makes them not enough prepared to face such problems. For this reason, rainfall-induced shallow landslides generally cause significant damages related to loss of life and properties, representing a real threat for the public safety. In this regard, the spatial prediction of shallow landslides is a complex task that attracts many researchers. Numerous techniques has been proposed in literature to assess landslide susceptibility. Despite many studies concentrating on the application and validation of different techniques are available in literature, few works deal with the landslide susceptibility assessment considering different types of landslides. The aim of this work is to investigate the role of the main predisposing factors of different landslide types using a statistical method known as Generalized Additive Model (GAM). GAM is a non linear regression method used to assess the shallow landslide susceptibility. This statistical technique takes into account the linear and non-linear smoothing relationship between the explanatory variables (predisposing factors) and the binary response variable (landslide occurrence), which takes value of 1 (landslide presence) or 0 (landslide absence). This methodology has been applied to the Gravegnola catchment (35 km^2 wide, Northern Apennines, Italy), which was heavily hit by an extreme rainfall occurred on 25 October 2011. More than 500 shallow landslides mainly referable to roto-translational debris slides and complex translational debris slide-flows were triggered during the previously mentioned event. We have produced a susceptibility model of the study area for each landslide type. Nine terrain parameters has been extracted from a 5—5 DEM and from land use and geological maps and combined for producing the model. The predictive performance of the different combinations has been evaluated through a cross-validation technique and the ROC curve analysis. The parameters that make up the combination with the highest performance are those that mainly describe the instability conditions for each landslide type. The preliminary results show the higher ability of GAM than a single regression technique in selecting the most influent predisposing factors for the shallow landslide occurrence, allowing for an effective differentiation in their contribution on slope instability on the basis of the type of movement involved. The resulting landslide susceptibility maps for different types of movement may be useful for local hazard mitigation plans.

Abstract: The contribution of large-scale synoptic weather types to the occurrence of weather-induced landslides was investigated for southern Norway. Landslides from the period 2000-2014 were analyzed on a regional scale, using existing climatic and landslide regionalizations. The classification provides a time series of landslide classes and Kruskal-Wallis tests and chi-tests were conducted to analyze how well the classification performs for each landslide region. The synoptic classification (SynopVis Grosswetterlagen, SVG) of daily weather types was later compared with the precipitation classification. In order to predict the occurrence of landslides within a region, a logistic regression analysis was used where the independent variables were the SVG classes, mean daily rainfall and snowmelt. The results showed that in seven of the twelve landslide regions in southern Norway the SVGs have the highest predictive power in terms of landslide occurrence. In these regions, with the exception of one, the models are significantly better than a null model, and the models are good in predicting weather-induced landslide occurrence. The highest predictive probability of weather-induced landslide occurrence is given by the weather type Zonal Ridge across Central Europe (BM), which yields a 90% probability of weather-induced landslides on the west coast.

Abstract: In this paper, authors focus attention on different threshold schemes, which can be adopted when a model is used for landslide forecasting. In some cases they represent the occurrence probability of a landslide, in other cases the exceedance probability of a critical value for an assigned mobility function Y (a function of rainfall heights), indicated as Ycr, and in further cases they only indicate the exceeding of Ycr or its prefixed percentages. Clearly, the discussion here reported can be easily extended to the case of flood forecasting models. The empirical model named FLaIR (Forecasting of Landslides Induced by Rainfall, Capparelli and Versace 2011) is used for the study area of Gimigliano municipality (located in Calabria region, southern Italy), characterized by a database with 27 historical landslide events in the period 1940-2011.

Definition of Rainfall Thresholds Triggering Landslides in Slovenia, page 177

Ascanio Rosi, Tina Peternel, Mateja Jemec-Auflič, Marko Komac, and Nicola Casagli

Abstract: In this paper the definition of rainfall thresholds for rainfall-induced landslides in Slovenia is presented. The thresholds have been calculated by collecting approximately 900 landslide data and the relative rainfall amounts, which have been collected from 41 rain gauges all over the country. The thresholds have been defined by the use of an existing procedure, developed for a test site with very different geological and climatic characteristics (Tuscany, central Italy). A single national threshold has been firstly defined, subsequently the country was divided into four zones, on the basis of major the river basins and a single threshold has been calculated for each of them. The effectiveness of the thresholds has been verified by the use of several statistical parameters and it resulted in quite good performances, even if with some uncertainties, probably due to the quality of the available data. Beside the setting of a threshold system, usable for civil protection purposes at national scale, an additional outcome of this work was the possibility of applying, with good results, a methodology defined for another region, therefore testing its degree of exportability in different settings.

Regional Rainfall Thresholds for Shallow and Deep-Seated Mass Movements Triggering in the South Eastern French Alps, page 183

Alexandre Remaître, and Jean-Philippe Malet

Abstract: Concern is still growing over the last decades about rainfall-induced landslide temporal and spatial prediction. Since the 1980', considerable efforts have been made in order to (1) define qualitatively the relationships between precipitations and triggering or reactivation of landslides and (2) determine quantitatively amount of precipitation needed to trigger slopes failures. For rainfall-induced landslides, hydro-meteorological thresholds (expressed in terms of antecedent rain, intensity of precipitation, soil moisture or ground water levels within the slope) can be defined as rainfall, soil moisture or hydrological conditions that, when reached or exceeded, are likely to trigger landslides. Usually, the thresholds are based on analysis of statistical relations among historical landslide catalogues (event dates) and antecedent hydro-meteorological conditions; other approaches based on conceptual or process-based models can also be used in specific cases such as limited information in landslide catalogues. Both the large variety of landslide types and the extreme variability of climatic conditions in mountain regions limit definition of regional relationships between landslide occurrence and associated hydro-meteorological conditions.

The main objective of this work is to propose hydro-meteorological thresholds for the triggering of shallow (slides, debris/mud flows) and deep-seated mass movements within a vast area of Southeast French Alps (including Queyras, Ubaye, Tinée, Var…) characterized by different rainfall patterns. For this purpose, we exploit a landslide catalogue (containing more than 600 events) for the period 1928-2014 describing the date (and sometimes time) of occurrence, type of mass movement, geographical location and nearest meteorological station. Rainfall data are available for 32 stations For the analysis of triggering of deep-seated mass movements, slope hydrological time series (ground water levels, soil moisture) and simple water balance models are used to define hydrological thresholds for landslide reactivation. The statistical analysis of rainfall conditions associated to triggering of shallow mass movements at different time scale (yearly, monthly, daily and hourly) reveals that rainfall thresholds are varying within our study site. Indeed, 4 sub-areas can be distinguished according to their morphology and local climate context. Frequency analysis of rainfall events (for a duration from 1 to 72h) intensity reveals a clear distinction between the 4 sub-areas and shows a clear North-South gradient. Furthermore, each sub-area exhibits a specific relationship between landslide triggering and associated rainfall patterns. For example, there is a clear difference for antecedent cumulative rainfall associated to slow gravitational movements features for each sub-areas; this could be partially explained by the influence of the Mediterranean Sea.

Explore on Hydro-Mechanical Threshold for Early Warning of Rainfall Induced Shallow Landslides, page 193

Zong-ji Yang, Jian-ping Qiao, Taro Uchimura, Lin Wang, Dong Huang, Xiao-qin Lei, and Li-li Shi

Abstract: After the Ms=8 Wenchuan earthquake on May 12th, co-seismic landslides and fractured slopes were more susceptible to rainfall-induced mass re-mobilization and post-earthquake disasters were gained widespread significance for the disaster mitigation in earthquake hit regions. However, the hydrological characteristics of rainfall induced mass re-mobilization in natural enviroment of Wenchuan earthquake regions is not well understood. In this study, shallow rainfall triggered slope failures under partially saturated conditions was proved by instrumental evidence of in-situ experimental tests in a natural co-seismic landslide for simulating the failure process of the rainfall-induced mass re-mobilization in earthquake hit region. In addition, the results revealed the transient process and unsaturated condition for mass movement in response to rainfall, and the preferential flows were found to be dominant in the hydrological process during rainfall infiltration in post-earthquake landslides, and demonstrated the importance of hydrological parameters includes soil matrix suction and moisture content for slope stability and suggested a hydro-mechanical mechanism in partial saturation for predicting the initiation of rainfall induced landslides and debris flows in post-earthquake disaster relief.

Influences of Rainfall on Shallow Slope Failures, page 201

Taworn Teerametatiparat, Avirut Chinkulkijniwat, and Somjai Yubonchit

Abstract: Assessment of rainfall-induced shallow slope failures is very important to reduce damages of infrastructures and lives of people living close to hazardous areas. Although the rainfall intensity-duration thresholds for initiation of slope failure (ID thresholds) based on the historical slope failure data is commonly used to assess slope failure, critical influence factors triggering shallow slope failures are often disregarded. Three sets of parametric study were therefore performed through finite element model to investigate the effect of saturated permeability of soil, slope angle and antecedent rainfall on instability of shallow slope. It is found that the hydrological mechanisms involving the rainfall induced shallow slope failure are either 1) the rising of water table mode or 2) the rainfall infiltration mode. The hydrological mode during the failure depends on the magnitude of rainfall intensity comparing with the infiltration capacity at soil saturation state. The rate of reduction in safety factor increases with an increasing the intensity of rainfall, only in a range of lower than the infiltration capacity at soil saturated state. As such the saturated permeability of the soil, which is equal to the infiltration capacity at soil saturated state, plays an important role in the shallow slope failure. The saturated permeability was found also to govern a range of applicability of the ID thresholds. If the rainfall intensity is not greater than the infiltration capacity at soil saturated state, the rainfall duration to failure (T_rf) can be read from the ID thresholds. Slope angle and antecedent rainfall were found to play role on instability of the shallow slope. They control the initial stability of slope, which results in the different linear relationship of ID thresholds. In addition, the slope angle might accelerate the rate of rain water infiltration, and hence it reflects the slope of the ID thresholds.

Modelling Shallow Landslides Triggered by Rainfall in Tropical and Mountainous Basins, page 207

Edier Aristizábal, Hernán Martínez-Carvajal, and Edwin García-Aristizábal

Abstract: Shallow landslides triggered by rainfall in tropical environments are controlled by the weathering tropical profile and its water storage capacity. Although landslides triggered by rainfall are common in tropical and mountainous basins, few studies have been applied to the case of tropical regions, which are characterized by intense rainfall and deep weathering profiles. Thus, it is necessary to implement over these areas physical models and methodologies to determine the spatial location of landslides and their susceptibility level. In this work, a conceptual and physically based model called SHIA_Landslide (Simulación HIdrológica Abierta, or SHIA, in Spanish) that is supported by geotechnical and hydrological features occurring on a basin-wide scale in tropical and mountainous terrains is described. This model incorporates a comprehensive distributed hydrological tank model that includes water storage in the soil coupled with a classical infinite-slope stability analysis under saturated conditions. Additionally, this work presents the analyses and results of the implementation of the SHIA_Landslide model to estimate the landslides caused by a rainfall occurred on September 21th, 1990, in a basin of tropical and mountainous terrains of Colombian Andes. In less than 3 hours, a precipitation of 208 mm fell within the study area, triggering more than 800 landslides. The results obtained by the model are compared with a landslide inventory presented during the event. Finally, the efficiency of SHIA_Landslide is evaluated in terms of landslide density and susceptibility classes (degree of fit and success-rate curve), and the prediction capacity by ROC (Receiver Operating Characteristics) analysis. It is possible to show a good performance of the model suggesting that SHIA_Landslide is able to simulate the physics involved on landslides triggered by rainfall in tropical and mountainous terrains.

Probabilistic Analysis of Shallow Landslide Susceptibility Using Physically Based Model and Fuzzy Point Estimate Method, page 221

Jung-Hyun Lee, Hyuck-Jin Park, and Jung-Yoon Jang

Abstract: The geomechanical parameters of soils used in physically based model for landslide susceptibility analyses are uncertain due to the inherent uncertainty and variability. In addition, limited sampling is another source of the uncertainty since the input parameters were obtained from very wide study area. Therefore, the analysis of rainfall-induced shallow landslides susceptibility using physically based model requires accounting for the uncertainty. Subsequently, the probability theory has been used to quantify the uncertainty. However, some uncertainties, caused by incomplete information, cannot be managed satisfactorily by probability theory, so fuzzy set theory is more appropriate in the case. In this study, the uncertain parameters in landslide susceptibility analysis were expressed as fuzzy numbers and fuzzy set theory was employed. In order to take into account the fuzzy uncertainties in the evaluation of the probability of failure, point estimate method was applied with fuzzy set theory. This proposed process was performed in GIS based environments since GIS has strong spatial data processing capacity. In order to check the feasibility of the proposed approaches, the proposed methods were applied to a practical example. To evaluate the performance of the model, the results of the landslide susceptibility assessment were compared with the landslide inventories using ROC graph. Based on the results of the practical application, it was concluded that the application of fuzzy set theory shows consistent analysis results and can obtain reasonable results.

Assessing Potential Effects of Climate Change on Rainfall-Induced Shallow Landslides in the Peloritani Mountains Area, Sicily, page 229

David J. Peres, and Antonino Cancelliere

Abstract: Climate change due to atmospheric greenhouse gas emissions may cause significant modifications to precipitation and other meteorological processes, with potential consequences on the frequency of occurrence of shallow landslides. This study aims at investigating the potential effects of climate-change induced rainfall modifications on the future occurrence of rainfall-induced shallow landslides, based on the analysis of RCM projections and hydrologic and slope stability simulations. Changes in precipitation are assessed by comparing future RCM-simulated rainfall series with hindcasts valid for the historical baseline (assumed as 1961-1990), and by considering the two emission scenarios RCP4.5 (intermediate) and RCP8.5 (high-emissions). The estimated changes enable to adjust the parameters of a stochastic rainfall model, used as input to carry out Monte Carlo simulations allowing to estimate the probability of landslide triggering for future periods. The method is applied to the Peloritani mountains area in Sicily (Italy), which has been hit several times by diffused shallow landslides in the past decade. The obtained results prevalently indicate a future decrease of the probability of landslide triggering, directly connected with climate-change induced increase of the inter-arrival times of rainfall events. Outcomes of the study also evidence the importance of assessing RCM data uncertainty, given that different climate-projection data may provide opposite indications.

Variations in Landslide Frequency Due to Climate Changes Through High Resolution Euro-CORDEX Ensemble, page 237

Guido Rianna, Alfredo Reder, Veronica Villani, and Paola Mercogliano

Abstract: The paper presents the main findings of a research aimed to provide probabilistic projections about the variation of local weather patterns recognized as relevant for triggering of rainfall-induced landslide events affecting pyroclastic covers in Campania Region (Southern Italy). The study focuses on the municipality of Nocera Inferiore affected by several events (1960, 1972, 1997 and 2005). Euro-CORDEX multimodel ensemble at high resolution (about 12 km on the area of interest) provides daily precipitation data weighted on the basis of the performances and scenario consistency through the REA (Reliability Ensemble Averaging) method proposed by Giorgi and Mearns (2002). The results indicate a general worsening of the slope stability conditions in the investigated area up 2100 under the two different concentration scenarios. The developed approach is easily deployable for all impact studies and then it could represent a valuable tool in developing effective adaptation strategies and proper prioritizations of interventions to cope with Climate Changes.

Potential Effects of Climate Changes on Landslide Activity in Different Geomorphological Contexts, page 243

Guido Rianna, Luca Comegna, Stefano Luigi Gariano, Fausto Guzzetti, Paola Mercogliano, Luciano Picarelli, and Paolo Tommasi

Abstract: The anthropogenic global warming could significantly affect weather patterns, with variable impacts at the regional scale. Geo-hydrological hazards represent an interesting example of the possible impacts. We present a study of the effects of potential climate change on slope stability conditions in two different contexts in the Italian Apennines. Although the two examined sites are 400 km apart, climate simulations return similar variations in weather patterns, which are characterized by a strong increase in air temperature, a reduction in seasonal cumulative precipitation, and an increase in daily precipitation. In spite of the similar input, the response of the two sites, lying respectively on saturated clays and on unsaturated non-plastic silts, might be completely different. Although these studies do not currently provide quantitative estimates, they represent a valuable support to policy makers and communities for the definition and prioritization of adaptation actions and for investments to cope with the expected climate changes.

Historical Patterns of Heavy Rainfall Event and Deep-Seated Rapid Landslide Occurrence in Japan: Insight for Effects of Climate Change on Landslide Occurrence, page 251

Taro Uchida, Wataru Sakurai, and Atsushi Okamoto

Abstract: Not only soils but also weathered bedrocks were sometimes sliding simultaneously. These landslides sometimes move rapidly and triggered debris flow. In this study, these landslides are referred to "deep-seated rapid landslide". In the last two decades, deep-seated rapid landslide induced several serious disasters in Japan. Moreover, it has been considered that the frequency of deep-seated rapid landslide will increase due to climate change. However, we don't have adequate information to quantify effects of climate change on deep-seated rapid landslide frequency. So, the aim of this study is to clarify effects of rainfall magnitude on deep-seated rapid landslide frequency. We compiled about 300 landslides information through a literature search, comprising journals, conference proceedings, and event and technical reports. We included only rainfall and snowmelt triggered landslide and landslide occurred and excluded earthquake triggered landslide and volcanic landslide. We confirmed the area of landslide using current topographic maps, current and historical aerial photographs or field surveys. Then, we did not include the landslide which cannot be confirmed, although we can find the report in literature. Further, Japan Metrological

Agency recorded more than 100 years rainfall data at around 80 metrological stations. Also, they monitored rainfall at more than 1000 stations since late 1970s. We used these rainfall dataset to clarify the temporal variation of the heavy rainfall frequency and to clarify rainfall threshold for deep-seated rapid landslide occurrence. We defined the frequency of the heavy rainfall was the number of the days which the daily rainfall has more than 200 mm. Using these datasets, we examined (1) the temporal change of frequency of deep-seated rapid landslide occurrence in the last 400 years (2) the rainfall threshold for deep-seated rapid landslide occurrence (3) the relationship between frequency of the heavy rainfall occurrence and deep-seated rapid landslide occurrence in the last 100 years The periods that has high frequency deep-seated rapid landslide occurrence appeared around 50 year intervals in the last 400 years, indicating that the frequency of deep-seated rapid landslide was not constant in time. We analyzed around 50 events occurred since late 1970s to clarify rainfall threshold for the occurrence of deep-seated rapid landslides. We found that 48-h or 72-h rainfalls are more effective in assessing temporal changes in deep-seated rapid landslide susceptibility compared to 1-h to 12-h rainfall amounts. Especially, if the 48-h rainfall amounts exceeded 600 mm, the frequency of deep-seated rapid landslides dramatically increased. We also found that since 1900, there were three high frequency periods, the beginning and the mid of the last century and the beginning of this century. These periods agreed well with the periods which the frequency of the heavy rainfall was large. According to these results, it can be thought that if the frequency of the heavy rainfall occurrence will increase due to climate change, the frequency of deep-seated rapid landslide should become large. Especially, if the frequency of relatively long lasting rainfalls, not intense rainfalls, will increase, effects of climate change on deep-seated rapid landslide should be large.

Geomorphologic and Structural Controls on Landslide Types in Nigeria, page 259

Ogbonnaya Igwe

Abstract: Complex rock-debris avalanches, debris flow, soils slip and earth slumps in Nigeria lead to the destruction of lives and resources worth several millions of dollars annually. While long travel landslides, which are almost always catastrophic, mostly occur on igneous and metamorphic terrains at the boundary of Nigeria and Cameroon, the south east sedimentary terrains are subject to deep and wide gullies resulting from aggressive erosion and slumping movements. Slope failures in the two regions are therefore distinctively different with research revealing that the differences are in geology, structural geometry, style of deformation, slope gradient and the volumes involved. At the Nigeria-Cameroon border, complex, rock-debris avalanches are found on steep dipping slopes, where slope parallel, basal sliding planes along foliation and lineation surfaces control failure and mobility of materials downslope.

Geomorphology and Susceptibility to Rainfall Triggered Landslides in Gudbrandsdalen Valley, Norway, page 267

Håkon Heyerdahl, and Øyvind A. Høydal

Abstract: During the last decade, several high-intensity landslide events have changed the image of the Gudbrandsdalen valley in Central Eastern Norway from a region with moderate landslide activity to being considered one of the most active landslide areas in Norway. Succeeding a localized, but intense, landslide event in the Northern part of the valley in year 2008, two larger regional events occurred in the years 2011 and 2013. Many landslides were triggered in each of these events, including flash floods and debris flows/debris slides in small and steep tributary rivers along the valley slopes, as well as translational and rotational slides on open slopes. In the first phase of the 2008 landslide event, landslides were triggered in dry weather, by ground-water flow from infiltration of snowmelt in areas far away from the landslide zone. In the 2011 and 2013 events, most landslides were triggered by intense rainfall, sometimes with daily rainfall of 30-50 mm and more. For this region, with annual rainfall as low as 300 mm, such daily rainfall values are unusual, and the landscape is sensitive to extreme rainfall. Although high susceptibility to extreme rainfall events has been clearly demonstrated through these events, the effect on landslide activity of an expected climate change towards a generally more humid regional climate needs further research. In the Centre for Research-based Innovation (CRI) "Klima 2050", financed by the Research Council of Norway and other public, private and scientific partners in the period 2015-2022, work is underway in order to improve the understanding of landslide processes and triggering mechanisms in this environment. This research activity has been funded by the Norwegian Centre of Innovation Klima 2050 (www.klima2050.no).

Overview of Rainfall Induced Landslide Events and Importance of Geotechnical Investigations in Nilgiris District of Tamil Nadu, India, page 281

V. Senthilkumar, S.S. Chandrasekaran, and V.B. Maji

Abstract: Landslide is a major natural hazard, which possesses serious threat to human population and various other infrastructures such as road, rail routes and other structures in the hilly terrain. Nilgiris district, located in southern state of Tamil Nadu in India, is basically a hilly region, lying at an elevation of 1000 to 2600 meters above Mean Sea Level (MSL). The district regularly receives rainfall during both the southwest and the northeast monsoons. The average rainfall in this region is between 1500 to 3000 mm. Due to the steep slopes and heavy rainfall during monsoons, the district is highly prone to landslides. In recent times, occurrence of landslides in Nilgiris is increased due to sudden burst of development activities in the region. The present study gives an overview of landslide events and remedial options practiced so far in Nilgiris and emphasises the importance of

geotechnical investigation in that region. The history of landslide events has been collected and soil samples have been taken from the places where, major landslides have occurred in the past to characterise them. The rainfall data have been collected to understand the influence of rainfall on landslide occurrence. From this study, it is observed that the main triggering factor for landslide in Nilgiris is heavy intense rainfall. Though the rainfall is main triggering factor, many causal factors are also involved in triggering of landslides. It is also observed that, the remedial measures practiced in this area was not site specific and mainly concentrated on construction of retaining walls and small gabion walls. To understand the failure mechanism of landslides, various effects of pore water pressure and to suggest suitable site specific remedial measure to prevent the recurrence of such failures in the future, detailed geotechnical investigations are required.

Abstract: The societal risk related to rainfall-triggered rapid debris flows is commonly managed in urbanized areas by means of early warning systems based on monitoring of hydrological parameters (such as rainfall or soil moisture) and analysis of thresholds values. In this paper are exposed results of physically-based modelling of ash-fall pyroclastic soil coverings involved in debris flows along mountain slopes nearby the Somma-Vesuvius volcano (Campania, southern Italy), which represent one of the major geohazards of Italy. The methods adopted combine deterministic approaches at the source area and distributed scales to estimate Intensity-Duration rainfall thresholds triggering debris flows. The first approach is based on the reconstruction of detailed physical models of ash-fall pyroclastic soil coverings in representative source areas of debris flows and on the related hydrological and slope stability modelling. The second is focused on a regional distribution model of ash-fall pyroclastic soils over mountain slopes surrounding the Somma-Vesuvius volcano, which takes into account both total thicknesses of pyroclastic coverings and variable stratigraphic settings. For both, effects of different initial antecedent hydrological conditions, associated with summer and winter, were considered.

Abstract: Landslides cause many damage to people, structures and infrastructure. The prediction of these natural processes is of great important. A good predictive model can allow the implementation of an equally good warning system, reducing the risk caused by such phenomena. There are many researches to understand the underlying processes trigger a landslide. Rainfall is the most common cause of landslides, so it is important to know the infiltration processes responsible for a failure. In our research, we study the infiltration processes, using an integrated approach, comparing data station in situ with the results and interpretations of physical models, trying to simulate with mathematical models. The aim is to observe and interpret laboratory tests to reproduce and simulate the phenomenon with mathematical models. The physical model is composed by two channels 1 meter wide and 3 meters long each one, with variable angles. The first one is adopted for analysing the triggering mechanisms, the second one for the propagation phases. Both channels are equipped with suitable sensors for monitoring the main physical variables. In particular, the trigger channel is equipped with: * spray nozzle systems, to apply a rainfall intensity; * minitensiometers, placed at different locations and depths, for measuring suction values; * TDR (Time Domain Reflectometry) system for volumetric water content; * miniaturized pressure transducers on the bottom of the channel for pore water pressures; * laser displacement sensors which monitor settlements of the ground surface. A complex monitoring system comprises five high definition digital video cameras and appositely dedicated software PIV, which allows reconstruction of the overall displacement and flow fields.We made different tests, reconstructing a homogeneous deposit of volcanic ash and reconstructing a stratified deposit of pumice and volcanic ash, with the same stratigraphy found in site. The soil used for the tests was taken from the site Sarno (Southern Italy), near the volcano Vesuvio. It was possible to study the infiltration processes responsible for the triggering of a landslide. It was also possible to evaluate the different response of the homogeneous slope and of the stratified slope.

Abstract: A wide area around the town of Naples is mantled by shallow unsaturated volcanoclastic soils that are highly susceptible to fast rainfall-induced flow-like landslides. Some casualties and huge damage recorded in the last twenty years testify the serious threat posed by such events. Due to the impact of these phenomena, the local research community is strongly committed in studies whose results have allowed to understand some key aspects of the triggering and propagation mechanisms. However, the way to run for risk mitigation is still long: given the density of population and of infrastructure, the setting up of reliable early warning systems would be a fundamental tool to this aim. Based on a rich data-base about the features of the rainfall-induced landslides in unsaturated volcanoclastic soils occurred on January, 10th, 1997, in a small area located in the Sorrento peninsula, and the history of precipitations occurred in the same area in the last fifty years, the paper examines the relation between rainstorms and landslides, showing the fundamental role of the recent precipitation history.

Role of Land Use in Landslide Initiation on Terraced Slopes: Inferences from Numerical Modelling, page 315

Luca Schilirò, Andrea Cevasco, Carlo Esposito, and Gabriele Scarascia Mugnozza

Abstract: Land use/land cover is widely considered as a relevant factor for shallow landslide occurrence; therefore, in this work we used a physically-based model, whose input parameters have been evaluated taking into account the land use setting. In detail, assuming that vegetation affects the surface runoff and infiltration rate, as well as increases the shear strength of soil due to the root reinforcement effect, we calibrated several specific model parameters (such as friction angle, cohesion and hydraulic conductivity) by varying their values within a reasonable range, on the basis of a detailed land use map specifically prepared for some small coastal basins located in the Cinque Terre area (eastern Liguria, Italy). Since this area is characterized by the widespread presence of agricultural terraces, mainly abandoned, their degree of abandonment has also been considered. Different numerical simulations have been performed with TRIGRS (transient rainfall infiltration and grid-based slope stability), a well-known regional, physically-based stability model, with the aim of reproducing the landslide event occurred in the study area on October 25th, 2011. The safety factor (FS) maps obtained by using TRIGRS have been compared with the inventory map of the landslides triggered during the event. Then, a ROC (receiver operating characteristic) curve analysis has been carried out in order to quantify the performance of the model. The obtained results emphasize the influence of land use in shallow landslide occurrence.

Analysis of the Impact of Precipitation on Landslide Activity Within the Erosive Slopes of River Valleys of the South of Ukraine, page 321

Galina Pedan, Olena Dragomyretska, and Oleksandr Dragomyretskyy

Abstract: The formation of landslides depends on many factors: the geological structure, geomorphological and hydrogeological conditions, physical and mechanical properties of rocks, neotectonic movements and climatic features. One of the important factors of formation of landslides on the slopes of river valleys is their moisture, which is determined by the relationship between precipitation, evaporation and runoff from the territory. It is known that the activation of landslides on the slopes occur during the years with abnormally high rainfall. However, the extent of the impact of meteorological conditions on the formation of landslides requires more detailed study. This study focused on the links between precipitation and landslide processes on the erosion slopes of the river valleys of the south of Ukraine. The time series of the amount of landslides (block, flow and mud-stream) have been analyzed for 22 sites during the period of 1982-1995 years to identify patterns of spatial and temporal variability of the landslide process. It was discovered that the characteristics of the spatial distribution of landslide is a decrease in their intensity from 0.8-0.9 landslides /km^2 in the north-west to 0 - 0.3 landslides /km^2 in the southwest on the study area. On the erosion slopes of river valleys shallow landslides (mud-stream and flows) predominate. These types of landslides develop in the upper parts of the section and do not affect the underlying rocks. In these cases, precipitation is one of the most important factors in the process of formation of landslides. It has been found that periods of landslides activation coincide with years in which atmospheric moisture had been increased. Synchronization of changes in precipitation and their positive trend of the average annual values are identified at all observed sites. Changing precipitation over time is periodic. Using spectral analysis, periods of 9-12, 3-4, and 2-year were identified as typical to all areas. This makes it possible to predict years with increased atmospheric moisture and drought in the region. The period of 9-12 years is proved to be the most significant. The correlation between the number of landslides and precipitation was found. The correlation coefficient is r> 0,5 and it occurs at 25% of all cases. Most of such sites are located in the north-western and central parts of the territory. Studies have shown that increased landslide activity takes place in years when precipitation exceeds the average norm. Erosion processes alter the balance of power on the slope and act with cumulative effect. Periods of high moisture trigger landslides. The lack of a statistically significant association between the amount of precipitation and landslides in the remaining areas is due to accumulative effect of other factors that make a variety of abnormalities. The studies allow to forecast a surge of landslide activity on the erosion slopes of river valleys of the south of Ukraine in the years of high humidity, specifically at the beginning of the next decade.

Heavy Rains and Flash Floods at Rocky Coast. The Costiera Amalfitana (Southern Italy), page 329

Crescenzo Violante, Eliana Esposito, Giuseppe Tranfaglia, and Giovanni Braca

Abstract: Bedrock rivers are commonly affected by debris torrents during periods of heavy rain. This is particularly true in steep rocky coastal areas characterized by headwater catchments and alluvial fan at stream mouths. In these settings sudden torrents of water (flash floods) are caused by high-intensity and very localized cloudbursts of short duration, inducing slope erosion and sediment delivery from slope to stream. The elevated bed load transport produces fast-moving hyperconcentrated flows ranging from debris flood to coarse-grained flow with significant catastrophic implications. At Amalfi Coast alluvial fan flooding has been the most frequent and destructive geologic hazard since historical times. The steep coastal slopes are deeply dissected by a complex fluvial system with small catchments that are very high relative to the base sea level. These rivers show a distinct seasonality and torrential behavior with main delivery areas into the adjacent marine shelf. The reported rainfall events last from about 1 h to few hours with maximum rainfall intensity ranging from 100 to 200 mm h-1, and are strongly conditioned by the orographic features and the thermic anomalies of the coastal waters. The analysis of historical data indicate that more than 100

events have occurred in the last five centuries on the Amalfi coast, confirming the severe impact produced by flash floods in this area.

Drainage and Shear Velocity Dependent Shear Characteristics of Abandoned Imgi Mine Waste Materials in Ring Shear Tests, page 337

Sueng-Won Jeong, Sung-Sik Park, Hiroshi Fukuoka, Sang-Woo Ji, and Choon-Oh Lee

Abstract: This paper presents the ring shear characteristics of abandoned Imgi mine waste materials (Busan Metropolitan City, Republic of Korea) as a function of drainage and shear velocity with the help of ring shear tests. The soil samples are mainly composed of gravelly sands with little percentage of fines. Normal stress, drainage (drained/undrained condition) and shear velocity (0.01-100 mm/sec) were applied under the unlimited shear deformation. The test results show that the peak and residual shear strength were influenced as a function of shear velocity. The shear stresses increase with increasing shear velocity. The shear stresses measured from drained condition is much larger than those from undrained condition at the same shear velocity. It is due to the fact that a progressive grain crushing and sedimentation may occur strongly in the drained condition. Grain crushing is also significant with shear velocity: the higher the shear speed, the larger the crushed fines. Thus, high mobile characteristics of failed masses should be examined in terms of grain crushing and pore water generation.

Landslide Monitoring and Management Challenge in Remote Papua New Guinea, page 343

Norbert Baczynski, and Neil Bar

Abstract: The Star Mountains range spans across the border between Indonesia and Papua New Guinea. It contains some of the highest and most rugged mountains on the island, including Mt Juliana (4,700m). Apart from a few isolated small townships, the region is sparsely populated, remote and mostly accessible only by air. It is covered by dense rainforest. Many areas, including the Ok Tedi river system and open cast mine, receive an annual rainfall of 8,000mm to 13,000mm. Tabubil, Ningerum townships and several smaller villages that provide mine labour and support services to Ok Tedi copper-gold mine are linked by an all-weather major gravel road to the Fly River port of Kiunga. Ore concentrate from the mine is shipped from this port by barges 700km down the meandering river to its mouth where it is uploaded onto mother ships and transported for further processing and smelting in South-East Asia and Europe. This road mostly traverses along terrain ridges and the banks of the high volume, fast moving and volatile Ok Tedi River. The cycle of massive to minor landslides and deep erosion is an on-going process that has shaped regional and local topography for thousands of years. Near-vertical backscarp faces of major landslides are an impressive landform feature. Such steep in-situ rock slope faces are prone to instability; a situation often compounded because old regional landslide debris materials are exposed in these escarpment faces and comprise the lower foothills. Reactivation of old debris causes many of the present instabilities in both natural and excavated slopes. Several factors contribute to instability. These include combinations of steep terrain, intense rainfall erosion, presence and exposure of adverse geological features, vegetation removal and farming practices, river valley erosion and undercutting of river banks during peak flows; situations compounded by periodic earthquakes. Slope failure mechanisms commonly include rotational and translational landslides, block slides, toppling, rock falls, debris avalanches or complex combinations of these. Run-out distances depend on the scale and type of landslide and vary from a few metres to several kilometres. Landslide velocities vary from slow creep (1-5m per year) to fast (Â±20m per second). The social and economic impact of landslides depends on landslide type, size, speed, location and travel path. Minor landslide impacts include temporary blockage of the highway or just a reduction in width roadway and need for traffic control whilst repairs are undertaken. Major impacts include prolonged periods of restrictions in supply delivery, loss of services such as water and electricity, loss of slurry pipe transfer of mine ore to the port, and complete isolation of villages. Risk to people can be high. Houses are often built along riverbanks, roads and beneath overhanging cliffs. Many of these areas are constantly undercut by the Ok Tedi River. An extreme example of this is Bultem Village almost completely built on top of an old regional rotational landslide. This landslide is continually reactivated by progressive undercutting and erosion of its toe by river flow. This paper presents three case studies (i.e. Bultem Village, Km 145 and Yuk Creek) and discusses the associated challenges, successes and failures of monitoring approaches and risk mitigation strategies adopted in the mining area and along its roadway connection to the port.

Part III: Rapid Landslides: Debris Flows, Mudflows, Rapid Debris Slides

Abstract: Debris flows are rapid gravity-induced flows of high-concentration granular-liquid mixtures, consisting of clay, silt, sand and boulders with a variable quantity of water. Due their high speed and energy, they represent a severe hazard in mountain regions. In this study, we investigate the properties and the dynamic of a debris flow occurred on 29th August 2003 in Valcanale valley (Friuli Venezia Giulia, Italy). Among the many watersheds affected by debris flow during the catastrophic alluvial event of August 2003, a dolomitic one was chosen in order to understand the flow behavior through the back analysis and to test the efficiency of the mitigation works, built up in the last decade. Grain size and mineralogical distribution were characterized through laboratory analysis. The rheological behavior of the finest fraction was assessed with a controlled stress rheometer on samples at 44 to 64 per cent in solid concentration by volume. The limiting values are due to the kind of material and its stability on the measurement device. Through different models (Bingham, Roberts-Barnes-Carew and Ellis) were derived the rheological parameters, later compared with the ones available in the literature. Two-dimensional simulations, using the Flo-2D software, were performed in order to replicate the event on a 5*5 m grid obtained by the extrapolation of elevation values of the Regional Technical Map (surveyed in 2003). The computations were carried out also on a 5*5 m grid obtained by the resampling of a LiDAR DTM (surveyed in 2008 by the Regional Civil Defense) to test the efficiency of the mitigation works, built up after the alluvial event and constituted of an artificial channel and a deposition basin, able to contain 15000 m^3 of debris. The back analysis using the literature models replicate satisfactorily the real event, in terms of inundated area and depositional features of the debris flow. The modeling on the newer morphology shows the efficiency of the deposition basin and proves the security of infrastructure downstream. The simulations with experimental rheological coefficients are affected by the issues encountered at low viscosities during the analysis that express themselves in terms of overestimation of the depositional extent of the debris flow. The dolomitic materials show a liquid-like behavior that does not adequately describe the real debris flow properties. In conclusion, the results point out that dolomitic and granular debris flow cannot be assessed solely on the contribution of the finer matrix, neglecting the frictional effects.

Abstract: Debris flows are one of the most frequent mass movement processes which develop on the mountain river network. With high flow velocity, long run-out, and high impacts, they are one of the most hazardous types of landslide. The material involved is heterometric debris with an extremely heterogeneous grain size distribution. The present research is focused on the interaction between the potential debris flow deposits from Rio Conzen and Canalone Andrea rivers with one of the four settling slag basins created during mining operations in the Cave del Predil mine (Tarvisio, Friuli Venezia Giulia, NE Italy). The mine is historical, the first written record of its existence dates back to 800BC. It remained active for a long period, and was the cause of dispute between the Italians and Austrians during WWI when the Austrians used a tunnel to transport troops and war material. After 1991 when the mine was closed, some levels were partially flooded in order to grant stability to the mine. The latter was later converted into a touristic area that along with the whole Val Canale valley was hit by an extremely intense alluvial event in August 2003 when more than 100 debris flows occurred. The valley is orthogonal to Val Canale where more intense damages occurred, but the possibility of the occurrence of new events (return period of 300y) is still high. The aim of this study was to create a possible scenario of the event, using FLO-2D software. The scenario obtained allow to study the interactions between debris flow deposits and the slag basins, and provide an understanding of the possibility of a river interruption. Scenarios can be considered extremely useful data to assist in informed future territorial planning of the area providing a good indication for hazard definition.

Abstract: In mountainous areas after long or intense rains, landslides may evolve into debris- or mud-flows. Their impact against obstacles may produce huge damages, sometimes with loss of lives. Prediction of the impact forces is required for a proper design of the flow barriers protecting risk prone areas. To this aim, both the effective characterization of the mud rheology and a suitable mathematical model of the flow propagation are needed. The present paper proposes a modeling framework in which the mudflow is idealized as the flow of a power-law fluid over an incline with a rigid impervious wall at the downhill end. The flow model employs the von Kármán depth-integration of the one-dimensional mass and momentum conservation equations, in the long-wave approximation. The governing equations have been solved through a space/time second-order accurate numerical method. This modeling framework is applied to a test-case, based on the soil collected from Cervinara site (Avellino, South Italy), affected by a catastrophic landslide in 1999. The investigated soil is both the raw one and a washed one, the latter introduced to mimic the effect of an intense rain in terms of removal of the dissolved soil organic carbon. The rheology of both the shear-thinning mixtures has been deeply characterized in the form of a power-law function, and the dynamics of a dam-break

wave ad its impact on an obstacle, has been numerically analyzed. It is shown that the removal of the soil organic carbon affects the propagation of the mudflow and at a minor extent the maximum forces and torques acting on the downstream wall. Remarkably, in the investigated conditions, the mudflow action consists of a strong impact occurring few seconds after the landslide triggering, and a subsequent cyclic loading of about three minutes.

Observation and Numerical Simulation of Debris Flow Induced by Deep-Seated Rapid Landslide, page 399

Taro Uchida, Yuki Nishiguchi, Naoki Matsumoto, Wataru Sakurai, and Atsushi Okamoto

Abstract: Deep-seated landslide sometimes lead to large-scale debris flow and triggered serious damages. To prevent these landslide disasters, the prediction method for assessing the spatial extension of hazard area and the magnitude of damages is one of key techniques. To predict hazard area and magnitude of damage due to deep-seated rapid landslide, several numerical simulation methods have been proposed. In large-scale debris flow, fine particles can behave as fluid and this process has been called as "phase-shift". It is widely recognized that the effects of a phase shift of fine sediment in large-scale debris flows are likely to be large. Therefore, in numerical simulations, it is essential to describe fine sediments in the fluid phase, and not in the solid phase to describe large-scale debris flow induced by deep-seated landslide. We had developed new numerical simulation model for describing pha se-shift and confirmed that the spatial pattern of erosion and deposition could be described, if we considered effects of phase-shift. When we test the applicability of numerical simulation using the past landslide data, we have to set input parameters. However, information about input parameters were commonly limited. Moreover, since information about flow depth and velocity was very limited, we can validate small part of our calculation, such as hazard area, but cannot validate our calculation for the magnitude of damage. So, here we conducted detailed field survey for clarifying input parameters and for validation of flow depth and velocity for the deep-seated rapid landslide occurred on July 28th in 2015 at Fukaminato River in Kagoshima prefecture in Japan. Video images at the bottom of landslide scars and the 1 km downstream from the landslide are available. We interpreted duration of landslide at the bottom of scar using the video camera image. Also, we evaluated time variation of velocity and flow depth at the 1 km downstream from the landslide using the video camera image. We clarified erosion and deposition patterns using LiDAR data sets. We also surveyed underground condition around landslide scars using several bore-holes. Further, we surveyed grain-size distribution of deposited sediment. Then, we run numerical simulation using our model which describe the phase-shift of fine particle. Simulated result of erosion/deposition pattern and flow depth of the front of debris flow agreed well with observed data. However, the duration of observed debris flow was short, but that of calculation was relatively long. It might suggest that different processes, such as turbulence of interstitial water of debris flow becoming low, should be taken into consideration in the simulation model.

Analysis on Debris Flow Non-rectilinear Motion—From Case Study to Hazard Zone Delimitation Discussion, page 407

Tingyeh Wu, and Su-Chin Chen

Abstract: This study aims to discuss the possibility of debris flow non-rectilinear motion and the current debris flow torrent delimitation method. The recent debris flow disaster in Taiwan triggered by torrential rainfall caused turning curve at alluvial fan and damaged community which was thought out of disaster potential. In order to clarify the factors causing this phenomenon and recognize torrents with similar susceptibility, numerical simulations were carried out by Flo-2D. In the previous study, simulations were given to the disaster case during Typhoon Soula and verified with investigation data. The result shows possible factors may trigger debris flow non-rectilinear motion, including slope gradient difference, geologic materials, and sediment material at the flooding part. In order to clarify the similar potential of non-rectilinear motion of the other torrents, this study selected five torrents in Kao-Ping basin for further analysis. Three accumulation types will occur by comparing the last and the first of accumulation areas. The type of entirely different accumulation areas after three times of debris flow occurrence was the one with non-rectilinear motion susceptibility, and the other types include extended accumulation area by more debris flow occurs and the same accumulation area but increasing depth. These types caused completely different risks to the communities inside or nearby the alluvial fan of the torrent. The qualitative analysis of flowing and accumulation parts of each torrent was given. Torrents with debris slide potential distributing along the flowing part, gradient difference between flowing and accumulation parts, and obvious gully terrain, have higher susceptibility of non-rectilinear motion. The geologic material that easily generates large border is also a significant factor, but it relies on detailed onsite investigation. This study successfully built an analysis process to clarify the possibility of non-rectilinear motion of debris flow torrents and some conclusions were therefore summarized.

Frequency Difference of Debris Flows in Moxi Basin, Southwestern China, page 415

Yongbo Tie, Jintao Jiang, Zhi Song, Alena V. Kadetova, and Artem A. Rybchenko

Abstract: Debris flow is one type of remarkable geomorphological hazards in mountain area. The primary objective of this study is to investigate the relationship between active fault and debris flow frequency (including high-frequency debris flow (HDF) and low-frequency debris flow (LDF)) in Moxi basin. The study area is a typical high mountain environment dominated by tectonic uplifting and glacier movement, where debris flow frequency shows a distinct difference and many debris flow fans occupy the valley bottom. Based on the field survey, literatures study and the interview with residents, this paper uses geographic

information systems (GIS) techniques to outline their relation with fault, and analyse possible effects on their frequency differences. Results show that the spatial distribution, topographic characteristics of debris flow gully, return period and numbers of debris flow are mainly controlled by the Xianshuihe fault because of the tectonic uplift. The frequency difference between HDFs and LDFs is mainly controlled by the glacier distribution, because the glacier deposits act as the available loose debris in source area of debris flow.

Debris Flow Activity in Permafrost Regions in Austria During the 20th Century, page 421

Roland Kaitna, and Thomas Huber

Abstract: Debris flows typically result from a critical combination of relief energy, water, and sediment. Hence, besides water-related trigger conditions, the availability of abundant sediment is a major control on debris flows activity in alpine regions. Increasing temperatures due to global warming are expected to affect the periglacial environment and by that the distribution of alpine permafrost and the depth of the active layer. This might lead to increased debris flow activity and increased interference with human interests. Here we assess the importance of permafrost on documented debris flows in the past by connecting the modeled permafrost distribution with a large database of historic debris flows in Austria. The permafrost distribution is estimated based on the model PERMAKART 3.0, which mainly depends on altitude, relief, and exposition. The database of debris flows includes more than 4500 debris flow events in around 1900 watersheds in the Austrian Alps. We find that around 10% of documented debris flows occurred in watersheds having a permafrost fraction larger than 5% in their headwaters. Only around 50% of historic debris flow events were documented in watersheds where permafrost is clearly absent. Our results indicate that watersheds without permafrost experience less, but more intense debris flow events than watersheds with modeled permafrost occurrence. We find no trend of increased debris flow occurrence rate from permafrost regions in recent years. Our study aims to contribute to a better understanding of geomorphic activity and the impact of climate change in alpine environments.

Statistical Methods for the Assessment of Rainfall Thresholds for Triggering Shallow Landslides: A Case Study, page 429

Yuri Galanti, Michele Barsanti, Roberto Giannecchini, Giacomo D'Amato Avanzi, and Gianni Benvenuto

Abstract: La Spezia Province (880 km²; Liguria, northwestern Italy) is frequently hit by intense rainfalls, which often cause shallow landslides and damage to population and environment. In this regard, the Provincial Administration of La Spezia and the Earth Sciences Department, University of Pisa, promoted a study to define the rainfall thresholds for shallow landslides occurrence. In fact, on 25 October 2011 a very intense rainfall hit two parts of the provincial territory (Cinque Terre-Riviera area and Vara Valley) causing at least 3500 shallow landslides. This event was analyzed together with other 134 shallow landslide events occurred from 2008 to 2014. The rainfall conditions of these events were determined using an algorithm implemented by the CNR-IRPI of Perugia. The rainfall thresholds at different exceedance probability levels of landslide were defined using two statistical techniques: least-squares linear fit (LSF) and Quantile Regression (QR). The results highlight that the LSF thresholds seems to be the best performing from a statistical point of view and, consequently, the "best" for the study area.

Using Weather Radar Data (Rainfall and Lightning Flashes) for the Analysis of Debris Flows Occurrence in Emilia-Romagna Apennines (Italy), page 437

Giuseppe Ciccarese, Alessandro Corsini, Pier Paolo Alberoni, Miria Celano, and Anna Fornasiero

Abstract: During the last years, the Emilia-Romagna Apennines have been severely affected by debris flows, a type of landslide that is relatively uncommon in this area. These phenomena occur as a result of intense rainfall. The two most significant events are the one that affected the Province of Parma in October 2014 and the one that affected the Province of Piacenza in September 2015, in the night between the 13th and 14th. The objective of this work is to identify relationships between rainfall and debris flows occurrence for the Piacenza 2015 event, through the analysis of the distribution of debris flows with respect to rainfall data from weather radar and rain gauges recorded by ARPAE. The analysis of the relationships between spatial occurrence of debris flows and rainfall peaks has been based on the definition of the % of debris flow triggering points that can be contoured inside isohyets and on the ROC curve method. Moreover, we analyzed possible correlations between rainfall intensity and density or number of lighting flashes. The rainfall intensity vs duration plot showed that the September 2015 event largely exceeded debris-flows triggering thresholds proposed in literature. Analysis of debris flows occurrence with respect to hourly precipitation peaks retrieved by weather radar data, evidenced that 100% of the debris flows points occurred above the 30mm/h isohyet, 97%, above the 50mm/h isohyet and 82.5% above the 60mm/h isohyet. Using ROC curves, the spatial distribution of debris flows triggering points can be more precisely predicted by considering, rainfall peaks at 1h and 30min over the event or by considering hourly rainfall between 02:00 and 03:00 of 15/09/2015. Rainfall classes of the best cut-off points in these ROC curves, i.e. most significant classifiers of the location debris flows points, are 75-90 mm/1h and 45-60 mm/30minutes. The analysis of lightning data shows that rainfall intensity was directly correlated to the lightning density but, also, that in some sub-areas a better correlation is obtained by considering rainfall intensity versus the lightning density recorded in the previous 30 minutes.

Monitoring of Debris Flows with an Improved System Setup at the Lattenbach Catchment, Austria, page 449

Johannes Hübl, Andreas Schimmel, and Richard Koschuch

Abstract: The Lattenbach creek, District of Landeck, Tyrol is a very active torrent located in a geologic fault zone in the western part of Austria with a catchment area of 5,3 km². The channel separates the Northern Limestone Alps in the North from the Crystalline Alps in the South. The highest elevation in the watershed is around 2900 m above sea level (asl), the confluence with the river Sanna at 840 m asl. Aside from the regular flood events with bedload transport, the torrent produced five debris flows and three debris floods within recent years (16/08/15, 09/08/15, 26/08/12, 10/07/10, 01/09/08, 20/06/07, 30/08/07 and 22/08/05, respectively). Due to the frequent debris flows and debris floods events the torrent is monitored by the Institute of Mountain Risk Engineering since several years. The parameters that are currently measured during an event include meteorological data (rainfall, temperature, etc.) in the upper part of the catchment (station Dawinalpe) and run-off data from the middle and lower reach of the torrent at the villages Grins and Pians. In the last years the monitoring equipment has been constantly improved. Additional to the standard sensors like radar for water level measurements, seismic sensors for ground motion detection, infrasound sensors for acoustic wave identification a high frequency Pulse Doppler Radar has been installed, which provides the opportunity to measure the surface velocity of a debris flow in different range gates. Together with a recently installed 2D-Laser scanner this setup provides the possibility to determine a very precise approximation of the discharge with a high temporal resolution. In August 2015 this setup worked properly for three debris flows, which occurred within eight days. The first took place on the 09/08/15 at 8 pm. It was a medium sized event with a peak discharge of 64 m³/s. The average velocity measured by the high frequency radar ranges from 0.7 to 4.3 m/s and the cross sectional welted area measured by the 2D Laser was up to 18.6 m². The second debris flow passed the station about 3 hours later, consisting of two significant surges with a peak discharge of about 50 m³/s and slightly lower velocities. The third debris flow took place on August 18th, with a different characteristic. The discharge reaches up to 15 m³/s with flow velocities lower than 2.5 m/s. According to the precipitation measurements the amount of rainfall to trigger these debris flows was rather low. The cumulative rainfall for the three events was calculated with 25, 8 and 3.2 mm, respectively. These torrential events proved the applied concept to record data of debris flows in a high temporal resolution.

Natural Hazard Analysis for a Small Alpine Catchment in the Nepalese Himalayas, page 459

Klaus Schraml, Christian Uhlir, and Johannes Hübl

Abstract: Owing to the disastrous damages due to the earthquakes in spring 2015 and the following monsoon period, numerous debris flows, land- and rockslides occurred in the Nepalese mountains. Within this study, the complex natural hazard system of the Gongar Khola (GK) catchment area consisting of large rockslides and rockfall areas in the uppermost part to slope processes such as landslides and channel processes including high water, debris- and mudflows that deliver material to the fan, respectively into the Tamakoshi River was investigated. Magnitudes of rockslides up to approx. 1.3 million m^3 in the upper part as well landslide areas between 10,000 m^3 and several 100,000 m^3 in the lower regions were estimated. Torrential process such as debris- and mudflows endangered the Gongar Khola village as well as operations buildings and infrastructure of the 456 MW Upper Tamakoshi Hydroelectric Project (UTKHEP) that are situated in the lower GK catchment. Debris flow modeling for the lower GK catchment was performed using the numerical simulation tool RAMMS-DF. In a final step, a protection concept was designed for the affected areas consisting of structural measures such as gabion walls (partially with reinforced soil) in combination with armour stone rows taken resources available on-site into account.

Experimental Study of Fluidized Landslide, page 477

Hu Wei, Hicher Pierre-Yves, Qiang Xu, van Asch Theo, and Wang Gonghui

Abstract: Fluidized landslides that travel long distances at high speed are one of the most dangerous types of landslides. A fluidized slope movement can occur in both artificially designed slopes and natural slopes and generally results in extensive property damage and significant loss of life. However, the initiation mechanisms triggering this type of landslide are still not clearly known. This study attempts to assess the initiation of fluidized landslides through data from flume tests. The samples were collected from the rock avalanches deposits in Wenchuan earthquake area of China, where many huge debris flows which were transformed from fluidized landslide were triggered after earthquake. With the installation of ultra-high sensitivity seismic accelerometers at the bottom of the flume, it was possible to record the vibrations induced by the movement of soil particles during the fluidization of the slope. It was found that just before the liquefaction of the slope, indicated by a sudden rise of pore water pressure, a vibration signal appeared which was weaker than the vibration signal caused by the subsequent movement of the slope. This signal was related to the instability of the soil assembly. Furthermore, the flume tests showed evidence of internal erosion, a phenomenon responsible for the instability of soil structures which can also play a key role in triggering fluidized landslides.

Part IV: Landslides in Rocks and Complex Landslides

Abstract: By using Aydan's idea in this paper, the basal failure plane of anti-dipped rock slope will be regarded as a linear type plane. However, we consider that there is an angle (also called failure angle) between the basal failure plane and plane normal to the discontinuities, and the value of the failure angle is determined by the stress state of the rock stratums. Based on the principle of the minimum factor of safety, we suppose that the best failure angle is the one with the minimum factor of safety, and a new method to search for the best failure angle is introduced in this paper. The scope of slope failure angle will be in zero to □0 (the difference between face slope angle and plane normal to the discontinuities). By changing the failure angle constantly, a series of slope safety factors can be obtained through the limit equilibrium method. The minimum one is defined as the final safety factor and the failure angle corresponding to the final safety factor is the final failure angle. The linear type failure plane corresponding to the final safety factor is the basal failure plane of slope. Taking Galandrood highway slope as a numerical example, the result shows that the obtained safety factor is smaller than that obtained by Aydan's method.

Abstract: Lessons learned from several case studies of deep-seated rockslides in foliated metamorphic rocks in Tyrol (Austria) are presented. Based on surface and subsurface investigations as well as monitoring and modelling campaigns the main topics are the geometry, structure, kinematics, hydrogeology and geomechanics of deep-seated rockslides. Experience was gained from geological field surveys, monitoring campaigns based on remote sensing and classical geodetic methods, sub-surface investigations by core drillings and drifts, geophysical methods and numerical modelling studies. These insights may help to understand the processes and mechanisms of case studies in similar geological situations where comprehensive investigations are not feasible or new investigation campaigns should be planned.

Abstract: The Karakoram Highway (KKH) connects Pakistan and China by traversing through rapidly rising mountainous Karakoram area, which is the junction between the Indian and Eurasian plates including the Kohistan Island Arc. Being a plate boundary, the area is highly prone to active tectonics. The Main Mental Thrust, Main Karakorum Thrust, Main Continental Thrust and Panjal Thrust are the major fault systems operating in the region. The area is seismically active and various major earthquakes (Muzaffarabad Oct, 2005: M=7.6, Afghanistan Oct, 2015: M=7.5) occurred. The geology of the area primarily consists of rocks ranging from sedimentary, metamorphic and plutonic rocks. Granite and ultramafic rocks, slates and quartzites are the dominant lithologies of the area. Alterations of these rocks result in large amount of incompetent and weak lithologies. The KKH passes through world's deepest gorges having high relief. The floor of these gorges is filled by glacial deposits (moraines). Since its construction in 1979, it has been damaged at various locations by a number of mass movements. In our study, data of mass movement events was acquired from Frontier Works Organisation. Then a spatial distribution map was prepared along KKH by using ArcGIS. Furthermore, this mass movement distribution data was correlated with active faults, seismic information and rainfall data aiming to quantify the regression of mass movements and individual distance to active faults in the study area. Moreover, the impact of rainfalls on slope stabilities in the region is investigated. The active faults in area have caused brittle deformation of crystalline rocks. This has resulted into poor to fair rockmass close to faults with densely populated joints having low shear strength. As a result, distances from active faults have inverse effects on mass movement events. Furthermore, rockmass quality close to the active faults is very poor having multiple joint sets. In addition, during heavy rainfall water seeps down into these joint which results in further decrease of shear strength and increase of pore water pressure, ultimately resulting in mass movements. Mass movements in Hassan Abdal-Gilgit Section showed dependence on rainfall intensity, whereas, mass movements in Gilgit-Khunjrab Pass section are function of temperature and rainfall intensity.

Abstract: The catastrophic nature of the Vajont landslide (volume of about 300 million m^3) that occurred on 9 October 1963 in northeastern Italy emphasises the decisive role of a good geological model on the understanding of the mechanical behaviour of a large unstable rock slope. This large rockslide is a reference case study that is very useful for understanding the decisive role of the assumed geological model on the analysis criteria adopted in the slope stability evaluation. A recent (2006-present) survey performed on the failed mass and on the detachment surface allowed us to acquire considerable new geological data on the landslide structure and on the materials involved in the 1963 slope failure. The catastrophic en-masse sliding that occurred in

1963 was effectively a reactivation of a prehistoric large rockslide, as already hypothesised by previous studies dealing with the Vajont slide, but the structure of the prehistoric landslide was different from what was previously thought. The main result of the recent geological re-examination of the 1963 Vajont landslide is the identification of a thick shear zone (40-50 m) located at the base of an overlying unstable block. The occurrence of the basal shear zone, made up of limestone angular gravel, clay lenses and displaced rock masses, permitted a rapid seepage inflow triggered by the reservoir filling and also favoured the unusual en-masse movement of the upper unstable block. In particular, two specific unfavourable geologic conditions played an important role in the 1963 catastrophic event: the high permeability of the thick shear zone and the considerably low shear strength of some very thin clay lenses. Without considering this recently acquired geological data, it is very difficult to perform hydromechanical analyses or more sophisticated numerical models capable of reproducing the catastrophic Vajont slope failure and its unexpected final en-masse movement.

Claudio Margottini, Daniele Spizzichino, Giovanni Gigli, Heinz Ruther, and Nicola Casagli

Abstract: The present paper describes a specific research performed in the framework of the project "Sustainable monitoring techniques for assessing instability of slopes in the Siq of Petra, Jordan" carried out by ISPRA from July 2012 to May 2015. Focus is given to true 3D kinematic analysis for slope stability assessment in the Siq from high resolution terrestrial laser scanning (TLS). The effectiveness of the model and its algorithm implemented for the analysis has been verified and tested after the May 2015 rockfall. The sudden rock collapse, affecting a portion of the Siq cliff, was previously identified by the model as potentially unstable. This knowledge, associated to the outcome of the stability analyses, also through a numerical model, will help in identifying the most sustainable actions to be realized to mitigate the risk of collapse in such a vulnerable and complex context

Roberto Iannucci, Salvatore Martino, Fabio Martorelli, Luca Falconi, and Vladimiro Verrubbi

Abstract: Since the Roman Age and until the last century, an intense quarry activity took place at Favignana Island (Sicily, Italy) that significantly changed the morphology of the eastern part of the Island. This mining activity produced an extensive network of open air quarries, underground quarries and tunnels, locally named "Pirrere", that are hosted into Pleistocene porous carbonate grainstones. The resulting effect is an impressive landscape which makes the Favignana Island a highly frequented touristic site. Although greatly influenced by past human activity, the sea cliffs are affected by diffused instabilities as proved by the evidence of wide block-size talus distributed all along the coast line. Slope stability analyses were performed on the sea cliff of the Cala Rossa bay, in the north-eastern part of the Island. The Cala Rossa cliff slope is a sub-vertical scarp with an elevation between 20 and 25 m and an extension of about 300 m. To constrain such analyses, detailed engineering-geological and remote surveys were carried out to reconstruct the geological setting as well as to characterise the mechanical properties of the rock mass joints. In addition, 10 sub-vertical quarry walls were surveyed to realise a 3D model of the joints net. The collected field evidences account for a mixed genesis of the intense joints net that involve the calcarenite as it results by both tectonic and gravitational effects. Based on the surveyed joints attitude and on their spatial distribution, a detailed kinematic-compatibility analysis allowed to identify three types of rock landslide mechanism (i.e. planar sliding, wedge sliding and toppling) that affect the sea cliff and 78 rock blocks particularly prone to failure were identified. Considering hydrostatic pressure related to joints saturation condition (dry, half-saturated and full-saturated joints) as well as pseudostatic forces due to earthquake (values of PGA associated with return times of 0, 50, 475 and 2475 years), a total of 12 hazard scenarios were analysed each of which was specifically considered for one of the sea cliff sectors. The results obtained at Cala Rossa sea cliff demonstrate that: i) planar and wedge sliding are more suitable landslide mechanisms respect to toppling; ii) the eastern sectors of the sea cliff show higher susceptibility to failures; iii) water pressures within joints play a more destabilising action respect to earthquakes. These represent a relevant contribution to manage protection strategies to reduce the landslide risk in the touristic site of Cala Rossa bay and to preserve the unique cultural heritage represented by the "Pirrere" quarries.

Tien-Chien Chen, Feng-Long Chou, and Cheng Meng Hsieh

Abstract: This study investigated the creep deformation of a gentle dip slope induced by river erosion. In the Ai Liao River (Southern Taiwan), more than 20 rainfall events have induced massive landslides in the dip slope terrain as a result of lateral erosion of the river channel. Numerical simulations revealed that when the riverbank cutting angle is less than 30°, only circular slip and creep folds occur in the slope, with multiple small folds occurring from the toe to the top of riverbank (but no rapid damage occurs). When the river cutting angle is between 30° and 45°, drag bending folds are likely to occur on the contact surface between the surface and bottom layer, and a sliding surface appears along the contact surface. Finally, when the river cutting angle is more than 45°, slope movements occur, leading to significant, rapid block damage.

Mass Movement Processes of Quaternary Deposits in the Vipava Valley, SW Slovenia, page 571

Tomislav Popit, Jernej Jež, and Timotej Verbovšek

Abstract: Complex geological structure combined with relatively steep topography in Slovenia causes intense slope processes. The Vipava Valley (SW Slovenia) offers a unique insight into a variety of different mass movement processes, including an opportunity to study the characteristics of slope sediments of large fossil landslides and the activity of recent movement processes. While the movement of a few relatively large events is being studied in detail, it is also necessary to take into consideration all other types of transport. Slope processes in the Vipava Valley are closely related to the geologic and tectonic predisposition of the area. The topography is defined by thrust edges of nappes composed of Mesozoic carbonate rocks, thrusted on folded and tectonically fractured Tertiary flysch. The uppermost part of the slopes are thus marked by steep carbonate cliffs, while the other parts are more gently-sloping and are composed of marlstone and sandstone flysch bedrock, covered by an apron of coarse-grained Quaternary deposits. The thickness of the scree deposits and breccia may locally exceed 50 meters. Our research shows that the slope sediments of the Vipava Valley represent a complex sedimentary system deposited by very different mechanisms of transport and sedimentary processes that are controlled by a specific lithological and tectonic structure as well as climate conditions of the valley. Varying intensities and dynamics of mass movement processes in this area during the recent geological history (late Pleistocene and early Holocene) influenced the spatial distribution of slope sediments. Additionally, the hydrogeological setting is also highly conducive to further degradation of geomechanical characteristics of the slopes. The lithological and structural predisposition of the Vipava Valley landscapes enables the formation of different and extremely complex types of landslides. Starting with the biggest and oldest, Pleistocene fossil landslides of volumes more than several 10's of million m^3 occur in the valley, with mudflow/debris flow Selo being the greatest, with a volume of approximately 190 million m^3. Other debris avalanches, mudflows and debris flows are characterized by extensive tongue and fan-shape sedimentary bodies. Several large-scale deep-seated rotational landslides of carbonate gravel and breccia inside the tectonically deformed flysch are recognizable by flat horizontal surface in the upper part of the individual landslide bodies. These landslides significantly affected a highway, regional roads and other infrastructure. Translational movement comprises a relatively smaller amount of gravel moving on weathered flysch. Locally, an extensive rock-fall can be observed, while large carbonate megablocks with dimensions up to more than 100 meters also slid down from the edge of the carbonate plateau. Regarding more historical and recent events, approximately one million m^3 of material has moved and destroyed a local road at the rainfall-induced landslide Stogovce, and some of the unconsolidated material still presents a risk. In addition, we can observe mass flows also on the active Slano blato landslide that moved mainly as a viscous earth flow with occurrences of rapid mudflows a few years ago. Finally, the slowest movement is creep of thick mostly unconsolidated gravel, moving on a flysch base, that is present in several slope-situated villages with slow but continuous creep causing increasing deformation of village infrastructure and residential areas.

Characteristics, Causes and Hazards of Large-Scale Debris Flows on June 23 at Haitong Watershed, Tibet, China, page 581

Ge Yonggang, Zou Qiang, Zhang Jianqiang, and Guo Xiaojun

Abstract: Debris flows seriously endanger the highway from Chengdu to Lhasa（G318）and often interrupt traffic in rain seasons, especially at the southeast of Tibet. A large-scale debris flow, occurred on June 23, 2012 at Haitong Watershed, blocked the Xiqu River and formed a dammed lake with the average width of 60m, the length of 300m and the reservoir volume of 90,000~100,000m^3. The traffic of G318 Highway was interrupted until June 30th as the result that the highway base was buried about 230m by debris flow deposits and inundated over 160m by dammed lake. The investigation and the analysis of debris flow deposit samples showed that the debris flow delivered about 100,000 m^3 sediment out of watershed, deposited along Xiqu River and formed a dam with the length of 230m, the width of 100m and the average thickness of 7~8m. The clay content and density of debris flow deposits was 0.41~0.86% and 1.89~2.01 t/m^3, respectively. Using the parameters of cross sections obtained by field measuring, the velocities and peak discharge for debris flow were estimated, and the velocities of flow reached 10.9~12.1m/s by virtue of steep channel as well as the peak discharge at the mouth, the right gully and the left gully was 924m^3/s, 642 m^3/s and 336m^3/s, respectively. The debris flow on June 23 formed a hazard chain which was composed of flash flood, debris flow, dammed lake and outburst flood, and the threshold of debris flow blocking river was that the discharge, the magnitude and the deposits at river channel of debris flow was 230~850m^3/s, 11,709m^3 and 9233m^3. The active tectonic movement, abundant erosion deposits and steep geomorphology are responsible for debris flow formation, the rainstorm after long-period drought triggered debris flows and the sediments induced by channel deposits initiation at the lower of the watershed further supplied and enlarged debris flow. The highway risk were assessed using the model which was established based on dynamic mechanism, and the high-dangerous zone and middle-dangerous zone occupied 86.5%, which agreed with the actual, where were buried by debris flow deposits or submerged by the following dammed lake. Based on the hazards and risk of debris flows on June 23, the protection measures, including dangerous debris flow identification, risk assessment, rational route, integrated control and emergency plans, were recommended.

Part V: Landslides and Other Natural Hazards

Abstract: Although often disregarded during natural hazard evaluation, sediment transport phenomena could represent a matter of major significance when dealing with hydro-geological instabilities with possible adverse impacts on river basin management, structural integrity of hydraulic structures, and public safety. Under conditions of high precipitation and consequent propagation of flood waves, the phenomenon is severely intensified, especially in Alpine and pre-Alpine areas, characterized by relatively high slopes and intense sediment supply from the upstream valleys. This study investigates the application of RFID (Radio-Frequency IDentification) transponders (also referred to as tags) as qualitative and quantitative sediment transport monitoring tool. Preliminary laboratory and field tests have been carried out on both transponders and transponder-equipped pebbles under various conditions of the surrounding environment such as burial and water depth in order to evaluate the performance of the technology. Results of the laboratory experiments indicate that the detection distance depends on the orientation of the tag itself and therefore insertion of two or even 3 tags in a single pebble according to its axes is necessary in order to ensure higher recovery rates. Further, characteristic grain size curves have been used to identify 90 RFID-equipped and painted grains divided in several size classes and used in a first field experiment. The groups have been deployed at predefined locations characterized by similar granulometry and flow conditions. Two recovery campaigns have been since carried out, where the former some 15 hours after a relatively intensified rainfall event and the latter two days later. A relatively high recovery rate has been recorded (74% during the first and 76% during the second campaign) to a distance of up to 50m downstream of the initial deployment point. However, it has been noted that the detection distance is often insufficient for the identification of particular grains. Therefore, it has been deducted that color identification of the samples greatly improves the recovery rate although colored objects could attract interference with animals or passing people, depending on the ease of access to the river. The use of RFID transponders of greater dimension has been scheduled in order to further tackle the detection distance issue. This however, would limit the minimum detectable grain size as tags are directly inserted and sealed within each pebble. On the other hand, during the second campaign, the water surface level had decreased while the clarity of the water increased and therefore the identification process was greatly facilitated. Despite the above mentioned limitations, the technology appears to yield promising insights in the more detailed understanding of sediment transport.

Abstract: Over the past 50 years, at least seven major flash floods have affected catchments of the Rwenzori Mountains. The Rwenzori Mountains are not only subject to flash floods; forest fires, earthquakes and landslides occur as well. Many of the flash floods therefore co-occurred with other hazards. One of the most devastating of these events occurred on May 1st 2013, in the Nyamwamba catchment. Here we reconstruct the circumstances under which this flash flood event was triggered and its effects in this multi-hazard region. This includes the identification and characterization of different processes acting upon the catchment dynamics, their controlling and triggering factors and the estimation of the damaging effects of the flash flood within the catchment. The combined occurrence of intense rainfall, a forest fire having burned 18% of the catchment area and the occurrence of 29 landslides providing debris to the river system, induced a debris-rich and very destructive flash flood which caused several fatalities, the destruction of 70 buildings, several bridges, a hospital and a school, a tarmac road and several life lines. Peak flow discharge is estimated between 850 and 1,300 m^3/s. This case-study demonstrates that flash floods in the region should not be considered as self-determined phenomena but as a result of several cascading and interacting hazard processes including wildfires and landslides, occurring within a short time period.

Abstract: Wildfires affect large forested areas in many countries worldwide, producing damage and economic losses, both as direct effect of the fires and as consequent events, including erosion and sedimentation in the recently burned areas. In addition to destruction of the vegetation, and direct losses to the built-up environment, further effects may be registered as a consequence of the fire, even weeks or months after its occurrence. Wildfire can have, in fact, profound effects on the hydrologic response of watersheds, and debris-flow activity is among the most destructive consequences of these effects. The two primary processes that have been identified for the initiation of fire-related debris flows are i) erosion and entrainment of material by surface runoff, and ii) infiltration-triggered failure and mobilization of a discrete, shallow landslide mass. The first process is reported by far as the most frequent. Field evidence indicates that unlike landslide-triggered debris flows, those produced in recently burned catchments have no identifiable initiation source and can occur with little or no antecedent moisture. Runoff-initiated debris flows have been produced in response to storms that occur typically from a few months to three years after the fire, often in response to the first significant rainfall of the storm season. After a wildfire, and in consequence of the following rainstorms, rills typically develop on

hillslopes, initiated as miniature soil slips, and involving a few mm-thin saturated layer of soil. The persistence of such features downslope, until producing a true debris flow, depends upon a series of factors, including slope steepness, presence of loose materials, and availability of stream flow water. Typically, a discreet landslide mass of significant size is lacking at the head of the flow, whilst erosion and entrainment of significant amounts of surficial material is observed within hollows and in low-order channels. It therefore seems that the main process acting consists of surface runoff from a rainfall event, eroding sediments from hillslope and channels until a position within the drainage network where sufficient material has been entrained, relative to runoff volume, for a debris flow to be generated. The present paper analyzes, with some examples, the generation of debris flows in burned catchments, with the aim to describe the processes at the origin of these dangerous phenomena.

Residual Slope Stability in Low Order Streams of Angangueo Mining Area (Michoacán, Mexico) After the 2010 Debris Flows, page 651

Stefano Morelli, Veronica Pazzi, Victor Hugo Garduño Monroy, and Nicola Casagli

Abstract: Mexico, largely a tropical mountainous region, is continually subjected to natural hazards like landslides induced by heavy rainfalls. At the end of January 2010, two cold fronts and low-pressure storms moved over the State of Michoacán (central Mexico) and in February the town of Angangueo, in the eastern sector of the Monarch Butterfly Biosphere Reserve, was devastated by a huge muddy debris flow. The in situ observations after the event showed that considerable material was removed from the countryside surrounding the urban area. In this framework two low order streams were indicated as the main suppliers of granular material to the Angangueo River: Melon and Catingón creeks. To evaluate the residual risk and slope stability along these two torrential watercourses, specific investigations were carried out. A GIS-based map of the most relevant hazardous features was performed at high level of detail by means of targeted field surveys that distinguished natural and anthropogenic elements like: i) riverbanks and slopes with new signs of instability and already collapsed areas; ii) large accumulations of debris and plant remains in channels and slopes; iii) deposits of mining waste and abandoned mining areas; iv) hydraulic works along the riverbeds and v) cultural elements potentially at risk. In both circumstances, a generalized criticality emerged; moreover, all the riverbanks along the Catingón creek are almost still under unstable conditions, whereas Melon creek has precarious riverbanks only for about 1/3 of the considered slopes. In both cases, the depth of their rupture surfaces seems directly related to the different geotechnical properties of existing materials with some influence from gradients.

Monitoring Eruption-Induced Mass-Wasting at Active Volcanoes: The Stromboli Case, page 669

Federico Di Traglia, Teresa Nolesini, and Nicola Casagli

Abstract: With the aim of understanding the relationship between eruptive activity and slope instability at active volcanoes, in this work displacement data from a permanent-sited, Ground Based Interferometric Synthetic Aperture Radar (GBInSAR) installed at Stromboli (Italy), were compared with the evolution of reflectivity (amplitude) of SAR images collected by means of X-band, space-borne, COSMO-SkyMed satellites (CSK-SAR). The analysis of the dataset (May-December 2014) cover a period characterized by "normal" Strombolian activity, punctuated by episodes of "high-intensity activity", with the occurrence of overflows from the crater terrace toward the Sciara del Fuoco (SdF), and by the occurrence of the August 7th 2014 - November 13th 2014 flank eruption. The integration of GBInSAR displacement data and the analysis of CSK-SAR amplitude images, allowed us to identify the evolution of the slope instability phenomena and geomorphological process affecting the SdF slope. GBInSAR data recorded the inflation of the summit plumbing system two months before the onset of the 2014 flank eruption. Moreover, evidence of mass-wasting recorded by the GBInSAR preceded the fracture opening by ~11 hours, the fracture propagation and North East Crater (NEC) collapse by ~15 hours, suggesting that 11-15 h before the onset of the effusive eruption, magma was intruding below the NEC area, inducing the slope instability observed on the NEC. SAR images were used with the aim of understanding the relationship between eruptive activity, geomorphologic evolution and slope instability. CKS-SAR data results highlights phases of erosion of the volcanoclastic deposits of the SdF during the "normal" Strombolian activity, whereas in periods characterized by higher-intensity volcanic activity, amplitude images revealed lava flow emplacement, as well as the deposition of dry gravel/debris flows.

Development of a Rockfall Risk Mitigation Plan in the Montserrat Massif (Central Catalonia, Spain), page 677

Marc Janeras, Guillem Domènech, Judit Pons, Elisabet Prat, Ferran López, and Pere Buxó

Abstract: The Montserrat Massif is located about 50 km North-West of Barcelona (central Catalonia, North-Eastern Spain). The rock massif is constituted by an intercalation of conglomerate and fine layers of sandstone and siltstone. The relief, with a total height difference close to 1000 m, shows stepped slopes with cliffs up to 250 m high which are prone to rockfalls. The increasing number of annual visitors, reaching 2.4 and 0.8 million for the monastery area and for the rest of the Natural Park, respectively, has highlighted the risk derived from rockfalls. The main exposed infrastructures are the buildings of the basilica area as well as the roads, funiculars and rack railway. Within the last years, several rockfall events have affected different roads and facilities, e.g. the one occurred in the Degotalls rockwall, in 2008, with a volume of about 900 m^3 or the block fallen onto the kitchen of the Hotel Cisneros during 2010 (4 m3), both without injuries or fatalities. Nevertheless, these episodes motivated the implementation of a rockfall risk assessment and mitigation plan in the whole massif in order to guarantee the safety for the population, as well as

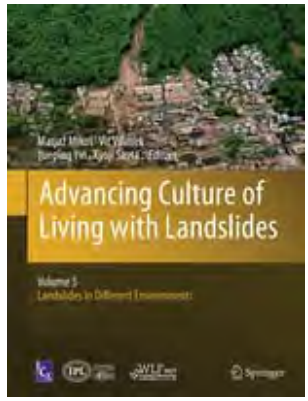
the tourists and mountaineers. Although a surveying and protection plan is already ongoing for the rack railway (working since 2003), which provided a remarkable improvement in terms of safety after its first 10 years, in the monastery area, a different approach was necessary due to the interaction with the natural and cultural heritage facilities: from hazard assessment (or risk), by means of different techniques, to countermeasures and also post-event solutions. The current challenge for the cultural and natural heritage management consists in widening the perspective all along the cycle of risk mitigation to achieve an optimized response in terms of sustainability. To this aim, a geological risk Mitigation Plan in Montserrat was born in 2014. It is funded by the Catalan Government (Generalitat de Catalunya) and promoted by the Board of the Montserrat Mountain (Patronat de la Muntanya de Montserrat). The Catalan Geological Survey (Institut Cartogràfic i Geològic de Catalunya) conducts the technical direction and its execution. A first implementation phase, carried out during the period 2014-2016, was established with a total budget of 1.45 M€, followed by a second phase from 2017 for the complete development of the strategy, before reaching the final third phase of permanent conservation. Concerning the first phase, the rockwalls around the monastery area have been subject to protective and reinforcement works such as fences, bolts and wire meshes according to priorities set in previous inventories. Furthermore, 6 sites with potential unstable blocks have been monitored by means of jointmetric sensors configuring a wireless sensor network. Also, several remote sensing techniques have been tested: Terrestrial Laser Scanner (TLS), Ground Based Synthetic Aperture Radar (GBSAR) and Surveying Total Station (STS). Additionally, a quantitative assessment of the rockfall hazard has been carried out in different parts of the massif based on inventoried data gathered during systematic field trips and TLS campaigns. Besides the operability of the developed plan, and the maintenance of the current works carried out as of today, many questions have appeared throughout this first stage. They require further investigation that will be conducted within the second term. The main goals are: a) assessment of the spatiotemporal variability of the rockfall hazard; b) analysis of the pre-failure mechanisms leading to rockfalls of different volumes and c) application of monitoring techniques and any other kind of predicting tools in order to prioritize the installation of countermeasures in places identified as a potential menace.

Assessment of Rockslide Dam Scenarios at Catchment Scale in the Context of Cascading Hazards, page 685

Christian Kofler, Francesco Comiti, Bernhard Gems, Benni Thiebes, Stefan Schneiderbauer, and Romy Schlögel

Abstract: In rivers, temporary dams formed by landslides, rock falls or debris flows pose a severe threat to human life, public infrastructure and private assets. Besides the on-site impacts from the mass movement itself, these phenomena can cause disastrous off-site impacts by backwater inundation or catastrophic outburst floods. These secondary fluvial hazards can affect areas at substantial distances both up- and downstream of the site where the blockage occurred. In the present case study, the formation of rockslide dams and their subsequent impacts are viewed as a cascade of linked geomorphological and hydrological phenomena and assessed accordingly. The case study area extends over the two municipalities of Stilfs/Stelvio and Prad am Stilsferjoch/Prato allo Stelvio in the Autonomous Province of Bozen/Bolzano (South Tyrol) in Northern Italy, where the upper part of the slope above the village of Trafoi is at risk of a sudden failure. The present work builds on previous modelling attempts that predicted deposition heights up to 75 m in the channel of the Trafoi River. In this paper, we qualitatively identify all involved processes and create scenarios of various dam heights and dam breach processes. Modelling results show that the river downstream of the temporary dam features a channel conveyance sufficient for the peak discharge associated to a dam height of 4 m whereas dam heights of 16 m and 75 m would lead to severe flood events within the downstream municipality of Prad am Stilfser Joch. The modelled peak discharge values range from 35 m^3s-1 to 2554 m^3s-1, which fits well with values reported from other dam breach occurrences.

Volume 5: Landslides in Different Environments



Part I: Landslide Interactions with the Built Environment

Abstract: This paper presents an overview of the findings from a series of country-scale landslide risk assessments conducted on behalf of the governments of five Sub-Saharan countries, the World Bank and the Global Facility for Disaster Reduction and Recovery (GFDRR). Ethiopia, Kenya, Uganda, Niger and Senegal sample a wide range of Sub-Saharan Africa's different geographies and are characterised by contrasting levels of development. Landslide hazard, exposure and vulnerability therefore differ from country to country, resulting in significant spatial variation of landslide risk. In East Africa; Ethiopia, Kenya and Uganda are characterised by mountainous and seismically active terrain which results in a relatively high landslide hazard. In conjunction with rapid urbanisation and a population which is expected to rise from around 170 million in 2010 to nearly 300 million in 2050, this means that landslides pose a significant risk to the built environment. In West Africa, a combination of low landslide hazard and lower exposure in Niger and Senegal results in comparatively low landslide risk. This paper also describes areas with perceived misconceptions with regard to the levels of landslide risk. These are areas of only low to moderate landslide hazard but where urbanisation has resulted in a concentration of exposed buildings and infrastructure that are vulnerable to landslides, resulting in higher landslide risk.

Abstract: Rainfall-induced debris flows frequently cause disruption to the Scottish road network. A regional assessment of debris flow hazard and risk allows risk reduction actions to be targeted effectively. To this end a strategic approach to landslide risk reduction, which incorporates a classification scheme for landslide management and mitigation has been developed, in order to provide a common lexicon (or group of words) that can be used to describe goals, outcomes, approaches and processes related to risk reduction, and to allow a clear focus on those goals, outcomes and approaches. The focus is thus first on the desired outcome from risk reduction: whether the exposure, or vulnerability, of the at-risk infrastructure and people (and their associated socio-economic activities, which may be impacted over significant areas) is to be targeted for reduction or whether the hazard itself is to be reduced (either directly or by affecting the physical elements at risk).

Abstract: The landslide risk for the entire Czech road network is presented here. The risk was computed using data on landslide hazard and data on potential impacts of road blockage. Data from the official landslide database were used for landslide hazard computation combined with data from historical records on roads interrupted by landsliding. Vulnerability was computed as direct costs which are related to road construction costs and indirect costs. The latter express additional economic losses from the blocked roads. This concept was applied at II/432 road link as a case study where a landslide interrupted traffic in May 2010. Indirect losses were estimated as being 2.5 higher than costs related to mitigation works. All data can be viewed at rupok.cz website.

The Impact (Blight) on House Value Caused by Urban Landslides in England and Wales, page 27

William Disberry, Andy Gibson, Rob Inkpen, Malcolm Whitworth, Claire Dashwood and Mike Winter

Abstract: We examine how large, slow moving landslides impact urban house prices in three areas of England and Wales. 12,663 house transaction values were analysed covering all house sales 1995-2012 in Lyme Regis, Dorset; Ventnor, Isle of Wight and Merthyr Tydfil, Glamorgan. Values were analysed with respect to local landslide events and visible landslide damage. In all three study areas, individual landslide events caused little or no negative impacts on nearby property prices, though remediation is likely to have short-term positive impacts on local house prices. Localised blight and suppressed house prices to a distance of 75 m was found in areas affected by ongoing incipient movement. By comparison with other sources of property blight, the radius of influence is 25% of that expected from an abandoned property or electricity pylon and less than 5% that of a windfarm. The socio-economic environment was important in determining the degree of house price impact of landslide events and for most locations, landslides form only a minor impact compared to other factors.

Landslide Monitoring and Counteraction Technologies in Polish Lignite Opencast Mines, page 33

Zbigniew Bednarczyk

Abstract: The paper presents exemplar landslide investigations in lignite opencast mines. These are reported in two the largest Polish mines and spoil dumps. The Belchatow mine, one of the largest excavations in Europe is located in central part of Poland with lignite resources of 2 bln t and annual production of 42 mln t. The type of tectonic geological structure, high depth up to 310 m and low soil strength parameters are the main landslide triggers. Landslides of a few thousand to few mln m^3. Landslides were activated on structural and paleolandslide surfaces at the southern slope, near secondary ditch structure with the greatest depth of lignite deposit. The northern slope built of low strength Quaternary varved clayey soils posed numerous risks for transportation and power supply lines. The similar threats occurred in the past in the second largest in Poland Turow mine in the southwestern part of Poland. It is located in Lower Silesia District close to German and Czech border. The mine estimated lignite reserves of 760 mln t allows annual production of over 27 mln t. The reported in the pit and the spoil dumps landslide accidents caused damages for mine infrastructure. In the nineties the potential hazard of development of the landsliding, breaking through the Nysa Luzycka river, localized not far away from the mine, could resulted in trans-border environmental risks and destruction of mine infrastructure. In the past lack of Neisse river pillar stability in the worst scenario could lead to intrusion of water to the open-pit. Another landslide created in 1994 on spoil dump had a volume of approx. 9 mln^3 and was located near the border with the Czech Republic. Author of this paper had opportunity in previous years to participate in same parts of these investigations. It included landslides on the external spoil dump at Turow mine and one of the largest landslides in Belchatow mine. The research included CPTU, laboratory tests, displacement monitoring and numerical modeling. Interpretation of soil strength parameters was difficult. Soil dump soils had varied in strength due to its anthropogenetic nature. The interpretation of soil parameters of clayey soils in the pit was also complicated due to its high preconsolidation and partial saturation. The paper describe also tasks of a new Euracoal Project "Smarter Lignite Open Pit Engineering Solutions" which is now conducted by an international consortium of six European countries UK, Poland, Czech Republic, France, Spain and Greece. The project in Polish, Czech and Spanish opencast mines aims in practical implementation of a new geotechnical monitoring methods. At Polish site PSI satellite interferometry, UAV and ground based laser scanning will be implemented. In-situ monitoring will include 100 m depth real-time continuous monitoring system. Complementary monitoring methods should allow better understanding and prediction of landslide activity. Investigations will use shallow geophysics, laboratory triaxial and centrifuge testing for slope stability analysis. Obtained results will be used in local warning and risk mitigation. However, the mines have already advanced monitoring systems and counteraction methods, landslides in these deep and large mines are registered every year.

New Perspectives on Landslide Assessment for Spatial Planning in Austria, page 45

Arben Kociu, Leonhard Schwarz, Karl Hagen and Florian Rudolf-Miklau

Abstract: Settlement development issues in connection with gravitative natural hazards are increasingly prominent on national policy agenda in Austria. The biggest policy challenges consist in the development of an integrative evaluation of the threats and risks (security level, protection objectives), in preparing accepted standards about depictions of gravitative natural hazards as well as their use in spatial planning. The Austrian Concept on Spatial Development (ACSD), which is a strategic instrument for federal policies in regional development, was set up to create a new cooperation at the expert level and to develop basic approaches for key issues in an interdisciplinary forum. The ACSD-partnership for "Risk management for gravitative natural hazards" in spatial planning concerning mass movements and slope processes was established in 2012 to bridge the gap between hazard mapping, risk management and spatial planning for these relevant phenomena. The activities of the Working Group "Geology" consisted in the evaluation of the existing methods for the calculation of landslide susceptibility (and rock falls) and the affected area in terms of their suitability for spatial planning. For susceptibility and run-out assessment regarding shallow landslides and debris avalanches there is available a wide range of modelling methods. The appropriate application and the explanatory power of these models as well as the gained results are strongly depending on the input data quality, on the analysis scale as well as the size and homogeneity of the study area. The proposed standards represent a prerequisite in order to obtain comparable results within an administrative unit (e.g. federal states). Further recommendations were also given in terms of the quality assurance, uncertainties, model validation and traceability. Generally, for areas with low data information density and quality the application of expert based heuristic methods to generate susceptibility maps for shallow landslides is recommended,

while statistic models should be used only when sufficient landslide inventory data in good quality and density are available. - On the regional level the Hazard Index Maps offer a rough estimation of potentially endangered areas, including susceptibility map and run out assessment. According to run out, the reach angle approach is sufficient. - On the local level (Refined Hazard Index Maps) it is recommended to identify areas with different "needs for action" (consultation of regional planner /preliminary expert opinion/ expert`s report). For these maps the estimation of the run out needs to be calculated more precisely by the application of process-orientated approaches. - Only on the site specific level a detailed proof of the suitability for building land by means of an expert`s report should be performed. In case of modelling on this level, physically-based methods for the assessment of slope stability should be used. In terms of run out assessment, the estimation of frequency, magnitude and forces must be included. The published results of Ã–REK Partnership and the Ã–ROK Recommendation No. 54 provide a comprehensive package that contains not only a technical basic but also political recommendation for action.

Characterisation of Recent Debris Flow Activity at the Rest and Be Thankful, Scotland, page 51

Bradley Sparkes, Stuart Dunning, Michael Lim and Mike G. Winter

Abstract: The Rest and be Thankful (A83) in Scotland has been subject to frequent landslide activity in recent years and the trunk road has gained a reputation as one of the most active landslide sites in the UK. A recent upturn in activity has taken place, with an average of two road closures per annum recorded over the last five years. This paper compares the site with other locations in Scotland that are prone to debris flows and explores a range of geomorphological factors using high resolution Terrestrial Laser Scanning data. The site is found to be relatively active, although normalization for mean annual rainfall makes activity at the site comparable to the likes of the Drumochter Pass. Macro-scale slope morphology is found to correspond strongly with the spatial distribution of recent activity. Channelization is considered to be a significant factor in the overall debris flow hazard by confining flow and enabling entrainment. This was demonstrated during two recent events that mobilized at high elevations and entrained significant volumes of material along long runout paths.

The Use of Morpho-Structural Domains for the Characterization of Deep-Seated Gravitational Slope Deformations in Valle d'Aosta, page 59

Daniele Giordan, Martina Cignetti and Davide Bertolo

Abstract: Deep-seated Gravitational Slope Deformation (DsGSD) are a widespread phenomena in mountain regions. In the Valle d'Aosta alpine region (northern Italy) DsGSD occupy the 13.5% of the entire regional territory. A total amount of 280 phenomena has been inventoried in the IFFI project (Italian Landslide Inventory). These large slope instabilities often may affect urbanized areas and strategical infrastructures, involved entire valley flanks. The presence of different settlements over DsGSD leads the regional Geological Survey to assess the possible effects of these phenomena over the human activities. This study is aimed at implement a methodology, based on SAR data observation and elaboration, to recognize the most active sectors of these phenomena. Starting from the available RADARSAR-1 dataset, we try to purpose a methodology for the identification of the main morpho-structural domains that characterized these huge phenomena, and the definition of the different sectors that compose the DSGD characterized by different level of activity. This subdivision is important to link those different kinematic domains inside the DsGSD to the level of attention that should be done in the study that supported the request of authorization of new infrastructures. We apply this method over three case studies represented by significant phenomena involving urban areas of the Valle d'Aosta region. In particular, we analyse the study area of: the Cime Bianche DsGSD; the Valtourenenche DsGSD; the Quart DsGSD. These phenomena present different levels of evolution controlled by the interaction of diverse factors, and involving buildings and other infrastructures. This setting has been useful to test the development methodology that taking advantage of remote-sensing investigations together with the local geological, geomorphological and structural setting of each case study analyzed. This method aims at achieve a useful instrument to trying to delineate a sort of guidelines for the realization of new infrastructures, as support of the Regional Agency.

Gediminas's Castle Hill (in Vilnius) Case: Slopes Failure Through Historical Times Until Present, page 69

Vidas Milkulėnas, Vytautas Minkevičius and Jonas Satkūnas

Abstract: The remaining buildings of Gediminas's Castle in Vilnius stand on the top of a 40 m high hill composed of Quaternary glacial, glaciolacustrine, glaciofluvial inter-layered deposits and technogenic (cultural layer) accumulations. The city center and castles are located in an area at the very margin at the maximum advance of the Weichselian glaciation. There was no direct erosion impact in the area of Vilnius's hills from meltwater for the formation of the upper reaches of the highest ravines. Therefore, it is proposed that the main features of the Vilnius Castles hills were formed by periglacial thermal erosion - the movement of land masses due to the thawing of permafrost at a time of climate change and the beginning of the vanishing of the Weichselian ice body. Over the course of history people reshaped the slopes of these hills for living and defense purposes. The saddle connecting Gediminas's Hill and the massif of the Hill of Three Crosses goes back to historical times when the artificial channel for the Vilnia River was dug and it became a separate hillfort. Due to the steep slopes of the hills, slope deformations and landslides have been occurring since the historical past until the present. Recently a landslide formed on the eastern slope in 2004 and reactivated in 2008. In early spring of 2016 two new landslides appeared on the northwestern slope preceded by a number of cracks on the ground surface. Causes of slopes failure and general problems of stabilization are dealt with this article, also

covered is the necessity of early warning system installation, slopes surfaces permanent monitoring based on 3D laser scanning, etc.

Design Criteria and Risk Management of New Construction in Landslide Areas: The Case of the Djendjen–El Eulma Highway (Algeria), page 77

Mirko Vendramini, Attilio Eusebio, Fabrizio Peruzzo, Patrizia Vitale, Alessandro Fassone and Francesca Guazzotti

Abstract: The new highway Djendjen -El Eulma (Algeria) develops through more than 110 Km in mountainous and instable areas. The North-South oriented alignment crosses different environments starting from the plain area of the Djendjen valley, passing through a very irregular and geomorphological composite area of the "Petit Kabylie "massif (Texenna city) up to the future connection with the existing East- West Highway. The alignment includes several civil works among which more than 100 viaducts, 1 tunnel, embankments and up to 90 m high large excavations in instable and seismic areas. Civil works design and construction, basically located in complex and irregular mountainous areas, faced with various and relevant natural hazards related to the geological, structural and geomorphological context of the area, as well as to large extended landslides areas. The geological context is characterized by the presence of several complex rock formations, including heterogeneous rock masses: shales/siltstones and sandstones, marls and limestones sequences (Tertiary and Cretaceous Flysch). Gneiss, mica schists and evaporitic rocks are locally present. More than 60 landslides with different geometry, dimensions, kinematics features and evolution degree have been detected. The definition of a reliable Geological Reference Model (GRM) has been elaborated in order to define the geometric and kinematic landslide features. A detailed analysis of the most likely design and construction risks has been carried out during one of the most critical phase as the construction design phase. A dynamic and multidisciplinary approach has been implemented considering several aspects among the most efficient site investigation methodologies, technical needs and schedules to complete activities. The definition of the geological, geomorphologic and geotechnical contest and the consequential landslide characterisation has been a key element at the base of the implemented approach. The GRM as well as the risks management represented a solid base for the assumptions and design choices, constantly updated with a data flows coming from both geological and geotechnical site investigations and feedback from works construction (follow up and monitoring). The parallelism and partially superimposition between design and construction phases had mainly two consequences. Notwithstanding the fact it forced the timing of the two phases, on the other hand, it allowed designers to quickly update the base reference model and design choices in several cases, with significant improvements and advantages in terms of time and cost.

Numerical Analysis of a Potential Debris Flow Event on the Irazú Volcano, Costa Rica, page 89

Marina Pirulli and Rolando Mora

Abstract: The active Irazú Volcano is the highest of several composite volcanic cones which make up the Cordillera Central in Costa Rica, close to the city of Cartago. The top of the volcano is strategic for the Country, since at the height of over 3400m sit 84 telecommunication towers used by government agencies and several TV and radio stations, which guarantee the station coverage of more than 60 percent of the national territory. Since December 2014, a series of minor tremors, or microseisms, occurred at the IrazÃº and some open and deep fissures formed on the upper part of the volcano associated with formation of landslides. More research is needed to determine if these fissures are directly related to recent seismic activity. However, the landslide formation has made it necessary to relocate the towers and there is evidence of the possible destabilization of a volume of about 3.5 million cubic meters of material. In particular, if the landslide triggers in conjunction with heavy rains the movement could evolve into a huge debris flow that could affect Cartago city, similar to the debris flow disaster of December 1963. The dynamics of this potential event have been analyzed using the numerical code RASH3D. The calculated flow intensities and flow paths could be used to support hazard mapping and the design of mitigation measures. The reliability of the obtained results are a function of assumptions regarding source areas, magnitudes of possible debris flows and calibration of rheological characteristics, but also digital terrain model (DTM) quality. As to this last aspect, a systematic comparison of numerical results, DTM and air photos enabled identification of various weak points of the digital terrain model and identified potentially critical zones due to the presence of man-made structures.

Landslides Impact Analysis Along the National Road 73C of Romania, page 101

Andreea Andra-Topârceanu, Mihai Mafteiu, Razvan Gheorghe, Mircea Andra-Topârceanu and Verga Mihaela

Abstract: Landslides are the most common geomorphic hazard processes in Sub-Carpathians regions. Crossing the Getic Sub-Carpathians between Campulung Muscel city (the first royal residence of Romanian Country) and Ramnicu Valcea city, the 73C National Road is constructed for more than 90% on sloping surfaces. A wide variety of landslide types, a high landslide frequency (over 5 landslides reactivations/year and other new triggering) and a high density (between 0.5 - 3.3 landslides/km) are the main characteristics of the slope intastability along the 73C National Road. Many stabilisation and repair works have been completed, but diffrent section remain vulnerable to landslide damage. The study aims are to map the different types of landslides, to identify the landslides causes and their impact of landslides related to 73C National Road and its communities, to identify new morphological surfaces which may have a high landslide susceptibility at and to assess the impact of landslides. The main causes of landslides along 73C National Road are hydrogeologically controlled and are linked to high degree of drainage

density and deforestation. A multy-disciplinary approache was taken, consisting: landslides mapping, historical maps analysis, geomorphological and geophysical methods, topographic and geotechnical surveys. The results highlight considerable vulnerability of slope stabilisation works as a consequence of an incomplete understanding of landslide processes and limited stabilisation works involving just the road embankment.

Evaluation of Building Damages Induced by Landslides in Volterra Area (Italy) Through Remote Sensing Techniques, page 111

Silvia Bianchini, Teresa Nolesini, Matteo Del Soldato and Nicola Casagli

Abstract: This paper aims to detecting terrain movements in landslide-affected and landslide-prone zones and their damaging effects on the urban fabric. The case study is the Volterra area in Tuscany region (Italy), covers about 20 km^2 and is extensively affected by diffuse slope instability. Firstly, the spatial distribution and types of the landslides were studied on the basis of the geological and geomorphological setting coupled with a geotechnical monitoring. Secondly, satellite SAR (Synthetic Aperture Radar) images acquired by ENVISAT and COSMO-SkyMed sensors respectively in 2003-2009 and 2010-2015 and processed with Persistent Scatterer Interferometry (PSI) techniques, were exploited. In particular, these satellite radar data combined with thematic data and in-situ field surveys allowed the improvement of the geometric and kinematic characterization of landslides, as well as allowing a deformation and damage assessment to be undertaken on built-up zones. The classification of damage degree and building deformation velocity maps of the study area were also evaluated through PSI displacement rates. Furthermore, as a single building-scale analysis, maximum differential settlement parameters of some sample buildings were derived from radar measurements, and then cross-compared with constructive features, geomorphological conditions and with field evidences of known landslide areas. This work allowed the correlation of landslide movements and their effects on the urban fabric and provided a useful stability analysis within future risk mitigation strategies.

The Resilience of Some Villages 36 Years After the Irpinia-Basilicata (Southern Italy) 1980 Earthquake, page 121

Sabina Porfido, Giuliana Alessio, Germana Gaudiosi, Rosa Nappi and Efisio Spiga

Abstract: The aim of this study is to describe the modifications of the built environment that have occurred in 36 years following the Irpinia-Basilicata, 1980 earthquake. In particular, especially in the villages of the epicentral area, changes in the urban and territorial setting have been examined, as well as the consequences of ground effects that have influenced the choices of reconstruction, both in situ, and far from the original historical centers. The November 23, 1980 Irpinia-Basilicata earthquake (Mw=6.9; Io=X MCS; Io=X ESI-07), killing 3,000 people, hit 800 localities over a large area of Southern Italy; 75,000 houses totally collapsed and 275,000 were badly damaged. The earthquake induced primary and secondary environmental effects, over all slope movements. The total amount of surface faulting was 40 km in length with the maximum displacement of 100 cm; the total area affected by slope movements was estimated to be about 7,400 km^2, with 200 landslides classified. One of the largest landslides damaged Calitri village, in Avellino province. We have examined, as case histories, the reconstruction of Calitri and San Mango sul Calore villages, that were affected by severe landslides and were rebuilt in situ; we have also studied Conza della Campania that was reconstructed far from the original location. In the so-called Anthropocene age, the role of technical experts both in the built environment and in the social and ethical context is extremely important, for rebuilding the villages destroyed by earthquakes, especially in respect of the people resilience.

Urgent Need for Application of Integrated Landslide Risk Management Strategies for the Polog Region in R. of Macedonia, page 135

Igor Peshevski, Tina Peternel and Milorad Jovanovski

Abstract: Results from a recent study on landslide distribution in the Republic of Macedonia have shown that the northwest part of the country is most prone to landsliding processes. In the past, there have been numerous landslides which have caused great damage to the infrastructure and endangered many villages. Unfortunately, the last catastrophic event occurred on 3 August 2015 in the wider area of town Tetovo. The triggering factor for the flooding and number of slope mass movements was a heavy rainfall. The storms and floods were described as the worst to hit the area in over a decade. Relevant seismic events before and during the rainfall were not recorded. As a result of fast debris flow, 6 people lost their life in village Poroj, while parts of it were covered by deep debris deposits. Roads and communal infrastructure in the entire region suffered significant damages which caused problems in search and rescue operations. The study area Polog is located in the foothills of the Sar Mountain and divided by the river Pena. The broad area of the Municipality Tetovo itself has complex geological and tectonic conditions which also contributed to the degree of damage of the affected areas. Therefore, Tetovo and surrounding areas are vulnerable to both storm run-off and river flooding and consequently to different slope mass movements processes. In order to prevent such disasters in the future it is crucial to develop an integrated landslide risk management strategy. Efforts are made to prepare basic landslide susceptibility map of the region, which can serve as an integral part in the development of the strategy. Certain applications for risk management projects have been submitted by teams of domestic and international experts, which if approved can be of great value for the regional and local population and infrastructure.

Comprehensive Overview of Historical and Actual Slope Movements in the Medieval Inhabited Citadel of Sighisoara, page 147

Andreea Andra-Topârceanu, Mihai Mafteiu, Mircea Andra-Topârceanu and Mihaela Verga

Abstract: The perspective of this study is based on the relationship between geomorphological and hydrogeological environments as natural support of the Sighisoara Citadel UNESCO heritage site and the impact of human activities on both of these. Since this system of the heritage site of the Sighisoara Citadel is composed of both natural and anthropogenic elements, the slope morphodynamic are controlled by their spatial distrubution. The achievement of the main objectives of our study was possible using complex methodology: historical landslides mapping, geomorphological and geophysical methods, topographic and geotechnical survey and statistical analysis. Our results show that the geomorphological environment has changed dynamic features in the last decades. Also the hydrogeological conditions at shallow depth are different in the new context of higher values of human pressure generated especially by tourism phenomenon.

Analyze the Occurrence of Rainfall-Induced Landslides in a Participatory Way for Mid-Hills of Nepal Himalayas, page 159

Hari Prasad Pandey

Abstract: Involvement of local people in landslides disaster risk reduction planning, implementation and benefit sharing is the key to a participatory sustainable development approach at a local level. With this approach, Rolpa district which covers an area of 1879 km^2 in the foot hills of Nepal Himalayas has been chosen as the study site. Almost 103 landslides were recorded through the participatory method, analyzed and compared with rainfall data and topographic features. Linear regression model showed that occurrence of landslides is increasing significantly over time but rainfall trend is decreasing gradually. Physical infrastructures and properties such as settlement areas, arable lands, roads, forests, spring (water sources) and irrigation canals were found to be damaged. More than 80% of the landslides affected settlements whereas only 20% affected irrigation canals. The ANOVA test showed that the size of landslide has insignificant ($p>0.05$) effect on the number of places caused damage except in settlement areas. Moreover, slope failure due to steep relief is not significant rather larger sized and higher numbers of landslides occurred in gentle slope areas (slope <= 30 degree). Almost 80% of landslides occurred between elevations of 1200-2400 m asl with the majority in northern aspect. This study concluded that the causative factor of occurring of landslides is rain but occurrence further accelerated by anthropogenic activities either changing the topographic reliefs or application of improper conservation measures or both reasons. Major anthropogenic activities could be construction of roads, slope farming practices, houses constructed without due consideration of conservation measures in the recent decades. These results will be helpful to guide land use related planning related to soil and its productivity conservation, and water for the government, development agencies, stakeholders of Nepal, in general, and locals of Rolpa district, in particular to get the optimum benefits from those natural resources.

Part II: Landslides in Natural Environment

analyzed rock cores from the borehole. We present the results of laboratory soil tests and use these results in mathematical models. We examine all landslides (rainfall-triggered and earthquake-induced) recorded at Chandmari Locality during the past five decades. Simple calculations demonstrate that when the input parameters of the models mimic the field conditions precursory to an actual landslide, the factor of safety of the slope is less than unity. Gangtok City lies close to the Main Central Thrust, MCT2, which separates the gneissic rocks of the Paro/Lingtse Formation from the mica schists of the Daling Formation. Our field investigations revealed that at Chandmari Locality, gneissic rock overlies highly weathered mica schist. We postulate that surface runoff infiltrates through fractures in the overlying gneiss and results in an extrusion of the finer micaceous material, leading to subsidence which is routinely observed during the monsoon season. During torrential rains, rainwater infiltration causes the sliding of the soft micaceous bands underlying the gneissic rock, leading to rockslides at the hill. We suggest that similar processes are responsible for the frequent and widespread occurrences of landslides and subsidence observed throughout the region.

Activation of Cryogenic Earth Flows and Formation of Thermocirques on Central Yamal as a Result of Climate Fluctuations, page 209

Artem Khomutov, Marina Leibman, Yury Dvornikov, Anatoly Gubarkov, Damir Mullanurov and Rustam Khairullin

Abstract: Study area in continuous permafrost zone, characterized by tabular ground ice distribution, is known for active slope processes. In 90-s main attention was paid to translational landslides (active layer detachments). Due to climate trends summer temperature became warmer, active layer depth increased. As a result, active-layer base ice thawed and stopped development of translational landslides. At the same time, tabular ground ice table got involved into seasonal thaw and triggered earth flows at the lake shores, the second known type of cryogenic landslides found previously mainly at the sea coasts. Earth flows are the main process in thermal denudation: a complex of processes responsible for formation of thermocirques. Thermocirques are semi-circle shaped depressions resulting from massive ground ice thaw and removal of detached material downslope. Monitoring of thermocirque activation and development allows analyzing climatic controls of thermal denudation, and rates of thermocirque enlargement. At present in the Yamal Peninsula tundra predominance of processes associated with tabular ground ice thaw (cryogenic earth flows) over the processes associated with the ice formation at the bottom of the active layer (cryogenic translational landslides) is observed. This is caused by deepening of the active layer and exposure of the massive ground ice (tabular ground ice or ice-wedges) within permafrost to first seasonal and then perennial thaw. Activation of thermal denudation which started on Yamal Peninsula in summer 2012, is associated with extremely warm spring and summer of this year, and the warmest July of 2013. By the end of the warm season thawing of the top of icy permafrost and tabular ground ice on some slopes resulted in cryogenic landsliding in the form of earth flows and further thermocirque development. Thermocirques may form on slopes of various aspects but develop faster on south-facing slopes.

Landslide Investigations in the Northwest Section of the Lesser Khingan Range in China Using Combined HDR and GPR Methods, page 217

Zhaoguang Hu, Ying Guo and Wei Shan

Abstract: In the northwest section of the Lesser Khingan Range located in the high-latitude permafrost region of northeast China, landslides occur frequently due to permafrost melting and atmospheric precipitation. High-density resistivity (HDR) and ground penetrating radar (GPR) methods are based on soil resistivity values and characteristics of radar-wave reflection, respectively. The combination of these methods together with geological drilling can be used to determine the stratigraphic distribution in this region, which will allow precise determination of the exact location of the sliding surface of the landslide. Field measurements show that the resistivity values and radar reflectivity characteristics of the soil in the landslide mass are largely different from the soil outside the landslide mass. The apparent resistivity values exhibit abrupt change at the position of the sliding surface in the landslide mass, and the apparent resistivity value decreased suddenly. In addition, the radar wave shows strong reflection at the position of the sliding surface where the amplitude of the radar wave exhibits a sudden increase. Drilling results indicate that at the location of the sliding surface of the landslide mass in the study area, the soil has high water content, which is entirely consistent with the GPR and HDR results. Thus, in practice, sudden changes in the apparent resistivity values and abnormal radar-wave reflection can be used as a basis for determining the locations of sliding surfaces of landslide masses in this region.

Part III: Landslides and Water

Abstract: Landslides are one of the most dangerous natural hazards in the world causing fatalities, destructive effects on properties, infrastructures, and environment. A correct evaluation of landslide risk is based on an accurate landslide susceptibility mapping that will affect urban planning, landuse planning, and infrastructure designs. Great effort has been devoted by the scientific community to develop landslide susceptibility models. Only few studies have been focused on defining accurate procedures for model selection, assessment, and inter-comparison. In this study we applied a methodology for objectively calibrate and compare different landslide susceptibility models in a framework based on three steps. The first step involves the automatic model parameter calibration based on different objective functions and the comparison of the models results in the ROC plane. The second step involves the intercomparison of a set of model performance indicators in order to exclude objective functions that provide the same information. Finally the third step involves a model parameter sensitivity analysis to understand how model parameter variations affect the model performances. In this study the three-step procedure was applied to compare two different simplified physically based landslide susceptibility models along the highway Salerno-Reggio Calabria in Italy. The model M2, able to consider the spatial variability of the soil depth respect to the model M1, coupled the distance to perfect classification index provided the most accurate result for the study area.

Abstract: In hilly and mountainous regions, landslide dams can be recurring events involving river networks. A landslide dam can form when sliding material reaches the valley floor and closes a riverbed causing the formation of a water basin. Unstable landslide dams may collapse with catastrophic consequences in populated regions because of the resulting destructive flooding wave released. To prevent these consequences, the assessment of landslide dam evolution is a fundamental but not easy task, because of the complex interaction between watercourse and slope dynamics. Several researchers proposed geomorphological indexes to evaluate dam formation and stability for risk assessment purpose. These indexes are usually composed by two or more morphological parameters, characterizing the landslide (e.g. sliding material volume or velocity) and the river (e.g. catchment area or valley width). In this work, a procedure to evaluate landslide dam evolution is applied and reviewed. About 300 obstruction cases occurred in Italy were analyzed with two recently proposed indexes, the Morphological Obstruction Index (MOI) and the Hydromorphological Dam Stability Index (HDSI). The former, which combines the landslide volume and the river width, is used to identify the conditions that lead to the formation of a landslide dam or not. The latter, which combines the landslide volume and a simplified formulation of the stream power (composed by the upstream catchment area and the local slope), allows a near real time evaluation of the stability of a dam after its formation. The two indexes show a good forecasting effectiveness (61% for MOI and 34% for HDSI) and employ easily and quickly available input parameters that can be assessed on a distributed way even over large areas. The indexes can be combined in a convenient procedure to assess, through two subsequent steps, the final stage in which a landslide dam will evolve.

Abstract: Despite the fact that landslide-dammed lakes represent less common lake type (n = 23; 2.6 % share) in the Cordillera Blanca of Peru, these entities require appropriate scientific attention, because: (i) significantly influence geomorphological processes (erosion-accumulation interactions) at the catchment spatial scale; (ii) act as a natural water reservoirs and balance stream fluctuation on different temporal scales (daily to seasonal); (iii) may represent threat for society (lake outburst flood; LOF). The main objective of this study is to provide inventory of landslide-dammed lakes in the Cordillera Blanca, overview on their typology and discuss their geomorphological significance exemplified by two case studies. Existing, failed and infilled landslide-dammed lakes are simultaneously present in the area of interest. Three sub-types of existing landslide-dammed lakes are distinguished: (i) landslide/rockslide-dammed lakes situated in the main valleys; (ii) debris cone-dammed lakes situated in the main valleys; (iii) lakes situated on landslide bodies irrespective their location. Lakes of sub-types (i) and (ii) reach significant sizes, while lakes of sub-type (iii) do not. The dam formation of lake sub-types (i) and (iii) is usually connected with a single event, while the dams of sub-type (ii) are usually formed by several generations of debris deposition over time. It was shown, that landslide-dammed lakes in the study area are characterized by relatively low mean lake water level elevation (4,115 m a.s.l.) and large catchments (in some cases up to 80 km^2), compared to other lake types. Lakes of sub-type (ii) are predominantly situated in central glacierized part of the Cordillera Blanca, while lakes of sub-types (i) and (iii) are situated rather in the already deglaciated piedmont areas, reflecting the conditions and mechanisms of dam formation. Two illustrative examples are, further, studied in detail: rockslide-dammed Lake Purhuay close Huari in Marañon River catchment; debris cone-dammed Lake Jatuncocha in Santa Cruz valley, Santa River catchment.

Recommending Rainfall Thresholds for Landslides in Sri Lanka, page 267

Udeni P. Nawagamuwa and Lasitha P. Perera

Abstract: Triggering factors for landslides could vary from heavy rainfalls/glacial activities to earthquakes, volcanisms or even vibrations due to nuclear explosions or heavy vehicle movement. However, in Sri Lanka landslides are mostly triggered due to heavy and prolonged rainfall. During last few decades, landslides have occurred with increasing frequency and intensity, causing extensive damage to lives and properties. Therefore, it becomes a necessity to predict and warn landslide hazards before it actually takes place which is still a mammoth task to achieve. Although several researches were done based on daily rainfall data in Sri Lanka, it has been identified that the extreme rainfalls with shorter durations could trigger more disastrous landslides. Hence, recommending hourly rainfall thresholds for landslides is much important in terms of hazard warning and preparedness. In this research an hourly rainfall trend was proposed in order to predict occurrences of landslides in Sri Lanka considering hourly rainfall data from twelve hours before to any disastrous event. Special attention was paid to data from Badulla District where more than 200 people were believed to be dead due to one major landslide in November 2014. The developed relationships are compared with Caine (1980) and observed to be matching to a considerable accuracy. Obtaining hourly rainfall data at exact location was almost impossible with the available rainfall measurement procedure in Sri Lanka. Much finer conclusions could have been made with more accurate data.

Brahmaputra River Bank Failures—Causes and Impact on River Dynamics, page 273

Archana Sarkar

Abstract: The Brahmaputra River has been the lifeline of north- eastern India since ages. This mighty trans-Himalayan trans-boundary river runs for 2880 kms through China, India and Bangladesh. The Brahmaputra river system is one of the largest in the world, and majestic in multiple aspects: in the volumes of water and sediment that it gathers and passes on, the power with which these flows are routed, and the scale of changes that these powerful flows bring upon the landscape. It is ranked fourth in respect of the average discharge. The annual sediment load of 500 metric tons, that the river carries, ranks it as the second largest sediment laden river. The gradient of the Brahmaputra River varies from very steep near the source at the Tibetan plateau (1:385) to very flat in the lower part of Bangladesh (from 1:11,340 to 1:37,700). Geomorphologically, the Brahmaputra basin is very unstable as it is located in a high seismic zone. The Brahmaputra is a large alluvial river with highly variable channel morphology and a high degree of braidedness. The dominant flow regime is multichannel flow over a movable bed, which is acknowledged to be very complex. The problems of flood, erosion and drainage congestion in the Brahmaputra basin are gigantic. The bank of the Brahmaputra River is non-clayey. The composition varies in the proportion of silt and fine sand. The inhomogeneous composition of bank material along the river channel results in uneven bank slumping and subsequent bank failure. Other types of bank failures like bowl-shaped failure due to liquefaction, rotated step-like shear failure of the bank and large-scale flow failure triggered by adjacent waterlogged areas have also been observed in various reaches of the Brahmaputra River in India. The river bank failures are in turn responsible for large scale bank erosion, aggradations and widening of the river channel. This in turn is responsible for lateral channel changes of the Brahmaputra River in many reaches leading to a considerable loss of good fertile land each year. Bank oscillation is also causing shifting of outfalls of its tributaries bringing newer areas under waters. Thousands of hectares of agricultural land is suffering from severe erosion continuously in the Brahmaputra basin covering parts of states like Assam, Arunachal Pradesh, Meghalaya, Nagaland and Manipur. Frequent changes of channel courses and bank erosion with high rate of siltation have also been identified as major threats to the riverine biota as they have a great bearing on the faunal composition of the river, some of which belong to the most rare and endangered species. This in turn has a negative impact on the sustainability of the wetlands. Degradation and destruction of the wetlands have considerable impact on the deteriorating flood hazard scenario in the state. This paper outlines the types of river bank failure mechanism and erosion process in the Brahmaputra River. The paper also presents information on the river reaches of Brahmaputra suffering from high bank erosion rates and the impacts of bank erosion on the Brahmaputra basin and people of the region.

Downstream Geomorphic Response of the 2014 Mount Polley Tailings Dam Failure, British Columbia, page 281

Vanessa Cuervo, Leif Burge, Hawley Beaugrand, Megan Hendershot and Stephen G. Evans

Abstract: On August 4th 2014, the failure of the Tailings Storage Facility dam at the Mount Polley copper and gold mine in British Columbia (Canada) produced a dynamic and complex geomorphic response downstream. A Panel investigation concluded that the breach was caused by dislocation of the embankment due to foundation failure, resulting in sudden loss of containment of water and tailings. The resulting flow displayed characteristics of both debris flood and channelized debris flow. The flow travelled approximately 10 km down the Hazeltine Creek valley, eroding soil, sediment, and vegetation. A total of 237.4 ha, extending from the perimeter of the embankment downstream to Quesnel Lake, were impacted by the flow. The estimated outflow volume was 25 Mm^3. Field evidence suggests the event occurred as a sequence of pulses characterized by alternating increases and decreases in sediment concentration related to sediment supply from the Tailing Storage Facility. This investigation documents and analyzes the general downstream geomorphological response of the event in the Hazeltine Creek channel and floodplain. The study utilizes an integrated approach of geomorphological mapping, topographic analysis, historical aerial photograph analysis, and field surveys to identify and quantify the impact of the event. Data sources included: pre- and post event

satellite imagery, post-event LiDAR data, Digital Elevation Models, pre-event aerial photographs, helicopter video made by the Cariboo Regional District during failure, and field data. Applied methods and techniques comprised three main stages. The first stage was intended to determine the pre-event hydrologic and geomorphic conditions of the Hazeltine Creek pre-event channel and floodplain. Sequential historical aerial photographs along with previous technical studies were reviewed to characterize typical cross-sections and dominant geomorphological processes. The second stage described and reconstructed the event. Ten post-event channel reaches were analyzed to identify active processes during and after the event. Flow velocity was estimated at key sections. Main hydrological and geomorphological impacts observed within the flow path included large vertical knick points, removal of vegetation, changes in channel geometry and thick deposits of tailings and reworked native surficial material. The last stage involved the evaluation and quantification of flow impacts to Hazeltine Creek. Volumes of deposition were estimated through geomorphological and surficial material mapping. Net volume and maximum depth of erosion was estimated based on the difference in elevation between the pre-event floodplain elevation and the post-event surface. A qualitative slope stability analysis of river banks and valley walls was also conducted. Overall results indicate that the observed impacts of the breach and subsequent flow are comparable to those impacts resulting from extreme flood events. Finally, we discuss how the analysis of the geomorphological response of dam failure events can contribute to the design of better hazard and risk assessment guidelines.

The Sediment Production and Transportation in a Mountainous Reservoir Watershed, Southern Taiwan, page 291

Chih Ming Tseng, Kuo Jen Chang and Paolo Tarolli

Abstract: This study examined differences in landslide sediment production and sediment transportation abilities of reservoir watersheds in different geological environments after extreme rainfall. The watershed in this study covered an area of 109 km^2; the upstream river banks of the reservoir contained interbedded shale and faulted shale and had a sandstone dip slope. This paper uses a LiDAR-derived DTM taken in 2005 and 2010 to investigate the landslide sediment production and riverbed erosion and deposition in the watershed. This study also applied the conservation of mass concept to analyze the sediment outflux in the subwatersheds. The research results indicated that although the right bank, which had interbedded shale and a sandstone dip slope, had a substantially greater number of landslides, the sediment production of it was less than that of the left bank, which had numerous deep-seated landslides caused by fault zones. However, affected by the higher sediment production of the left bank and under the same stream power, the left bank subwatersheds also had higher sediment outflux.

Integration of Geometrical Root System Approximations in Hydromechanical Slope Stability Modelling, page 301

Elmar Schmaltz, Rens Van Beek, Thom Bogaard, Stefan Steger and Thomas Glade

Abstract: Spatially distributed physically based slope stability models are commonly used to assess landslide susceptibility of hillslope environments. Several of these models are able to account for vegetation related effects, such as evapotranspiration, interception and root cohesion, when assessing slope stability. However, particularly spatial information on the subsurface biomass or root systems is usually not represented as detailed as hydropedological and geomechanical parameters. Since roots are known to influence slope stability due to hydrological and mechanical effects, we consider a detailed spatial representation as important to elaborate slope stability by means of physically based models. STARWARS/PROBSTAB, developed by van Beek (2002), is a spatially distributed and dynamic slope stability model that couples a hydrological (STARWARS) with a geomechanical component (PROBSTAB). The infinite slope-based model is able to integrate a variety of vegetation related parameters, such as evaporation, interception capacity and root cohesion. In this study, we test two different approaches to integrate root cohesion forces into STARWARS/PROBSTAB. Within the first approach, the spatial distribution of root cohesion is directly related to the spatial distribution of land use areas classified as forest. Thus, each pixel within the forest class is defined by a distinct species related root cohesion value where the potential maximum rooting depth is only dependent on the respective species. The second method represents a novel approach that approximates the rooting area based on the location of single tree stems. Maximum rooting distance from the stem, maximum depth and shape of the root system relate to both tree species and external influences such as relief or soil properties. The geometrical cone-shaped approximation of the root system is expected to represent more accurately the area where root cohesion forces are apparent. Possibilities, challenges and limitations of approximating species-related root systems in infinite slope models are discussed.

Patterns of Development of Abrasion-Landslide Processes on the North-West Coast of the Black Sea, page 317

Olena Dragomyretska, Galina Pedan and Oleksandr Dragomyretskyy

Abstract: The development of abrasion-landslide processes on the north-west coast of the Black Sea depends on several factors: geological structure, slope exposure, neotectonic, climatic and hydrodynamic conditions. However, the nature of this relation is not always obvious and insufficiently studied. The goal is to identify patterns of spatial and temporal development of landslide processes in the north-west coast of the Black Sea. Methods of correlation-regression, and spectral analysis were used. Periods of activation of landslide processes depending on changing climatic and hydrodynamic conditions were determined. On the south-

west from the Odessa bay, abrasion process is described by dependence model abrasion indicators from wind wave energy, width of a beach and a precipitation. On the east from the Odessa bay the most proved model is dependence between abrasion indicators, sea level and a precipitation. Beaches have a significant role in the rate of abrasion and landslide processes. Gentle slopes at some sections of the beaches are the result of the predominance of silt and clay components in abraded loess strata of coastal slopes. All identified patterns have significant correlation coefficients (r> 0,5). It was found that the landslide processes in relation to climate and hydrodynamic impacts have a delay of 1-2 years, due to the inertia of the coastal geological system.

Part IV: Landslides as Environmental Change Proxies: Looking at the Past

Abstract: We have compiled recently published and unpublished cosmogenic 10Be exposure ages of rock-avalanche deposits and break away scars in western and southern Norway in order to compare those to the retreat of the Scandinavian ice sheet. In total 22 rock-avalanche events were dated by their deposits (19) or break away scars (3). Sampling of rock-avalanche deposits and failure surfaces was not systematic over the region but with few exceptions we sampled all deposits within the same valley. All ages were recently calculated using the CRONUS online calculator and the geochronology ensemble reveal five late Pleistocene events, eight Preboreal events, and nine younger events. The decay of the Scandinavian ice sheet was not spatially synchronous but differed regionally and lasted over several thousand years in places, hence the requirement for widespread dating targets. One rock avalanche (at Innerdalen at 14.1 ka) occurred when ice existed in the valley, which is in agreement with the latest deglacial models. Depositional characteristics of ten (44 %) of the rock avalanches suggest ice free conditions although they occurred within the first millennia following local deglaciation. Five events (22 %) occurred between 9-7.5 ka at a time when climate was warmer and moister than today. Finally seven events (30 %) appear to be relatively evenly distributed throughout the rest of the Holocene. Although limited in number we interpret that the dated events are representative of the temporal distribution of post-ice sheet rock avalanches in western Norway. However, the number of rock avalanches occurring onto the decaying ice sheet is likely underrepresented as those deposits are reworked and can be difficult to distinguish from moraine deposits. Our widespread data reveal a rapid rock slope instability response to the initial local decay of the Scandinavian ice sheet followed by a lower and constant frequency following the climate optimum (ca.8.5 ka) in the Holocene.

Abstract: Urbanization in hazardous zones, abandonment of rural and mountain areas, and changed agricultural and forest practices have increased the impact of landslides through the years. Hence, the changing climate variables, like rainfall, acted and will act on a landscape that was modified by human actions. This should be always taken into account when analysing past and future changes in landslide risk. For this purpose, we analysed the role of rainfall variation and land use change in the occurrence of landslides in Calabria in the period 1921-2010. We exploited a catalogue with information on historical landslides from June 1920 to December 2010, and daily rainfall records obtained by a network of 318 rain gauges in the same period, to reconstruct almost 500 thousand rainfall events (RE). Combining the rainfall and the landslide information, we obtained a catalogue of 1466 rainfall events with landslides (REL), where a REL is the occurrence of one or more landslide during or immediately after a rainfall event. We found that (i) the geographical and the temporal distributions of the rainfall-induced landslides have changed in the observation period, (ii) the monthly distribution of the REL has changed in the observation period, and (iii) the average and maximum cumulated event rainfall that have resulted in landslides in the recent 30-year period 1981 - 2010 are lower than the rainfall necessary to trigger landslides in previous periods, whereas the duration of the RE that triggered landslides has remained the same. We attributed the changes to variations in the rainfall conditions and to an increased vulnerability of the territory. To investigate the impact of land use changes in the occurrence of landslides, we considered two maps of land use: the "Land Use Map" made by CNR (Italian National Research Council) and TCI (Italian Touring Club) in 1956, and the "Corine Land Cover" map released in 2000. Since the landslide catalogue was at municipality scale (i.e., for each landslide we known the municipality in which it occurred), we attributed a prevailing land use class to each of the 409 municipalities of Calabria. We split the catalogue of REL in two 45-year subsets (1921-1965 and 1966-2010) and correlated the landslides occurred in the first period to the 1956 land use and the landslides occurred in the second period to the 2000 land use. We found that: land use has changed in Calabria between the two periods, with a huge decrease of arable land and an increase of heterogeneous agricultural areas and forests; in both periods, most of the landslides occurred in areas characterised by forests and arable land; in the second period, there was an increase of landslides occurred in agricultural areas and a decrease of landslides occurred in arable lands.

Abstract: Within a project aimed at understanding past catastrophic rock slope failure in the Trentino Province of Italy, we studied the Castelpietra landslide. Castelpietra encompasses a main blocky deposit, with an area of 1.2 km2, which is buried on the upper side by more recent rockfall debris. The release area is the Cengio Rosso rock wall, which is comprised of Dolomia Principale and overlying Calcari Grigi Group dolomitized limestones. 36Cl exposure dates from two boulders in the main blocky deposit indicate that the landslide occurred at 1060 ± 270 AD (950 ± 270 yr ago). The close coincidence in time of the

Castelpietra event with several events that lie within a maximum distance of 20 km, including Kas at Marroche di Dro, Prà da Lago and Varini (at Lavini di Marco) landslides, strongly suggests a seismic trigger. Based on historical seismicity compilations, we have identified the "Middle Adige Earthquake" at 1046 AD as the most likely candidate. Its epicenter lies right in the middle of the spatial distribution of the discussed landslides.

Coupled Slope Collapse—Cryogenic Processes in Deglaciated Valleys of the Aconcagua Region, Central Andes, page 355

Stella Maris Moreiras

Abstract: This paper presents coupled geomorphological processes such as glacial advances, gravitational collapses, and solifluction engaged to the environment climate changes. Complex landslides with a puzzling classification were identified by a landslide inventory of the Aconcagua Park involving the highest peak of South America (Aconcagua peak 6958 masl). These deformed deposits were interpreted as gravitational collapsed moraines occurred after the Holocene- Pleistocene ice retreat on these Andean valleys. The stabilized huge masses began to be partially remobilized by solifluction phenomena generating protalus ramparts. At present well developed debris rock glaciers are established at the top landslide surfaces. This finding confirms glacial/interglacial cycles in the Central Andes are related to glacial advances supported by preserved moraines and gravitational collapses caused by ice loss during glacial retreat. However, the occurrence of cryogenic processes after collapse could evidence a periglacial environment restoration linked to a colder period. Therefore, available debris/sediments infilling deglaciated valleys will be mainly mobilized by glaciers, slope collapses or periglacial processes depending on the climate environment conditions.

Rock Avalanches in a Changing Landscape Following the Melt Down of the Scandinavian Ice Sheet, Norway, page 369

Markus Schleier, Reginald L. Hermanns and Joachim Rohn

Abstract: Rock avalanches can form complex deposits for which the interpretation can be challenging, especially if they occur in valleys affected by other 'fast' geological processes, such as, glaciations or isostatic rebound. The mountains of western Norway enable to study rock avalanches in such a complex geological setting. Within the two valleys of Innerdalen and Innfjorddalen (~70 km afar), several rock avalanches occurred since the Late Pleistocene. The rock avalanches in Innerdalen have volumes of 31×10^6 m³ and 23×10^6 m³ and yielded terrestrial cosmogenic nuclide 10Be ages of 14.1±0.4 ka and 7.97±0.94 ka, while those in Innfjorddalen have volumes of 15.1×10^6 m³, 5.4×10^6 m³ and 0.3×10^6 m³ and yielded ages of 14.3±1.4 ka, 8.79±0.92 ka and 1611-12 CE, respectively. Although being of similar age, the rock avalanches in both valleys occurred under different environmental settings associated with the decay of the Scandinavian ice sheet. One of which fell onto a retreating valley glacier, partly depositing as supraglacial debris (Innerdalen), while the contemporaneous one fell into a fjord, partly forming a subaqueous deposit which is today exposed due to post-glacial isostatic uplift (Innfjorddalen). The younger rock avalanches fell into the ice-free valleys onto the older rock-avalanche deposits. All of the observed rock avalanches are preserved in rock-boulder deposits distributed on the valley floor and its slopes showing a variety of geomorphological features and landforms, which are diagnostic for their paleodynamics. Numerical runout modeling using DAN3D supports the landform interpretations, which are further confirmed by 10Be ages of the rock-avalanche deposits. The presented description of rock-avalanche deposits can enable a better identification and interpretation of similar deposits in other mountain areas and contributes to the knowledge of Quaternary landscape evolution in western Norway, such as, ice-sheet thickness and post-glacial isostatic rebound.

Multi-Temporal Landslide Susceptibility Maps and Future Scenarios for Expected Land Cover Changes (Southern Apennines, Italy), page 379

Luca Pisano, Veronica Zumpano, Žiga Malek, Mihai Micu, Carmen Maria Rosskopf and Mario Parise

Abstract: Landslides are among the most problematic natural hazards in Italy for casualties and economic losses. Human activities, including extensive land use practices such as deforestation and intensive cultivation, may severely affect the landscape, and have caused important changes to the extent of the natural forest in the last century. Such changes had a strong influence on the natural hazards occurrence frequency, including landslides. Being the land use one of the most significant factors conditioning slope movements, any variation in its pattern could determine changes in the landslide distribution. The Rivo Basin is located in the Southern Apennines, in Molise, a region severely affected by landslides. Previous studies have documented intense land use and landslide distribution changes in the study area from 1954 to 2003. Starting from these outcomes, in this paper we exploit the connection between the two factors, by performing multi-temporal landslide susceptibility analyses for 1954, 1981 and 2003. We prepared multi-temporal land use and landslide inventory maps, aimed at developing different susceptibility maps to evaluate the effect of land use changes in the predisposition to landslides. Further on, based upon the observed results, we address future scenarios of land use, in the attempt to assess potential future landslide distribution and susceptibility zoning in the study area. By investigating the relationship between the spatial pattern and distribution of past change, and location factors (such as elevation, slope, distance to settlements), we were able to calibrate a land use change model to simulate the future. The model was developed in Dinamica EGO, which enables high-resolution, spatially explicit, environmental simulations. To allocate changes, we used a cellular automata algorithm, where the potential for change was trained using the weights of evidence

technique. Landslide susceptibility was evaluated using the logistic regression multi-variate statistical method, by means of GIS software and statistical tools. For the susceptibility analysis, a set of conditioning factors known to be relevant for the study area, along with the land use maps compiled for the past and for the future scenarios, were used. The obtained results give important information regarding both past trends of human impact on landslide occurrence, and expected future directions. These data could be useful to provide insights toward a better land management for the study site, as well as for similar landslide-prone environments in southern Italy, contributing to establish good practices for the mitigation of the landslide risk in the future.

Part V: Student Papers

Alberto Bolla and Paolo Paronuzzi

Abstract: The bi-planar failure, sometimes referred to as "bi-linear failure", is a particular type of rupture of rock slopes that occurs when a steep rock joint intersects a discontinuity having a lower inclination and that daylights at the rock face. The bi-planar configuration requires, differently from other well-known failure types (such as planar, wedge and circular failures), a considerable inner deformation and/or rock fracturing to make the block movement and the subsequent collapse possible. In the present paper, a forward analysis has been performed on a high natural rock slope (height = 150 m) made up of stratified limestone and characterised by a bi-planar sliding surface. The slope stability has been investigated adopting a 2D finite difference analysis (FDA). Two specific failure mechanisms (1 and 2) have been identified, based on the different strength parameters assumed in the models. In failure mechanism 1, a combination of internal shear and tensile fracturing occurs so as to form a deep, curvilinear rupture surface that links the two pre-existing planar surfaces. The block kinematism is an en-block roto-translation that, in turn, causes additional internal fracturing to accommodate deformation. In failure mechanism 2, a large shear band with obsequent dip enucleates within the unstable block, thus subdividing it into two main sub-blocks with different kinematisms. Model results demonstrate that bi-planar rock slope failures are associated with internal block damage that can also determine possible inner block splitting and differential movements between the secondary blocks. Stress-strain modelling is a very effective study approach that can be used to understand the key role played by rock fracturing and inner deformation occurring during the long preparatory phase that precedes the final collapse.

Saroj Kumar Lenka, Soumya Darshan Panda, Debi Prasanna Kanungo and R. Anbalagan

Abstract: Slope instability is a major problem in hilly terrains. Stability assessment of road cut rock slopes is of paramount importance for planning and construction of infrastructures in hilly terrain. Slope Mass Rating (SMR) technique developed by Romana (1985) is a geomechanical method to assess the stability of rock slopes, that in principle uses basic Rock Mass Rating (Bieniawski 1979, 1989) and geometrical relationship between slope and rock discontinuities. In the present study, 39 rock slopes along Gopeswar-Almora road from Karnprayag to Narainbagarh in Chamoli district of Garhwal Himalayas have been studied in detail for their slope mass assessment using the mentioned technique. Based on the field observations, quartzite is the dominant lithotype with maximum of three sets of discontinuities in the study area. Meta Volcanic and Meta Sedimentary rocks are also present, but within narrow patches along the road, with phyllitic and schistose rocks. The parameters pertaining to Rock Mass Rating (RMR) and Slope Mass Rating (SMR) techniques were collected from field and laboratory studies for all the rock slopes. The basic RMR values of quarzitic rocks range between 50 and 88 whereas the SMR values vary from 07 to 84 depending upon the geometrical relationship between orientation of Slope face and discontinuities. For most of the schistose and phyllitic rocks basic RMR values are observed to be below 50 and the SMR values lie between 0 and 38. Based on the SMR values, these cut slopes were categorized in to five different failure potential classes (Romana 1985). From the results, it is inferred that out of total 39 rock slopes, six slopes are completely unstable, 17 slopes are unstable, another six slopes are partially stable, nine slopes are stable, and only one slope is completely stable. From the kinematic analysis of slope face in relation to discontinuities, it was found that planar mode of failure is the most predominant type followed by wedge mode of failure in these rock slopes. Out of total slopes, 19 slopes are prone to planar failure, 8 slopes are prone to wedge failure, 3 slopes are more likely to fail by planar mode but has significant wedge failure component, 1 slope is prone to topple failure and 8 stable slopes.

Sowedi Masaba, N. David Mungai, Moses Isabirye and Haroonah Nsubuga

Abstract: Decentralized governance is critical to reducing disaster risks. This paper evaluates the decentralized landslide disaster risk governance in Uganda. Primary data were collected through household surveys and key informant interviews conducted in the landslide disaster prone Mount Elgon district of Bududa, Eastern Uganda. Secondary data were collected through document review. Primary and secondary data were analyzed using descriptive statistics and content analysis. The study findings reveal that in Uganda, landslide disaster risk reduction is perceived as a shared responsibility between different actors and involves wider stakeholder participation that has enhanced resource mobilization. Coordination of landslide disaster risk reduction has also been streamlined. Decentralized landslide disaster risk governance however, faces several challenges, including; financial and human resource constraints, political interference, corruption, uncooperative constituents and lack of an enabling sectoral law. Decentralized governance should therefore be upscaled to achieve landslide disaster risk reduction. Future research should focus on mapping key actors and institutions using Social Network Analysis to enable better resource allocation for landslide disaster risk reduction in the Country.

Automatic Landslides Mapping in the Principal Component Domain, page 421

Kamila Pawłuszek and Andrzej Borkowski

Abstract: The availability of digital elevation model (DEM) delivered by airborne laser scanning (ALS) opens new horizons in the geomorphological research, especially in the landslide studies. This detailed geomorphological information allows for mapping of landslide affected areas using DEM data only. In order to map landslide areas in the automatic manner using machine learning classification algorithms and only DEM, generation of several DEM derivatives is needed. These first and second order derivatives provide information about specific properties of the terrain. However, involving a set of topographic features in the machine learning process increases significantly time of computations. Moreover, the topographic features are correlated since they are generated using the same DEM. The objective of this study is an in-depth exploration of the topographic information provided by the DEM data as well as the reduction of the computational time while the automatic landslide mapping. For this reason, a set of DEM derivatives have been generated and transformed into the principal component domain. The Principal Component Analysis (PCA) is a procedure that converts the set of correlated features into a set of linearly uncorrelated components using the orthogonal transformation. For the automatic landslide detection, the support vector machine (SVM) algorithm was used. The achieved results were compared with the existing landslide inventory map and overall accuracy and kappa coefficient were calculated. For the non-reduced original topographic model, we received 73% of overall accuracy. For the PCA-reduced models, accuracy parameters are not significantly worse. For instance, using only 7 principal components, which provide 90% of the total variability of the original topographic features, we received the overall accuracy of 72% while the computation time was reduced.

Geological Aspects of Landslides in Volcanic Rocks in a Geothermal Area (Kamojang Indonesia), page 429

I. Putu Krishna Wijaya, Christian Zangel, Wolfgang Straka and Franz Ottner

Abstract: This Kamojang area is an Indonesian geothermal field that produces electricity since 1983. As many other geothermal fields in Indonesia, Kamojang area is located in high relief volcanic terrain where landslides frequently occur. Hydrothermal alteration of volcanic rocks is an important geological process which reduce slope stability due to the reduction of the rock mass strength properties. Landslides in a geothermal area are hazards that can adversely affect roads, pipelines, as well as injection and geothermal wells. The aim of this study is to enhance the understanding of landslide processes in highly weathered and hydrothermal altered volcanic rock masses based on field, laboratory and numerical modelling studies. Exemplarily for this geological situation, the study site of the geothermal area of Kamojang in Indonesia was chosen. This article presents an overview of the study area and some preliminary results from a data compilation study and a field survey during this summer.

Adaptive Learning Techniques for Landslide Forecasting and the Validation in a Real World Deployment, page 439

T. Hemalatha, Maneesha Vinodini Ramesh and Venkat P. Rangan

Abstract: A forecasting algorithm using Support Vector Regression (SVR) used to forecast potential landslides in Munnar region of Western Ghats, India (10.0892 N, 77.0597 E) is presented in this paper. Forecasting for the possibility of landslide is accomplished by forecasting the pore-water pressure (PWP) 24 hours ahead of time, at different locations and across soil layers under the ground at varying depths, and computing Factor of Safety (FoS) of the slope. It is done by learning from the real-time sensor data gathered from Amrita University's Wireless Sensor Network (WSN) system deployed in Western Ghats for monitoring and early warning of landslides. We use two variations of SVR, SVR-Historic and SVR-Adaptive. SVR-Historic algorithm is trained with the data from July 2011 to December 2015 and tested for the period from January to November 2016. SVR-Adaptive algorithm is adaptively trained from July-2011 onwards and tested for the period from January to November 2016. PWP and the computed FoS from both the algorithms are compared with the actual PWP and FoS data and the Mean Square Error (MSE) for the SVR-Historic model is found to be 48.726 and 0.002 whereas the MSE for SVR-Adaptive model is found to be 12.438 and 0.0007 respectively. The PWP and the computed FoS from both the algorithms are tested for correlation using Pearson's correlation test, with 95% confidence interval and the coefficients for PWP is found to be 0.804 and 0.959 respectively with p-value of 2.2e-16, whereas for FoS it is 0.802 and 0.955 with p-value of 2.2e-16. The confidence intervals for PWP and FoS from both the models is 0.763 to 0.839 and 0.950 to 0.969 respectively. Among the two forecasting models, SVR-Adaptive model performs better with a low MSE of 12.438 and 0.0007 in forecasting PWP and the computed FoS values respectively and correlates with the real-time data ~ 95 % of the times. Application of this forecasting algorithm in real-world can thus provide 24 hours extra time for early warning which is a boon for government and public to prepare for landslides after early warnings.

Influence of Mixture Composition in the Collapse of Soil Columns, page 449

Lorenzo Brezzi, Fabio Gabrieli, Simonetta Cola and Isabella Onofrio

Abstract: The collapse and consequent spreading of a column of granular or cohesive material is a simple experiment used by many research groups to study the rheology of the soils and for calibrating numerical propagation models. This paper deals with the results of a comprehensive experimental program carried out with mixtures of sand, kaolin and water: the main aim of the program is to know and understand how the mixture composition influences the collapse and run-out mechanism. In particular,

the run-out length and the profile of the final deposit are the two fundamental characteristics taken into consideration to distinguish each test and to find a relation with the mixture composition. Four percentages of kaolin and water are considered for the experiments and different amounts of sand are added to these matrices. The main aim is the comprehension of the role of the coarser granular material in a cohesive collapsing mass. Finally, the dependency of the final runout on the aspect ratio of the initial column is discussed.

New Thoughts for Impact Force Estimation on Flexible Barriers, page 457

Daoyuan Tan, Jianhua Yin, Jieqiong Qin and Zhuohui Zhu

Abstract: Flexible barriers have received increasing attention in debris flow control because they are more economical and easier to install when compared with rigid barriers. However, in the design of a flexible barrier, the debris impact force is difficult to estimate, even if the sophisticated numerical analysis is employed. In this paper, suggestions for simplified impact force estimations are given. At first, the existing approaches to estimate the impact force for impermeable rigid barriers are modified to cater for the case of a flexible barrier. We consider that there are two key characteristics of flexible barriers when compared with rigid barriers: flexibility and permeability. Flexibility exemplifies itself in a longer duration of impact. A simple spring-mass system is used to represent the interaction of the debris flow and barrier and observed impact times are considered. It is deduced that the impact force on a flexible barrier should be less than half of that for a rigid barrier, both being impacted by the same/similar debris flow. Furthermore, for a ring net which is impacted by a debris flow of substantial mass and velocity, it is considered that the impact load is proportional to the elastic deformation of the flexible barrier in the direction of flow. Impact force calculated using the preceding assertion has been compared with the impact force in published results, and a satisfactory comparison is found. Large-scale experiments are proposed so that the validity of the above assertions can be ascertained. Permeability, the other key characteristic of a flexible barrier, can also influence the impact force as less force will be imposed on the barrier if less debris mass is retained by the barrier. Large-scale experiments are also proposed to investigate the relationship between the barrier net opening size and the debris impact force. Besides, existing approaches for estimating debris flow loading on impermeable rigid barriers are reviewed and improved by introducing a drag force which can impede the impact force. Then the largest force combination during the impact process cannot be simply determined as the largest dynamic loading or the largest earth pressure loading, and it can only be decided by calculating the largest force of all three stages.

A Check-Dam to Measure Debris Flow-Structure Interactions in the Gadria Torrent, page 465

Georgl Nagl and Johannes Hübl

Abstract: To design technical mitigation structures against debris flows in torrents it is important to define realistic design impact loads. Published impact forces were mostly derived from back calculation of past events and yielded a rough estimation. There are just a few measurements available of impact forces of debris flows on structures at the full scale. The majority of published impact forces are based on small scale experiments in the laboratories, but the transfer to real scale problems is limited due to scaling issues. Another aspect is that the dynamic force similarity is quite impossible to find of the used fluid-debris mixtures. Also the Froude number range of miniaturized measurements fits not very well to observed Froude regions found in field data. Monitoring of debris flows is necessary to understand the process and the apparent phenomena. The Gadria valley in the Autonomous Province of Bozen-Bolzano is one of the rare areas were debris flows frequently occur. Therefore the Gadria torrent is already equipped with a monitoring station to provide data to analyse the occurring debris flows. To measure the impact force of a debris flow and the variables that are necessary to calculate and understand the impact process and the debris flow/structure/ground interaction a special monitoring checkdam is designed and will be built in August 2016. The impact pressure will be measured by 14 load cells which are arranged on the upward directed front of the structure. The accelerations of the construction will be measured by a 3D accelerometer on the top. If a displacement will occur, it can be measured by two extensometers which will be mounted on the front. Also the earth pressure under the building will be monitored by 9 earth pressure cells. The bulk density will be calculated with the weight which will be recorded by two weighing devices together with the flow height. Also the shear stress can be measured in two directions additional to the pore water pressure. In future it is planned to measure the velocity distribution over the height.This arrangement of sensors should help to understand the debris flow-structure interaction to facilitate the calibration of numerical models and to improve guidelines for national standards.

Detail Study of the Aratozawa Large-scale Landslide in Miyagi Prefecture, Japan, page 473

Hendy Setiawan, Kyoji Sassa, Kaoru Takara and Hiroshi Fukuoka

Abstract: Reservoir landslides often occurred due to the water impoundment and or significant earthquakes. An antecedent factor such as continuous cracks, prolonged heavy rainfall and weathered bedrock layers might also contributed to the scale of the landslides. Hazard assessment efforts for the reservoir landslides are very important to reduce its effect to the reservoir capacity, infrastructure performance and damage as well as human casualties and economic loss. The deep large-scale landslide near Aratozawa Dam in Miyagi Prefecture was occurred in 2008 and still the initiation mechanism and motion behavior were not explained in detail up to now. This paper aims to report thoroughly the detail study of the Aratozawa landslide. We conducted several experiments to test the Aratozawa samples using the newest version of the undrained dynamic loading ring shear apparatus. As reported by Sassa et al. (2014), the ring shear apparatus was designed with the single central axis-based for the

normal stress loading system, with the normal stress and pore pressure measurement capacities of up to 3.0 MPa. The friction coefficient, shear displacement at the start and end of shear strength reduction, mobilized friction angle and steady state shear resistance of the Aratozawa samples were obtained from the ring shear tests. Experiment results implied that the shear strength reduction in progress of shear displacement of the Aratozawa samples was caused not only by the earthquake but also by the factor of the initial pore pressure (Setiawan et al. 2015 and 2016). Further analysis has been conducted by occupying soil failure parameters resulted from experiment as a critical inputs for the LS-RAPID geotechnical simulation. LS-RAPID landslide simulation model is used to observe the overall process of landslide phenomena started from the initiation to the moving process. The Aratozawa landslide was successfully simulated using the LS-RAPID model which involves the pore pressure increase, seismic loading, and the landslide volume enlargement during traveling process. However, factor of the reservoir and its relation to the groundwater and bedrock is still needed to analyze in further.

Identification of Rock Fall Prone Areas on the Steep Slopes Above the Town of Omiš, Croatia, page 481

Marin Sečanj, Snježana Mihalić Arbanas, Branko Kordić, Martin Krkač and Sanja Bernat Gazibara

Abstract: The aim of this paper was identification of rock fall prone areas above the historical town of Omiš, located at the Adriatic coast in Croatia. Unstable areas were identified by kinematic analysis performed based on relative orientations of discontinuities and slope face. Input data was extracted from the surface model created from the high-resolution point cloud. The town of Omiš is threatened by rock falls, because of its specific location just at the toe of Mt. Omiška Dinara. Rock fall risk is even higher due to rich cultural and historical heritage of the town. Collection of spatial data was performed by Time of Flight and phase-shift terrestrial laser scanners in order to derivate high resolution point cloud necessary for derivation of surface model. Split-FX software was used to extract discontinuity surfaces were semi-automatically from the point cloud data. Spatial kinematic analysis was performed for each triangle of TIN surface model of the investigated slopes to identify locations of possible instability mechanism. From the results of the spatial kinematic analysis, the most critical parts of the slope have identified for planar and wedge failure and flexural and block toppling. Verification of identified rock fall areas was performed by visual inspection of hazardous blocks at the surface model. Identified rock fall prone areas, unstable blocks and probable instability mechanisms on the steep slopes above the town Omiš, present the input data for risk reduction by efficient design of countermeasures.

Automatic Detection of Sediment-Related Disasters Based on Seismic and Infrasound Signals, page 489

Andreas Schimmel and Johannes Hübl

Abstract: The automatic detection of sediment related disasters like landslides, debris flows and debris floods, gets more and more important for hazard mitigation and early warning within the fast socio-economic development of mountain areas. Past studies showed that such processes induce characteristic seismic signals and acoustic signals in the infrasonic spectrum which can be used for event detection. So already many works has been done on signal processing and detection methods based on seismic or infrasound sensors. But up to date no system has been developed which uses a combination of both technologies for an automatic detection of debris flows, debris floods or landslides. This work aims to develop a system which is based on one infrasound and one seismic sensor to detect sediment related processes with high accuracy in real time directly at the sensor site. The developed system compose of one geophone, one infrasound sensor and a microcontroller where a specially developed detection algorithm is executed. This detection algorithm analyses the evolution in time of the frequency contend of the infrasound and seismic signals to detect events as early as possible without any false alarms. The combination of infrasound and seismic signals makes this system more robust against false alarms and enables a higher detection rate, since advantages of both methods can be used and disadvantages can be reduced (like strong dependency on the geology for seismic signals but lower disturbances due to wind; little attenuation in the air of infrasound signals but high background noise induced by wind). The use of low cost sensors like standard geophones and Electret microphones in combination with a microcontroller for data processing and as datalogger and the easy installation of this system opens the possibility for several applications. So future applications of this systems could be the protection of traffic lines, or protecting construction sites inside torrents like cleaning up a retention basin after an debris flow. Further work tries to get out more information of the seismic and infrasound signals to enable an automatic identification of the process type and the magnitude of the event. Also an extension of the system to an array is possible to identify the direction of the signals, to enables an event localisation which could be of interest especially for the detection of landslides. Currently the system is installed on five test sites in Austria, one in Switzerland and two in Italy and these tests show promising results.

Simulating the Formation Process of the Akatani Landslide Dam Induced by Rainfall in Kii Peninsula, Japan, page 497

Pham Van Tien, Kyoji Sassa, Kaoru Takara, Khang Dang, Le Hong Luong and Nguyen Duc Ha

Abstract: The Akatani landslide triggered by heavy rainfall during Typhoon Talas on 4 September 2011 is one of 72 deep-seated catastrophic rock avalanches in Kii Peninsula, Japan. The landslide is about 900 m in length, 350 m in average width and 66 m of maximum depth of the sliding surface. A rapid movement of the landslide was downward the opposite valley and formed a natural reservoir that has a height of about 80 m and a volume of 10.2 million m^3. This paper presents preliminary results of the

simulation of the formation process of the Akatani landslide dam by using ring shear apparatus incorporated with a computer simulation model LS-Rapid. Ring shear tests on Sample A1 (sandstone-rich materials) and Sample A2 (mudstone-rich materials) taken near the sliding surface indicated that a rapid landslide was triggered due to excess pore water pressure generation under shear displacement control tests and pore water pressure control tests. The pore water pressure ratio (ru) due to rainfall was monitored from 0.33 to 0.37 in the ring shear tests on rainfall-induced landslides, approximately. Particularly, the formation process of the Akatani landslide dam and its rapid movement were well simulated by the computer model with physical soil parameters obtained from ring shear experiments. The actual ratio of pore water pressure triggering landslides was 0.35 in the computer simulation model. The results of the Akatani landslide simulation would be helpful to the understanding of failure process of deep-seated landslide induced by rainfall for future disaster mitigation and preparation in the area.

Diversity of Materials in Landslide Bodies in the Vinodol Valley, Croatia, page 507

Sara Pajalić, Petra Đomlija, Vedran Jagodnik and Željko Arbanas

Abstract: Numerous landslides of different types and mechanisms are common hazardous phenomena in the Vinodol Valley (area of 64.57 km^2), situated near the City of Rijeka in the western Croatia. During the previous and present geological and geomorphological investigations almost all landslide types were identified: falls, topples, slides and flows. The Vinodol Valley is characterized by irregular, elongated shape. The northeastern and the southwestern border of the Vinodol Valley are composed of Upper Cretaceous and Paleogene carbonates. Along the most part of the NE border, the valley is surrounded by steep karstified rocky cliffs. The lower slope parts and the bottom of the Vinodol Valley are composed of Paleogene flysch deposits (sandstones, siltstones and marls in alteration), which crop out only sporadically. Flysch bedrock is mostly covered by Quaternary superficial deposits and individual sedimentary bodies of lithified talus breccias. Quaternary superficial deposits represent heterogeneous mixture of fine grained soils originating from the flysch bedrock, with fragments (cobbles and boulders) of carbonate rock originating from the steep cliffs and talus breccias. In the Vinodol Valley, more than 200 landslides formed in soils were identified. They can generally be divided into two main groups: active landslides associated with process of extensive erosion, and relatively old (> 100 years) dormant landslides. Most of the landslides are located under dense forest vegetation, and also original landslide topography of dormant landslides is significantly modified by the anthropogenic agricultural activities. For this reason, the appropriate landslide identification and mapping method is the visual interpretation of the high-resolution LiDAR-derived imagery. Landslides are generally shallow to moderate shallow, with shear plane depth of several meters, and small to moderate small, with landslide volumes in a range of 10^3 - 10^5 m^3. Due to the large number of identified landslides and diversity of geological conditions in the Vinodol Valley, the relationship between the different types of landslides and the landslide-forming materials was investigated. Sampling of soil material from the individual landslide bodies was performed with the aim of determination of index and classification properties of soils. In this paper, results of preliminary investigations are presented, respectively indicating the established relationship between types and mechanism of landslides and soil materials.

Small Flume Experiment on the Influence of Inflow Angle and Stream Gradient on Landslide-Triggered Debris Flow Sediment Movement, page 517

Hefryan Sukma Kharismalatri, Yoshiharu Ishikawa, Takashi Gomi, Katsushige Shiraki and Taeko Wakahara

Abstract: Rainfall-induced landslide might transformed into more severe disaster, namely debris flow and natural dam which both holds serious threats on human life and material. The runout distance has crucial role for determining affected areas of a landslide. Our previous research found the correlation of inflow angle and stream gradient to transformation of landslide collapsed sediment either into natural dam or debris flow. This research intended to test our previous research result with a small flume experiment and aimed to analyze the influence of sediment inflow angle and stream gradient to the sediment deposition percentages as representative of runout distance. Soil samples were taken from landslide-triggered debris flow disaster initiation zone in Hiroshima (Hiroshima Prefecture) and Izu Oshima (Tokyo Prefecture), Japan which were induced by heavy rainfall. The small flume was 10 cm width and 15 cm height, the inflow segment angle was varied to 60° and 90°, and the stream segment gradient was varied to 10° and 15°. From the experiment results, stream gradient influence the sediment movement effectively rather than inflow angle, and it was sufficient to examine the possibility of collapsed sediment to form natural dam or debris flow. Soil samples from natural dam initiation zones and consideration of water content factor are essential for further experiment.

Relative Landslide Risk Assessment for the City of Valjevo, page 525

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

Abstract: This paper represents a relative landslide risk assessment of the City of Valjevo in Western Serbia. After the extreme rainfall during the May 2014, many new landslides were triggered, and Valjevo was one of the most affected areas in Serbia. The modeling was preceded by the data selection, and included ranging and preprocessing of the conditioning factors. The following eight factors were chosen as representative: stream distance, slope, lithology, elevation, distance from hydrogeological borders, land use, erodibility and aspect. Landslide susceptibility analysis was completed using the Analytical Hierarchy Process (AHP) multi-criteria method. Validation was performed by cross-referencing with an existing landslide inventory, which was made by field mapping and interpretation of satellite images. Finally, the relative risk was determined for the City of Valjevo by using a

realistic population distribution model as a source for elements at risk. The results show the distribution of risk and suggest that 20% of the inhabited area falls into the high risk class, but this encompasses less than 5% of the total population.

Flat-slab subduction and crustal models for the seismically active Sierras Pampeanas region of Argentina, page 535

Sebastián Junquera Torrado, Stella Maris Moreiras and Sergio A. Sepúlveda

Abstract: The study area is located along the Andean active orogenic front comprising the most seismically active region of Argentina. Main Quaternary deformation is concentrated in this Western central part of the country associated with active faults linked to an intense shallow seismic activity (<30 km depth). During the last 150 years, the region has suffered at least six major earthquakes with a magnitude greater than Ms ≥ 7.0. The focus of this research is to analyse the landslide behaviour along this Andean active orogenic front. To that end, we carried out a landslide inventory along Precordillera (31º-32ºS). We analysed type, size, activity grade and other morphological parameters of these landslides. We found huge collapses coincide with traces of active Quaternary faults in this region. However, landslides are clustered being denser splayed in the centre of study area. Furthermore, activity grade of such landslides is higher in this central zone decreasing gradually towards the north and the south. This central area is affected by the Juan Fernandez Ridge which is likely related to higher deformation rate.

WLF4 Photo Proceedings

Category I: Landslides from above (aerial photos)

I-1. San Andrés megalandslide detachment plane, El Hierro, Canary Islands

Jan Blahut

Photo abstract: This photo was taken using DJI Inspire Pro UAV during field mapping of the megalandslide detachment plane on the volcanic island of El Hierro, Canary Islands, Spain. The detachment plane is formed by well visible fault plane, which is being monitored since 2013. The megalandslide is generally considered as an aborted one without any activity. The monitoring results however, proofed the continuous creep occurring on the detachment plane.

I-2. Landslide and debris flow in post-Wenchuan-Earthquake region

Zongji Yang

Photo abstract: Prevention and mitigation of rainfall induced geological hazards after the Ms=8 Wenchuan earthquake on May 12th, 2008 were gained more significance for the rebuild of earthquake hit regions in China. After the Wenchuan earthquake, there were thousands of slopes failure, which were much more susceptible to subsequent heavy rainfall and many even transformed into potential debris flows. An typical example can be found in the Yindongzi valley, Dujiangyan County, Chengdu City in which the fractured slope up the mountain was triggered by a downpour and transformed into subsequent debris flow which threat the community downstream, about 200 villagers were reported in that community.

I-3. Aerial view of Jemblung Landslide

I Putu Krishna Wijaya

Photo abstract: The rapid Jemblung landslide in Banjarnegara was one of the worst landslides in Indonesia since 2006 and caused 95 fatalities. Still 13 people were missing and 1308 of people had to move to safer areas. The lack of significant volcanic activity at Mt. Tegalele over the past has led to increased human settlements and economic activity along its flanks. This in turn increased the riskwhich is associated with landslides events. Concerning the Jemblung landslide the village's residential area has been developed downstream of the main scarp and runout area. The 400 m long landslide caused the destruction of a 500 m stretch of an important access road connecting the Karangkobar District, Banjarnegara. In addition, about 18 ha of farmland and settlement area were buried.

I-4. Subarctic Retrogressive Thaw Flow

David Huntley

Photo abstract: This oblique aerial photograph shows a retrogressive thaw flow on the Redstone River, Mackenzie Mountains, in the Northwest Territories of Canada. Rising summer temperatures, extensive taiga fires, increased stream erosion are triggering retrogressive thaw flows and contributing to significant changes in the northern landscape. Particularly prone to mass wasting are ice-rich glacial lake sediments and peat deposits that blanket the subarctic plains. These extensive permafrost-rich units were deposited around the receding margins of the Laurentide Ice sheet during the last Ice Age and in postglacial times.

I-5. Aerial view of the collapse at Tateno due to 2016 Kumamoto Earthquake

Kiminori Araiba

Photo abstract: 2016 Kumamoto Earthquake (Mj7.3, Mw7.0, Apr. 14) triggered many landslides around Aso Volcano. This collapse of slope is located on the somma and is one of the biggest ones, about 300m high, 200m wide. The mass, estimated to approx. 5*105m^3 in volume, destroyed a national road (running from lower left to upper right in the picture) for the interval of about 300m then completely destroyed a 205m-long bridge (having connected the national road and a road on the right bottom of the picture; abutment of the national road side is visible as a grey rectangle in the deposit), ran into a river and is considered to block the stream according to the water level record. A small pond upstream of the deposit and a flow channel were formed before this picture was taken about fourteen hours after the quake. Open cracks can be seen on the slope surrounding the head scarp which fact was considered indicating the danger of the secondary collapse. Water flow on the collapsed surface is not visible. The epicentral distance is about 20km and this slope is considered right above the seismogenic fault plane. This picture was taken through a window.

I-6. Photo of landslide in Medellin-Bogota Highway

Johnny Vega

Photo abstract: This photo shows a landslide in Medellin-Bogota Highway ocurred in the month of January, which caused a lot of economic losses in one of the most important roadway of the country. In the photo, it is possible to see the impact and magnitude of the sliding mass, then of two months of happened.

I-7. Khait Rock Avalanche

Martin Mergili

Photo abstract: This rock avalanche was triggered by a major earthquake on July 10, 1949. It destroyed the village of Khait, leading to the death of hundreds, maybe thousands of people. The same earthquake also triggered many loess landslides in the Yasman Valley (right background of the photograph), coalescing to a catastrophic loess flow.

I-8. Aerial view of the 3.6 km long Capriglio Landslide

William Frodella

Photo abstract: The Capriglio landslide (Northern Appennines, Emilia Romagna Region, Italy), activated on April 6th 2013. The landslide, triggered by prolonged rainfall and snowmelt, is constituted by two main adjacent enlarging bodies with a roto translational kinematics. They activated in sequence and subsequently joined into a large earth flow, channelizing downstream of the Bardea Creek riverbed, for a total length of about 3600 m. In the crown area, the landslide completely destroyed a 450 m sector of provincial roadway S.P. 101, and its retrogression exposed to high risk the villages of Capriglio and Pianestolla, located in the upper watershed area of the Bardea Creek. Furthermore, the fast moving landslide toe seriously threatened the Antria bridge, representing the “Massese” provincial roadway S.P. 665R transect over the Bardea Creek, the only strategic roadway left able to connect the above-mentioned villages. In the framework of the emergency management activities aerial surveys were carried out on may 5th 2013, in order to map the area covered by the earth flow.

I-9. Aerial view of the landslide and debris flow hazard at Wulai area in northern Taiwan

Ching-Fang Lee

Photo abstract: The photo was taken on Sep. 5, 2016. Typhoon Soudelor brought severe rainfall intensity in northern Taiwan in August, 2015. From AM 5:00 - 7:00, 8th August, the average rainfall intensity exceeded 80 mm/hr and the accumulated rainfall had reached 792 mm, causing regional landslide and debris flow disasters and leading to the closure of roads. For this event, both short and long-term cumulated rainfall exceed 200-year return period. The wooden building in the photo was located on the flowing path of potential debris flow torrent (Jhangshu creek, No. DF231; upstream reach of creek is at the top of photo (West)) and in front of a shallow landslide area (120 m long and 150m wide). The great amount of landslide mass and gravel almost destroyed the main structure of building during the period of Typhoon Soudelor. The weathered layer sliding from western landslide inundated the second floor of building. One can clearly observe the past sliding mass still deposits at the toe of landslide area. In addition, the culvert where at the curved channel was blocked by gravel-type debris flow. Such great impact force even removed all the vegetation and public facilities around the creek. Fortunately, No one was injured due to early evacuation in this natural hazard. The failure building is reconstructed by using steel structure instead of wood. However, some boulders of debris flow remain at the stream bed of Jhangshu creek, it may influence the downstream reach again while the storm passing. Recently, a micro-topographic feature of deep-seated landslide behind the shallow landslide was interpreted by high resolution LiDAR DTMs. The housing is still at risk for landslide reactivation although partial vegetation recovery covers this circular landslide zonation.

I-10. UAV photo of Takanodai landslide, Minamiaso village, Kumamoto Prefecture, Japan

Khang Dang

Photo abstract: The Takanodai earthquake-triggered landslide occurred in Kumamoto Prefecture, Kyushu Region, Japan. This area includes three landslide blocks on the hillslope below the Aso volcanological laboratory of Kyoto University in Minamiaso village. The largest one destroyed seven houses of the Takanodai housing complex and killed five people. After triggering by earthquake, this landslide moved at least 150 meters. This landslide has a slope angle of 11.3 degrees and an average apparent friction angle of 9.5 degrees and a maximum depth of around 20 m.

I-11. Landslide range in golden sunlight of Kyrgyz October (UAV footage)

Robert Behling

Photo abstract: Kyrgyzstan is heavily affected by constant landslide activity. Most of them occur as rotational and translational slides in weakly consolidated Quaternary and Tertiary sediments, whereas large events of more than one million cubic meters frequently occur. Because of the limited living place in the Kyrgyz mountain ranges landslides cause fatalities and severe economic losses every year. The photo of the landslide range was taken by a quadrocopter during a joint field survey of GFZ German Research Centre for Geosciences, Kyrgyz Ministry of Emergency Situations, and the Central Asian Institute for Applied Geosciences. We studied geomorphological features of landslides of different types and ages, which were identified in advance by an automated approach using satellite time series imagery (WLF4 Behling & Roessner). The objective of combining ground-based measurements, satellite- and UAV-based remote sensing is to establish a multi-scale landslide monitoring system for this region. The UAV-photo shows a approx. 5km long range of a northwestern facing slope of frequent Loess landslide occurrence. The main landslides occurred in 1994, whereas several reactivations occurred ever since. In 2016, the mass of a recent large failure stopped literally only a few meters before the city Komsomol (located right of the photo). The runout length of several landslides exceeds more than 1000m and the width is a few hundred meters. The inclination of the slope is moderate with approx. 15° to 20° at the landslide source areas.

I-12. Sokutash Loess landslide 2016, Kyrgyzstan (UAV footage)

Sigrid Roessner

Photo abstract: Kyrgyzstan is heavily affected by constant landslide activity. Most of them occur as rotational and translational slides in weakly consolidated Quaternary and Tertiary sediments, whereas large events of more than one million cubic meters frequently occur. Because of the limited living place in the Kyrgyz mountain ranges landslides cause fatalities and severe economic losses every year.

The photo was taken by a quadrocopter during a joint field campaign in October 2016 of the GFZ German Research Centre for Geosciences, Kyrgyz Ministry of Emergency Situations, and the Central Asian Institute for Applied Geosciences. We studied geomorphological features of landslides of different types and ages, which were identified in advance by an automated approach using satellite time series imagery (WLF4 Behling & Roessner). The objective of combining ground-based measurements, satellite- and UAV-based remote sensing is to establish a multi-scale landslide monitoring system for this region.

The photo shows a rapid Loess landslide occurred on 27 April 2016 in two phases; a smaller failure of 0.1km³ and a larger failure of 1.6km³ displaced material. It killed a 14-year-old boy and destroyed several buildings. The length is approximately 1000m and the width up to 350m. The perspective view of the photo nicely shows fan-like shape of the landslide toe and that the landslide mass travelled up the slope as it has going around the bends in the valley, which are both strong indications of high travel velocities. A video which captured this failure (http://blogs.agu.org/landslideblog/2016/05/01/landslide-loess-kyrgyzstan/) confirms this fluid-like behavior of the landslide mass.

I-13. Aerial view of the Poggio Baldi Landslide

Paolo Mazzanti

Photo abstract: On 19th March 2010, a 4 million m^3 landslide was re-activation in Poggio Baldi, a small village located near Corniolo, in the municipality of Santa Sofia (FC, Italy), in the Central Apennine. Its previous catastrophic activation is dated back to March 1914. The landslide caused several damages on some private houses, the interruption of the 310 State Road, and a natural dam on the Bidente River.

The landslide, whose height ranges between 480 and 810 m asl and whose length is on the order of 800 m, involved the "Marnoso – Arenacea Romagnola" Formation, made of arenite-pelite alternation [Burdigaliansup – Langhian]. Started as a structurally controlled rockslide, its evolution has been represented by a partially confined flow-like landslide affecting the material originally mobilized by the 1914 landslide.

The landslide area is now made of an active high vertical rock cliff up to 100 m high and about 250 m large, a rock debris located below the cliff and an extensive mixed rock-earth debris mobilized by the 2010 landslide.

From the 2010 event, several monitoring activities have been performed. Furthermore, thanks to the joint effort of NHAZCA S.r.l., spin-off of the University of Rome "Sapienza", the Department of Earth Sciences of the University of Rome "Sapienza" and the Municipality of Santa Sofia, the Poggio Baldi landslide has been investigated by several innovative remote sensing technologies.

I-14. Flow versus flow

Milos Marjanovic

Photo abstract: The image captures a foot of a debris flow on The Leva Reka River, at Gledićke Mt. near Kraljevo City, Serbia. A massive landsliding took place and left many of such footprints in western and central Serbia in May 2014. This one is 350m long and 80m across, with total area of about 18,000 m^2. The river was dammed for a couple of months onward (note the remaining upstream lake, to the right), until it reestablished its previous flow path. The landslide was hosted in relatively thick weathered crust of flysch deposits of upper Cretaceous age, dominated by fine-grained clastites. It was also aligned with a gully system that corresponded to a local fault zone direction. The mechanism was likely complex, assuming that rainfall of over 100mm/day triggered the flow within the saturated weathered crust, whereas the sliding followed afterwards, along the edges, where the slope balance was disturbed.

It interrupted a local road and cut-off important connection between the mountain villages (nowadays reestablished), and destroyed significant volume of forest. The site was discovered and studied within BEWARE project (http://geoliss.mre.gov.rs/beware/) and will be elaborated in PhD thesis of our colleague Jelka Krušić, who will model the flow, using detailed aerial-photogrammetric and geophysical data, as well as mechanical properties from advanced laboratory tests. The image was taken on the 1st of April, 2017, by DJI Phantom 4, carrying 1" CMOS 20Mpx sensor (FOV 84° 8.8 mm/24 mm lens).

I-15. Godzilla in Serbia-aerial photo

Biljana Abolmasov

Photo abstract: Selanac debris flow (nicknamed Godzilla) was the largest debris flow triggered during extreme rainfall in May 2014 in Serbia. In study area had fallen over 200 mm of rain during 72 h, but cumulative rainfall from April to May 2014 reached more than 480 mm per one month, which is more than half of average yearly precipitation (850 mm) in that area. The geometry of debris flow is 1.4 km long and 300 m wide (in the widest part). The failure in the zone of depletion is 30 m high and depth of material in the zone of accumulation is more than 10 m. The estimated volume of flowed material is more than 2.000.000 m^3. Generally, geological setting of the Selanac debris flow area is very complex, and implies weathered ophiolite mélange - sandstone, limestone and diabase (J2,3), and dacite-andesite aq. The process has developed along two ravines and fortunately between two villages. Material damage was on farm land and forest as well as on the auxiliary houses and no victims fortunately were reported.

I-16. Aerial view of Landslide in the BudhiGandaki valley, Nepal

Basanta Raj Adhikari

Photo abstract: This landslide has triggered by Gorkha Earthquake-2015, Nepal in the Budhigandaki Valley. The landslide has destroyed the foot trail of famous Manaslu Trekking in the Nepalese Himalaya. This landslide has also reactivated in the monsoon. The gulley formation is mainly due to heavy rainfall.

Category II: Impacts of Landslides on infrastructure of any art

II-1. Shallow landslides in the Gradaščica catchment

Nejc Bezak

Photo abstract: During the August 2014 extreme event that happened in the upper part of the Gradaščica River catchment and was very localized (summer thunderstorm) several shallow landslides were triggered. This picture shows several smaller shallow landslides that endangered infrastructure in the area. These shallow landslides were triggered by the rainfall event with a return period exceeding 100 years, where maximum 1-minute rainfall intensities were up to 288 mm/h.

II-2. Interior Plateau Translational debris slide

David Huntley

Photo abstract: This photograph is a northward view of Canada's national railway corridor crossing a very slow-moving translational debris slide in the Thompson River Valley, Interior Plateau, British Columbia. Landslides in Canada have challenged the safety and security of transportation infrastructure since the late 19th Century. Current research in the Thompson River valley provides the national railway carriers, governments and local communities with better information to predict landslide movement and reduce the risks to the environment, natural resources, national economy and public safety.

II-3. Collapse of Mt. Haguro due to 2004 Chuetsu Earthquake

Kiminori Araiba

Photo abstract: 2004 Chuetsu Earthquake (Mj6.8, Oct. 23) triggered 267* landslides around the epicenter. This collapse of slope, 200m long and 60m wide, blocked two major roads and an important tunnel. Because road connections to outside of the village, as well as lifelines along them, were perfectly damaged by landslides, most residents of the village, populated by 2,200, evacuated using helicopters. A destroyed fire engine is seen on the lower left of the picture.

II-4. The only houses left after a massive Jemblung landslide

I Putu Krishna Wijaya

Photo abstract: The Research area is located in Banjarnegara, Central Java Province, which is one of the most landslide prone area in Indonesia. Data from National Disaster Management Authority (BNPB) showed that 248 people died due to several landslide events between the 2010 and 2016 in the province of Central Java. One of them the rapid Jemblung landslide in Banjarnegara was one of the worst landslides in Indonesia since 2006 and caused 95 fatalities. Still 13 people were missing and 1308 of people had to move to safer areas. The lack of significant volcanic activity at Mt. Tegalele over the past has led to increased human settlements and economic activity along its flanks. This in turn increased the risk which is associated with landslides events. Concerning the Jemblung landslide the village's residential area has been developed downstream of the main scarp and runout area. The 400 m long landslide caused the destruction of a 500 m stretch of an important access road connecting the Karangkobar District, Banjarnegara. In addition, about 18 ha of farmland and settlement area were buried.

II-5. Rails dragged away by debris flow

Martin Mergili

Photo abstract: A massive debris flow related to a localized heavy rainfall event has destroyed a former railway bridge near Tigre Dormido in the Mendoza Valley, Argentina, and dragged away the rails nearby. The photo was taken a few days after the event in February 2016.

II-6. Impact of the Monte Beni rockslide on both the regional rodway SR 65 and the quarrying activity

William Frodella

Photo abstract: Mt. Beni (1259 m a.s.l.) is located in the Municipality of Firenzuola, in the Province of Florence, close to the Regional Road n. 65, an important linear infrastructure connecting the regions of Tuscany and Emilia Romagna along the appennine mountainous area. The eastern slope of Mt. Beni, where jointed basalts and ophiolitic breccias overlie Mesozoic limestones, had been the object of quarrying activity from the 1940's to the 1980's, when the quarry was closed for safety reasons due to evidence of occurring potentially catastrophic instability phenomena. Based on the risk scenarios a barrier was designed, in order to protect the Regional Road from rockfalls; furthermore a monitoring survey was implemented in order to stop the roadway traffic and to order the evacuation of the houses threatened by the landslide. On December 28th 2002, a rock topple–rockslide took place, involving a total volume of about 500,000 m^3. Fortunately no injured or fatalities occurred and minor structural damages were reported (two quarrying excavators were destroyed). The aerial picture, acquired on April 13th 2013, shows a remarkable example of impact of landslide on human activities.

II-7. Mexican miner town affected by landslides (Angangueo, 2010)

Victor Manuel Hernandez-Madrigal

Photo abstract: Uncontrolled development without urban planning and abrupt relief, are some factors that increase the landslide susceptibility of Mexican mining towns. The Angangueo locality, located in the central sector of the volcanic region known as TransMexican Volcanic Belt, is an example of this. Its historical center, founded in the last quarter of the 18th century on ancient alluvial-colluvial deposits, is surrounded by slopes (up to 300m high and medium slope of 40°) constituted by basaltic-andesitic lava flows and covered by a shallow intercalation of debris, silts and soils. Under supersaturation condition these superficial deposits are highly susceptibility to landslide. On February 4, 2010, during a cumulative rainfall of 300mm / 48hrs (33% of the annual precipitation) on the eastern slope of Guadalupe Hill, in the northern sector of Angangueo, the complex landslide of photography developed. These are two translational slides (contemporary?) with evolution to debris flows, whose deposit of only 2,000m^3 was enough to cause the death of 22 people located in 12 houses at the base of the slope.

II-8. Landslide "Tobut" in Lopare Municipality - The Republic of Srpska, B&H

Cvjetko Sandić

Photo abstract: Landslide in LC Lopare (Republic of Srpska, B&H) represents an unusual phenomenon of instability of the terrain in our region. In the literature, this type of landslide is called lateral spreading, without a clearly defined slip surface. It is evident that the bedrock (marls) is affected by process of sliding besides the surface part. In addition to the heavy rainfall, for development of this process, unfavorable orientation of the bedrock layers is the crucial. The total length of the landslide is between 450-500 m. The width is in the range between 200 and 300 m.

II-9. Call 199

Michele Calvello

Photo abstract: A series of landslides, debris flows and flash floods occurred between 11 and 12 January 2011 in Nova Friburgo, in the Brazilian state of Rio de Janeiro, causing hundreds of casualties. At the end of 2012 a huge rock slide hit and destroyed, once again, a road and many houses within a neighborhood of the municipality (barrio Três Irmãos). This photo was shot about six months after the landslide.

II-10. Changet landslide 2015, Kyrgyzstan (UAV footage)

Robert Behling

Photo abstract: Kyrgyzstan is heavily affected by constant landslide activity. Most of them occur as rotational and translational slides in weakly consolidated Quaternary and Tertiary sediments, whereas large events of more than 1km³ frequently occur. Because of the limited living place in the Kyrgyz mountain ranges landslides cause fatalities and severe economic losses every year.

The photo was taken by a quadrocopter during a joint field campaign in October 2016 of the GFZ German Research Centre for Geosciences, Kyrgyz Ministry of Emergency Situations, and the Central Asian Institute for Applied Geosciences. We studied geomorphological features of landslides of different types and ages, which were identified in advance by an automated approach using satellite time series imagery (WLF4 Behling & Roessner). The objective of combining ground-based measurements, satellite- and UAV-based remote sensing is to establish a multi-scale landslide monitoring system for this region.

The Changet landslide occurred in May 2015 and is located in a secondary valley. Due to its high mobility and long travel distance (650m) it reached the main valley where it caused 5 fatalities and destroyed several buildings. Thus, this photo strongly reminds us that detailed knowledge of local landslide processes is needed to model meaningful landslide risk probabilities to minimize consequences of landslides. In 2016, one year after the failure,

the school (white large building) was rebuild a few meters next to the landslide mass. So the questions remain: Is it safe enough? From where and how far can the mass of future landsides travel down the valley?

II-11. Effects of landslides on a geotechnical structure

Andrea Carri

Photo abstract: The landslide of Monte Ardone occurred after the enlargement of a road, which reactivate a quiescent old landslide. In particular, the geotechnical intervention were not correct and caused major problems, instead of solving them. The landslide bypassed the first prop wall built, so the designer decided to build an extension of this one, not mechanically anchored to the first one. The result was the overturn of the new structure.

II-12. Landslide of Pietta

Laura Spaggiari

Photo abstract: The photo shows the village of Pietta threatened by a collapse landslide.

II-13. Disruption of a fast connection road in the Montescaglioso landslide

Stefano Morelli

Photo abstract: On 3 December 2013, the SW facing slope of Montescaglioso village (Italy) was affected by a rapid roto-translational landslide (0.75 m/min) after some days of persistent rainfall. From the afternoon of 30 November to the late evening of 2 December, the cumulative rainfall was of about 155 mm, which is the 30% of the average annual quantity. Such concentrated precipitation, immediately before the event, further contributed to increase the soil saturation, which was induced by significant rainfall occurred during the month of October and November, producing a high critical state. The landslide began to move at 13:00 in a sector characterized by a shallow piezometric surface and known in the past for numerous water springs. The movement (lasted 20 only minutes) immediately involved a strategic fast connection road, progressively moved southeast and then affected the northwestern part of the slope. The landslide has a total length of about 1200 m, a width of about 880 m and covers an area of about 0.4 km^2. This event resulted in a series of trenches (up to 2–3 m wide), scarps and counterscarps, tens of meters in length and with height up to 8–10 m. In the upper sectors of the landslide, graben-type features were also present. The landslide movement determined the complete alteration of the natural drainage of the surface water, the disruption of the whole road network and the damage of some private buildings, of commercial and artisan activities.

II-14. Walking down the street ... within the Montescaglioso landslide

Paolo Mazzanti

Photo abstract: Montescaglioso (Southern Italy) is a small village located on a hilltop at about 350 m a.s.l., along the left bank of the Bradano River. On 3rd December 2013, a huge landslide occurred, affecting several damages to commercial buildings, infrastructures and private houses, as proved by displacement up to 6 meters of their foundations. The slope instability followed a main SW movement direction. It covered an area about 500.000 m^2 wide and involved an estimated volume of about 8 millions of m^3, with a presumed failure surface sited at max 40 m in depth. The landslide shows a triangular-shaped area, with a total length of about 1200 meters and a width of about 800 meters. The intense and persistent rainfall, between 5th-8th October 2013 and the 30th November-2nd December 2013, have been considered as the main trigger for the landslide event. The evidences of ground-failures were collected starting from 01.00 PM CET of the same day, firstly in correspondence of the locality “Cinque

Bocche". The deformation generated several scarps and counter-scarps, characterized by a length of few tens of meters and 7-8 meters height. The 3rd December landslide had a complex manifestation. The last phase of the movement (occurred in the night between the 3rd-4th December 2013) was characterized by a retrogressive style, causing a northward replacement of the landslide area. The slope instability has been considered as a rapid complex earth-slide (1,8 m/h≤velocity<3 m/min). Indeed, the most of the movement was involved within a period of about 15 – 20 minutes.

II-15. Lengthy debris flow in high rainfall environment

Neil Bar

Photo abstract: A very large debris flow was initiated following several days of high rainfall in a mining operation in the tropics. The debris flow started with an erosive-landslide some 400m above the pit floor. Personnel were evacuated prior to the debris flow however not all of the equipment was as fortunate. The photograph illustrates the fluidity of the debris flow. For scale, the benches are each 15m high.

II-16. Carina rock slide, Serbia

Biljana Abolmasov

Photo abstract: "Carina rock slides" were formed in layered Triassic limestone during construction stage of road IIA141 (Ljubovija-Osecina, western Serbia) in early 80' of the previous century. The road section is endangered in length of more than 500 m. The Carina rock slides occurrences were typical for cases where strike and dip direction of layered sediments are unfavorable to the road cut direction. In the case of Carina rock slide the strike direction is almost parallel for road direction (120o-300o) and the angle of deep (45o) is less than cut (slope) angle (60o). Several rock slide events were occurred since 80' but no any remedial measures were performed. Almost every winter season it is necessary to remove new rock slide material of volume from less than 1 m^3 to more than 10 m^3. After many years of road maintenance on the road valley side was formed artificial rock talus similar to the natural. Mountain side of the road cut is formed nowadays by the limestone bedding planes.

II-17. Hongshiyan Landslide and Its Dammed Lake caused by Ludian Earthquake on August 3, 2014

Kaiheng Hu

Photo abstract: The Hongshiyan landslide is located in the Ludian county, Yunnan province, China. The high rocky landslide was triggered by the Ms 6.5 Ludian earthquake of August 3, 2014, and originated on the top of a cliff with slope > 54° in the hanging wall of the seismogenic fault. The seismic load produced 150m vertical tension crack on the top of the steep slope, and then the rock mass mainly composed by limestone rapidly slid on the weak structural surface. The rocky main body was disintegrated during high speed movement and collision, and fallen into Niulanjiang river resulting in a large-scale dammed reservoir with the storage capacity of 0.26 billion m^3. The elevations at the crown and the river channel are respectively 1740 m, and 1120 m. The sliding direction is 205°, and the total volume of sliding material is 15,000,000 m^3. The dam is 83-96 m high, 750 m wide, and 360 m long. The elevation of the dam's top is 1216 m. The landslide and dam destroyed Hongshiyan hydropower plant, and endangered three reservoirs downstream of it.

II-18. Circular failure along Shear escarpment highway, Saudi Arabia

Ahmed Youssef

Photo abstract: Shear escarpment highway is located in the north of the Abha city (Tayyah valley), Saudi Arabia. It is the crucial highway in the area, more than 10,000 heavy trucks and vehicles use this highway every day. It is the only corridor that connects the coastal areas in the western part of the Saudi Arabia with the Asir and Najran Regions. The upper portion of Tayyah valley of Shear escarpment highway posed several landslide events. One of them was occurred in 2005 at a location of 18o 27\ 40.1\\ N. and 42o 26\ 31.7\\ E. This failure is a circular failure. It was partially failed leading to close the highway for few weeks. The height of the zone is about 70 m from the road level and the site moved downwards approximately 30 m covering the highway. The department of transportation (DOT) removed materials from the highway without any removing of the entire hazard zone. The rest of the hazard zone has 40 m high, 50 m wide, and 25 m thick. It is still hanging above the highway. The DOT built a retaining wall ~5 m high and 5 m from the cliff to protect the highway. Recently, the site is under high risk because some new tension cracks were recognized (in 2016) at the upper surface of the failed area and with intense rainfalls, water could migrate inside the site and lubricate the materials along the sliding plane and may cause a catastrophic event.

II-19. Damaged houses in the Jure landslide reservoir

Tien Pham

Photo abstract: A massive rock avalanche that had not occurred before was induced by heavy rainfall on 2 August 2014 in Jure village, Sindhupalchowk district, Nepal. The landslide buried a large number of houses and a secondary school, claimed 156 casualties and people and displaced 436 people in the village. While its mass movement of 4.5 million cubic meters blocked the Sunkoshi River, created a dam and induced a large volume of debris material at existing Waterway of Sunkoshi River. The landslide reservoir approximately had 50 m of depth and 11.1 million cubic meters of water storage capacity. The impounded water behind the landslide dam seriously inundated tens of houses in the upstream of the river, which forced those to relocate to adjacent areas on the upper part of the valley. Besides, by blocking a long section of the Araniko Highway, the landslide severely interrupted lifelines activities along the road from the China border for a long time. Accordingly, this disaster event was responsible for extensive impacts not only to Jure communities but also to the country.

II-20. Impact of landslides on mankind in Ganesh Tok, Sikkim, India

T Hemalatha

Photo abstract: Chandmari Hill is located in the Eastern Himalayan mountain ranges of Gangtok city, the capital of Sikkim State. Its UTM coordinates are 27°20' N, 88°33' E, and the elevation is 1459 m. The common rocks here are the Daling Group of rocks (quartzites, phyllites, dolomites), along with foliated augen gneisses having streaky character, such as the Lingtse Gneiss. Bands of weathered biotite-muscovite schist are also frequently encountered. There is thick soil overburden mixed with boulders and weathered mica gneiss. The predominant minerals include quartz, feldspar and mica. Subsidence was first observed in 1966. The landslide was fairly active during the period 1975–1976, but thereafter, it remained relatively stable until its reactivation in June 1984 as a landslide and subsidence zone. A rainfall of 211 mm in 4 hours on the night of 8–9 June 1997 triggered at least nine landslides in and around Gangtok, including one at Chandmari. Rainfall-triggered landslides occurred in July 2007 and June 2011, while an earthquake on the Sikkim-Nepal border on 18 September 2011 triggered minor debris slides. Currently, downward creep is observed here. The factors contributing to landslide occurrences include heavy rainfall, the presence of weathered rocks, the contrast in permeability in adjacent soil layers, seismic activity, and anthropogenic factors such as improper construction activities.

II-21. Landslide along the Karakorum Highway, Pakistan

Sajid Ali

Photo abstract: The Chochang landslide is located along the Karakoram highway (KKH), Pakistan. The landslide is active and has blocked the highway several times since its completion in 1979. Geologically, it is part of Kohistan Island Arc and composed of amphibolites. It has been found that it is an historical landslide (1300m*700m) whose failure was due to Kamila- Jal shear zone (500 meter wide). Due to heavy precipitation in April 2016, a part (120m*150m) of the old mass movements was triggered leading to blockage of the highway.

II-22. Slope failures of different shape and development on the representative slope of Gediminas's Hill in in the very historical centre of Vilnius

Vidas Mikulėnas

Photo abstract: Gediminas's Castle Hill is located in the very historical centre of Vilnius, which is for its outstanding universal value included in the UNESCO World Heritage List since 1994. Vilnius historic centre began its history on the erosional hills at the confluence of the Neris and Vilnia rivers that had been intermittently occupied from the Neolithic period; a wooden castle was built around 1000 AD to fortify Gediminas's Hill. The settlement did not develop as a town until the 13th century, during the struggles of the Baltic peoples against the Teutonic Order. Later it was the centre of political and economic power in Medieval Lithuania. From the point of view of recent geological processes and phenomena, the steep slope bases were affected actively by landsliding till the middle of the 20th century. The first crack on the NW slope surface was noticed in 1st February, 2016. Over a period of two months it developed into a set of different deformations and landslides. The most notable failure appeared next to the funicular. A circular crack on the surface appeared on 1st February, it developed into a landslide in a week and 12 cub. m. volume reached the building of the administration of the National Museum situated at a base of the slope. The direction of movement was parallel to the track of funicular 3.5 m away from it. Later, landslide by landslide it developed into a large failure of the whole NW slope (April, 2017). Concluding, this steep slope is very sensitive to the interaction between natural processes and human activities effecting the unique Gediminas's Hill as a part of the Vilnius historical&cultural heritage.

II-23. Gorni Voden landslide after reactivation

Stefan Frangov

Photo abstract: The Gorni Voden landslide is located near the town of Asenovgrad, Bulgaria. It was triggered in November 2014 as a result of slope undercutting for aqua park construction followed by intensive rainfall. The road connecting Gorni Voden and Asenovgrad was interrupted completely. An urgent site investigation was carried which determined the landslide dimensions – length up to 140 m, width up to 60 m, area of 8 000 m^2, slip surface at about 2.5 m and volume of more than 20 000 m^3. The slope is made of deluvial Quaternary clay in soft to medium consistency sliding on the boundary with underlying stiff Paleogene gravelly clay. In April 2015, the landslide was reactivated as a consequence of the adverse conditions - further undercutting the foot of the slope combined with heavy rainfall during the winter months. Compared to the first activation, the second landslide had more than twice its area (18 200 m^2) and the volume was increased 2.5 times to 45 300 m^3. The destructed road pavement was moved more than 30 m downslope. Typical landslide morphology was observed – hilly terrain, bended trees, ponds formed on the reverse slopes. The aqua park construction site (still in progress) can be seen at central part of the photo and the housing blocks of Asenovgrad are at far back. This example illustrates how the negative effects of a landslide can be further amplified by neglecting nature's power along with lack of proper coordination between all interested parties.

II-24. Massive Infrastructural Damages by Mantam Landslide, Sikkim, India

P Thambidurai

Photo abstract: The Mantam village of North Sikkim, India (27° 32.121'N, 88° 29.878'E) is densely populated on the river bank of Kanka which is prone to the landslide activity. The instable slope of Kanaka River banks having water seepage through foliation planes and joint planes which caused loose materials and intensive debris flow spreads over the settlements. The landslide spreads around 350m width and length of 1km. This landslide incident occurred after a heavy rainfall in the 2016 monsoon of Sikkim. The landslide has affected livelihood of resident and submerged twenty four houses including junior high school of the village by water pounding on Kanaka River due to debris block downstream side of the river.

II-25. Impact of Varecola Landslide on a mountain hydraulic structure

Dario Pezzotti

Photo abstract: The Varecola landslide, located in Cimbergo (Brescia,Italy), was formed on July 5, 2015 after heavy rainfall. About 20.000 to 30.000 cubic meeters of debris material has fallen into the Varecola stream, for 1300 m length, covering two roads and most of the riverbed. This picture focuses on three hydraulic pipes located at 1002 m a.s.l., clogged by the material, where water is forced to flow above the street. The landslide remained stable till July 2015, but debris material causes several problems to the natural water flow. A gradual recostruction of the area is expected and material will be removed in few years (starting from the 2017), using regional funds.

Category III: Landslides and Mankind

III-1. Autumn in the landslide

Marco Mulas

Photo abstract: The Corvara landslide is a complex phenomenon located in the Dolomites area (Bolzano Province, Italy). During fall 2014 the landslide experienced a re-activation with planimetric displacements up to 20 meters in 45 days. This picture was taken at the crown of one source area, where the retrogession of the landslide involved in the movement a mountain hut.

III-2. Interactions between human and erosion processes

Nejc Bezak

Photo abstract: The August 2014 extreme situation where a summer thunderstorm (140 mm of rainfall in approximately 9 hours, 1-minute rainfall intensities were up to 288 mm/h) induced intensive erosion processes and sediment transport (several shallow landslides were also triggered) in the upper part of the Gradaščica River catchment in Slovenia caused large problems for the local society (3 road bridges were destroyed and more than 40 km of road damaged). This picture shows situation in the area after this extreme event: in front is damaged road bridge, in the back several shallow landslides and large amount of woody debris.

III-3. Folisolic Slides in the British Columbia Coastal Rainforest

David Huntley

Photo abstract: Recurrent landslides, storms, floods, earthquakes and tsunamis challenge development of safe, secure infrastructure and communities in coastal northwestern British Columbia, Canada. Folisolic slide at N53.54o, W128.72o in the Kitimat fjord, British Columbia, Canada. Vegetation and organic soil (Folisol) is removed as elongate debris slides that terminate at sea level. High annual rainfall and snow fall amounts, combined with logging on steep bedrock slopes are contributing factors to slope failure. Folisolic slides are frequent small-volume events that do not generate damaging displacement waves in the fjord, although they may contribute loose woody debris and so pose a marine safety risk. Rare, large submarine slides triggered by flooding and human activities generated tsunamis that damaged port infrastructure and dwellings.

III-4. Collapse of gentle slope due to 2016 Kumamoto Earthquake

Kiminori Araiba

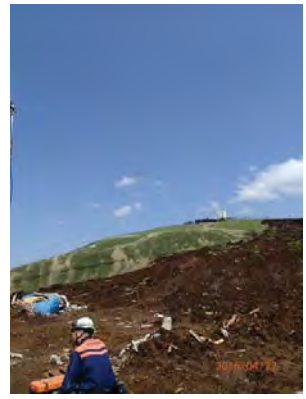


Photo abstract: 2016 Kumamoto Earthquake (Mj7.3, Mw7.0, Apr. 14) triggered many landslides around Aso Volcano. This collapse, whose head scarp was about 150m wide and 10m high, occurred on a slope with inclination about 9 degree on a lava dome covered by volcanic soil. The failed mass flowed towards three directions and one of them attacked a newly developed residential area and killed 5 persons. Apparent friction angles for these three masses were 7.6, 8.0 and 9.1. Because one person was still missing at the moment this picture was taken, the search and rescue effort was being done; the one in the picture is a fire fighter in charge of the safety management. An UAV ("drone") can be seen in the sky (upper left). This one picture shows us geology, humanity and technology concerning the landslide.

III-5. Wangjiayan Landslide

Martin Mergili

Photo abstract: The 1.4 million cubic metres landslide detached from the slope in the left centre of the image 10 minutes after the main shock of the Wenchuan Earthquake (May 12, 2008). It buried part of the town of Beichuan, but the extreme landslide velocity led to additional destruction by air blasting. Approx. 1,700 people were killed. Due do the consequences of the earthquake and the related landslides, the town was abandoned and rebuilt in another place.

III-6. Reflections at a landslide scene

Jan Maes

Photo abstract: The photo illustrates a deep-seated landslide that occurred in the rift alluvium of Bundibugyo district (West Uganda) in August 2013. This landslide was caused by prolonged rainfall during the rainy season. As a consequence, it destroyed several houses, blocked the community road and broke down a subsurface water pipe between a water tank and some houses. The local chairperson of Nyangasa village (see picture) claimed that seven households were displaced due to this landslide.

III-7. Landslide "Gulcha"

Ulan Abdybachaev

Photo abstract: The landslide is located N 40.314867; E 73.460271 (dd.dddd) in the north-eastern outskirts of the village of Gulcha (Alai region,Osh oblast, Kyrgyz Republic). At 5 o'clock in the morning on April 27, 2002 (the locals heard a rumble and a crack), the movements of an ancient landslide on the border of previously displaced soils began. Clays with fragments of limestone and gypsum are involved in the displacement. From 22 hours on April 27, 2002, the speed of the landslide movement increased. At 23 o'clock the Residential buildings began to crumble. By 7 a.m. on April 28, 2002 the landslide passed a distance of about 150 meters while destroying 48 houses. During 28/04/2002, the landslide moved at a speed of 1 m/hr on the left side, at an middle of -2.5 m/hr in the right part -3.5 m/hr. The volume of the landslide was about 14 million m^3. On April 30, the landslide movement ceased. The causes of landslide formation were deposition of atmospheric precipitation 2.3 times more than the mean annual norm and an increase in groundwater levels along tectonic disturbances.

III-8. Schools and warning “tools”

Michele Calvello

Photo abstract: An “Alert and alarm system by means of sirens” (Sistema de Alerta e Alarme por meio de Sirene) was deployed in many communities of Nova Friburgo, in the Brazilian state of Rio de Janeiro, after a series of landslides, debris flows and flash floods caused hundreds of casualties in the city in January 2011. This photo, shot in April 2013, shows a school used for two purposes within the warning system: hosting a set of sirens for disseminating the warnings, being a gathering point for people (Ponto di Apoio) during emergency phases.

III-9. Landslide Koi-Tash (view towards SE), which is situated on the left bank of Maily-Suu river, opposite the uranium tailings №5,7

Isakbek Torgoev

Photo abstract: Landslide description: Koi-Tash landslide (volume 5-7 million m^3) is located on the east (left) bank of the Maily-Suu river. The Maily-Suu river valley is situated in the south of Kyrgyzstan and characterized by a very complex geohazard situation: high landslide susceptibility is combined with a non-favorable disposition of uranium tailings. The area is underlain by Tertiary rocks (Palaeogene to Miocene, Massagetski Sequence). In terms of structural geology these rocks are building up the central part and northern limb of the Main Syncline. Moreover the Central Fault Zone passes underneath the main body of the landslide striking SW – NE. Since 1994 up to the present time Koi-tash landslide is in a state of constant displacements. The Koi-Tash landslide is moving slowly, averaging less than 40 cm per year in the upper part and about 60 cm per year in the middle part. Failure or sudden unloading of this landslide may cause river blockage and formation of an up to 20-25 m high dam. This dam will cause flooding of the areas located upstream, with consequent erosion and wash outs of tailings N° 5 and 7). Subsequent rupture of such a natural dam may induce sudden release of the impounded water creating a mud flow, impacting on the territory Mailuu-Suu sity. Destabilization of the protective layers of the tailings can bring very dangerous radioactive waste material into the river, which after flows towards the densely populated Fergana valley.

III-10. The Landslide of Boschetto (PR), Italy

Andrea Carri

Photo abstract: Boschetto (650m a.s.l.) is a small settlement located on the left slope of the valley of T. Parmossa, a tributary of T. Parma, the main watercourse of this area. The slope starts about at 800 m a.s.l and reaches the Parmossa watercourse at about 400 m a.s.l. During the spring of 2013, several other landslides became active. The high rainfall during that period caused the activation of a new portion of the debris cover, determining the enlargement of the already known, dormant landslide. The event caused the collapse of an important road and the consequent temporary isolation of the whole Parmossa valley upstream.

III-11. Folkestone

Laura Spaggiari

Photo abstract: This photo show a railway in Folkestone damaged by a landslide.

III-12. The damaging impact on working activities in the Montescaglioso landslide

Stefano Morelli

Photo abstract: On 3 December 2013, the SW facing slope of Montescaglioso village (Italy) was affected by a rapid roto-translational landslide (0.75 m/min) after some days of persistent rainfall. From the afternoon of 30 November to the late evening of 2 December, the cumulative rainfall was of about 155 mm, which is the 30% of the average annual quantity. Such concentrated precipitation, immediately before the event, further contributed to increase the soil saturation, which was induced by significant rainfall occurred during the month of October and November, producing a high critical state. The landslide began to move at 13:00 in a sector characterized by a shallow piezometric surface and known in the past for numerous water springs. The movement (lasted 20 only minutes) immediately involved a strategic fast connection road, progressively moved southeast and then affected the northwestern part of the slope. The landslide has a total length of about 1200 m, a width of about 880 m and covers an area of about 0.4 km^2. This event resulted in a series of trenches (up to 2–3 m wide), scarps and counterscarps, tens of meters in length and with height up to 8–10 m. In the upper sectors of the landslide, graben-type features were also present. The landslide movement determined the complete alteration of the natural drainage of the surface water, the disruption of the whole road network and the damage of some private buildings, of commercial and artisan activities.

III-13. Landslide stranding villagers for almost a week

Neil Bar

Photo abstract: The Yuk Creek landslide (Papua New Guinea) blocked the only roadway between the main township of Tabubil and smaller villages higher in the Star Mountains (Finalbin, Bultem, etc) and Ok Tedi mine for almost a week. The roadway was and remains the only safe and cleared access and is prone to landslide activity. The photograph depicts villagers and security personnel waiting patiently for the road to be cleared further down, while this portion is monitored with crude tape extensometers for further movement.

III-14. Landslide and landfill, Vinca, Serbia

Biljana Abolmasov

Photo abstract: Vinca landfill - The huge landslide was triggered after heavy rainfall in May 2014 within Central Belgrade City Landfill in Vinca village on the right bank of Danube river. The main scarp was approximately 500 m long and 10 m high. The landslide body was made by mixed, unsorted and unconsolidated communal waste. The estimated depth to sliding surface was between 8-10 m. It was impossible to estimate precisely landslide volume (more than 3 000 000 m^3) because width (approx. 600 m) and length (approx. 500 m) of landslide were masked by landfill material. Landslide/landfill material interrupted drainage system and maintenance infrastructure. The leakage of polluted water was endangered Danube river. UNDP RNA Team was conducted a reconnaissance of the Vinca landfill and recommended urgent remediation measures in the June 2014. Geotechnical investigations and design activities on the landfill recovery and stabilization are still ongoing activities. The photo was made on the edge of landslide main scarp within Vinca landfill body.

III-15. Livelihood by Landslide Damming in Jure Village

Tien Pham

Photo abstract: A deep-seated catastrophic landslide was triggered by heavy rainfall around 2:30 AM, Saturday morning on 2 August 2014 in Jure Village, Sindhupalchok District, Nepal. The rapidly moving landslide not only killed 156 people but it also demolished a large number of houses in the Jure community. The massive movement of the landslide rushed down to the Sunkoshi River, stopped at the toe and formed a huge natural dam with an impoundment capacity of 11.1 cubic meters. The impounded water in the upstream area induced a disastrous flood inundation that seriously affected to households living along the right bank of the river. The landslide dam was breached by overtopping and piping phenomena on September 7, 2014. Although the disaster had caused extensively human and economic losses, the damping has been providing benefits to poor people by creating a livelihood from sand exploitation activities. By damping the river course, several hundred thousands of cubic meters of sedimentary material were accumulated on the river bed behind the dam in the upstream area. For poor people in the landslide-affected area of Jure village, sand exploitation brings more economic advantages for their daily lives. This landslide case has not only shown for the first time the positive aspect on human lives but it has also presented human adaptability to landslide hazards by exploiting construction sand.

III-16. "Pirrere" quarries and unstable sea cliff in Cala Rossa bay (Favignana Island, Italy)

Roberto Iannucci

Photo abstract: In Favignana Island (Sicily, Italy) a mining activity was actuated since the Roman Age and until the last century, significantly changing the morphology of the eastern part of the Island. In fact, this mining activity produced an extensive network of open air quarries, underground quarries and tunnels, locally named "Pirrere", that are hosted into Pleistocene porous carbonate grainstones. Currently the landscape shows sea cliffs greatly modified by these abandoned quarries and affected by diffused gravity-induced instabilities. In Cala Rossa bay, the landslide process is led by a lateral spreading phenomenon due to the presence of a Pliocene clay under the Pleistocene calcarenites: the horizontal deformations affecting the clayey materials induce cracks in the overlying stiff rock, favouring the detachment of single rock blocks by typical rock landslide mechanisms (i.e. planar sliding, wedge sliding, toppling and falling).

III-17. Attabad Landslide

Sajid Ali

Photo abstract: The Attabad landslide is located along the Karakoram Highway (KKH), North Pakistan. The landslide body was composed of boulders of granodiorite of Karakoram batholith and matrix. Its occurrence resulted into burial of one big village, dammed Hunza river (20 Km long lake) and submerged the KKH (24 km). This landslide was triggered by Astore earthquake (2002; M=6.2). Due to the formation of lake around 30 village were vacated and road communication between Hunza and rest of the country was totally disrupted.

III-18. Debris Dam formed on the River Kanaka (Tributary of Tista)

P Thambidurai

Photo abstract: On 13th August 2016 the Kanaka tributary of Tista River had been blocked by the rock debris from slide on the left bank of the river at Mantam village at 4th mile on the way to upper Dzongu in North Sikkim, India (27° 32.291'N, 88° 29.664'E). The length of the slide is 875km from crown to Toe and 350m of width. The debris consists of gneissic boulders and flakes of biotites and Muscovite. The landslide caused due to heavy precipitation at high degree of dip angle more than 400 where intense weathering observed across the slope. At the time of landslide, debris flow has made 65 meters

height of dam structure on the River Kanaka, it caused water pounding around 3.0km on upstream side, submerge of bridge, threat to down streams areas for flooding.

III-19. Rock landslide in Gambatesa mine gallery, northern Italy

Matteo Del Soldato

Photo abstract: The landslide is located into the fifth level, at 595 m above sea level, of the Gambatesa Mine in the hinterland of Genoa, western Liguria (northern Italy). In this mine was exploited the Manganese ore until 2011, found into the Jurassic Cherts of the Ligurian Ophiolitic Sequence since the end of the nineteenth century. The mine was originally set up as open pit, but subsequently galleries were excavated realizing until 25 kilometers of tunnels. They were divided in seven overlapping levels interconnected to each other by means of inclined galleries for the passage of air, material or miners. The gallery landslide-involved in the mass- movement, completely excavated into cherts, conducts to the bigger mining cavities in gallery of Europe, with approximate dimension of 220 m in length, 50 m in width and 40 m in height. This was created exploiting the largest mineralized lens, so-called ""Lente Nord" (north lense), intercepted by various levels, providing several thousand tons of manganese ore. The cause could be ascribed to the creation of several important empty spaces, also to connect the upper and lower levels very close together. An important fracture parallel to the left side of the gallery is visible with a prosecution involving the floor of the gallery. Another important separation is recognizable in the right side with a comparable displacement. These cracks allow to suppose that along the rupture surfaces the available shear strength of the rock was probably overcoming due to the drastic excavation in adjacent tunnels.

WLF4 Poster Proceedings

P1. The erosive power of rainfall

Neil Bar, Mark Reynolds

Abstract: The erosive power of rainfall has shaped our planet for millions of years. In Papua New Guinea, it is possible to see such changes in a relatively short timeframe. High volumes of rainfall in different environments induce numerous landslides across the country in both natural and constructed slopes.

P2. The updated scenario in Europe of Landslide susceptibility Vs UNESCO Cultural heritage: the PROTHEGO project

Carla Iadanza, Gabriele Leoni, Claudio Margottini, Daniele Spizzichino, Alessandro Trigila

Abstract: The present paper describes a specific research performed in the framework of the PROTHEGO project "PROTection of European Cultural HEritage from GeO-hazards" a collaborative research project funded in the framework of the Joint Programming Initiative on Cultural Heritage and Global Change (JPICH) in the Seventh Framework Programme (FP7) of the European Commission. The project (www.prothego.eu) will make an innovative contribution towards the analysis of geo-hazards in areas of cultural heritage in Europe. The aim of the project is to develop and validate an innovative multi-scale methodology for the detection and monitoring of European Cultural Heritages exposed to natural hazards, namely monuments and sites potentially unstable due to landslides, subsidence, ground settlement, as well as monument deformation. By applying this methodology to the UNESCO world heritage sites in geographical Europe (399 sites), and by integrating these data with existing landslide databases, PROTHEGO project will identify and rank the most critical cultural heritage sites over the entirety of Europe. A clear and update picture of the most endangered WHL sites at European level is carried out as useful tools for any kind of conservation and management plans as well as future conservation policies.

P3. A new method evaluating the 3D roughness of discontinuity surface in rock mass (Forun Theme 3)

Yi Cai, Huiming Tang, Tao Wen

Abstract: The surface roughness of rock mass discontinuity (RMD) has a strong influence on the mechanical properties and behaviour of rock mass, which can affect the rocky landslide stability. In order to obtain the evaluation index with a clear geometric meaning, the PAP (Projection Area Percent) was put forward as a new evaluation index, which was associated with the shear failure mechanism of the RMD. Based on the 3D laser scanning technology and the Matlab programming, the 3D geometric model of the RMD was built and PAP was calculated. Via an engineering example, the process and effect of PAP computation were presented and studied.

P4. Rockfall hazard mitigation using ditch charts modeled with CRSP-3D (part of session 3.3)

Jorge Yepes, Candida Garcia-Gonzalez, Miguel A. Franesqui

Abstract: Rockfalls on roadways are a serious hazard to users. Many resources are invested in rock slope maintenance and measures of stabilization and protection to mitigate the risk.

Catchment areas (ditches) are one of the least expensive and most effective protective measures to contain and restrict rockfall onto roadways. While their effectiveness depends directly on their design criteria, previous studies have mainly been limited and based on empirical studies. Ritchie (1963) drew up the first design charts and tables, establishing the impact distance of a rockfall as a function of the slope height and steepness. Though his work is still accepted, it has some significant limitations: his design relies on such a deep, steeply sloped ditch that it reduces road safety, restricts the slope geometry and complicates the maintenance of these catchment areas. Pierson et al. (2001) created new graphic charts based on real rockfall tests carried out on different slope-ditch arrangements, but their research presents certain drawbacks: the examined situations are limited to a specific type of material, shape and possible rock size, the dimensions proposed to obtain certain percentages of rockfall retention are very large and, in most cases, the costs are unreasonably high.

This present research complements previous studies by using a CRSP 3D computer simulation model (Colorado DoT, USA) and analyzing a wider number of slope-ditch arrangements and input parameters: (A) 5 talus heights, 5 slope gradients and V-ditches with 3 foreslopes. The highest slopes (≥18m) have an intermediate 1 m bench at 12 m height. (B) Different kinds of materials are handled: 4 bedrock lithologies, two of them for the slope (hard rock and soft rock), one for the ditch (concrete) and the other for the road pavement (asphalt). The properties of these materials (density, elasticity, roughness) have been established according to the CRSP 3D methodology and adapted to previous empirical knowledge of each material. (C) A wide array of blocks was studied considering various possible combinations of geometries (cube, cylinder, sphere) and sizes (0.31, 0.62 and 0.94 m). A total number of 270 different cases for hard rock and 180 for soft rock have been evaluated. (D) Rocks are released randomly (along the whole slope) and the initial velocity is zero.

As a result of the numerical analysis, a set of practitioner-friendly charts were drawn up, not only for infrastructure planning and design tasks, but also to evaluate existing catchment area effectiveness and to reduce rockfall hazard. The proposed design charts offer an estimation of the dimensions required for the ditch, depending on the relation between the optimal stop distance and the cumulative percentage retained along the trajectory, satisfying specific retention requirements (95%).

P5. Analysis of the rockfall stop-distance factors with CRSP-3D in volcanic talus (part of session 3.3)

Jorge Yepes, Candida Garcia-Gonzalez, Miguel A. Franesqui

Abstract: The costs associated with rockfall risk are high. Many resources are invested in rock slope maintenance and stabilization, and protection measures to reduce rockfall hazards on transport infrastructures. However, few studies aim to evaluate the relative influence of the different factors (geometrical and material properties) affecting falling rock trajectories and the efficiency (retention capacity) of catchment areas. Numerous factors influence both the characteristics of rockfall motion, and their impact and stop-distance. Ritchie's empirical research (1963) was the first to identify these characteristics and determine the expected impact distance of rockfalls depending on slope geometry. Later studies showed that Ritchie's results were not as conservative as previously thought, and also that it was hard to apply his ditches on roadways due to their excessive depth (dangerous for vehicles) and width (expensive construction and maintenance). The Ritchie ditch has therefore been improved by computer simulation programs, and the proposed use of concrete walls or fences at the edge of the road. Optimization of the catchment area geometry requires systematic and quantitative analysis of the effect of each factor on rock stop-distance through application of a simulation model. With this aim, this study applies a CRSP 3D computer simulation model (Colorado DoT, USA) considering 75 different configurations of slope-ditch geometries, 4 types of materials and 9 size and shape combinations of falling rocks. In all we examined 270 different cases for hard rock and 180 for soft rock. A statistical analysis was performed with the simulated rock stop-distances to assess the different variables affecting rockfall motion.

P6. Risk analysis of debris flow on public expressway in Korea using GIS

Beom-Jun Kim, Kyung-Suk Kim, Chan-Young Yune, Sang-Don Lee

Abstract: The prediction of debris flow hazard is difficult because of complicated triggering and flowing mechanism of debris flow. Especially, debris flows occurring around expressway should be treated with extra caution because it can produce severe damage to high-speed cars and drivers inside. Also the blocking of expressway for several hours can additionally cause substantial indirect cost. For the effective prevention of debris flow hazard on expressway, potential basin areas vulnerable to debris flow need to be selected and a quantitative risk assessment should be conducted for those basin areas beforehand. In this study, the risk assessment of debris flow on 3,062 sites (2,454km) of public expressway was conducted by the risk evaluation method suggested by Korea Expressway Corporation. Based on the risk assessment, basin characteristics of high and low risk areas around expressway were analyzed. Analysis results showed that the basin area at 958 sites (31%) out of total 3,062 sites were at high risk for debris flow. And they have a higher inclination than low risk area for both basin and stream channel.

P7. LANDSLIDE STABILIZATION BY INNOVATIVE ELECTROPNEUMATIC DRAIN® SYSTEM (Forum Theme 3)

Youssef Chahid, Sebastien Bomont, Alessio de Melas

Abstract: The Electropneumatic Drain® is an annotative technique in deep drainage developed by our company TPGEO, mainly to stabilize landslides by pumping the underground water within vertical wells reaching all the aquifer to treat. The system manages ground water lowering up to 40 m, at flows of 0 – 1.0 l/s per well and permeability of 10-5 – 10-7 m/s.

P8. Landslide displacement prediction using the GA-LSSVM model and time series analysis: a case study of Three Gorges Reservoir, China (Forum Theme 4)

Tao Wen, Huiming Tang, Yi Cai

Abstract: Predicting landslide displacement is challenging, but accurate predictions can prevent casualties and economic losses. Many factors can affect the deformation of a landslide, including the geological conditions, rainfall, and reservoir water level. Time series analysis was used to decompose the cumulative displacement of landslide into a trend component and a periodic component. Then the least squares support vector machine (LSSVM) model and genetic algorithm (GA) were used to predict landslide displacement, and we selected a representative landslide with step-like deformation as a case study. The trend component displacement, which is associated with the geological conditions, was predicted using a polynomial function, and the periodic component displacement which is associated with external environmental factors, was predicted using the GA-LSSVM model. Furthermore, based on a comparison of the results of the GA-LSSVM model and those of other models, the GA-LSSVM model was superior to other models in predicting landslide displacement, with the smallest root mean square error (RMSE), mean absolute error (MAE), and mean absolute percentage error (MAPE). The results of the case study suggest that the model can provide good consistency between measured displacement and predicted displacement, and periodic displacement exhibited good agreement with trends in the major influencing factors.

P9. Debris flow in Vrátna dolina Valley: field investigation and the causes of a recent disaster

Róbert Jelínek, Pavel Liščák, Andrej Žilka, Mário Olšavský, Michal Sentpetery, Ivana Pešková

Abstract: On July 21, 2014, after extremely intense rain-storm, an enormous debris flow evolved, fed by tens of small landslides in the uppermost parts of a cirque-shaped valley in Vrátna.

In addition to the field research, airborne laser scanning and photogrammetry were used in order to generate a very precise DMR of the territory with an area of about 4 km^2 affected by this event. The DMR has enabled to elaborate very precise landslide and debris flow map of the area on the updated geological map.

In the geological setting of the area Tatricum and Fatricum rocks are present. The greater part of landslides and their head scarps land were located mainly in the youngest rocks of the Fatricum sequence (Tithonian - Neocomian marly limestone of the Mráznica Fm.) with inclination 25 °- 35 °; in general to the W up to N.

Quaternary sediments are represented by colluvial sediments of varied lithological composition of rocky debris through loamy stone rubble up to deluvial loams. In fact colluvial sediments cover the major part of the area; their thicknesses, however, generally do not exceed 2 m.

Engineering geological conditions of the territory are derived from the geological setting. Formerly it had been postulated that the northern slopes of Chleb represent glacier cirque of fan-shaped form. Baliak et al. (1981) recognized that the northern flank of Chleb Peak is a slope deformation in a form of a rock slide along predisposed stratification planes. The maximum length of rock accumulation is 1400 m (NS), the maximum width of 700 m (EW), the maximum thickness is about 30-50 m.

Altitude difference between the head scarp and toe of the slide is 600 m. In the head scarp two main horseshoe-shaped escarpments have formed. One of them reaches to the Chleb summit and strongly violates its original dome shape. The maximum height of escarpment rock walls is 50 m. Sliding, or collapse of Jurassic limestone rock masses took place along the shale strata of the Carpathian Keuper (Upper Triassic). As in dozens of cases in Mesozoic mountains of Slovakia, the rigid, tectonically broken blocks of Jurassic limestone, lying on a plastic Keuper shale strata, have induced the formation of slow creep deformation, which over time transformed into a large-scale rockslide.

Colluvial deposits are characterized by large lithological variability depending on the basement rock. On marly sediments of the Mráznica Fm. loamy-stony and clayey deluvia are developed. In these deluvial sediments below the ridge of about 1600-1500 m a.s.l. activated debris flows.

The slope movements along the planar slip surface were conditioned by the favourable inclination of bedding/foliation. Within the detachment areas of these landslides of rather small thickness broke away quite small, but numerous "plates" of sliding material (with an area of several hundred m^2), which were generally moving at a speed of several meters per second, preferentially down avalanche chutes, often above strongly wetted vegetation cover (grass, blueberries).

Approximately 800 meters from the lower lift station Vrátna the thickness of a rolling mass of water-rock-earth-trees was measured on upright trees. It seems that the thickness of the flow here achieved up to 2m - at the time of inspection (July 28, 2014) the creek reached a depth of mere 20 cm. A flow of a mixture composed of water-clay-stones continued down the narrow valley. It absorbed also bottom fills, which had accumulated in the previous period. From the tributaries joined similar, although smaller, debris flows. Most of them eroded valleys down to the bedrock. Approximately at a distance of 560 m from the cable car station 2 main debris flows joined together (funnel-like confluence). Moreover from the surrounding slopes there was a mobilization of rocky debris that contributed to the material of the debris flows. In these parts of the area rock falls of fragments and blocks likely occurred. In many trees that remained intact stand are registered fresh incisions on the bark, no doubt due to the impacts of fragments and blocks (at a height of up to 2 m above surface), which also contributed to the material of debris flows.

The total cubic capacity of the displaced material is estimated at a minimum of 100 000 m^3. The toe of the debris flow reached the cable line terminal, which indeed experienced property damage, but without any serious static damage to buildings and poles line.

P10. The difficulty of obtaining field data for landslides, due to its diversification in tropical humid environment, the case of the coast of São Paulo, Brazil

Carolina Perdomo, Estefano Gobbi, Francisco Ladeira

Abstract: Brazil has observed an increase in both frequency and intensity of landslide events. Brazil is a country of great extension, and is divided in 5 regions, South, Southeast, Center-West, North and Northeast, the Southeast region suffers most from the events of landslides, in addition to being the most densely occupied. The study area is located on the coast of the State of São Paulo, which is cut by the Tropic of Capricorn, covering two different municipalities, but which have the same geomorphological and climatic characteristics. The work aims to show how a place that presents the same characteristics of the environment, the soils can be so different. Both in relation to the municipality itself and in relation to the other, the granulometric difference found in the studied profiles is quite significant, showing the difficulty of using data from pedological charts in tropical humid environments with geological diversity, such as the studied area.

P11. Land-cover of landslides in rural commune; the Outer Carpathians, Łososina Dolna commune, Poland

Pawel Kroh

Abstract: Land use of landslides is still a poorly investigated problem. Landslides cannot be regarded as areas unsuitable for use since they occupy a significantly large surface. The Łososina Dolna municipality in the Outer Carpathians is characterized by a very large number of landslides (16% of the total area, about 500 landslides). Land-cover analysis of this agricultural and forest municipality showed a relatively similar structure of land-cover types on areas affected and unaffected by landslides. Six categories of land cover: forest, woodland, agricultural fields, meadows, orchards and built-up areas occupy in total 98% of landslides and 89% of the municipality. On landslides forests had an 11% higher and agricultural fields a 3% lower share in land cover compared to the whole municipality area. The shares of other types of land cover, such as built-up areas, orchards, and shrubs, were very similar, with not more than a 1% difference. This indicates that despite the occurrence of landslides, these areas can still be used for economic purposes, and on sites under extensive management (e.g. meadows and pastures) landslides may cause no land-use changes.

P12. FLOW-LIKE LANDSLIDES VS DEBRIS FLOOD: CASE STUDIES FROM CAMPANIA (SOUTHERN ITALY) (Forum Theme 4)

Antonio Santo, Nicoletta Santangelo, Luciano Picarelli, Melania de Falco, Giovanni Forte

Abstract: The study focused on two peculiar phenomena occurring in the carbonate ridge context, represented by flow-like landslides (namely debris flow, debris avalanche and flowslides sensuHungr et al., 2014) and debris flood events (sensu Hungr et al., 2014).This study is a first attempt to identify and quantify the similarities and the differences for both phenomena, considering the main events occurred in Campania in the last decades (Di Crescenzo & Santo, 2005; Santangelo et al., 2012). Our goal is to point out the main differences in terms of triggering, propagation and depositional phase and more importantly in terms of velocities, impact forces and associated damage. As a consequence, these differences have to be accordingly accounted for the definition of the most appropriate risk mitigation strategies.

P13. Rock avalanche and a rock glacier: a compound landform study from Svalbard

Filip Hartvich, Jan Blahut, Josef Stemberk

Abstract: A study of rock block accumulations situated at the foot of Rotjesfjellet ridge on the northern side of the Hornsund fjord showed that the block accumulations are not always only the widely known post-glaciation period rock glaciers, but that there are other influences on their formation. Detailed study of one particularly unusually shaped block accumulation employed morphometric profiling and terrain analyses, lichenometry, Schmidt hammer measurements, geophysical measurements using electric resisitivity tomography and geodetic measurements using terrestrial LiDAR. While the morphometric analysis of detailed (0,5 m) DEM and relief profiles showed distinctly unusual morphology and suggested possible explanation of the sequence of events. The electric tomography revealed ice core in the accumulation and the Schmidt hammer we were able to establish younger age of the lobe-like left part of accumulation and finally, the lichenometry helped us to place the event on the approximate position on the timescale. In conclusion, we have explained the unusual block accumulation as a result of two consequent processes, as after formation of the rock glacier a large rockfall occured, adding material and deforming the NW part of the accumulation. We estimate the rockfall event to be 250 +/- 50 years old.

P14. Predictive performance of rainfall thresholds for shallow landslides in Switzerland (Forum Theme 3)

Elena Leonarduzzi, Peter Molnar, Brian W. McArdell

Abstract: In Switzerland floods are responsible for most of the damage caused by rainfall-triggered natural hazards (89%), followed by landslides (6%, ca. 520 M Euros) as reported in Hilker et al. (2009) for the period 1972-2007. The prediction of landslide occurrence is particularly challenging because of their wide distribution in space and the complex interdependence of predisposing and triggering factors. The overall goal of our research is to develop an Early Warning System for landsliding in Switzerland based on hydrological modelling and rainfall forecasts. In order to achieve this, we first analyzed rainfall triggering thresholds for landslides from a new gridded daily precipitation dataset (RhiresD, MeteoSwiss) for Switzerland combined with landslide events recorded in the Swiss Damage Database (Hilker et al.,2009). The high-resolution gridded precipitation dataset allows us to collocate rainfall and landslides accurately in space, which is an advantage over many previous studies.

Each of the 1670 landslides in the database in the period 1972-2012 was assigned to the corresponding 2x2 km precipitation cell. For each of these cells, precipitation events were defined as series of consecutive rainy days and the following event parameters were computed: duration (day), maximum and mean daily intensity (mm/day), total rainfall depth (mm) and maximum daily intensity divided by Mean Daily Precipitation (MDP). The events were classified as triggering or non-triggering depending on whether a landslide was recorded in the cell during the event. This classification of observations was compared to predictions based on a threshold for each of the parameters or a combination of them such as in the intensity-duration curve. The predictive power of each parameter and the best threshold value were quantified by ROC analysis and statistics such as AUC and the True Skill Statistic (TSS).

By applying the method to define an intensity duration power law threshold, a maximum TSS of 0.67 was obtained for: intensity = 18.3*duration-0.21.

The analysis was repeated for sub-regions of the country based on erosivity and climate, using MDP and erodibility (Kuehni and Pfiffner, 2001), or a combination thereof, in the classification. While the performance improved only slightly compared to the country-wide analysis, the regional maximum daily intensity thresholds varied greatly among classes, with differences of up to 43 mm/day, showing some clear trends: the amount of precipitation required to initiate a landslide is higher in region with higher MDP and/or lower erodibility.

In order to demonstrate the quality and robustness of the results, we also show reference cases obtained by randomization of landslides in space and time, and resampling the data to equal sample size between triggering and non-triggering events (prevalence).

P15. Dynamic analysis of a landslide in Caucasus

Kai Kang, Oleg Zerkal, Andrey Ponomarev

Abstract: The area of cableway Karusel-1 in western Caucasus is always subjected to landslide hazard. For safety of cableway facilities, stability assessment of the slope at mountain foot was conducted. In addition, the seismic hazard for the studied area is earthquakes with Mmax=7.0 and intensities of up to 9 on the MSK-64 scale. Therefore, the dynamic analysis of the slope is necessary to perform in order to ensure the safety of cableway facilities.

P16. Geological condition of landslides occurrence in the Bardzkie Mountains and adjacent areas (Sudetes, SW Poland)

Rafał Sikora, Tomasz Wojciechowski, Marta Tomaszczyk, Andrzej Piotrowski

Abstract: The Sudetes are a mountain range situated on NE margin of the Bohemian Massif. They form natural border between Poland and Czech Republic. The Sudetes Mountains are poorly recognized in terms of mass movements, however our latest research shows that landslides occur often in this area. One of terrains with large number of landslides is the Bardzkie Mountains and adjacent areas. About 118 landslides were identified based on analyses of LIDAR data and cartographic field works. Geological conditionof landslides susceptibility was determined based on comparison of landslides occurrence and geo-environmental factors of the slopes. The Weight of Evidence (WoE) method was used to analyse the impact of lithology, tectonics, gradient of slopes, exposure of slopes, distance from water courses and flow accumulation. The result of the analysis is a landslide susceptibility map of the Bardzkie Mountains and adjacent areas. Landsides are concentrated in the areasof the prevalence of the Pleistocene sediments and the Upper Devonian and the Lower Carboniferous flysch rocks. Especially fault zones in the basement rocks were an important, structural factor in the landslides development. Mass movements most frequently occur on slopes of the southwestern, western and southeastern exposure and inclined in the range of 9 to 24 degrees. Also vulnerable are areas with significant flow accumulation.Larges landslides susceptibility was found in the major rivers and streams valleys (eg. Nysa Kłodzka, Ścinawka, Wilcza, Jaśnica).Geological and geomorphological factors determined the formation of different types of landslides as confirmed by field observation. All indicators show good relevant to present knowledge relation to landslide susceptibility. The only exception is the factor that describe the distance between faults and landslide scarps. Our calculation shows that the susceptibility increase with the distance from faults which is diffrent from our field study and lineaments analisys. We suppose that this difference is connected with incoherence between archival maps we used in presented study.

P17. Daily to seasonal movement patterns of a large, slow-moving landslide, central North Island, New Zealand

Charlotte Holdsworth, Samuel McColl, Ian Fuller

Abstract: New Zealand has thousands of large (> 2 ha) landslides, most of which occur in the Neogene marine sedimentary cover rocks, and many of which are active. Active landslides in New Zealand damage lifeline infrastructure, entire suburbs, agricultural land, and they deliver large but little-quantified sediment load to rivers. Previous research has indicated that both river incision over decadal to millennial timescales and seasonal rainfall patterns play a role in the initiation, movement, and long-term evolution of large landslides in New Zealand's soft-rock terrain. This research assesses how toe cutting and rainfall on daily to seasonal timescales can drive movement of a large (50 hectare) slow-moving, reactivated, translational rockslide that is severely damaging a farm in central North Island, New Zealand. Geomorphological mapping, informed by field observations and high-resolution topographic data produced by photogrammetry, was undertaken to define the landslide boundary, drainage lines and to assess zones of movements. Since July 2015, 3-monthly RTK GPS-occupations of a network of 29 survey marks, and hourly time-lapse photography of the toe of the landslide have been used to identify the distribution and patterns of landslide movement. Pixel-tracking of time-lapse photos is allowing movement to be measured at a sub-daily frequency. Movement data are being compared with river flow data (i.e. toe cutting potential) and local rainfall. Results so far reveal that block sliding occurs in the upper part of landslide (with graben development, and annual movement < 1 cm), and this transitions to more

mobile earth flow-slide behaviour towards the toe (where annual movements are > 10 m). The failure surface is exposed at the toe, which is being actively cut by a major river, and reveals a highly remoulded landslide body 1-3 metres thick, overlaying intact sandstone. Based on existing structural data and the landslide surface morphology it is assumed that the landslide thickens to about 60 m towards the head. The geomorphology suggests the entire landslide is undergoing extension (with no evidence of toe compression), suggesting near-continuous toe-unloading is facilitating movement. Movement is fastest in the winter-spring months when water tables are high due to reduced evapotranspiration and slightly greater rainfall. However, this period also coincides with a period of higher river flow and flood events (i.e. toe cutting), and the landslide appears to be particularly sensitive (i.e. surges forward) following high river flow events that cut the toe. This observation suggests that movement is driven by both local and catchment-scale rainfall events, with rainfall and toe cutting driving movement, at daily to seasonal time-scales.

P18. The Influence of Hydrological Events and Check Dams upon the Geomorphic Changes of the Meng-Gu Waterfall

Su-Chin Chen, Cheng-Wei Kuo, Feng-Jyi Chang

Abstract: Most studies of waterfalls and focused on erosion process and recession rate. The influences of depositional process upon the form of waterfalls are seldom discussed. Abundant sediment could be the tools and covers to reshape the morphology of waterfalls. The Meng-Gu Waterfall, located in the Central Taiwan, was a beautiful waterfall with two steps. After serious debris flow events, the waterfall experienced huge morphological changes. This study explored the relation between waterfall evolution and sediment disasters.

P19. Field monitoring to measure deformation of a mine waste-dump slope (part of session 3.1)

Young-Suk Song, Yong-Chan Cho

Abstract: This study surveyed and investigated the deformation of the coal waste dump slope and the natural ground slope under the waste dump at Dogye village in Samcheock city, Gangwon Province, Korea. Multiple sets of south-north tension cracks were observed at the crest of the coal waste dump slope. The size of these cracks was greater than 100 m in length, and the resulting drop head averaged 1.0-1.5 m. To investigate the behaviors of the waste dump slope and the natural slope under the waste dump, wire sensors and a rain gauge were installed at the crest of the waste dump slope, and inclinometers were installed in the natural slope of the ground under the waste dump. According to the monitoring results, the deformation at the crest of the waste dump slope steadily increased and then converged over time due to the effect of the infiltration of rain into the ground after rainfall. In addition, the horizontal deformation of the natural slope under the waste dump was affected by the accumulated precipitation. The basis of this effect is that the rate of increase of the maximum horizontal deformation tends to show increasing or convergent behavior according to the precipitation.

P20. Silk Road Disaster Risk Reduction (SiDRR)

Peng Cui, Yu Lei

Abstract: Belt and Road Initiative (BRI) is a Chinese national strategy which calls for cooperative economic, political and cultural exchange at the global level along the ancient Silkroad. The overwhelming natural hazards located along the belt and road bring great challenges to the success of BRI. In this framework, a 5-year international program was launched to address issues related to hazards assessment and disaster risk reduction (DRR). The first workshop of this program was held in Beijing with international experts from over 15 countries. Risk conditions on Belt and Road Countries (BRCs) have been shared and science and technology advancements on DRR have been disseminated during the workshop. Under this program, six task forces have been setup to carry out collaborative research works and three prioritized study areas have been established. This workshop kicked start this program which involved partners from different countries including Pakistan, Nepal, Russian, Italy, UK, Sri Lank and Tajikistan. The program adopted the objectives of Sendai Framework for Disaster Risk Reduction and Sustainable Development Goals and was implemented to assess disaster risk in BRCs and to propose suitable measures for disaster control which can be appropriate both for the individual country and for specific sites.This poster points out current progress and opportunities for the near future international cooperation on this matter.

P21. Stability Analysis of Potential Rock Slides in El Rincón Cliff (GC-2 Highway, Gran Canaria, Spain) (part of session 2.2)

Martín J Rodríguez-Peces, Jorge Yepes, Moises Martin-Betancor

Abstract: In this work we have found landslides that may be developed in El Rincón cliff (Gran Canaria) and its impact on the GC-2 highway, at the base of the cliff. The stability analysis performed for the current conditions indicates that the slope is stable. The long-term analysis considers the water-saturated rock mass and defines the presence of two rocky blocks that are most likely to experience sliding, one along the mid-slope and another in the head. The mid-slope landslide would be favored by failure through the Formación Detrítica de Las Palmas, while the landslide located on the head of slope would have a more superficial

character and would be favored by the failure through the pyroclastics of the Post-Roque Nublo Group. The landslide of the block of the top seems more likely since it only requires the saturation of the pyroclasts and is favored by the reduction of strength related to the progressive opening of the sub-vertical cracks.

P22. Evolution of the Pajonales Landslide (Tirajana Depression, Gran Canaria): a Case of Advancing Landslide (part of session 2.2)

Martín J Rodríguez-Peces, Jorge Yepes, Cristina Fonollá, Alejandro Lomoschitz, Meaza Tsige

Abstract: We studied the evolution of different stages of the Pajonales landslide (Tirajana Depression, Gran Canaria), based on geotechnical research on both in situ and mobilized volcanic matter. The deposit extends over 560 ha and has been reactivated on several occasions, some during the 20th century. The landslide comprises four large bodies that have successively broken away from a single initial rock mass. The main scarp affects the lava flows with intercalations of pyroclastic matter of the Roque Nublo Group and later volcanic activity (5.5 Ma to present-day). The basal surface of the landslide developed in old rocks of the Mogán Group (14.0-13.3 Ma), which are rhyolitic and trachytic ignimbrites with hydrothermal alteration related to the infilling of the Tejeda caldera. This alteration caused silty-clay layers with a low friction angle, high plasticity and expansive behavior. We collected representative samples of pyroclasts and soils from landslides and performed laboratory tests to identify them and to determine unit weight, grain-size, plasticity, and shear strength. We reconstructed the morphology of the slope prior to sliding taking into consideration the location of first and second generation failure surfaces and scarps. We used limit equilibrium analysis software to identify failure surfaces for each stage of sliding. These surfaces developed through clayey-silt levels resulting from the alteration of pyroclastic materials, showing the most unfavorable geotechnical parameters (minimal or residual values). Moreover, the presence of water is a triggering factor, since total or partial saturation of the materials is required. Finally, the landslide is of the advancing type: as successive reactivations occur, the sliding masses are broken down into smaller ones moving towards the Tirajana ravine.

P23. Evolution of Landslide Susceptibility Patterns in Areas of Rapid Urban Development. Case Study Lanzhou City, Northwest China

Jewgenij Torizin, Lichao Wang, Michael Fuchs, Bin Tong, Dirk Balzer, Tingshan Tian, Dirk Kuhn, Liqin Wan, Ang Li, Liang Chen

Abstract: Lanzhou is a city with 3.5 million inhabitants, situated at the western margin of the central Loess Plateau. Since 2001, the city is under rapid urban development by cut and fill activity of the loess mountains and greening, associated with enormous impact on the environment. The current study investigates the evolution of the landslide susceptibility patterns from the early 1990's up to the year 2016 in the light of the anthropogenic influence. Evolution of the landslide susceptibility patterns was assessed using data-driven generative Bayesian approach. To catch the dynamic changes of the landslide-controlling conditions, multi-temporal landslide inventory, multi-temporal DEMs, morphological change detection, and historical and recent land use data were utilized. As result, three states of the landslide susceptibility pattern for the years 2000, 2012, and 2016 were estimated.

Understanding the causal relations between human activity and landslide susceptibility will allow to create scenarios and strategies for spatial panning of the new city development areas.

P24. POST EVENT LANDSLIDE MAPPING USING C– AND X– BAND INSAR DATA (Forum Theme 2)

Lorenzo Solari, Matteo Del Soldato, Federico Raspini, Nicola Casagli

Abstract: In this work we exploited the potentialities of a multi-temporal and multi-band interferometric analysis to derive the pre and post event deformations in an area affected by a large complex landslide, mobilized the 12 February 2017, in the Abruzzo Region (Ponzano hamlet). C- and X-band SAR (Synthetic Aperture Radar) data, analyzed by means of the SqueeSAR algorithm, have been used to reconstruct the development of the movement starting from 2003. The satellite data were finally compared with in situ evidences, derived from ground surveys and from a helicopter reconnaissance, to derive a post event map of the landslide. This output represents a fast way to obtain the area affected and damaged by an event, ideally suited for Civil Protection practices.

P25. Testing the awareness of landslide risk in some schools in Tuscany (Italy) (Forum Theme 5)

Laura Pastonchi, Veronica Pazzi, Stefano Morelli, Federico Marini, Luca Valori, Luca Gambacciani, Nicola Casagli

Abstract: It is sadly known that calamities related to geological hazards occur frequently all over the world, causing destruction, victims and economic losses. These phenomena, unfortunately, also affect schools. In Italy there are 51,113 school buildings (latest ministerial survey, February 2017). According to a recent report on the state of the Italian territory and school buildings (2014) approximately the 10% of these schools is located in areas subject to landslide and flood risk. Investing in activities aimed

at preventing these natural disasters is a necessity no longer negligible, even because the cost of such activity is lower than the economic effort needed to repair the damages.

This project developed a multi-hazard risk assessment in public school buildings, i.e., the evaluation of landslide, hydraulic and seismic risk. Twenty-five schools in Tuscany (central Italy) were selected as representative sample of different geo-morphological contexts, structural typologies, number and age of occupants. Six of these schools were chosen on the basis of the high landslide hazard prone area, according to the national landslide inventory (IFFI project-http://www.progettoiffi.isprambiente.it/cartanetiffi/), the landslide risk mapping of the "Piano Stralcio di Assetto Idrogeologico" (PAI), and the movements detected by satellite SAR (Synthetic Aperture Radar) data for the unstable areas.

The multi-hazard method is based on the definition of the GSC (Geohazard Safety Classification) that is obtained weighting the maximum specific risk with the resilience ($GSC=1-\max(Hi*Vi)/\rho$). The maximum specific risk of a school could be quantified on the basis of a) data collection (ancillary data and thematic maps), b) processing field data (seismic noise measures according to the H/V technique, thermographic immages and GPS surveys). The resilience is the ability of each community to resist and recover from the effects of a hazard to which it is exposed. Therefore, resilience could be a damper ($\rho>1$), an invariant ($\rho=1$) or an amplifier ($\rho<1$) of the maximum specific risk. For the aims of this work this parameter is obtained through the analysis of a questionnaire filled in by the school-population, and the quality and completeness of the school Emergency Plan and Risk Assessment Document (DVR, Italian acronym) with respect to the abovementioned geological risks. The illustrated methodology turns out to be straightforward, non-invasive and economic.

The results of this work are: i) no one of the selected school has a very low specific risk (class A of the GSC), ii) three schools have high specific risk (class D), and iii) the remaining three have very high (class E), low (class B), and medium specific risk (class C), respectively. In half of these schools the landslide risk was found to be the highest and therefore influenced the GSC value. The resilience turned out to be a risk amplifier ($\rho<1$), but only in one school the GSC is worst than the considered specific risk. The negative resilience is here due to both the lack of consideration of the landslide risk into the DVR/Emergencies Plan and the poor perception of the school personnel concerning this risk. This work also shows how the GSC can be affected by landslide risk and resilience. It is therefore evident that the knowledge of geological criticalities involving school buildings, coupled with the awareness of the community about the landslide risk, should become a common practice for minimizing the interaction of a landslide with school life and avoiding potential socio-economic losses.

P26 and P27. NEW GX GEORADAR GENERATION IN LANDSLIDE MONITORING

Željka Sladović, Zoran Mikić, Damir Halužan

Abstract: During the winter 2016/2017 geophyisical surveying with georadar MALÅ GX 80 MHz rough terrain antenna was performed in Samoborsko Gorje hills. During processing few historical landslide were noticed and analysed. Georadar signal processing workflow included data sorting, profile summation, velocities calculating based on hyperbolas, correction for elevation and interpretation. Measuring with GPR is an high frequency electromagnetic method, but data processing is very similar to reflexive seismic processing. Further analyses were performed in Opendect software that is designed for reflection seismic data analyses and interpretation. Multi-attribute analyses improved visibility of cross sections and enabled detecting timing and extension of landslides. The signal detection is up to 800 ns. After the processing the visibility of signal reached detection depth level and enable recognition of surface of rupture,main landslide body,landslide foot,scarps, ridges and faulting . GPR surveying, is a non-invasive and up to 100 m penetrating geophysical method could reduce the risks of the earthslide in the future.

P28. A landslide susceptibility map for Africa (Forum theme 2, session 4 Landslide Hazard, Risk Assessment & Prediction)

Jente Broeckx, Matthias Vanmaercke, Jean Poesen

Abstract: Understanding regional variations in landslide susceptibility is vital from a societal but also from an environmental and geomorphic point of view. Therefore, numerous local and regional studies on landslide susceptibility have been made over the past decades. However, relatively few studies focus on the continental or global scale. In addition, most of these studies for larger areas are based on relatively limited data of mapped landslides and the effect of seismic activity is often not taken into account. This is especially the case for Africa. Given that landslides form one of the deadliest natural geohazards in Africa and the fact that population growth in Africa is projected to be the highest in the world for this century, a better insight into the patterns of landslide susceptibility across the African continent is required. Therefore, this study aims at developing a first continent-wide landslide susceptibility map for Africa, that is calibrated by available landslide data that are well-distributed over the continent, and that is also tested for the effects of seismic activity. Such a map can be used as a tool to confront susceptible areas with inhabited areas to identify current areas at risk. Given the continent-wide uniform assessment of landslide susceptibility, this map allows for interregional susceptibility comparison across Africa.

As a first step, we compiled all available landslide inventories in Africa, in order to improve the robustness of our analyses, these mapped landslides were supplemented by additional landslide mapping in data-poor regions, using Google Earth. This resulted in ca. fifty different landslide inventories for more than twenty African countries, comprising a total of more than 6000 landslides. Several variables, such as slope, lithology, soil, land use, precipitation and seismic activity, were tested for their explanatory

power with respect to landsliding. As a result, a multiple logistic regression model was obtained, which was applied to construct a continent-wide landslide susceptibility map for Africa. We applied Monte Carlo simulations to calibrate this model. Further validation was carried out, with independent landslide data, not used for the Monte Carlo simulations. The results show that topography, seismic activity (peak ground acceleration) and precipitation are the most significant variables, explaining the spatial distribution of landslides all over the African continent. Interestingly, our analyses showed that also seismic activity is a highly relevant factor in simulating spatial patterns of landslides across Africa. This is surprising, given the overall low degree of seismic activity and the limited occurrence of strong earthquakes, directly triggering landslides. These observations concur with several other recent studies, indicating that earthquakes may not only trigger landslides, but can also increase landslide susceptibility (e.g. by weakening surface lithologies).

P29. Influence of diatoms content in relation to the slope deformations and soil behavior in the cuts of line constructions (Forum Theme 5)

Pavlína Frýbová, Radka Drápalová, Věra Glisníková, Alexandra Erbenová

Abstract: Within the field of geotechnics, diatom clay soils are considered as one of the risk groups of soils because of their specific mechanical behaviour. Clay properties have been investigated depending on the content of diatoms. To investigate the effects of diatom microfossil content on the index properties of clay soils, measuring tests were performed on cohesive soils with different diatom microfossils content. Based on the observed nature of the soil's behaviour, it was possible to design a simulation of the mixture's behaviour for an established amount of diatoms in the mixture.

P30. LANDSLIDE DAMMING IN A HIGH RISK AREA

Guido Paliaga, Fabio Luino, Francesco Faccini, Laura Turconi, Peter Bobrowsky

Abstract: The landslide dam of Prato Casarile, in the Bisagno valley (Genoa metropolitan area) is a classic case study illustrating the interactions between degradation processes and structural stabilization interventions aimed to reduce the risk level in a densely-populated area. The stabilization structures realized after the 1953 and 1970 disastrous events have been highly damaged by the recent ones, in particoulr in 2014. Actually the structures need important maintenance interventions and wider prevention actions are needed in order to control and mitigate the risk level in the highly populated area downstream from the landslide dam.

P31. LANDSLIDES AT ANGANGUEO (MEXICO): Shallow and deep reactivation from 2010 rainfall (Forum Theme 4)

Cecilia Irene Villaseñor Reyes, Víctor Manuel Hernández Madrigal, Sócrates Figueroa Miranda

Abstract: The 4th of February of 2010 the town of Angangueo, as all the Eastern part of Michoacán, was affected by climatological phenomena that produced heavy and prolonged rain in which the accumulated precipitation was of 300mm/48 hrs (33% of the annual precipitation in two days). These caused floods, debris flows, landslides, human losses, loss of crops, damage in infrastructure and economic loss. The investigations obtained by this investigation team allowed the elaboration of landslide inventory map of Angangueo and the numerical modelling of debris flow deposit (FLO-2D). Also, posteriori works of cartography-inventory and GPS monitoring have allow us to found the correlation of the extraordinary rainfall of 2010 with the reactivation of Deep Slides in Las Pilas and Jungapeo. Additionally, it was established that this rainfall event was the primary triggering factor in both kind of mass wasting, however, other factors as the lithology (slightly resistant, highly permeable and weathered) and the land use (especially perennial crops and its flood irrigation system) had the same importance.

P32. Landslide monitoring at the Cala Rossa sea cliff (Favignana Island, Sicily) (part of session 2.1)

Luca Falconi, Roberto Iannucci, Salvatore Martino, Antonella Paciello, Augusto Screpanti, Vladimiro Verrubbi

Abstract: Favignana Island is a historical and environmental attraction site frequented by tourists especially during the long warm season of the year. Over several centuries the sea cliffs have been exploited for the production of building stone. Currently, the quarries used for the rock extraction as well as the natural cliffs are undergoing extensive erosional and gravitational processes. Besides putting at risk the safety of the people attending the area, the widespread rock falls are likely to threaten sites of great historical and anthropological value that, once destroyed, can no longer be reconstructed. The rock mass quality assessment and slope displacement monitoring of cliffs were carried on to identify the most unstable areas providing a support to the local authorities in the implementation of effective and sustainable mitigation measures. If adequate measures will be taken in future, operators and users of the tourist circuit will have the opportunity to enjoy these amazing sites with a reduced risk.

P33. Onshore record of ancient landslides in Taganana (Tenerife, Canary Islands) (part of session 2.2)

Jorge Yepes, Martin J. Rodriguez-Peces, Candida Garcia-Gonzalez

Abstract: This study presents a geomorphologic review of the northern sector of Anaga Massif in order to establish a relative sequence of geomorphic processes. The present-day relief shows a polygenic nature, combining fluvial erosion with other prior erosive processes. The analysis of slopes and watersheds suggests the existence of an active instability process during the Quaternary. However, the anomalies of the drainage system are related with the differential strength which shows basic dykes against erosion. Some geomorphologic features suggest the occurrence of an old great landslide affecting the slopes of Taganana village. This instability will be a stage of the retreatment of the slopes which occurs in a volcanic island along time, in both emerged and submerged flanks.

P34. Modelling the onset of Valles Marineris landslides in Mars

Giovabattista Crosta, Stefano Utili

Abstract: Several questions arise as to the acting forces and rock strength in the stability of the walls of Valles Marineris (VM) of Mars. This work is an attempt: to set the analysis of landslides in VM on the basis of sound geomechanical principles; to understand the root causes of the slope instabilities occurred in VM; to explore what type of events and rock conditions must be invoked to explain the observed massive landslides

P35. EFFECT OF SEISMIC ACTION ON FISSURED SLOPES

Akram Abd, Stefano Utili

Abstract: Aset of analytical solutions applying the upper bound theorem and the pseudo-static approach was derived for the assessment of the stability of homogeneous c, φ slopes manifesting vertical cracks and subject to seismic action.

P36. MECHANICALLY STABILIZED EARTH TECHNOLOGY FOR PASSIVE PROTECTION OF AREAS PRONE TO LANDSLIDES

Robert Lozano, Anne-Cécile Gass

Abstract: Mechanically Stabilized Earth (MSE) technology is a flexible, well understood technology that allows the use of soil by adding discrete inclusions. MSE technology, also called reinforced soil is being in use for over 50 years for applications ranging from walls, reinforced slopes, protection bunds, back to back walls incorporating steepened fascia with different possible facing finishes, a relative wide array of soils for backfill including lightened backfills, in-situ soils and even incorporating the use of modified soils or recycled materials.

The erosive power of rainfall

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PAPUA NEW GUINEA - RAINFALL

Papua New Guinea is a small island nation to the north of the Australian continent. It is host to several topographically, geologically and climatically different environments.

The central and western provinces of the main island ('the highlands'), are topographically elevated between 1,000m and 4,000m above sea level. The terrain is very rugged and the climate is cool all year round. This region is hosted by uplifted sea floor sedimentary rocks. There is no wet or monsoon season. Rather rainfall occurs steadily all year round. Annual rainfall can easily exceed 10,000mm and low magnitude earthquakes are frequently experienced.

The smaller outer islands are topographically flatter, seismically active and receive in the order of 5,000mm annual rainfall. Rainfall usually occurs in the form of high intensity thunderstorms. The climate is very hot and humid. These islands often comprise a combination of volcanics and some sedimentary rocks.

Mining is a major industry in Papua New Guinea (PNG), and very large open cast mines have been constructed with excavated slope heights ranging from 300m to 1,000m. Open cast mine slopes are designed with a serviceable life of no more than 10 to 20 years. As such, predicted and well-managed failures or landslides are usually considered acceptable.

Landslide activity is not uncommon in PNG. Road and infrastructure construction and maintenance in the highlands and the outer islands is often very difficult and prone to frequent unpredicted landslide events.

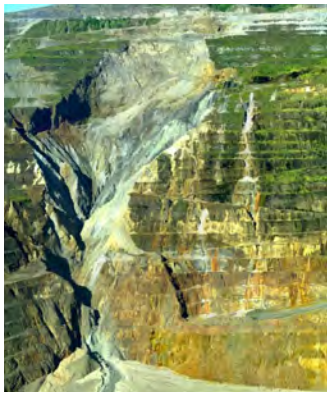

Figure 1 - 500m+ high gully on mine pit slope formed through rainfall-induced erosion and progressive failures over 10 year period. Highly fractured rock mass and structural control.

Figure 2 - 150m+ high gully on mine pit slope formed through rainfall-induced landslides over 5 year period. Deteriorating, clay-altered mass and relic geologic structures.

EROSION AND LANDSLIDES

In the highlands of PNG, prolonged rainfall events create almost 'never-ending' surface water runoff which facilitates constant erosion. In weak, or sheared and highly fractured materials, erosion can undercut large geologic structures and induce failures and landslides. Over time, this process creates large gullies or chasms as shown in Figure 1. This particular example extended vertically over 300m through several individual landslide events between 2013 and 2016, ceasing mining operations at the base of the pit. A 1000m+ high cutback operation has also been underway during this time and will eventually remove the gully entirely.

In the PNG outer islands, frequent tropical thunderstorms generate high volumes of surface water. Slopes are often excavated and stable for a significant period of time. However, rapid weathering can occur in some materials after exposure to the atmosphere. Rapid weathering coupled with the erosive power of rainfall can initiate landslides. The landslide in Figure 2 developed about 5 years after the slopes were initially excavated in a rock mass susceptible to argillic (clay) alteration. It is likely that the landslide has preferentially occurred on relic geologic structures within the weakening rock mass. It was triggered by high intensity rainfall. Landslide propagation is managed by surface water diversion drains and planned cutback to remove the back scarp.

Rainfall is a powerful force of nature that has shaped our planet for millions of years. Surface water generated from rainfall events can rapidly cause erosion and initiate landslide events, which can impede on mining operations and civil infrastructure.

The updated scenario in Europe of Landslide Susceptibility Vs UNESCO Cultural Heritage: the **PROTHEGO** project

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PROTHEGO Project

"**PROT**ection of European Cultural **HE**ritage from **G**e**O**-hazards" is a collaborative research project funded in the framework of the Joint Programming Initiative on Cultural Heritage and Global Change (JPICH) of the European Commission's 7th FrameWork Programme (FP7). The aim of the project is to develop and validate an innovative multi-scale methodology for the detection and monitoring of european Cultural Heritages (CH) exposed to natural hazards, namely monuments and sites potentially unstable due to landslides, subsidence, ground settlement and monument deformation. By applying this methodology to UNESCO World Heritage List (WHL) Sites in geographical Europe (399 Sites), and by analyzing geo-hazard databases, PROTHEGO Project will identify and rank the most critical European Cultural Heritage Sites. A clear and update picture of the most endangered WHL Sites at european level is carried out as useful tool for any kind of conservation and management plans as well as future conservation policies.

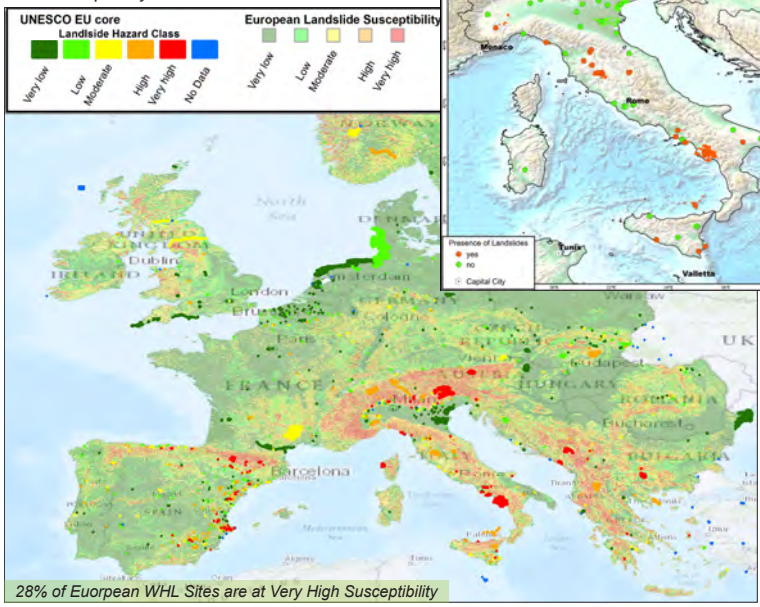
WHL European Sites

WHL European Boundaries

Landslide Hazard

The available european database concerning landslide hazard (European Landslide Susceptibility Map, ELSUS v1) was investigated for a preliminary spatial analysis in order to produce an overview of WHL Sites at risk. So far 28% of UNESCO Sites are at High and Very High landslide susceptibility.

A more detailed analysis has been carried out in Italy by comparing WHL with national Landslide Inventory (IFFI), finding that 45% of Italian Sites are affected by landslides.



28% of Euorpean WHL Sites are at Very High Susceptibility

Conclusion

In the framework of the PROTHEGO Project (PROTection of European Cultural Heritage from GeO-hazards) European UNESCO World Heritage List Sites have been analyzed with respect to landslide hazard. For the first time a specific database with all the UNESCO WHL boundaries (Core Areas and Buffer Zones) was produced.

Through spatial analysis the Sites were overlaid with the European Landslide Susceptibility Map (ELSUS, v1). The first output is that 28% of European UNESCO Sites are at High and Very High landslide susceptibility.

A specific downscaling analysis for Italy point out that 23 of 51 UNESCO Sites are interested by landslides.

The proposed methodology could provide a useful tool to identify priorities and to plan field surveys, detailed studies and monitoring systems, allowing job scheduling of Cultural Heritage maintenance.

A NEW METHOD EVALUATING THE 3D ROUGHNESS OF DISCONTINUITY SURFACE IN ROCK MASS

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Introduction

The surface roughness of rock mass discontinuity (RMD) has a strong influence on the mechanical properties and behaviour of rock mass, which can affect the rocky landslide stability. In order to obtain the evaluation index with a clear geometric meaning, the *PAP* (Projection Area Percent) was put forward as a new evaluation index, which was associated with the shear failure mechanism of the RMD. Based on the 3D laser scanning technology and the Matlab programming, the 3D geometric model of the RMD was built and *PAP* was calculated. Via an engineering example, the process and effect of *PAP* computation were presented and studied.

Theory basis of the *PAP*

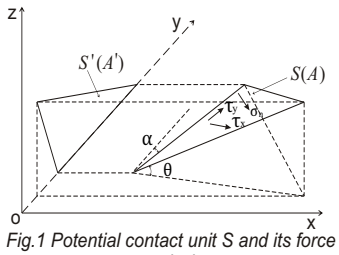


Fig.1 Potential contact unit S and its force analysis

Force analysis:

$$\tau_x = \tau\cos\alpha\cos\theta - \sigma\sin\theta \qquad \tau_n = \sigma_n \tan\phi$$

$$\tau_y = \tau\sin\alpha \qquad \tau = f(\sigma, \phi, \alpha, \theta)$$

$$\tau_n = \sqrt{\tau_x^2 + \tau_y^2} \qquad \tau = h(A')$$

$$\sigma_n = \tau\cos\alpha\sin\theta + \sigma\cos\theta$$

Definition & calculation of the *PAP*

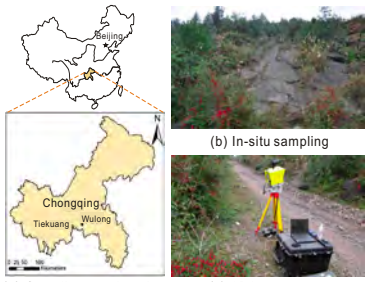
Two projection areas of the RMD surface were calculated. One was the potential contact area projection on the plane which was perpendicular to the shear direction (A_T), and the other was the whole RMD surface projection on the horizontal plane (A_h). The *PAP* is defined as:

$$PAP = \frac{A_T}{A_h} = \frac{\sum_{i=1}^{n} A_i'}{A_h} \times 100\%$$

Calculation procedure of the *PAP*:

1.Data acquisition and modeling of the RMD;
2.Distinguish the potential contact area, and calculate its projection area on the plane which was perpendicular to the shear direction (A_T);
3.Calculate the projection area of the whole RMD surface on the horizontal plane (A_h);
4.Calculate the *PAP* of the RMD.

Application example

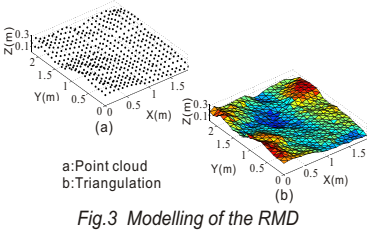


(a) Sampling area location

(b) In-situ sampling

(c) 3D laser scanner

Fig.2 In-situ data acquisition



a:Point cloud
b:Triangulation

Fig.3 Modelling of the RMD

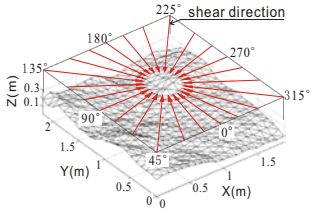


Fig.4 Shear directions of the RMD

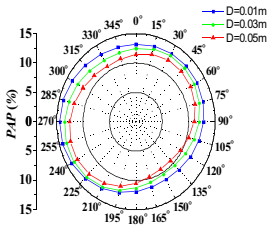


Fig.5 Radar plot of PAP of the RMD and shear direction（D is the sampling interval.）

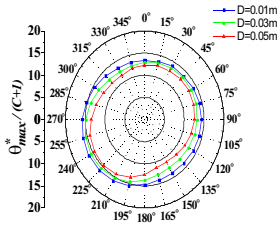


Fig.6 Radar plot of rock surface roughness and shear direction (Grasselli's method)

Conclusions

(1)The 3D geometry information of the RMD in the shear direction was embodied by *PAP*, which was an anisotropic index;
(2)The *PAP* increased with the increasing of the elaborate degrees of models;
(3)The results from Grasselli's method and the *PAP* method were similar.
Furthermore, a good relationship was established between the *PAP* and the shear strength of the RMD, which laid the foundation for further study on the shear strength evaluation model of the RMD.

Rockfall hazard mitigation using ditch charts modeled with CRSP-3D

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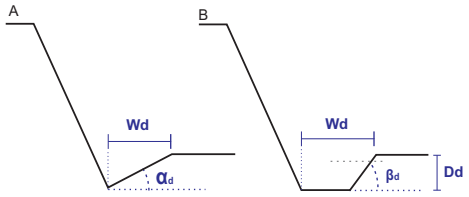
ABSTRACT

Catchment areas (ditches) to contain and restrict rockfall from roadways are one of the less expensive and most effective protective measures. Its effectiveness depends directly on the design criteria. This research complements previous studies by using a computer simulation model CRSP 3D (Colorado DoT, USA) and analyzing a wider number of slope-ditch configurations and input parameters: **1305** different **cases.** As a result, **50** design charts of narrow ditches are proposed to restrict rocks from rolling up onto the roadway.

1.INTRODUCTION

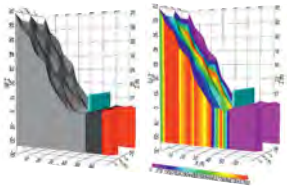
There are proposed design charts to reduce risk associated with the standard model (Ritchie, 1963) that relied on the use of a deep ditch that do not provide a recoverable slope for errant drivers who are likely to fall into the ditch and possibly overturning.



Proposed design parameters for the catchment areas construction according to different authors. ***Legend:*** *(αd) ditch gradient (αt) slope gradient. (βd) ditch foreslope. (Dd) ditch depth. (Ht), slope height. (Wd) optimal ditch width. The slope gradient and the ditch gradient are expressed as the relation between the horizontal and vertical distance (H:V).*

2. METHODOLOGY

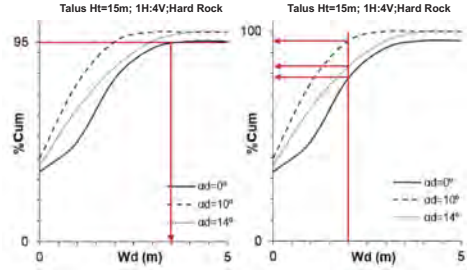
Simulation conditions:



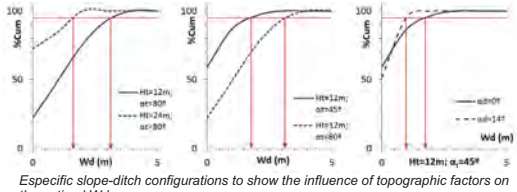
- 5 talus heights (Ht) = 12, 15,18, 21 and 24m
- 5 talus slopes (H:V)t = 1:1, 1:2, 1:3, 1:4, 1:6
- 3 ditch inclinations (H:V)d = 1:0, 6:1, 4:1
- 2 lithotypes: hard rock , soft rock.
- 3 block shapes: cube, cylinder, sphere
- 3 block size: 0.31, 0.62 and 0.94 m
- Random launch point
- No initial velocity

150 slope-ditch configurations.
1305 different cases.
30 events in each case.
TOTAL: 39150 events

3.RESULTS



50 design charts: Wd (m)-% Cumulative retention. Estimated ditch dimensions for a specific retention (95%). Useful for infrastructures planning and to evaluate existing catchment areas.

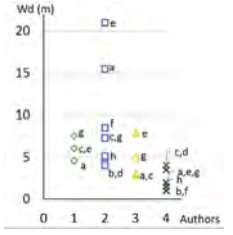


Especific slope-ditch configurations to show the influence of topographic factors on the optimal Wd

4.CONCLUSIONS

- More realistic technical studies.
- More economic and adequate solutions for the time in service of the infrastructures.

Slope height	Ht (m)	12				24			
Slope gradient	α_t (°)	45° (1H:1V)		80° (1H:6V)		45° (1H:1V)		80° (1H:6V)	
Ditch gradient	α_d (°)	0° 1H:0V	14° 4H:1V	0° 1H:0V	14° 4H:1V	0° 1H:0V	14° 4H:1V	0° 1H:0V	14° 4H:1V
REF.		(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
(1)	D_d (m)	1.5-1.8	-	1.2-1.5	-	1.8-2.1	-	1.5	-
	β_d	1:1.25	-	1:1.25	-	1:1.25	-	1:1.25	-
	W_d (m)	4.6	-	4.6-6.1	-	4.6-6.1	-	6.1-7.6	-
(2)	W_d (m)	15.5	4.3	7.3	4	21	8.5	7.3	5.2
(3)	D_d (m)	1	-	1	-	1	-	1	-
	β_d	1:1	-	1:1	-	1:1	-	1:1	-
	W_d (m)	3	-	<3	-	8	-	3-5	-
(4)	W_d (m)	2	1	4	3.5	2	1	2	1.5



Graphic representation of ditch widths (Wd) . ***Legend:*** *(1) Ritchie ,1963; (2) Pierson et al. ,2001; (3) Pantelidis,2010; (4) Yepes et al., 2017.*

REFERENCES
Pantelidis et al. (2011) International Journal of Rock Mechanics & Mining Science,48:1369-1375
Pierson et al. (2001) Report nº US FHWA-OR-RD0204
Ritchie (1963) Highway Reseach Board, Record 17:13-28.
Yepes et al. (2017) World Lansilde Forum 4. WLFO-D-16-00187R4.

Analysis of the rockfall stop-distance factors with CRSP-3D in volcanic talus

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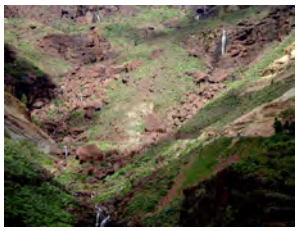
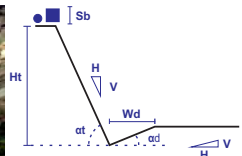
ABSTRACT

The current work analyze 5 factors that define the stop distance of falling rocks: block shape (F_b), block size (S_b), talus height (H_t), talus slope $(H:V)_t$ and ditch inclination $(H:V)_d$. The principal goal is to determine the influence of each factor to improve the territory planning decisions.
We conclude that the lithology is a significant factor of the maximum stop-distance: The probability distribution in soft rock (SR) tends to be unimodal and bimodal in hard rock (HR). The differences are related to the material elasticity and density. The combination of both properties implies an amplification of this effect. An increment of the ditch inclination reduces the maximum reach distance.

1.INTRODUCTION



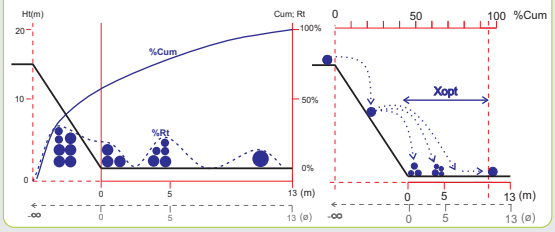


LEGEND: *(F_b) Block shape. (S_b) Block size. (H_t) Talus Height. $(H:V)_t$ Talus slope. $(H:V)_d$ Ditch inclination.*

The Computer simulation was done with CRSP 3D considering **9** parameters during the process: height and slope of the talus; the dicth inclination, block shape and size; density, roughness and hardness of the lythology. A total number of **1305** talus-ditch-block configurations what implies **39150** studied events.

2. METHODOLOGY

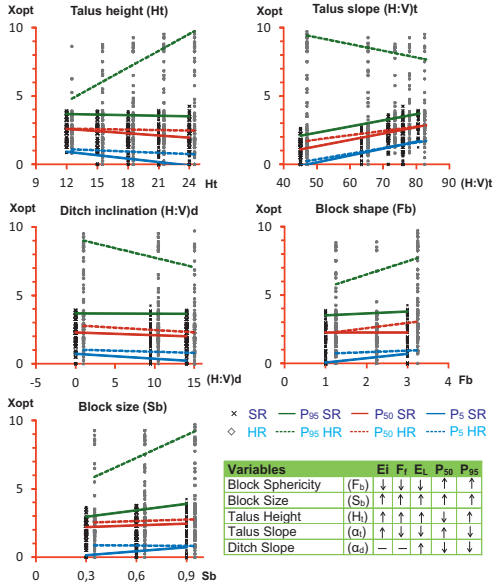
- Estimate Stop distance (X stop) by simulation.
- Modify Stop distance (X stop*) to compare different cases.
- Count the number of blocks retained per section of the platform.
- Calculate Retained percentage (% Rt)
- Calculate Cumulative percentage (% Cum)
- Define the Optimal Stop distance (X opt) from a 95% Cum.



- Lithology is a significant factor. Differences related to the material elasticity and density.
- Higher elasticity→lower energy loss in bounces→ larger Xstop
- Greater density→ higher mechanical work→higher initial energy.
- The combination of both amplify the effect.

3.RESULTS

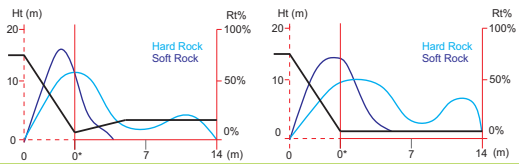
Relation between the optimal distance and the **5** variables.



Variables		Ei	F_f	E_L	P_{50}	P_{95}
Block Sphericity	(F_b)	↓	↓	↓	↑	↑
Block Size	(S_b)	↑	↑	↑	↑	↑
Talus Height	(H_t)	↑	↑	↑	↓	↑
Talus Slope	(α_t)	↑	↓	↓	↑	↓
Ditch Slope	(α_d)	–	–	↑	↓	↓

LEGEND: *(Ei) Initial Energy. (Ff) Friction force.(E_L) Energy Loss. ($P_{50Pcstop}$) Percentil 50 of X_{stop}. ($P_{95Pcstop}$) Percentil 95 of X_{stop}.*

4. CONCLUSIONS



4thWLF 2017
4th World Landslide Forum
LJUBLJANA SLOVENIA EU

Risk Analysis of Debris Flow on Public Expressway in Korea using GIS

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INTRODUCTION

BACKGROUND

- The frequency of debris flow hazard around expressway has increased by localized extreme rainfall and typhoon occurring from June to September in Korea.
- Recently, a quantitative risk assessment on debris flow based on GIS technique has been used over the world.

RESEARCH NECESSITY

- The debris flow occurring around expressway can cause serious direct and indirect damages not only on cars and drivers on the road but also on national infrastructures.
- For the effective prevention of debris flow on expressway, potential basin areas with high possibility of hazard need to be selected in advance and a quantitative risk assessment should be performed.

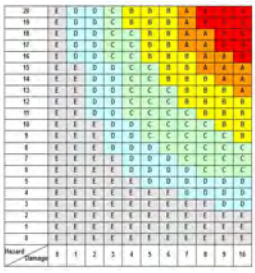
RESEARCH SCOPE

- Assessment of quantitative risk by risk rank matrix incorporating GIS technique
- Analysis on basin characteristics of high and low risk area around expressway

RISK ASSESSMENT METHOD

RISK ASSESSMENT METHOD OF KOREA EXPRESSWAY CORPORATION

- For the quantification of debris flow risk, 4 factors for debris flow hazard and 2 factors for road vulnerability were selected and weighted by logistic regression analysis using 46 debris flow cases.
- Risk of a basin area was evaluated by the risk rank matrix incorporating GIS technique in order to consider the possibility of debris flow hazard and road damage.



Risk ranking matrix

Schematic chart for risk assessment

ASSESSMENT RESULTS

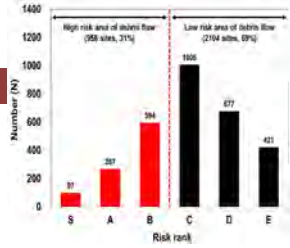
STUDY AREA

- Risk assessment of debris flow on 3,062 sites (2,454km) along 9 expressway lines were conducted.

Expressway lines for risk assessment

No	Expressway	Length (km)	Risk assessment (No. of sites)
1	Yeongdong	234.40	399
2	Donghae	85.08	138
3	Jungang	288.71	537
4	88 Olympic	181.87	229
5	Jungbu Naeryuk	301.71	242
6	Gyeongbu	416.05	238
7	Jungbu	332.50	617
8	Seohaean	340.80	297
9	Namhaean	273.10	365
	Total	2,454.22	3,062

RESULT OF RISK ASSESSMENT



Number of basin according to the risk rank

	Rank	Average inclination of basin (°)	Average inclination of stream (°)	Number of basin (No/%)
High risk area	S	32.4	30.3	97/3
	A	28.2	26.5	267/9
	B	25.0	22.2	594/19
	Ave.	28.5	26.3	958/31
Low risk area	C	22.4	18.3	1006/33
	D	19.4	14.4	677/22
	E	15.0	10.5	421/14
	Ave.	18.9	14.4	2104/69
Total				3062/100

- Analysis results show that the basin areas at 958 sites (31%) out of total 3,062 sites are at high risk for debris flow.
- Basins of high risk area have a higher inclination than the basins of low risk area for both average inclination of basin and stream.

CONCLUSIONS

- Potential basins on 3,062 sites along expressway for debris flow hazard were selected and quantitative risk assessment for those basins was performed.
- Analysis results show that the basin area at 958 sites (31%) out of total 3,062 sites are at high risk.

ACKNOWLEDGMENTS

- This work was supported by Korean Expressway Corporation and Disaster Prevention Institute of Gangneung-Wonju National University.

LANDSLIDE STABILIZATION BY INNOVATIVE ELECTROPNEUMATIC DRAIN® SYSTEM

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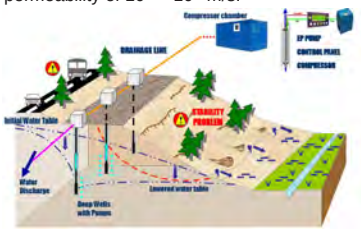
INTRODUCTION

TPGEO is a French geotechnical company that specializes in drainage work in the fields that are especially subject to groundwater drawdown and landslides stabilizations. We implement an innovative deep drainage technique developed by our company, mainly to stabilize landslides. In 1999, our technique was granted a patent and has since been protected by patent number ***EP 1 182 355*** .

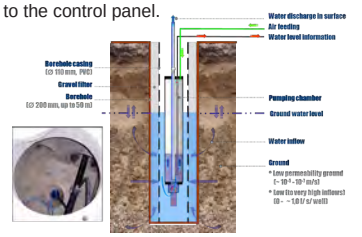
METHOD

The system manages ground water lowering up to 40 m, at flows of 0 – 1.0 l/s per well and permeability of 10^{-5} – 10^{-7} m/s.



Electropneumatic Drain® system

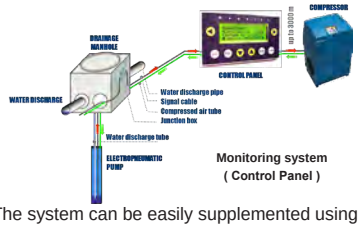
When the ground water rises in the well, it fills the pump and by the time it reaches the high-level sensor an electrical signal is transmitted to the control panel.



Basic working principle of the pump

The signal triggers injection of compressed air requires.

Once the water reaches the sensor at the lower level of the pump, the compressed air is not pushed anymore.



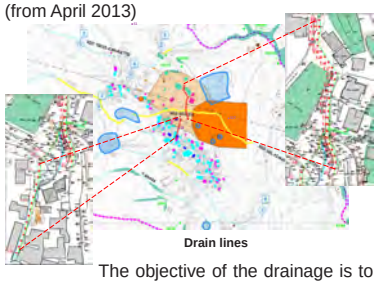
Monitoring system (Control Panel)

The system can be easily supplemented using monitoring and alarms management via GSM or phone line. The data is stored via an FTP server .

PREVIOUS EXPERIENCE (LIGURIA, ITALY, 2015)

General View of the Site

Village **Mendatica** is located within a Broad paleo-landslide (2,489,681 m^2). The major signs of instability have occurred recently (from April 2013)

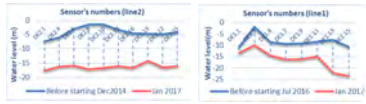


Drain lines

The objective of the drainage is to slow down the sliding. In order to lower the downstream , we would like to be able to stop the sliding by making several drain lines.

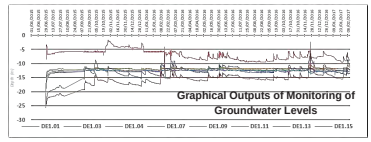
In this field, we positioned 40 drains with a distance of 5.5 m from each other and at a depth of 35 m, in order to lower the groundwater levels by 10 to 20 m.

Monitoring of Ground Water at Several Drains



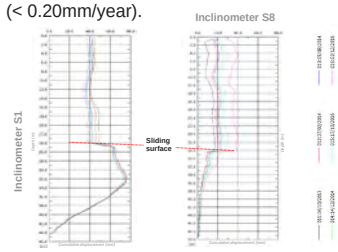
Water level variations between 2014 and 2017

In November 2016, the volume calculated at **Drain2.03** is 1.14m^3/h.



Inclinometer measurements :

The last two measurements of the inclinometer show a restricted shifting of the sliding (< 0.20mm/year).



Due to the last important rainfall in Liguria in November 2016, the site showed a slight movement, while parts of the region undergone an important sliding.

PREVIOUS AND CURRENT PROJECTS

- FAIRLIGHT Cove Landslide, **(UK)** 2005;
- CHABRILLAN, **FRANCE** (2008) Stabilization of the TGV High Speed Train Link Cutting";
- GRADINARY Project, CONGRESS PALACE IASI Project, **ROAMANIA** (2008-2009);
- MOUTIERS Tunnel **SWITZERLAND** (2005);
- Mendatica**,** Liguria, **ITALY** (2015);
- FORT l'ECLUSE, Railway French Company (SNCF), (current)

TPGEO Studio

4th World Landslide Forum LJUBLJANA SLOVENIA EU

Landslide displacement prediction using the GA-LSSVM model and time series analysis: a case study of Three Gorges Reservoir, China

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INTRODUCTION

In the Three Gorges Reservoir region, landslides are the main type of geo-hazard, and they cause critical harm to individuals and property each year.

Due to the influences of external factors, deformation displacement of landslide generally exhibits the same tendencies as the variations in external factors, which can result in misleading landslide prediction.

The displacement prediction of landslides is a major focus in the field of landslide research. Comprehensive analyses of landslide response and displacement predictions of landslide based on external factors are effective methods that rely on landslide deformation data.

The accurate prediction of reservoir landslide processes is an important basis for early prevention, and it can reduce the loss of property and lives.

METHODOLOGY

Time series analysis

The cumulative displacement:

$$y_t = p_t + q_t$$

The trend component displacement:

$$\overline{p}_t = \frac{a_t + a_{t-1} + \cdots + a_{t-k+1}}{k} (t = k, k+1, \cdots, n)$$

Genetic algorithm

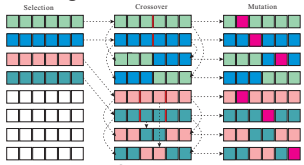


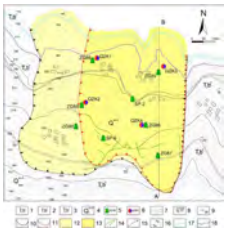
Diagram of genetic operations

GA-LSSVM model

The basic flowchart of the GA-LSSVM model

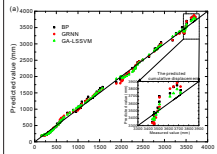
CASE STUDY

Location of the study area and panorama of the Shuping landslide and landslide subzones



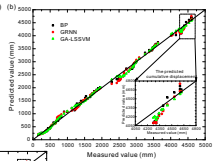
Geology and deformation monitoring map of Shuping landslide

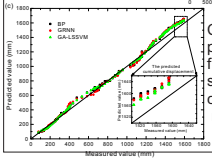
LANDSLIDE DISPLACEMENT PREDICTION



Measured values versus predicted values of the cumulative displacement:

(a) Zg85;
(b) ZG86;
(c) ZG87





Conclusion: The predicted values from all the monitoring stations show good consistency with the measured values.

VERIFICATION AND ERROR ANALYSES

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(s_i - s_i^*)^2}$$

$$MAE = \frac{1}{n}\sum_{i=1}^{n}\left|s_i - s_i^*\right|$$

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{s_i - s_i^*}{s_i}\right|$$

Comparison of the performance of cumulative displacement prediction for the three models

Model	RMSE (mm)			MAE (mm)			MAPE (%)		
	ZG85	ZG86	ZG87	ZG85	ZG86	ZG87	ZG85	ZG86	ZG87
GA-LSSVM	62.4146	87.7215	49.0485	53.0048	74.0601	48.5392	1.492	1.703	3.131
GRNN	125.8222	134.6764	59.8173	109.6146	115.1067	59.2756	3.079	2.643	3.821
BP	111.7842	123.1948	62.0223	96.5585	107.6724	60.9701	2.717	2.464	3.935

Conclusion:The prediction precision of the GA-LSSVM model based on time series analysis is better than that of the GRNN and the BP.

CONCLUSION

(1) The GA-LSSVM model displays the highest accuracy, the smallest RMSE of 62.4146 mm, the smallest MAE of 53.0048 mm, and the smallest MAPE of 1.492% at monitoring station ZG85.

(2) The study results show that GA-LSSVM provides good performance for landslide displacement prediction, and the GA is appropriate for determining the optimal parameters used in the LSSVM model.

Debris Flow in Vrátna dolina Valley: Field Investigation and the Causes of a Recent Disaster

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INTRODUCTION

Debris flow represents a common slope failure in the Slovakian high mountains regions, however due to their low frequency, difficulty to access, many of these failures have left unexplored.

Fig.1: The Malá Fatra Mts.

We present here recent debris flows event, which occurred in the Vrátna dolina Valley (north-west of Central Slovakia), following heavy and intense rainfall. As a consequence, flood situation followed down the valley in Terchová municipality.

A field survey accompanied with LiDAR data analysis is applied to study the causes of this disaster to provide prognosis for future landslide occurrence and prepare a detailed geological map of the area.

STUDY AREA

Vrátna dolina Valley belongs to the Malá Fatra mountain range. In the geological setting of the area Tatricum and Fatricum rocks are present. The greater part of landslides and their head scarps are located in the youngest rocks of the Fatricum sequence (*Tithonian - Neocomian marly limestone of the Mráznica Fm.)* with inclination 25° - 35°; in general to the W up to N. Quaternary deposits are represented by colluvial sediments of varied lithological composition of rocky debris through loamy stone rubble up to deluvial loams. Colluvial sediments cover the major part of the area, with a thickness up to 2 m.

The most common types of slope movements are deep-seated creeps, rock falls, slides, which often result in stream-like deposits typical of debris flows. Baliak et al. (1981) recognized that the northern flank of Chleb Peak is a slope deformation in a form of a rock slide along predisposed stratification planes. Formerly it had been incorrectly interpreted as glacier cirque of fan-shaped form.

The presented disaster in Vrátna dolina Valley was triggered by torrential downpour on 21 July 2014 between 15:00 and 18:00, when about 90 mm of rain fell in the local area within 1:40 hours. The wider area was hit by the range of storms followed by heavy rainfall which caused widespread landslides and flood in Vrátna dolina Valley.

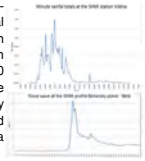

Fig.2: Rainfall data, Liová et al., 2015

As a result, a set of 15 main debris flows and 109 shallow landslides occurred on northern slopes of the main ridge of the Ma-

METHODS

- Field survey on slope deformation and geological mapping
- Airborne LiDAR to provide Digital terrain model (DTM)
- GIS analyses and updating of landslide database

RESULTS

Head scarps of small slides with transition into debris flows

The slope movements along the planar slip surface were conditioned by the favourable inclination of bedding from 11° to 16°. Within the detachment areas of these landslides of rather small thickness broke away quite small, but numerous "plates" (109, area 15 594,44 m^2) of sliding material, which were generally moving at a speed of several meters per second, preferentially down avalanche chutes, often above strongly wetted vegetation cover (grass, blueberries). The slope angle here was about 30°.

Fig.3: A set of debris flows below the Hromové Mt.

Fig.4: The rock slide on the Chleb Mt.

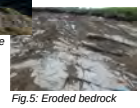

Fig.5: Eroded bedrock

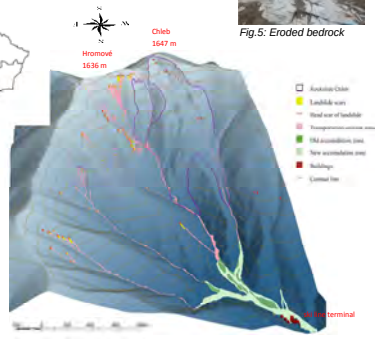

Fig.6: DTM of the Vrátna dolina Valley obtained by LiDAR

Transportation-erosion zone

A flow of a mixture composed of water-clay-stones continued down the narrow valley. It absorbed also bottom fills, which had accumulated in the previous period. From the tributaries joined similar, although smaller, debris flows. Most of them eroded ravines down to the bedrock.

Fig.7: Ravines carved out by flow

The thickness of a rolling mass of water-rock-earth-trees was measured on upright trees. It seems that the thickness of the flow here achieved up to 2 m.

Accumulation zone

Approximately at a distance of 560 m from the cable car station 2 main debris flows joined together. Moreover from the surrounding slopes there was a mobilization of rocky debris that contributed to the material of the debris flows. In these parts of the area rock falls of fragments and blocks likely occurred. In many trees that remained intact stand are registered fresh incisions on the bark (at a height of up to 2 m above surface), which also contributed to the material of debris flows.

The total cubic capacity of the displaced material is estimated at a minimum of 100 000 m^3, their area equalled 80 954,8 m^2.

Fig.8: Deposition of coarse material at the ski cable line terminal

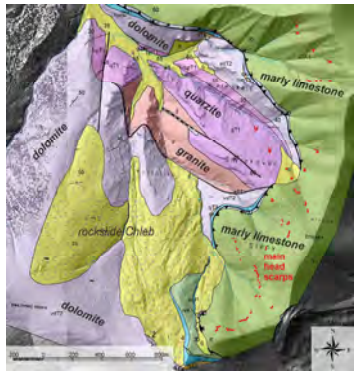

Fig.9: Geological map of Vrátna dolina Valley

CONCLUSION

We found main causes of this disaster, which are related to the favourable geological and geomorphological conditions in combination with rainfall anomalies.

Slope movements effect mainly the slopes on marls with bedding conform to the slope.

Colluvial deposits are characterized by large lithological variability depending on the basement rock. They are often soft or unconsolidated and very susceptible to erosion.

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The difficulty of obtaining field data for landslides, due to its diversification in tropical humid environment, the case of the coast of São Paulo, Brazil

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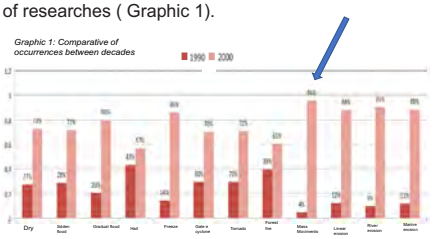
INTRODUCTION

Brazil is located in Latin America between parallels 5 ° 16'19 "N and 33 ° 45'09" S and meridians 34 ° 45'54 "W and 73 ° 59'32" W. All the Brazilian coast lies adjacent to the Atlantic Ocean with an extension of 7,491 km. Brazil is divided in five regions: South, Southeast, Center-West, North and Northeast. The Southeast region suffers most from the landslides events due to the geomorphology that serves as an orographic barrier and influences the climate. Besides it, Southeast is the most populous region and furthermore faces the most serious social and economics consequences. In the past few years, Brazil has witnessed an increased number of landslides events that require further intensification of researches (Graphic 1).



Graphic 1: Comparative of occurrences between decades

Source: Brazilian Atlas off natural disasters

Figure caption 2: View of the city of Santos

DISCUSSION

This area can be described as being pedologically complex. Analysing pedological charts, it is not feasible to notice all the soil diversity that it was collected in the fieldwork during the trenches excavations. Despite of the gemorphological characteristics, climatic and vegetation cover similarities, it is important to highlight the soil diversity in the area.

FINAL CONSIDERATIONS

Regions located in humid tropical environments present great diversification in the soils composition as we observe in the granulometry. In the same slope, there are clay and sandy soils and both have different behaviors in relation to the infiltration and retention of the water, which is the main cause of landslides in Brazil (Figure caption 3).

STUDY AREAS

The research area is located in the coast of São Paulo State which is cut by the Tropic of Capricorn and passes through two cities with very similar geomorphological and climatic characteristics and therefore very vulnerable to landslide events (Figure caption 1 and 2).

Figure caption 1: Vegetation of the study area

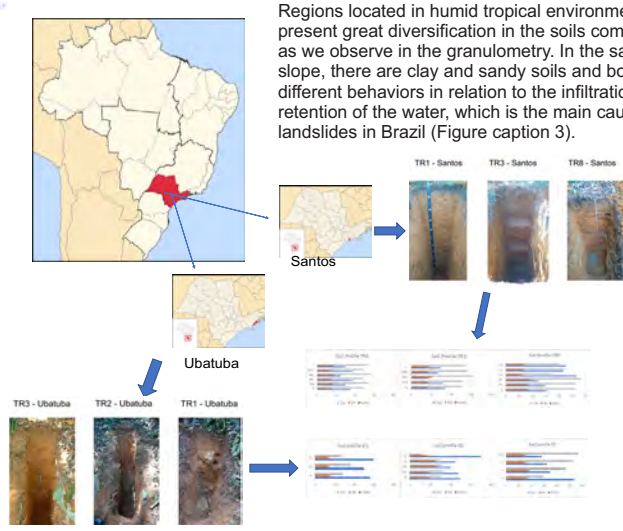


Figure caption 3: Location of the study areas with soil profiles and their respective grain size graphics

LAND-COVER OF LANDSLIDES IN RURAL COMMUNE

THE OUTER CARPATHIANS, ŁOSOSINA DOLNA COMMUNE, POLAND

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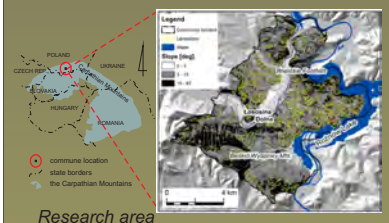
INTRODUCTION

The relationships between the occurrence of landslides and human activity are numerous and mutual.

Almost 60.000 landslides were mapped in the Polish Flysch Carpathians. They cover even 30-40% of the area in some municipalities. Most of these landslides are situated on private properties. It is impossible to cease the use of the lands affected by mass movements. The scale of the problem is substantial, therefore, the local communities need to face the problem:

„HOW TO COEXIST WITH LANDSLIDES?" because it is not sufficient "just" to avoid them. The analysis of land-cover on landslides shows how landslides transform land use structure in whole commune. It is the first step for research to respond to this phenomenon/problem of "coexistence".

STUDY AREA



Research area

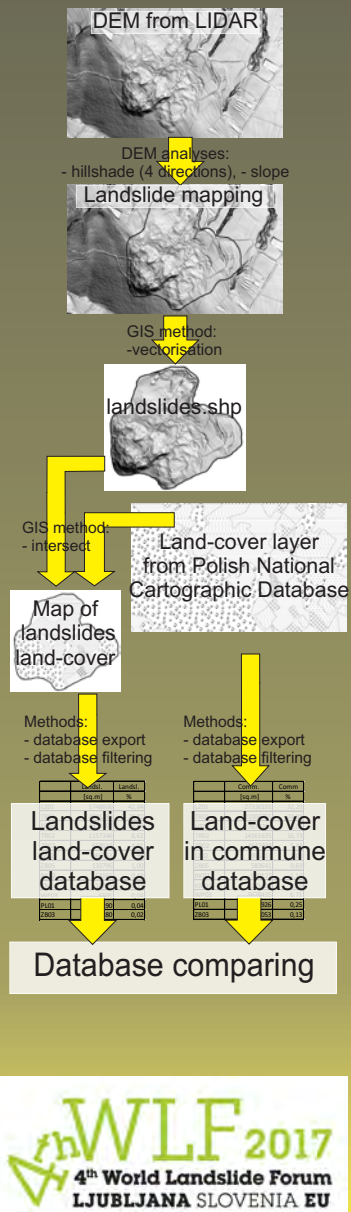
The Łososina Dolna municipality is located in the Outer Carpathians (the Flysch Carpathians), Beskid Wyspowy and Wielickie Foothills regions.

The slope gradients are predominantly in the range of 10 to 35°, the relative elevations are from 300 to 340 m in the montane part, and from 140 to 180 m in the sub-montane part. The landslide density ratio is 8 landslides/km^2.

Field mapping have shown 572 landslides. This included 298 fully active landslides, 69 partially active landslides and 205 inactive landslides (Kroh 2016).

Following Varnes classification (Hungr et al. 2014) all landslides have the slide type of movement. In the region discussed, there are rock rotational slide, clay/silt rotational slide, planar and compound slides.

MATERIALS AND METHODS

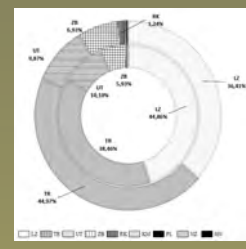


RESULTS

- On the landslides forests occupy over 11% more area compared to the municipality.
- Agricultural fields occupied 3% more of the municipality area compared to landslides.
- The shares of other types of land cover differed by no more than 1%.
- Chi-square test have shown that the presence of landslides does not influence land use structure in the whole municipality.

Land cover types	Area		Land cover		Land cover without „WP" type	
	[m^2]	[m^2]	[%]	[%]	[%]	[%]
	Landslides	Commune	Landslides	Commune	Landslides	Commune
LZ	6017783	28475952	44,84	33,63	44,86	36,41
TR	5158635	35168390	38,44	41,54	38,46	44,97
UT	1355178	7720273	10,10	9,12	10,10	9,87
ZB	795680	5419134	5,93	6,40	5,93	6,93
RK	64165	968127	0,48	1,14	0,48	1,24
KM	14755	171404	0,11	0,20	0,11	0,22
WP	5620	6463540	0,04	7,63		
PL	5190	207926	0,04	0,25	0,04	0,27
NZ	2274	57217	0,02	0,07	0,02	0,07
GN		15652	0,00	0,02	0,00	0,02
Σ	13419281	84667615	100	100	100	100

LZ - forests, TR - agriculture fields, UT - permanent crops, ZB - build-up area, RK - schrubby vegetation, KM - land under roads WP - surface water, PL-squers, NZ - other non-build-up areas



Comparition of land-cover types (without „WP" - water) affected and unaffected by landslides.
Inside ring: landslides
Outside ring: areas unaffected by landslides

CONCLUSIONS

- Landslides cannot be regarded as areas unsuitable for use.
- Landslides do not necessarily disrupt the economic activities.
- In specific areas, landslides may cause no land use changes.
- The resilience of mountain municipalities to the landslide problem could be very high, especially when good special planning is realized.

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FLOW-LIKE LANDSLIDES VS DEBRIS FLOOD: CASE STUDIES FROM CAMPANIA (SOUTHERN ITALY)

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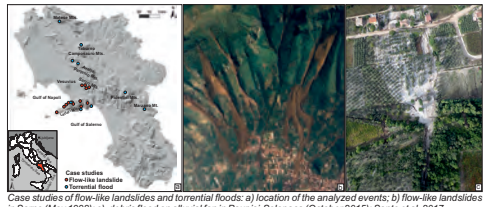
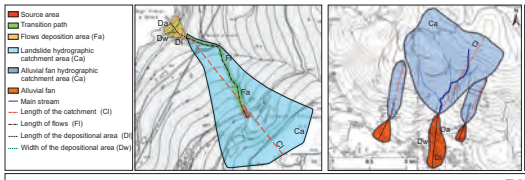
INTRODUCTION

The study area of this work is situated in Campania, in the Southern Apennines of Italy, a region that in recent decades has been affected by severe geohydrological disasters with serious damage and fatalities. We focused our attention on two peculiar phenomena occurring in the carbonate ridge context, represented by flow-like landslides (namely debris flow, debris avalanche and flow slides sensu Hungr et al., 2014) and debris flood events (sensu Hungr et al., 2014). From this moment for sake of semplicity they will be defined as flows and floods. Having some analogue stratigraphic and geomorphological features, there was sometimes a misunderstanding on the characterization of these events.

This study is a first attempt to identify and quantify the similarities and the differences for both phenomena, considering the main events occurred in Campania in the last decades (Di Crescenzo & Santo, 2005; Santangelo et al., 2012). Our goal is to point out the main differences in terms of triggering, propagation and depositional phase and more importantly in terms of velocities, impact forces and associated damage. As a consequence, these differences have to be accordingly accounted for the definition of the most appropriate risk mitigation strategies.



Case studies of flow-like landslides and torrential floods: a) location of the analyzed events; b) flow-like landslides in Sarno (May 1998); c) debris flood on alluvial fan in Paupisi-Solopaca (October 2015); Santo et al. 2017



MATERIALS AND METHODS

The study collected 70 cases for channelized flows and 60 floods. The landslides took place along steep carbonate slopes covered by pyroclastic soils. The floods occurred in high relief energy carbonate watershed, belonging to the category of small catchment.

The case histories derived from air photo interpretation, historical databases and field surveys. For each event, the source, the propagation and the depositional areas and the relative catchment were identified. Successively, for each sector some relevant morphometric parameters were calculated. In order to comprehend the role of the rainfall in the initiation event, the hydrological annals (when available) were checked. A literature review about the flow height and flow velocity values was also carried out.

The study was completed with some significant pictures and field observations (authors' unpublished data) about the damages derived from both the floods and flows.

DISCUSSION

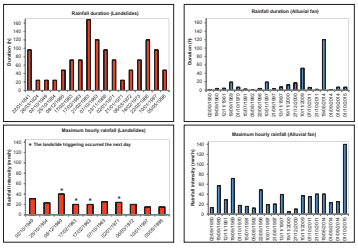
The collection of the available rainfall data resulted in 10 flows and 20 floods. The landslides are triggered by long triggering rainfall (between 1 to 4 days and a mean duration of the event around 72h (3 days). Conversely, the flood are chacterized by shorter and more intense rainfalls, spanning from 30min to 24h (with a mean value around 15h). The maximum rainfall hourly intensity value is around 20mm for the landslides and generally, it do not coincide with the triggering time. In fact, it can be observed the next day. For the floods, the event is closer to the maximum rainfall intensity and generally higher than the landslides. The two phenomena have also a different seasonal occurrence within the hydrologic year; flows are recorded in Winter (January-February) and Spring (April-May), the floods are mainly observed in Autumn (September-October).

The morphometric analysis permits to highlight some similarities and differences. Flows always originate as a detachment in the upper portion of a slope and are characterized by a crown zone. Floods collect materials from all the catchment and transport it down-valley, exclusively along the main stream, up to the fan. Flows occurred in catchment with an area < 0.2 km, while floods interested catchments larger than 2 km^2 . The main stream gradient has slope angles < 20° for debris floods and is > 20° for flows. There is no relevant differences between the sizes of the deposition zone for both phenomena. Conversely, considering the length/width ratio, the floods span on larger values (as they display a longer run-out).

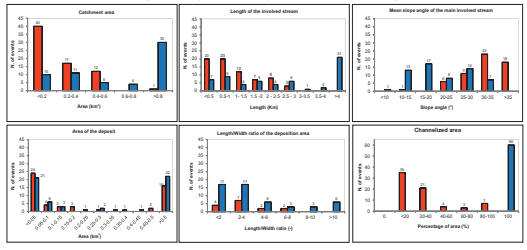
As regards flow velocity and peak discharge, flows always show higher values. The solid concentration is about 50-60% for flows and 10-20% for floods. This difference clearly influence the type of damage: in the case of flow-like landslides, the houses or their walls were completely destroyed while during debris floods the same were progressively buried.

In conclusion, the reported dissimilarities are a relevant factor to consider for the study of these phenomena. In fact, they should be analyzed and modeled with different approaches: the modeling of the flows pertains to the geotechnical engineering, while floods to the hydraulic engineering. Futhermore, the difference has a major impact on the planning of mitigation strategies and the assessment of early-warning studies.

RAINFALL DATA



MORPHOMETRIC PARAMETERS



FLOW VELOCITIES AND HEIGHT

FLOW-LIKE LANDSIDES	VELOCITY [Km/h]	FLOW HEIGHT [m]
APEX AND CENTER AREA	25 < V < 40	3 < h < 5
DISTAL AREA	5 < V < 20	0.3 < h < 1
DEBRIS FLOOD	**VELOCITY [Km/h]**	**FLOW HEIGHT [m]**
APEX AREA	5 < V < 30	0.3< h < 2
CENTER AREA	5 < V < 20	0.3 < h < 1
DISTAL AREA	5 < V < 10	0.05 < h < 0.5

Flows Floods

IMPACTS AND DAMAGES

Flow-like landslide (Pozzano January 1997) | *Flow-like landslide (Samo May 1998)* | *Flow-like landslide (Bracigliano May 1998)* | *Debris flood (Teglia October 2011)* | *Debris flood (Solofra September 2014)* | *Debris flood (Paupisi October 2015)*

Parameter	Flow-like landslide	Debris flood
Catchment area	<1km^2	>2km^2
Slope angle of the involved stream bed	>20°	<20°
Flow velocity *	~ 30 Km/h	~ 20km/h
Flow height *	>1m (max 5m)	>0.2m (max 2m)
Duration of the rainfall event (average)	~ 72h (3 days)	< 24h (1 day)
Max hourly intensity (average)	~ 20 mm	≥ 20 mm
% solid concentration	~ 50 - 60%	~ 10 - 20%

* Data taken from literature

Di Crescenzo G. & Santo A. (2005) - ***Debris slides–rapid earth flows in the carbonate massifs of the Campania region (Southern Italy): morphological and morphometric data for evaluating triggering susceptibility.*** Geomorphology, 66: 255-276
Hungr, O., Leroueil, S. & Picarelli, L. (2014) - ***The Varnes classification of landslide types, an update.*** Landslides, 11:167
Santangelo N., Daunis-i-Estadella J., Di Crescenzo G., Di Donato V., Faillace P., Martin-Fernandez J.A., Romano P., Santo A. & Scorpio V. (2012) - ***Topographic predictors of susceptibility to alluvial fan flooding, Southern Apennines***. Earth Surf. Proc. Land., 37, 803–81
Santo A., Santangelo N., Forte G., De Falco M. (2017) - ***Post flash flood survey: the 14th and 15th October 2015 event in the Paupisi-Solopaca area (Southern Italy)*** Journal of Maps, 13:2, 19-25

Rock avalanche and a rock glacier: a compound landform study from Svalbard

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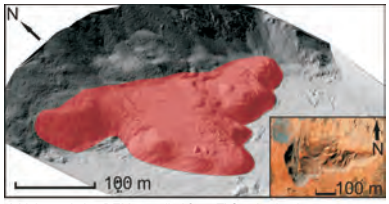
INTRODUCTION

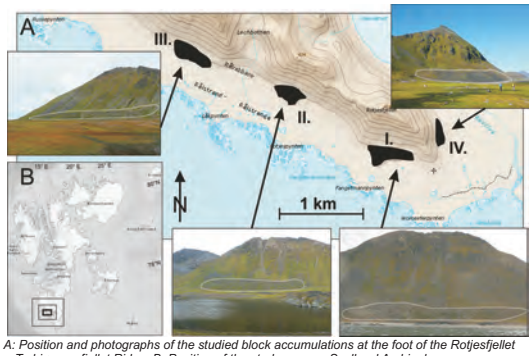
A study of rock block accumulations situated at the foot of Rotjesfjellet ridge on the northern side of the Hornsund fjord showed that the block accumulations are not always only the widely known post-glaciation period rock glaciers, but that there are other influences on their formation.



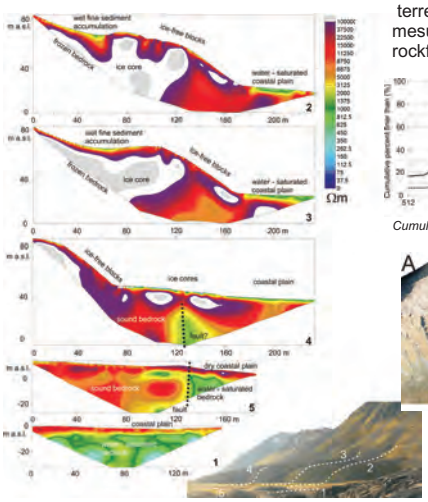
A high-resolution DEM compiled from TLS pointcloud

METHODS

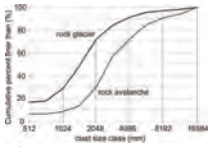
Detailed study of unusually shaped block accumulation employed morphometric profiling and terrain analyses, lichenometry, optical granulometry, Schmidt hammer measurements, geophysical measurements using electric resisitivity tomography, terrestrial LiDAR (TLS) mesurements and rockfall simulation



A: Position and photographs of the studied block accumulations at the foot of the Rotjesfjellet - Torbjørnsenfjellet Ridge. B: Position of the study area on Svalbard Archipelago



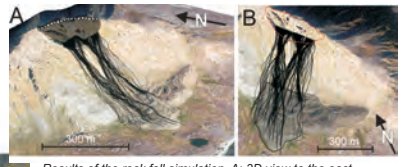
ERT profiles across the main studied accumulation (2,3,4) and in the coastal plain (1 and 5) in the forefront.



Cumulative granulometric curves

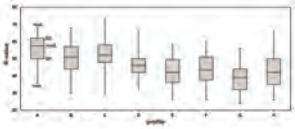
RESULTS

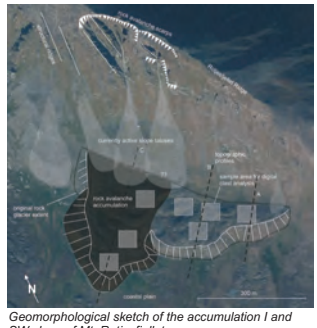
Morphometric analysis of detailed (0,5 m) DEM and relief profiles showed distinctly unusual morphology and suggested possible explanation of the sequence of events.
The electric tomography revealed ice core in the accumulation and using the Schmidt hammer and optical granulometry we were able to establish younger age of the lobe-like left part of accumulation.
The lichenometry helped us to place the event on the approximate position on the timescale and rockfall simulation tested the plausibility and shape of the rock avalanche accumulation



Results of the rock fall simulation. A: 3D view to the east. B: Plan view.

Distribution of the R-values measured using the Schmidt hammer





Geomorphological sketch of the accumulation I and SW slope of Mt. Rotjesfjellet

CONCLUSIONS

We have explained the unusual block accumulation as a result of two consequent processes, as after formation of the rock glacier a large rockfall occured, adding material and deforming the NW part of the accumulation. We estimate the rockfall event to be 250 +/- 50 years old.
Aside from these findings, the authors conclude that considering the high morphological variability of the landforms currently classified as rock glaciers, these landforms may have in many cases originated due to more than one geomorphological process contributing to their formation. Finally, the authors suggest re-considering of the importance of the slope processes in the recently deglaciated Arctic areas.

Predictive Performance of Rainfall Thresholds for Shallow Landslides in Switzerland

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1) INTRODUCTION

Landslides belong to one of the most impacting natural hazards in alpine landscapes with a high frequency of occurrence and significant economic losses. In **Switzerland** landslide related damages were estimated to **exceed 0.5 Billion USD in the period 1972-2007** (Hilker et al., 2009).
Given that rainfall is recognized as the most frequent triggering factor, one of the ways to connect rainfall with landsliding is with a **probabilistic approach** which exploits **simultaneous landslide and precipitation records.**

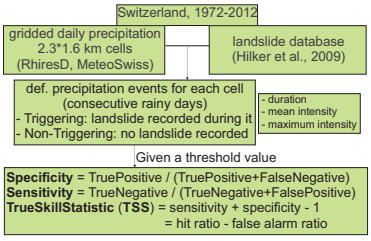
2) OBJECTIVES

a) Develop an **objective** procedure for defining **intensity duration threshold curves** accounting for both triggering and non-triggering events.

b) Investigate the **information** added by **erodibility and mean daily precipitation** (mdp) comparing regionalized and uniform thresholds.

c) Provide **reference performance measures** by resampling and randomization experiments.

3) METHODS



Applications:

- select the "best threshold" associated with the highest value of True Skill Statistic (TSS)
- build the ROC curve by plotting specificity and sensitivity associated with each possible threshold value

4) RESULTS

a) ID Threshold Curve

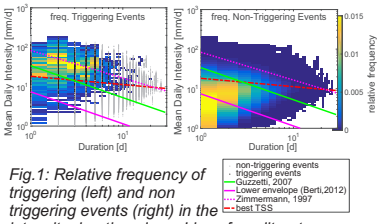


Fig.1: Relative frequency of triggering (left) and non triggering events (right) in the intensity duration plane. Lines from literature as well as the optimized line (best TSS) are shown.

Best intensity-duration power law threshold:
$I = 18.3\ D^{-0.21}$ (spec = 0.85, sens = 0.82)

b) Effect of erodibility and mdp

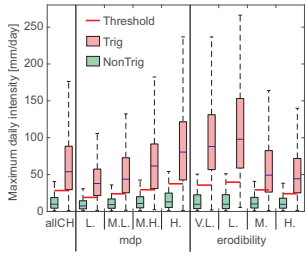


Fig.2: Boxplot of maximum daily intensity of triggering (red) and non-triggering (green) events for entire Switzerland, each mdp class (Low, MediumLow, MediumHigh, High) and each erodibility class (VeryLow, Low, Medium, High; according to Kühni et al., 2001). Best thresholds are indicated for each (sub-)region with red lines.

- The distributions of non-triggering events don't differ significatly among regions, differently from that of the triggering events.
- The differences in the triggering events are reflected in the best threshold (maximizing TSS).
- The best threshold increases consistently with mdp and is higher for low erodibilities.

c) Randomization experiments

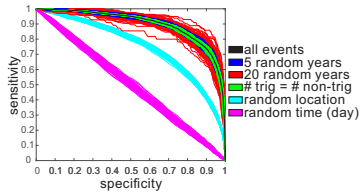


Fig.3: ROC curves of maximum daily intensity obtained: selecting only 20 or 5 random years, selecting as many triggering as non-triggering events, randomizing the location of the landslides or their day of occurrence.

- Only small variations are introduced by using equal sample sizes for triggering and non-triggering events (prevalence problem).
- Shorter records (5-20 yrs) increase variability in the ROC curves but not bias.
- Randomizing location (destroying spatial correlation) results in some predictive power.
- Randomizing time (the day of landslide occurrence) results in performance equal to that of a completely random model.

5) TAKE-HOME MESSAGE

Combining gridded precipitation data with a landslide database in Switzerland we conclude the following about rainfall triggering:

- TSS and ROC curves can be used to objectively define an ID threshold curve.
- Regionalized thresholds increase with mdp and decrease with erodibility.
- Landslides in Switzerland are usually associated with wide-spread storms affecting a large part of the country.
- Daily rainfall provides predictability for landslide occurence despite missing information on short convective scales.

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DYNAMIC ANALYSIS OF A LANDSLIDE IN CAUCASUS

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INTRODUCTION

The area of cableway Karusel-1 in western Caucasus is always subjected to landslide hazard. For safety of cableway facilities, stability assessment of the slope at mountain foot was conducted. In addition, the seismic hazard for the studied area is earthquakes with Mmax=7.0 and intensities of up to 9 on the MSK-64 scale[1]. Therefore, the dynamic analysis of the slope is necessary to perform.

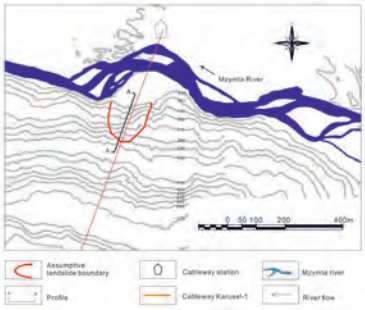

Fig.2 Topographical map of the landslide

Fig.1 Location of the study area in western Caucasus

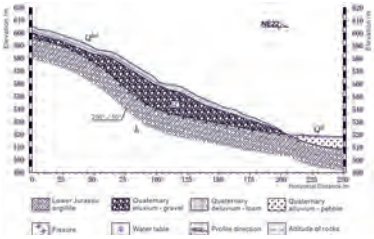

Fig.3 Schematic geological cross-section A-A'

Table 1. physical and mechanical parameters of the slope

Material	Unit weight (kN/m^3)	Cohesion (kPa)	Internal friction angle (°)
Loam	19.3	16.12	25.37
Gravel soil	20.9	19.84	33.42
Pebble	21.2	8.12	33.79
Weathering Argillite	22	72	25
Bedrock Argillite	22	93	27

STATIC ANALYSIS

The slope stability was analyzed using Geostudio. The Morgenstern-Price method (LEM) and the finite element stress method (FEM) were used to calculate factor of safety in static state.

FOS=1.143 (LEM)
FOS=1.132 (FEM)

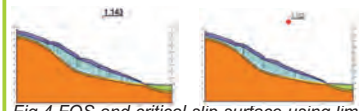

Fig.4 FOS and critical slip surface using limit equilibrium method (left) and the finite element stress method(right) in static state

DYNAMIC ANALYSIS

The dynamic analysis was conducted using Geostudio and Midas GTS respectively[2].

The PGA used in the analysis was modified from acceleration records from the Akhalkalaki strong-motion station during the Racha earthquake (Georgia, April 29, 1991, Mw=6.8)[3].

In case of 8-point intensity earthquake,

The north-south peak PGA=0.2g;
the east-west peak PGA=0.17g;
the vertical peak PGA=0.13g.

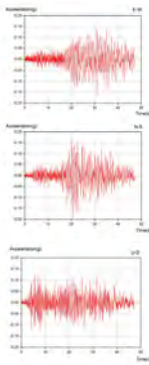

Fig.5 Acceleration records used in dynamic simulation

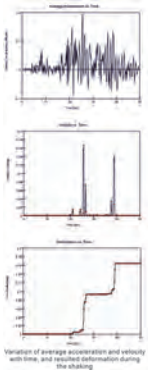

Fig.6 Results of newmark deformation analysis

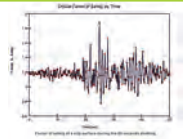

Fig.7 FOS of critical surface during the shaking

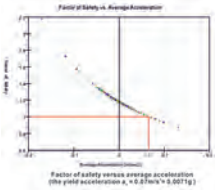

Fig.8 FOS versus average acceleration

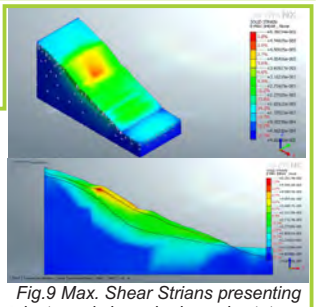

Fig.9 Max. Shear Strians presenting destroyed shape in dynamic state

CONCLUSION

It shows that the upper part of the slope should be reinforced in case of earthquake occurrence.

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[3] Fomenko I K, et al. Effect of seismic load in calculation of slope stability. Georisk, vol. 4, pp. 50-55. 2009.(in Russian)

Geological condition of landslides occurrence in the Bardzkie Mountains and adjacent areas (Sudetes, SW Poland).

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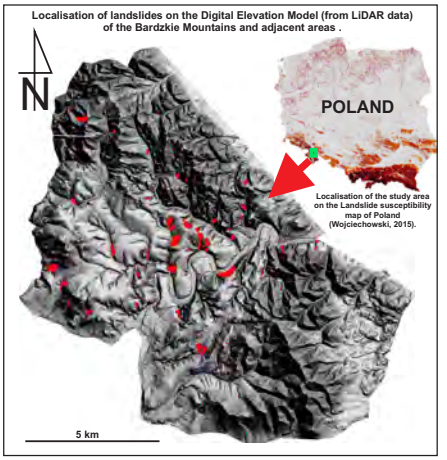
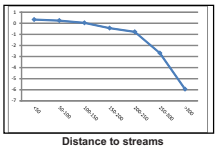
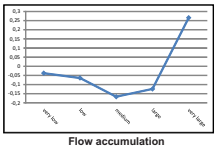
& andrzej.piotrowski@pgi.gov.pl

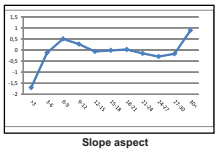
The Sudetes are a mountain range situated on NE margin of the Bohemian Massif. They form natural border between Poland and Czech Republic. The Sudetes Mountains are poorly recognized in terms of mass movements, however our latest research shows that landslides occur often in this area.

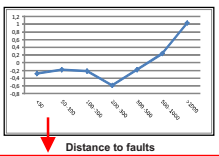
One of terrains with large number of landslides is the **Bardzkie Mountains** and adjacent areas. **About 118 landslides** were identified based on analyses of LIDAR data and cartographic field works. Geological conditionof landslides susceptibility was determined based on comparison of landslides occurrence and geo-environmental factors of the slopes. The Weight of Evidence (WoE) method was used to analyse the impact of lithology, tectonics, gradient of slopes, exposure of slopes, distance from water courses and flow accumulation. The result of the analysis is a landslide susceptibility map of the Bardzkie Mountains and adjacent areas. Landsides are concentrated in the areasof the prevalence of the Pleistocene sediments and the Upper Devonian and the Lower Carboniferous flysch rocks. Especially fault zones in the basement rocks were an important, structural factor in the landslides development. Mass movements most frequently occur on slopes of the southwestern, western and southeastern exposure and inclined in the range of 9 to 24 degrees. Also vulnerable are areas with significant flow accumulation.Larges landslides susceptibility was found in the major rivers and streams valleys (eg. Nysa Kłodzka, Ścinawka, Wilcza, Jaśnica).Geological and geomorphological factors determined the formation of different types of landslides as confirmed by field observation.

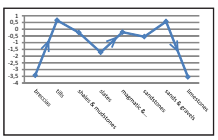



Distance to streams


Flow accumulation

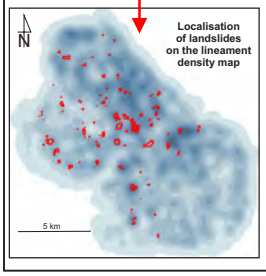

Slope aspect

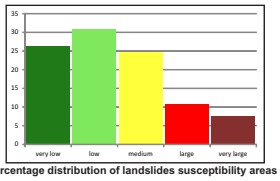

Distance to faults


Lithological factor of variability


Slope exposition

1. All indicators show good relevant to present knowledge relation to landslide susceptibility.
2. The only exception is the factor that describe the distance between faults and landslide scarps.
3. Our calculation shows that the susceptibility increase with the distance from faults which is diffrent from our field study and lineaments analisys.
4. We suppose that this difference is connected with incoherence between archival maps we used in presented study

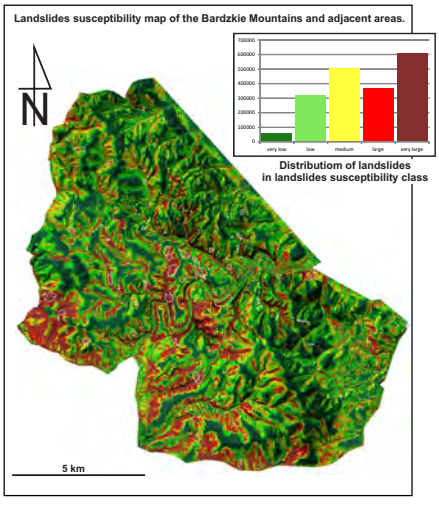




Percentage distribution of landslides susceptibility areas

	w_distance to streams	w_slope expositions	w_flow	w_litology	w_slope aspects	w_faults
w_distance to streams	1.00	0.01	0.07	0.07	0.06	-0.05
w_slope expositions	0.01	1.00	0.01	-0.06	0.00	0.09
w_flow	0.07	0.01	1.00	0.04	-0.02	0.02
w_lithology	0.07	-0.06	0.04	1.00	-0.26	0.07
w_slope aspects	0.06	0.00	-0.02	-0.26	1.00	-0.09
w_faults	-0.05	0.09	0.02	0.07	-0.09	1.00

Factors correlation matrix



Daily to seasonal movement patterns of a large, slow-moving landslide, central North Island, New Zealand

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BACKGROUND

New Zealand has thousands of large (hectare to km^2 scale), slow-moving landslides, many of which damage land and infrastructure, and deliver unknown quantities of sediment to rivers.

Previous research (e.g. Massey et al., 2016; Thompson, 1982), indicates that both decadal river incision and seasonal rainfall patterns play a role in the initiation, movement, and long-term evolution of large landslides in NZ's soft-rock terrain.

This research assesses the relative roles of river incision and rainfall on landslide movement at daily to seasonal timescales. A 50-hectare translational rockslide in central North Island (Fig. 1), which is devastating farmland (Fig. 2), is being mapped and monitored to assess the processes controlling movement over these timescales. The findings may help to evaluate mitigation strategies.

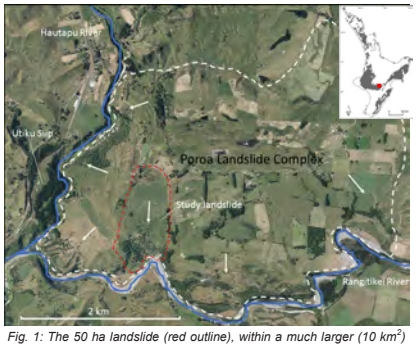

Fig. 1: The 50 ha landslide (red outline), within a much larger (10 km^2) structurally-controlled landslide complex (Poroa Landslide Complex; white outline). Location in NZs North Island shown by red dot on inset map. Grey areas show distribution of soft-rock (Neogene) sediments.

Fig. 2: Damage to pastures, from surface deformation.

METHODOLOGY

Repeat (3-monthly, since July 2015) RTK GPS-occupations of 29 survey pegs, hourly time-lapse photography, and a 0.5 m DEM were used to identify the distribution and patterns of landslide movement and deformation.

RESULTS

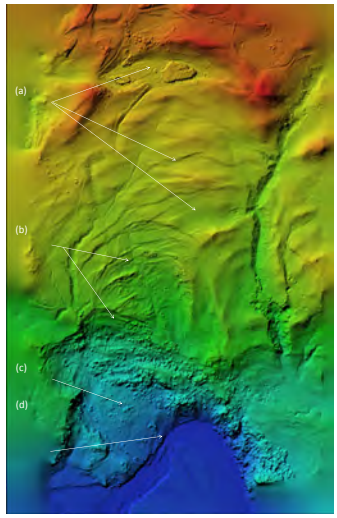

Fig. 3: DEM showing (a) graben development in upper slide blocks (extensional deformation); (b) transitional zone with arcuate scarp development (vertical deformation); (c) earthflow-slide in lower landslide zone; and (d) undercutting by Rangitikei River at landslide toe.

Block sliding occurs in the upper part of landslide (with grabens and annual movement < 1 cm), and transitions to more mobile earth flow-slide behaviour (with annual movement > 10 m) towards the toe (Figs. 3-5). The geomorphology suggests extensional stresses throughout landslide body (with no toe compression) suggesting near-continuous toe-unloading is facilitating movement.

Fig. 4: Survey pegs & movement vectors (Jul 2015 to Mar 2017).

Fig. 5. Two photos from the time-lapse camera. The red stars are points on the corresponding images being monitored with pixel tracking (Table 1).

Table 1: Pixel coordinates & displacements for the photos in Fig 5. Pixel displacements will be converted to real-world displacements, and pixel-tracking of photos at < daily frequency will provide near-continuous monitoring.

Point:	1		2		3		4		5		6	
Image date	(x)	(y)	(x)	(y)	(x)	(y)	(x)	(y)	(x)	(y)	(x)	(y)
(Oct 2015)	4659	2193	4063	2906	3130	1725	3122	959	1999	1062	1832	1310
(Dec 2015)	4564	2235	4053	2908	3070	1732	3110	961	1964	1070	1759	1347
Movement (pixels)	95	-42	10	-2	60	-7	12	-3	35	-9	73	-37

INTERPRETATIONS

GPS & time-lapse data reveal strong seasonal variability in movement (spring ~10 m/yr; summer ~1 m/yr). In addition, time-lapse data captures event-based (daily) pulses of movement associated with floods that erode the landslide toe; these events are more common in winter. Movement activity is thus influenced by both toe-cutting and rainfall, at daily to seasonal time-scales.

References:
Massey, C. I., Petley, D. N., McSaveney, M.J., Archibald, G. (2016). Basal sliding and plastic deformation of a slow, reactivated landslide in New Zealand. Eng. Geology 208: 11-26.
Thompson, K. (1982). Relationship of geology to slope failures in soft rocks of the Taihape-Mangaweka area, central North Island, New Zealand. PhD Thesis. Auckland: UOA.

The Influence of Hydrological Events and Check Dams upon the Geomorphic Changes of the Meng-Gu Waterfall

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INTRODUCTION

Most studies of waterfalls and focused on erosion process and recession rate. The influences of depositional process upon the form of waterfalls are seldom discussed. Abundant sediment could be the tools and covers to reshape the morphology of waterfalls. The Meng-Gu Waterfall, located in the Central Taiwan, was a beautiful waterfall with two steps. After serious debris flow events, the waterfall experienced huge morphological changes. This study explored the relation between waterfall evolution and sediment disasters.

STUDY AREA

The Meng-Gu Waterfall is located on the Nanshan Stream which belongs to the Wu River Basin. The elevation of the watershed ranges from 700 to 2,420 m and the average channel slope is 6%. The geology is composed mainly by black slates with cleavages and metasandstones. The largest two hydrological events, Typhoon Sinlaku (a 20 yrs flood) in 2004 and Mindulle (a 100 yrs flood) in 2008, caused debris flow events and damaged the downstream villages. After that, the Nanshan stream has been identified as a potential debris flow torrent in 2009.

Fig. 1 The satellite image of Nanshan Stream watershed

GEOMORPHIC CHANGES OF WATERFALL

Historical photographs were collected from the residents for comparing the morphological changes of the waterfall. Stable geomorphic features such as the rock outcrop in the upper step waterfall and the rock walls in the lower step waterfall were marked in the pictures and used to be the comparing references.

Fig.2 The geomorphic changes of the Meng-Gu Waterfall by historical photographs analysis

TOPOGRAPHIC SURVEY AND BED ELEVATION CHANGES

The bed elevation changes were inferred from various approaches. Unmanned aerial vehicles (UAV) were used to generate digital elevation model (DEM) and orthoimages for the current state in a reach scale. The depositional line features left on the valley walls caused by debris flows in 2008 can be identified in the field. The height of the depositional level was measured by a laser rangefinder. In addition, the height of the lower step waterfall was inferred from a photograph captured before the debris flow event in 2004.

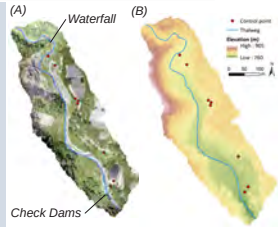

Fig.3 The orthoimage (A) and DEM (B) of the study reach

DISCUSSION AND CONCLUSION

The channel bed elevation near the waterfall experienced great aggradation and degradation twice in the past decade. Massive sediment supply could be attributed to the Chi-Chi earthquake (ML 7.3) in 1999 and typhoon events of large magnitudes. Two consecutive check dams with total height of 15 m were built downstream the waterfall in 2009 for protecting the downstream villages. However, the dams had been fully filled and the channel bed elevation rose at least 10 m. The rise of the base level of erosion lowered down the flow energy the waterfall. As a consequence, the lower step of waterfall has no chance to appear again.

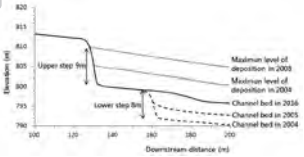

Fig.4 The longitudinal profile changes of the Meng-Gu Waterfall

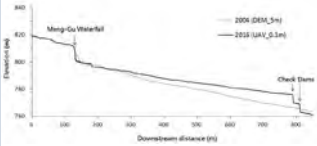

Fig. 5 The longitudinal profile changes along the Nanshan Stream before and after the dam construction

Field monitoring to measure deformation of a mine waste-dump slope

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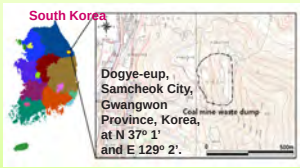
Korea Institute of Geoscience and Mineral Resources(KIGAM), Daejeon, South Korea

Introduction

- The deformation of the coal waste dump slope and the natural slope of the ground located under a coal waste dump were thoroughly investigated, and the primary factors to cause the deformation were analyzed.
- To measure the behaviors of the waste dump slope and the natural slope under the dump, wire sensors were located at the crest of the waste dump, and inclinometers were installed in the natural slope under the dump. The correlation between precipitation and the deformation of the waste dump and surrounding ground was studied.
- Based on the results obtained from the field data and the analysis, the main sources of the deformation of the waste dump slope were identified, and the pattern of deformation was characterized.

Study area



Location of study area

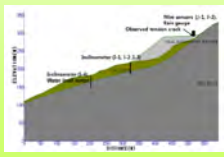
Panoramic view of study area

- Many houses and various parts of the social infrastructure of the area, including roads and railroads, are located under the coal waste heap at Dogye village.
- Multiple sets of tension cracks were observed at the crest of the coal waste heap slope. These cracks were greater than 100 m in length, and the resulting drop head averaged 1.0-1.5 m.
- Therefore, a slope failure at the waste heap would most likely cause significant losses of life and property.

Field monitoring system

- Various devices (inclinometers, wire sensors, and rain gauges) were installed to measure the deformation of the waste dump and the natural slope below the dump.
- Wire sensors and a rain gauge were installed at the crest of the waste dump to detect the deformation of the waste dump based on the amount of rainfall.
- Inclinometers were located in the natural slope below the waste dump to measure the deformation of the natural slope.

Aerial image of this site

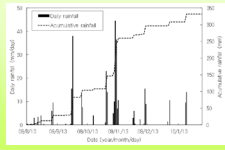


Cross-sectional view including field monitoring system

Monitoring results

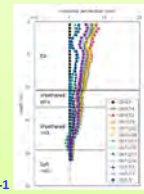
Precipitation

- The daily precipitation data collected at the site during the six-month study period (August 13, 2009, to February 5, 2010)

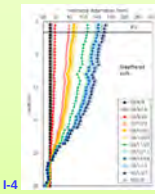


Precipitation records for the study area

- Deformation of the natural slope under the waste dump
  - The maximum deformation was observed in the fill layer at a depth of 1 m from the surface.
  - The slip surface of the natural slope was located in the middle and southern areas of the ground under the toe portion of the waste dump, and the depth of the slip surface ranged from 11 m to 14 m from the surface.



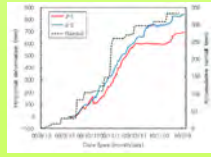
(a) I-1



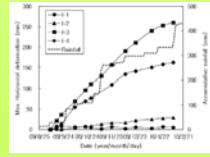
(b) I-4

Horizontal deformation of the natural slope under the waste dump

- Deformation of the slope induced by rainfall
  - The deformation at the crest of the waste dump slope increased steadily and then converged due to the effect over time of the infiltration of rain into the ground after rainfall.
  - The deformations of the waste dump slope and natural slope are closely related to the precipitation. It signified that self-load of coal mine waste dump was increased due to rainfall infiltration and it resulted in the deformations of the waste dump slope and the natural slope.



Deformation at the crest of the waste dump slope



Maximum horizontal deformation of the ground under the waste dump

Conclusions

1) The geological deposits at the waste dump were composed of coal waste, reclamation or residual soil, and weathered or soft rock. These layers were listed in order from the ground surface to the bottom of the deposits. Multiple sets of tension cracks were observed at the crest of the coal waste dump slope in a south-north direction. The length of these cracks was more than 100 m, and the resulting drop head averaged 1.0-1.5 m.

2) The deformation at the crest of the waste dump slope increased and then converged due to the temporal effect of the infiltration of rain into the ground after rainfall. The deformation at the crest of the waste dump slope was significantly influenced by precipitation, and the deformation continued to occur over a certain period of time after a rainfall event due to infiltration.

3) The horizontal deformation of the natural slope under the waste dump was affected by the cumulative precipitation because the maximum rate of horizontal deformation tended to increase or converge in response to the precipitation. In addition, the groundwater level was not substantially influenced by the precipitation.

4) According to the measurement results, the slope movement initiated at the crest of the waste dump. The waste dump slope and the natural slope under the waste dump experienced deformation due to the increasing self-load of the waste dump caused by rainfall infiltration.

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Silk Road Disaster Risk Reduction (SiDRR)

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INTRODUCTION

The Silk Road Economic **Belt** and the 21st Century Maritime Silk **Road** (a.k.a. "the Belt and Road" Initiative) covers more than 70 countries and 4.4 billion people (63% of the world). Due to the active underlying geological structure, rapid tectonic uplift, and the obvious climate differences, natural hazards (e.g., earthquakes, landslides, and debris flows, floods, etc.) occur frequently at these Belt and Road Countries (BRC).

Figure 1. Maps of the Belt and Road (Liu et al. 2016)

Natural hazards along "the Belt and Road" largely affect the development of BRCs and caused enormous economic loss.

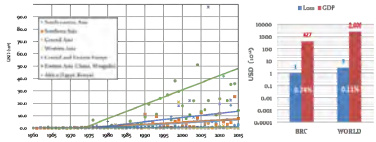

Fig.2: a. Economic loss for each region of BRCs; b. Economic loss against GDP for BRC and world average level (Source: EM-DAT)

Project SiDRR was established to deal with natural disaster in BRCs:

Fig.3: Type of Natural Disaster - SiDRR

MISSION AND TASK FORCE

1. Understand hazards mechanisms
2. New technology for Disaster Risk Reduction
3. Bridge gaps between scientists and policy-makers
4. Transboundary hazards treatment
5. Improve disaster resilience of BRC

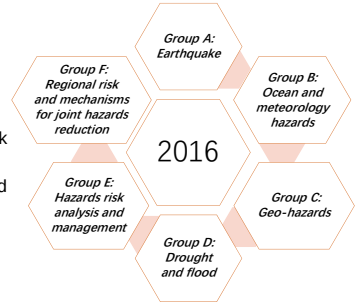

Figure 4. Task Force of SiDRR

PROGRESS ON DRR

Figure 5. Task Force of SiDRR
Seismic Disasters Research and Data Platform for Belt and Road

Figure 6. Concept of Mid/Eastern-Asia Seismic Model

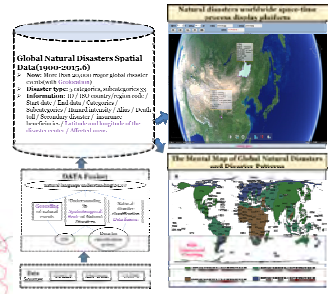

Figure 7. Construction of SiDRR Database

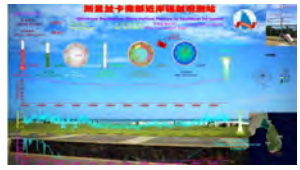

Figure 8. Marian Meteorological Forecasting Platform at Sri Lanka

Figure 9. Sarez Dammed Lake Monitoring at Tajikistan

INTERNATIONAL WORKSHOP OF SiDRR

Figure 3. International Workshop of SiDRR

- 1st International Workshop of SiDRR gathered scientist from 15 countries and 3 international organization (UNISDR, ICIMOD and IRDR)
- 2nd International Workshop of SiDRR: July 17-18th, Islambad, Pakistan, 2017 (Upcoming)

STABILITY ANALYSIS OF POTENTIAL ROCK SLIDES IN EL RINCÓN CLIFF (GC-2 HIGHWAY, GRAN CANARIA, SPAIN)

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University of Las Palmas de Gran Canaria, Department of Civil Engineering, IOCAG, Spain

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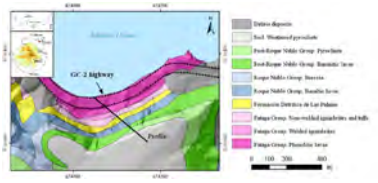
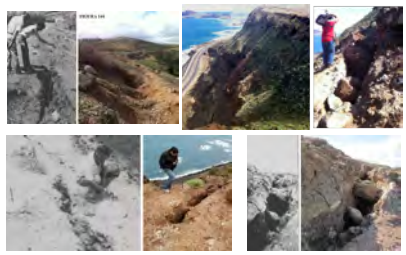
INTRODUCTION

We analyze the potential rock slides that might be developed in El Rincón cliff and its impact on the GC-2 highway, located at the base of the cliff, which is the main access road to Las Palmas de Gran Canaria by the north of the island. During the expansion works of the GC-2 highway, some cracks of hundreds of meters appeared at the coronation and the cliff side. These cracks are still active and the slope is not in equilibrium, so it is advisable to study its long-term behavior. If a landslide from such cracks takes place, the GC-2 would be affected greatly, causing its immediate closure. The slope stability study will permit to propose preventive measures to avoid the disruption of the GC-2 highway.



EL RINCÓN CLIFF

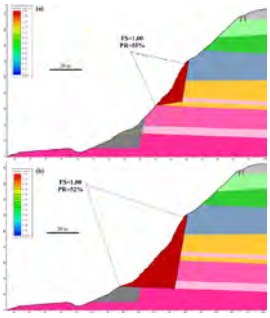
Cracks at the coronation and the cliff side (1985-today)



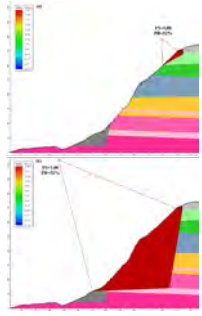
Rock slides of great volumen (~100000 - 450000 m^3)

STABILITY ANALYSIS

MID-SLOPE CRACKS



CORONATION CRACKS



CONCLUSIONS

El Rincón cliff could be considered stable against the occurrence of landslides, considering dry conditions. This is consistent with the present conditions. However, it would be possible sliding of two large blocks if the slope becomes saturated with water. Unstable blocks would be located at mid-slope and in the coronation of the cliff. The former would be favored by failure through the Formación Detrítica de Las Palmas. The second sliding block located on the top of cliff would be more shallow and favored by the failure of the pyroclasts of the Post-Roque Nublo Group. More likely case is the block located at top of the cliff, because it is more probable that the pyroclasts reach saturation compared to the Formación Detrítica de Las Palmas. Moreover, the segmentation of the upper block is favored by progressive cracking that undergoes in the top of the cliff.

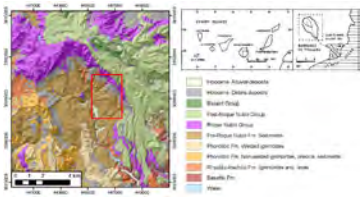
EVOLUTION OF THE PAJONALES LANDSLIDE (TIRAJANA DEPRESSION, GRAN CANARIA): A CASE OF ADVANCING LANDSLIDE

Martín Jesús Rodríguez-Peces, Jorge Yepes, Cristina Fonollá, Alejandro Lomoschitz & Meaza Tsige

University Complutense of Madrid, Department of Geodynamics, Spain
University of Las Palmas de Gran Canaria, Department of Civil Engineering, IOCAG, Spain

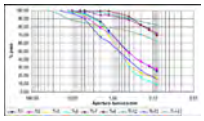
INTRODUCTION

The Pajonales landslide is located in the Tirajana Depression, Gran Canaria (Canary Islands). It is particularly significant because of its large size (560 ha) and because it has undergone successive reactivations, the last in 1956. The main aim of the study is to determine the conditions under which this slope instabilities can develop in the Tirajana Depression. In this way we can assess the hazard presented by the large volume of mobilized terrain and the proximity of human settlements, some located on the slipped masses.

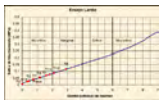


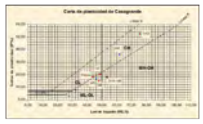
GEOTECHNICAL INVESTIGATIONS

Samples from tuffs and pyroclastic levels of basaltic or trachytic composition



Sands with a high content of silt and clay

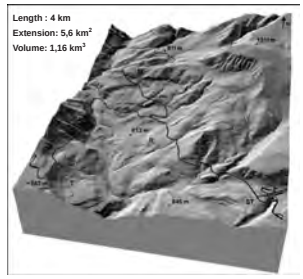




Rocky materials

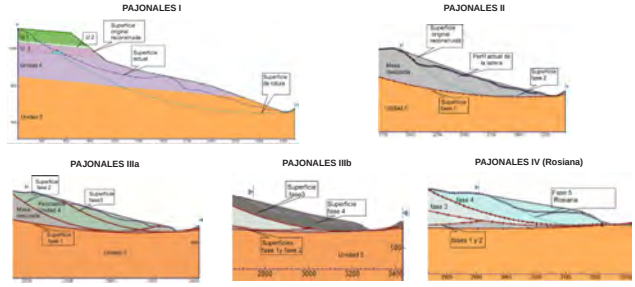
Material	Mean values			Minimum values		
	γ	c	ϕ	γ	c	ϕ
Scoriaceous basalt	20	0.15	35	13	0.15	33
Massive basalt	22	0.35	45	16	0.29	40
Weathered tuff	21	0.70	18	19	0.00	16
Ignimbrite	18	0.70	31	12	0.20	27
Agglomerate	18	0.40	30	18	0.40	27
Pyroclastic deposit	24	0.10	35	22	0.10	32

THE PAJONALES LANDSLIDE



Rosiana, 1956

STABILITY ANALYSIS



CONCLUSIONS

Evolution of Landslide Susceptibility Patterns in Areas of Rapid Urban Development. Case Study Lanzhou City, Northwest China.

J. Torizin*, L. Wang**, M. Fuchs*, B. Tong**, D. Balzer*, T. Tian**, D. Kuhn*, L. Wan**, A. Li**, L. Chen**

* Federal Institute for Geosciences and Natural Resources (BGR)
** China Institute for Geo-Environmental Monitoring (CIGEM)

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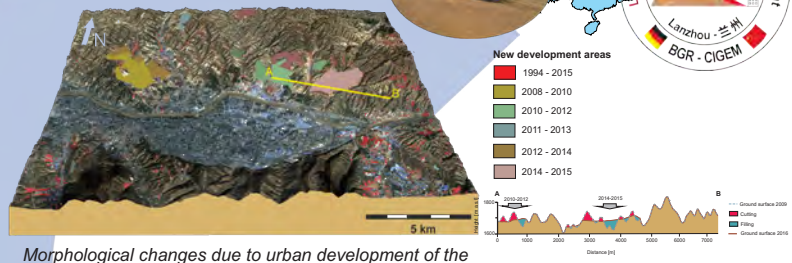
INTRODUCTION

Lanzhou is a city with 3.5 million inhabitants, situated at the western margin of the central Loess Plateau. Since 2001, the city area is under rapid urban development by cut and fill activity of the loess mountains and greening, associated with enormous impact on the environment. The current study investigates the evolution of the landslide susceptibility patterns from the early 1990's to the year 2016 in light of the anthropogenic influence using a statistical approach.

DATA

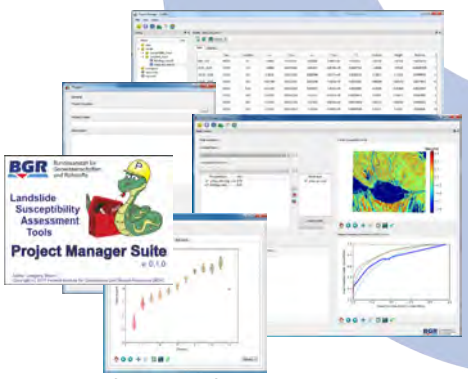
- Historical and recent land use data;
- Multi-temporal landslide inventory;
- Geological information;
- Multi-temporal DEMs;
- Change detection results.



Morphological changes due to urban development of the Lanzhou area (Data: Sentinel-2 over Terra-SAR-X DEM with10m ground resolution).

ANALYSIS

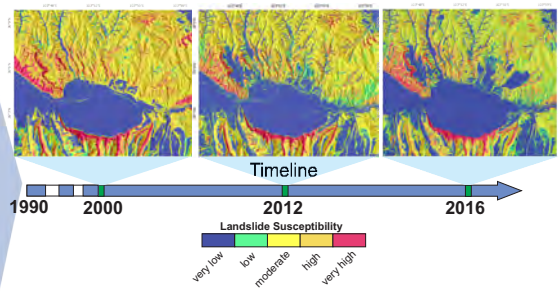
- Data-driven generative Bayesian approach;
- Development of application prototypes for statistical landslide susceptibility analysis.



Prototype of application for statistical landslide susceptibility analysis.

FIRST RESULTS

- Evolution of the landslide susceptibility pattern is mainly governed by bulk earth construction works and irrigation.



- Understanding the causal relations between human activity and landslide susceptibility will allow to create scenarios and strategies for spatial panning of the new city development areas.

4th World Landslide Forum
LJUBLJANA SLOVENIA EU

GeoZS
Geološki zavod Slovenije

POST EVENT LANDSLIDE MAPPING USING C– AND X– BAND INSAR DATA

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INTRODUCTION

The potentialities of a multi-temporal and multi-band interferometric analysis have been used to map the area affected by the complex landslide of Ponzano (Abruzzo Region). The landslide mobilized the 12/02/2017 as the result of the combination of snow melting, in a period of temperature increase during January 2017, and intense rainfalls between 10 and 12 February. The geological context of the area is characterized by the presence of the Laga Formation, a foredeep flysch succession represented, in this area, by its pelitic-arenaceous units. Twenty-five buildings were involved in the landslide movement, that reached a peak of 4-5 m/day in its initial phase, forcing the evacuation of the inhabitants.

SAR DATA ANALYSIS

RADARSAT-1 (RST) and SENTINEL-1 (SNT) C-band and X-band TerraSAR-X (TSX) SAR (Synthetic Aperture Radar) images were analysed by means of the SqueeSAR algorithm (Ferretti et al., 2011). Moreover, the amplitude-based Rapid Motion Tracking (RMT) technique has been applied to the TerraSAR-X data to derive the deformative field induced by the landslide (Raspini et al., 2015).

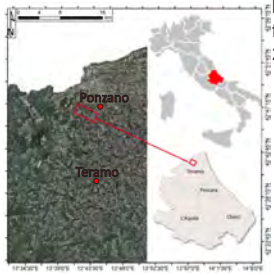

Fig.1 - Geographical setting

Satellite	Orbit	Number of images	Monitored period
RADARSAT-1	Ascending	84	04/03/2003 - 20/03/2009
	Descending	75	15/04/2003 - 14/03/2009
SENTINEL-1	Ascending	77	20/01/2014 - 18/02/2017
	Descending	101	07/10/2014 - 23/02/2017
TerraSAR-X	Ascending	92	13/12/2013 - 21/02/2017 10/02/2017 - 21/02/2017 for the RMT analysis

INSAR EVIDENCES

The analysed InSAR datasets shown that the landslide was already active in the recent past. In the central portion of the landslide (Villa Carosi district) the RST dataset (Fig.2A) registered, starting from 2003, LOS velocities higher than -20 mm/yr and 15 mm/yr in ascending and descending orbits respectively. This trend was confirmed by the analysis of the SNT and TSX datasets (Fig.2B,C). The peak LOS velocity registered in this area is 50 mm/yr in both orbits (SNT dataset). The deformative field induced by the phenomenon show a maximum displacement of 11 m in the crown area and southern than Villa Carosi (Fig.2D).

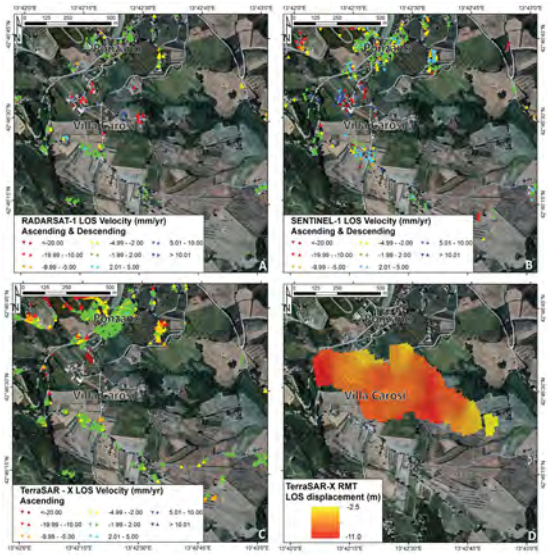

Fig.2 - InSAR datasets used. A)RADARSAT-1; B) SENTINEL-1; C) TerraSAR-X; D) RMT derived from pre- and post- landslide TerraSAR-X images.

CONCLUSIONS

Using satellite-derived information in addition to ground data obtained from a ground survey and from an helicopter reconnaissance, we were able to define the limit of the area involved by the landslide (Fig.3). This work represents an example of synergic use of ground and InSAR data for Civil Protection practices after a landslide event, for quickly deriving the area affected and damaged by the event.

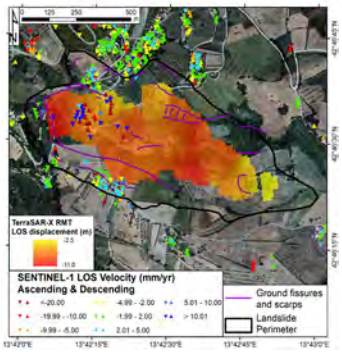

Fig.3 - Ponzano landslide perimeter derived from field and InSAR data.

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Ferretti, A., Fumagalli, A., Novali, F., Prati, C., Rocca, F., & Rucci, A. (2011). A new algorithm for processing interferometric data-stacks: SqueeSAR. IEEE Transactions on Geoscience and Remote Sensing, 49(9), 3460-3470.

Raspini, F., Ciampalini, A., Del Conte, S., Lombardi, L., Nocentini, M., Gigli, G., Ferretti A. & Casagli, N. (2015). Exploitation of amplitude and phase of satellite SAR images for landslide mapping: the case of Montescaglioso (South Italy). Remote Sensing, 7(11), 14576-14596.

TESTING THE AWARENESS OF LANDSLIDE RISK IN SOME SCHOOLS IN TUSCANY (ITALY)

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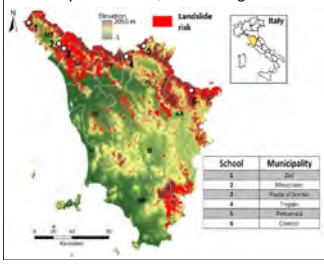
1) INTRODUCTION

Nowadays, the chronicles often deal with disasters related to geological hazards in urban landscapes. These phenomena, unfortunately, also affect school buildings. In Italy around the 10% of these facilities is located in areas subject to landslide and flood risk. Investing in activities aimed at preventing these natural disasters is a necessity no longer negligible, even because the cost of such activity is lower than the economic effort needed to repair the damages.

Following national and international action plans on risk prevention, this project developed a multi-hazard risk assessment (landslide, hydraulic and seismic risk) in school buildings. The method of this work is based on the GSC definition (Geohazard Safety Classification). The main goal of this research is to identify how the GSC can be affected by landslide risk and resilience, in order to strengthen landslide risk prevention and avoid any possible socio-economic losses.

2) SELECTED SCHOOLS

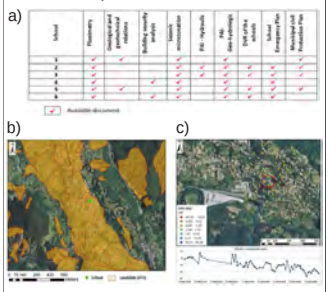
The six schools were chosen on the basis of the high landslide hazard prone area, according to the national landslide inventory (IFFI project), the landslide risk mapping of the "Piano Assetto Idrogeologico"(PAI), and the movements detected by satellite SAR (Synthetic Aperture Radar) data for the unstable areas.



Landslide risk mapping of the Tuscany Region from PAI and IFFI project, and localization of the six selected schools.

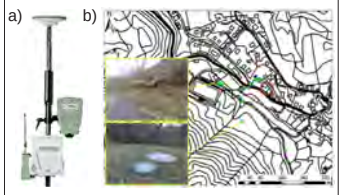
3) LANDSLIDE RISK ASSESSMENT AND GSC DEFINITION

A) Data collection



a) Building's ancillary data for each school.
b) Cartography of the national landslide inventory.
c) Satellite data and historical time series of a permanent scatterer (PS).

B) Field surveys

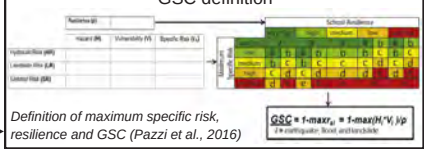


a) Topographic GPS instrument. b) GPS points location.

C) School resilience

a) Questionnaire.
b) Risk Assessment Document and Emergencies Plan of the schools.

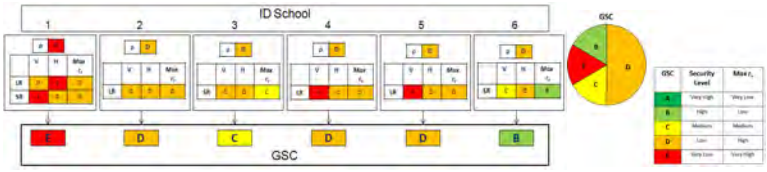
GSC definition



Definition of maximum specific risk, resilience and GSC (Pazzi et al., 2016)

The GSC is obtained weighting the maximum specific risk with the resilience. The maximum specific risk is quantified on the basis of data collection (A) and field data (B), while the resilience is evaluated through the analysis of a questionnaire and the quality of the school Emergency Plan and Risk Assessment Document (C).

4) *RESULTS*



Maximum specific risk, resilience and GSC of the six analyzed schools (for the ID school see figure in box 2)

This work highlights that in half of the selected schools the landslide risk was found to be the highest and therefore influenced the GSC value. The resilience turned out to be a risk amplifier (ρ=D,E), but only in one school the GSC is worst than the considered specific risk.

[Pazzi et al. 2016: *Assessing the safety of schools affected by geo-hydrologic hazards: the geohazard safety classification (GSC).* IJDRR, 15:80-93]

NEW GX GEORADAR GENERATION IN LANDSLIDE MONITORING

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INTRODUCTION

During the winter 2016/2017 geophyisical surveying with georadar MALÅ GX 80 MHz rough terrain antenna was performed in Samoborsko Gorje hills. During processing few historical landslide was noticed and analysed.

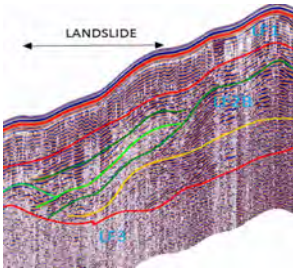
MALÅ GroundExplorer (GX) is based on innovative, MALÅ High Dynamic Range (HDR) technology and represents a leap forward in Ground Penetrating Radar.

Mala GX 80 MHz surveying

Over 25 km of GPR data were acquired, processed with ReflexW software and analysed.

MALÅ GX solution contains two separate components: the GX Controller and the GX antenna connected through. For Samoborsko gorje surveying it was configured as pull-system with an encoder wheel that was fitted to the mounting block on the back of the antenna.

RESULTS

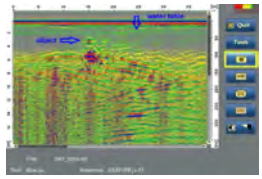


Cross-section 1—1'

Landslide on the southern part of the hill

Landslide cutaway

SURVEYING



GX Controller output - profile 1-1

GPR survey with GX 80 MHz antenna enable inside view of the landslide. The signal detection is up to 800 ns. After the processing the visibility of signal reached detection depth level and enable recognition of

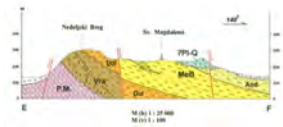
* Surface of rupture
* Main landslide body
* Landslide foot
* Scarps, ridges and faulting

GPR surveying, as non-invasive and up to 100 m penetrating geophysical method could mitigate the risks of the earthslide in the future.

4D modelling and monitoring with GX 80 MHz antenna is recommended.

GEOLOGY

Geological surveying implied pretty simple stratigraphic settings with minor lateral and vertical variation. Sedimentologic and stratigraphic units refer to upper Miocen shale and silts that could be according to Vrsaljko, 2004., divided to Andrasevci and Medvednicki Bregi sub-units overlain with Quarterly layer at the top of the hill. Regional fault pass nearby area.

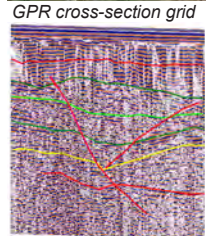


Geological cross section E - F

Part of surveying campaign was covering already repaired landslide with 8 GPR profile in the regular grid.

There were no significant hyperbolas exept the one caused by constructon object built during landslide mitigation. On rough GX Controler section before procesing the water niveux on crown profile of landslide could be noticed

GPR cross-section grid



Cross-section 2—2'

11th WLF 2017
4th World Landslide Forum
LJUBLJANA SLOVENIA EU

NEW GX GEORADAR GENERATION IN LANDSLIDE MONITORING - Processing and Analyses

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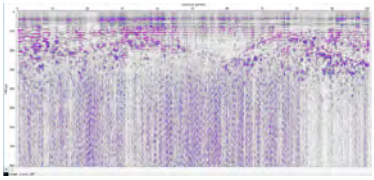
PROFILE 363

GPR profile 363 was conducted from Pusti breg hill to landslide that at the end of 2015th caused the damage on the hangars and shades and stopped at the vicinity of houses in Mala Gorica village. *The landslide mitigation works were performed* during 2016th.



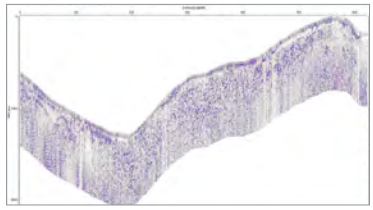
GPR row data, part of 363 row data

Landslide with red marked profile 386

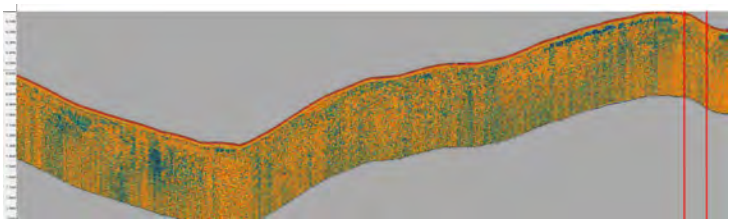
Georadar signal processing workflow included data sorting, profile summation, velocities calculating based on hyperbolas, correction for elevation and interpretation

PROCESSING

Software ReflexW enable signal stack traces, dewow, background removal, velocities calculating based on hyperbolas and correction for elevation.



363 profile—processing



GPR attribute Amplitude weighted frequencies

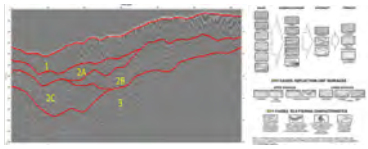
GPR ATTRIBUTES

Measuring with GPR is an high frequency electromagnetic method, but data processing is very similar to reflexive seismic processing.

Further analyses were performed in Opendect software that is designed for reflection seismic data analyses and interpretation.

GPR FACIES

The GPR facies was depicted based on method introduced by Neal 2014. and its later adaptations. Three main lithofacies were extracted, LF1, LF2 and LF3.



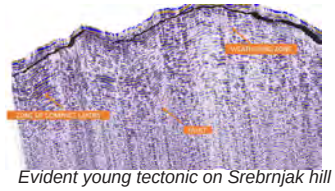
Cross-section 1—1'

On Pusti Breg hystoric lanslide were detected within lithofacies 2.

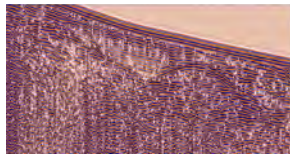
Multiattribute analyses improved visibility of cross sections and enabled detecting timing and extension of landslides.

GPR surveying, is a non-invasive and up to 100 m penetrating geophysical method could reduce the risks of the earthslide in the future.

4D modelling and monitoring with GX 80 MHz antenna is recommended.



Evident young tectonic on Srebrnjak hill



Hystorical landslide on Pusti breg hill

A landslide susceptibility map for Africa

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1. Objectives

i. To compile a first continent-wide landslide (LS) dataset for Africa.

ii. To construct a landslide susceptibility (LSS) map of Africa, calibrated by well-distributed landslide data.

2. Data collection

***Fig. 1**: LS examples from mapping in Google Earth.*

LS data was compiled from LS inventories based on a literature review. Additional LS were mapped in Google Earth to obtain a well-distributed LS dataset for the entire continent (**Fig. 1**). Non-landslide locations were randomly generated over Africa and were visually checked in Google Earth.

3. Landslide dataset

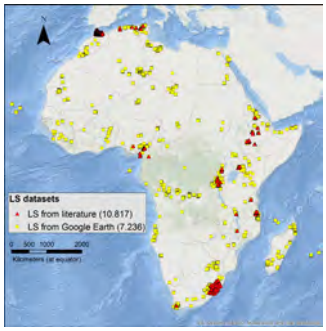

***Fig. 2**: spatial overview of all digitized LS.*

Our dataset contains 10,817 LS from 49 digitized LS inventories and 7,236 LS, of which 1,235 rockfalls, mapped in Google Earth. Together, both datasets contain 18,053 LS, with a good spatial coverage (**Fig. 2**), which is improved by LS mapping in Google Earth. LS are mapped in 51 out of 55 African countries and on the island of Reunion.

4. landslide susceptibility maps

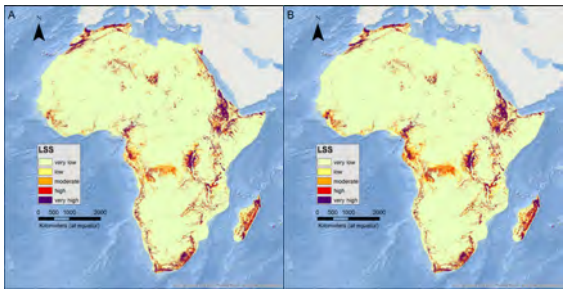

***Fig. 3:** LSS maps. (left) LSS with rockfalls, (right) LSS without rockfalls.*

• LSS (**Fig. 3**) is mainly determined by topography (slope, mean local relief), but also seismicity and the presence of siliciclastic sedimentary rocks significantly increases LSS.

• For the model with rockfalls, the presence of unconsolidated sediments decreases LSS and only for the model without rockfalls mean annual precipitation significantly contributes to LSS.

5. model validation

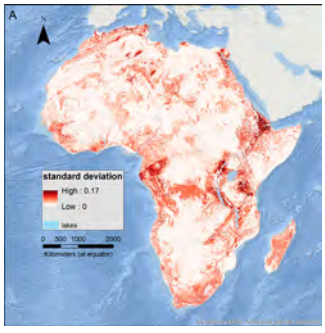

***Fig. 4**: standard deviation of LSS for model with rockfalls.*

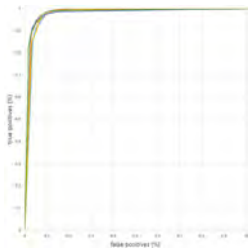

***Fig. 5**: ROC curves for 6 validation datasets.*

• Overall, standard deviations of LSS for 101 simulations are very low (mean: 0.009; **Fig. 4**). Uncertainty is larger in areas with high seismicity and the presence of siliciclastic sedimentary rocks and smaller in areas with steep slopes and the presence of unconsolidated sediments.

• ROC values for 6 validation datasets (3 for both LSS models), score very high: 0.97-0.98 (**Fig. 5**).

INFLUENCE OF DIATOMS CONTENT IN RELATION TO THE SLOPE DEFORMATIONS AND SOIL BEHAVIOR IN THE CUTS OF LINE CONSTRUCTIONS

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INTRODUCTION

From previous experiences, especially in the case of line constructions, frequent slope deformations and stability disturbances occur in the cut slopes and cuts formed by diatomaceous earths (Fig. 1). There are reasonable assumptions that this will happen after saturation of the slopes built from diatomaceous earths with water, most often after a period of frequent atmospheric precipitation. Within the field of geotechnics, diatom clay soils are considered as one of the risk groups of soils because of their specific mechanical behaviour.

Fig.1: Drilling works in the slope deformation location and defects caused by diatomaceous earth.

METHODOLOGY

All soil samples have been processed in accredited laboratories to determine the complex of physico-mechanical properties of the soils. The main purpose of the testing has been to detect changes in the properties of clays in relation to the diatom content in the soil. The pure soil samples from various localities in the Czech Republic (Brno-Vinohrady, Tušimice, Mikulov, Řehlovice) have been mixed together with diatomaceous earth from the deposit in Borovany, in established proportional ratios (100%:0%, 75%:25%, 50%:50% and 25%:75%).

RESULTS

Based on the results of the laboratory testing performed on the clay samples and the modelled mixtures and the evaluation of these results, following conclusions can be made, shown in the figure (Fig. 2). Real average values of the suitable indicators, established by laboratory analyses, were interspersed with quadratic regression curve (Fig. 3).

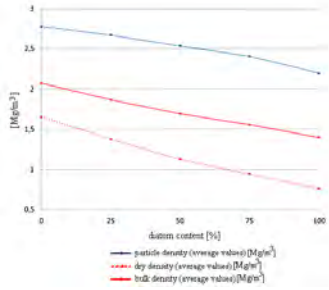

Fig. 2: Relationship between ρ_s, ρ_n, ρ_d and diatoms content

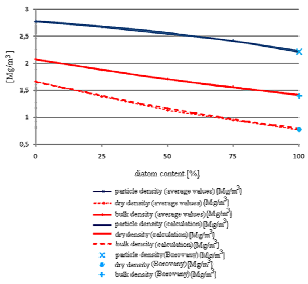

Fig. 3: Relationship between ρ_s, ρ_n, ρ_d and diatoms content with quadratic regression curve

The quadratic regression equation representing the relationship between ρ_s, ρ_n and ρ_d and content of diatoms in the soil. Generally, these equations can be expressed as shown below:

$$A = a^2 + b.x + c$$

A.....chosen parameter

a, b, c…values derived from quadratic regression curve

x.....diatom content [%]

From the quadratic regression equations chosen parameters applicable for a mixture of certain properties according to the current needs can be derived, in this case for the specified diatom content.

CONCLUSION

Clay properties have been investigated depending on the content of diatoms. To investigate the effects of diatom microfossil content on the index properties of clay soils, measuring tests were performed on cohesive soils with different diatom microfossils content.

Based on the observed nature of the soil's behaviour, it was possible to design a simulation of the mixture's behaviour for an established amount of diatoms in the mixture. The influence of diatoms on the basic index properties was discussed. Based on regression equations, it was also possible to derive basic index properties and the parameter for a mixture of certain properties (e.g. for a specified content of the diatoms).

Acknowledgement

The article has been written within the Technology Agency of the Czech Republic nr. TA02011350 project "Investigation of properties of diatomaceous clays and methods for improving their structure".

LANDSLIDE DAMMING IN A HIGH RISK AREA

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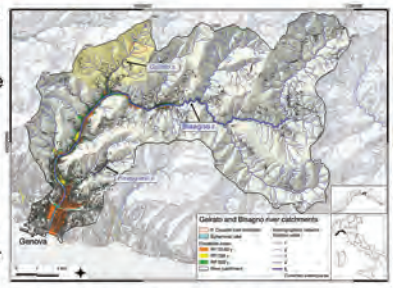
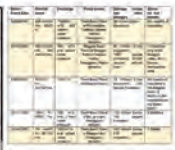
THE PRATO CASARILE LANDSLIDE DAM - GENOA, ITALY

The landslide dam of Prato Casarile, in the Bisagno valley (Genoa metropolitan area) illustrate the interactions between degradation processes and structural stabilization interventions aimed to reduce the risk level in a densely-populated area that has been hit by several floods events, both for peculiar meteorological and geomorphological conditions and for the intense urbanization.
The ancient dam has been re-activated during the 1953, 1970 and, modestly, 2014 event.
The landslide volume is 10 million m^3 and created a 1.75 million m^3 dam of type III (Costa and Schuster landslide dam classification scheme).The dam is 40 m thick, 450 m wide and 200 m long.
The ephemeral lake surface is 45000 m^2.



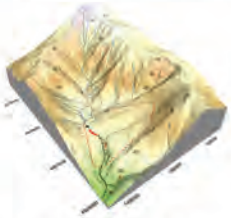
The landslide dam area localization.



5 flood events in the Bisagno catchment in the last 65 years; in brown the events that involved the landslide dam with a partial re-activation.

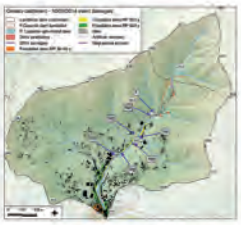
The urbanization evolution in the Geirato catchment with the saturation of the floodplain areas.

Geological map of the Geirato valley.

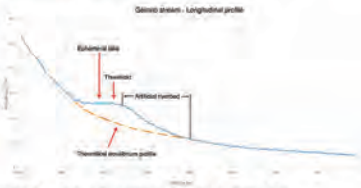


3D model of the landslide dam.

Damages in the stabilization structures realized after the 1970 event

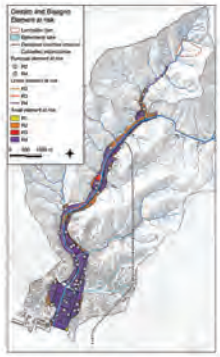


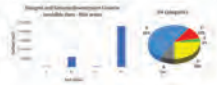
Damages after 2014 event:
RB=river bank collapse
F= ford collapse
W= weir collapse



The Geirato stream longitudinal profile.

The elements at risk along the Bisagno valley downward the landslide dam. R value describes the intensity of risk. In the graph the extension of the risk categories and (bottom) the repartition of the most severe risk areas (R4) in the categories:
A - residential;
B - industrial/artigianal;
C - hospital;
D - roads and railway;
E - others





RISK AND EVOLUTION

During 1970 Genoa flood the regressive erosion destabilized the dam causing a 100000 m^3 displacement that cased damages along the valley and hit Genoa. The stabilization structures that were realized, actually are largely damaged by the recent events that caused even some minor landslides. Regressive erosion toward the dam thresold is moving on too. The landslide reactivation would result in large damages donward the dam, where high vulnerable elements are settled: schools, residential and industrial buildings. Even the Bisagno designing overflow channel will be at risk.

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LANDSLIDES AT ANGANGUEO (MEXICO): Shallow and deep reactivation from 2010 rainfall.

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INTRODUCTION

The 4th of February of 2010 the town of Angangueo, as all the Eastern part of Michoacán (Fig. 1), was affected by climatological phenomena that produced heavy and prolonged rain in which the accumulated precipitation was of 300mm/48 hrs (33% of the annual precipitation in two days). These caused floods, debris flows, landslides, human losses, loss of crops, damage in infrastructure and economic loss (Fig. 2). The investigations obtained by this investigation team allowed the elaboration of landslide inventory map of Angangueo (Fig. 2) and the numerical modelling of debris flow deposit (Fig. 3). Also, posteriori works of cartography-inventory and GPS monitoring have allow us to establish the correlation of the extraordinary rainfall of 2010 with the reactivation of Deep Slides in Las Pilas and Jungapeo (Fig. 4). After 3 years of GPS survey we find this landslides have an accumulated displacement of 0.3 and 4.8 meters, respectively. The localizations of this Deep Slides endanger, at medium and long term, the population who is living in this zones. Therefore, studies in process involve the utilization of InSAR techniques in order to allow the detection of new affected places and a better characterization of the triggering and conditioning factors of these phenomena.

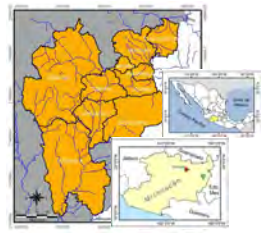

Figure 1.– Localization map.

Slides and debris flows

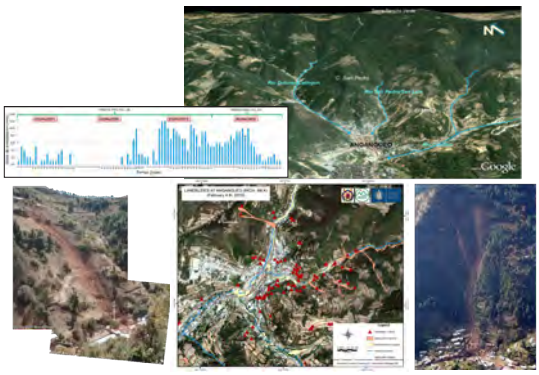

Figure 2. Above: perspective of Angangueo town (left); graph of daily and acumulated rainfall (right). Below: slide–mudflow in Cerro El Melón (left); inventary map of the mass wasting registered in 2010 (center); and slide-debris flow in Cerro Guadalupe (rigth).

Figure 3. Debris flow hazard map for Angangueo. Obtained with numerical modelisation using FLO-2D (Figueroa-Miranda, 2013).

Deep landslides reactivation

After the rain event of 2010, two places had been the center of various reports of deformations and crackings that have provoked several damages in small village houses, crops and federal roads. This affectation is provoked due the activity of two Deep Slides.

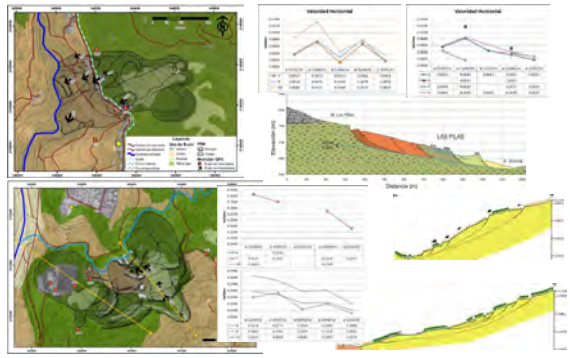

Figure 4.– Above: (left) inventory map of Las Pilas (volume 4,414,040 m3) with displacement vectors and (right) velocity graph from the GPS survey. Below: (left) inventory map of Jungapeo (volume 993,941 m3) with displacement vectors and (right) velocity graph from the GPS survey.

CONCLUSION

The rain event of 2010 was the initial point from which a number of shallow slides and debris flows developed into a catastrophe in Angangeo. Furthermore, other Deep Slides were reactivated and are endangering small populations. The extraordinary rainfall was the primary triggering factor in both kind of mass wasting, however, other factors as the lithology (slightly resistant, highly permeable and weathered) and the land use (especially perennial crops and its flood irrigation system) had the same importance.

Landslide monitoring at the Cala Rossa sea cliff (Favignana Island, Sicily)

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ABSTRACT

Favignana Island is a historical and environmental attraction site frequented by tourists especially during the long warm season of the year. Over several centuries the sea cliffs have been exploited for the production of building stone. Currently, the quarries used for the rock extraction as well as the natural cliffs are undergoing extensive erosional and gravitational processes. Besides putting at risk the safety of the people attending the area, the widespread rock falls are likely to threaten sites of great historical and anthropological value that, once destroyed, can no longer be reconstructed. The rock mass quality assessment and slope displacement monitoring of cliffs were carried on to identify the most unstable areas providing a support to the local authorities in the implementation of effective and sustainable mitigation measures. If adequate measures will be taken in future, operators and users of the tourist circuit will have the opportunity to enjoy these amazing sites with a reduced risk.

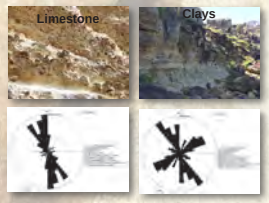
INTRODUCTION

The eastern side of Favignana Island offers some stretches of extremely beautiful coast, where it is possible to appreciate the remains of one of the traditional productive activities of the island: the "pirrere". These are open and underground quarries where a calcareous sandstone was extracted to be used as building stone. The open air quarries are located both in the interior of the island, forming deep pits, or along the cliffs overlooking the sea, while the underground ones form a branched network of caves and tunnels. The high resistance brought the biocalcarenite, improperly called "tuff", to be extracted in several hypogeal and open air quarries and used as building stone since the roman age.

Many buildings were constructed in Tunis with the "tuff" of Favignana, and Messina was rebuilt with it after the 1908 earthquake. After the World War II the "tuff" went out of the market and the mining areas were abandoned to a degradation fate which increased the risk of block collapse.
Although the area is frequented by tourists, currently the quarries as well as the natural rock cliffs are undergoing extensive erosional and landslide processes. Besides putting at risk the safety of the tourists attending the area, the widespread rock falls are likely to threaten sites of great historical and anthropological value that, once destroyed, can no longer be reconstructed.

STUDY AREA

Favignana, the largest of the Egadi Islands, is surrounded by 33 km of indented and mainly rocky coastline, marked by natural and anthropic cavities. The study is focused on the bay named "Cala Rossa", located in the eastern side of the island, where the Pleistocene biocalcarenites form some cliffs with height ranging from few meters up to over 30 meters. In the west side of Cala Rossa, the stiff rock slab lies on the ductile clays belonging to the Pliocene formation. The contact between the two formations can be recognised here above the sea level, while in the east side of the bay the surface is presumably below sea level. Such a juxtaposition leads to a lateral spreading phenomenon that induces the fracturing of the the stiff rock slab and the detachment of single rock blocks by typical rock landslide mechanisms (i.e. planar sliding, wedge sliding, toppling and falling). The resulting landslide process should be defined as a complex-type.
The calcarenite shows relatively high values of porosity related to the low diagenetic process, the low cementation (spathic calcite with meniscus structures) and to the textural characters (equi-dimensional, well sorted, loosely packed, low fine grained matrix). The value of the compressive strength offered in literature, and confirmed through some field measurements with a Schmidt hammer, indicates a weakly cemented carbonate rock.



METHODOLOGY

Geomechanical investigations

The rock mass features and the lithotecnical characteristics of the calcarenites were evaluate in 20 stations (7 in the west side and 13 in the east side), on the basis of 2 classification systems: Beniawsky/Romana (RMR/SMR) and Sicily Region. The latter proposes a simplified approach generating an aggregate of some geomorphological, environmental and historical parameters with the mechanical characteristics typical of the traditional classification.

Traditional monitoring

Discontinuos measurements were carried out between April 2012 and April 2015.

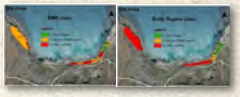
- A direct measurement system was implemented with 40 mechanical joint-meters (tell-tales, removable joint-meters and 3D joint-meters)
- A GPS monitoring network, linked with the Italian Geodetic Network (IGM95), was realized through four stable vertices used as references for four potentially unstable sites in proximity of the edge of the cliffs.

Seismic noise measurements

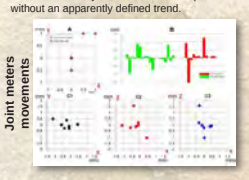
Seismic noise was recorded in 47 single-station measurement sites over an area of approximately 0.05 km², to cover both the unstable zones of the sea cliff and the stable carbonate plateau. Each station was equipped with a 3-component seismometer: 28 measurements were carried out using a LE-3D/5s seismometer by Lennartz Electronic GmbH and a REFTEK 130-01 datalogger set to a 250 Hz sampling frequency; 19 measurements were carried out using a 1.5 Hz SL06 acquisition unit by SARA Electronic Instruments, set to a 200 Hz sampling frequency. The seismic noise records were processed using Geopsy software (www.geopsy.org). The 1-hour time histories were divided into non-overlapping windows of 40 s and the Fast Fourier Transform was computed for each component in the frequency range between 1.0 and 60.0 Hz. By averaging over the windows, the amplitude spectra and the H/V spectral ratio were finally achieved for each single record.

RESULTS

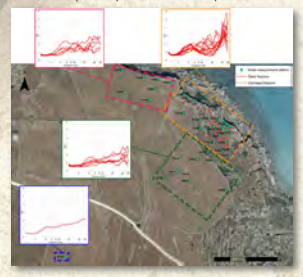
The biocalcarenitic slab shows a high degree of fracturing especially in the front portion of the cliffs. In the west cliff, upon the plateau, 3 major discontinuities have been recognized, longer than 100 meters, 50 cm open and with 40 cm of offset. If they would reach the contact with the underlying clays, a huge block of approximately 30,000m³ would find isolated.



GPS data: horizontal and vertical millimeter movements always inside the error ellipse and without an apparently defined trend.



The results of the noise analyses pointed out a marked difference in the seismic response between the unstable areas and the stable plateau zone. The HVSR curves show significant resonance peaks at frequency higher than 3.0 Hz in the measurements carried out within and in proximity of the unstable zones, while these peaks are not present in the measurements carried out on the plateau zone.
The seismic energy in the frequency higher than 3.0 Hz can be related to the vibrational behavior of the dislodged rock blocks and the seismic response at these frequencies can depend on geometrical and mechanical properties of the rock blocks.



DISCUSSION

- The plastic clay deformation induces stress conditions in the overlying rigid body of calcarenite and favors fracturation of the stiff rock slab and gravity-induced instability of single rock blocks..
- Two controlling factor play a significant role: the pre-existing neo-tectonic shear zones and the position of the contact surface between the two formations above or below sea level.
- The lack of significant movement registered by the integrated monitoring system in the periodic acquisition during the 36 months study does not exclude the possibility of future single or massive movements.
- The rock mass rating of the cliffs attributed to the different measuring stations shows good agreement between the traditional (RMR/SMR) and the recent experimental classification of Sicily Region (SR).

CONCLUSIONS

Although the geotechnical monitoring systems did not record significant precursor displacements, several portions of the sea cliff show evidences of rock slides or falls. The complex local seismic response at high frequencies (10-60 Hz) confirmed the presence of dislodged rock blocks, Consequently, a significant hazard level has been recognised in several measurement stations.
On this basis, identifying appropriate actions is absolutely crucial to prevent accidents to the users of these beautiful natural places and to avoid that the most significant quarries are further abandoned to an inexorable degradation process. The enhancement of the safety level of these areas is an essential step for a sustainable and safety tourism exploitation in the island. This is the way to ensure that what was left of the quarries can become an economic resource again, while respecting the historical and the environmental context.

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Acknowledgement
The field activities greatly benefited from the support of the entire staff of the "Area Marina Protetta Isole Egadi" and the "Cooperativa Galea". Special thanks are due to Dr. Stefano Donati for his interest and courtesy.

ONSHORE RECORD OF ANCIENT LANDSLIDES IN TAGANANA (TENERIFE, CANARY ISLANDS)

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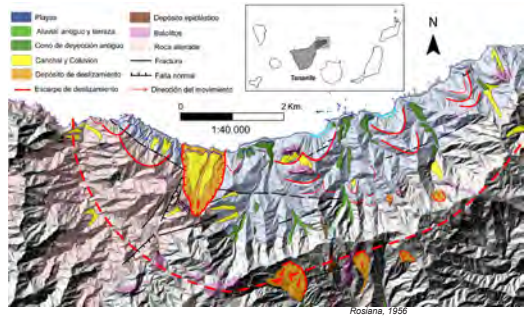
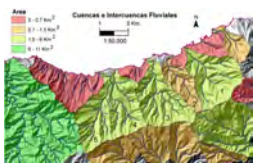
1.- INTRODUCTION

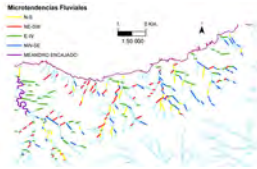
3.– RESULTS

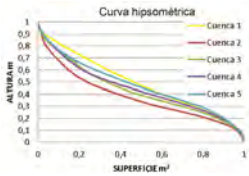


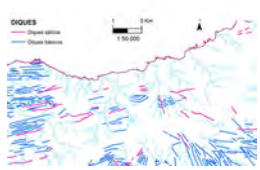
Rosiana, 1956

2.– METODOLOGY

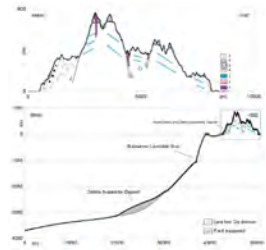


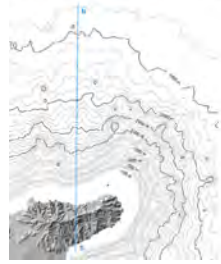






4.- CONCLUSIONS





Modelling the onset of Valles Marineris landslides in Mars

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1. MOTIVATION

Several questions arise as to the acting forces and rock strength in the stability of the walls of Valles Marineris (VM) of Mars. This work is an attempt:

- to set the analysis of landslides in VM on the basis of sound geomechanical principles;
- to understand the root causes of the slope instabilities occurred in VM;
- to explore what type of events and rock conditions must be invoked to explain the observed massive landslides.

2. METHODS

The finite element method (FEM) by shear strength reduction technique and the limit analysis upper bound method (LA) assuming a log-spiral curve for the failure surface, are employed to study the stability of rock walls in VM. The analysis is based both on synthetic, simplified slope profiles (slope angle varying from 20° to 50° and relief height from 4 to 8 km) and on the real shape of the walls of VM, taken from the MOLA topographic data. The Mohr -Coulomb criterion is employed to characterize the geomaterials strength. The role of groundwater flow and seismic action on the decrease of slope stability is also considered.

3. RESULTS AND CONCLUSIONS

A. Comparison of the failure mechanisms obtained by FEM and LA and slope profile obtained from MOLA data

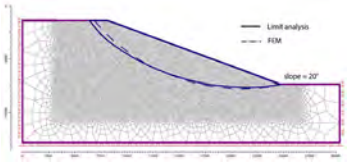

Figure 1a. *Adopted FE mesh with trace of the failure surface from FE and LA for an idealized 8km and 20° slope.*

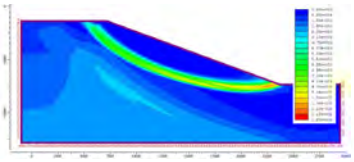

Figure 1b. *Deviatoric plastic strain; strength parameters at failure for both analyses are: c'=240 kPa and φ'=13°.*

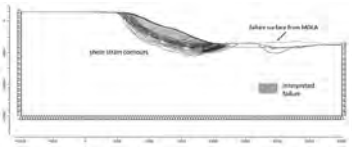

Figure 1c. *Comparison of failure surfaces obtained with FEM and interpreted from topographic evidence for a natural VM profile.*

B. Critical cohesion-friction angle plots

In Figure 2 every set of calculations identifies a region of instability in the c-φ' plane. A certain geological material is unstable if its area of c and φ' reported in the figure falls onto or bellow the mentioned curve, otherwise it is stable. The upper and lower limits for the light blue area describe the limit conditions in case of 20° and 30° slope inclination and 4H and 8H water surfacing position. It is shown that the presence of seepage would enlarge the region of instability increasing the max critical φ' up to 53° while the critical value of c would nearly double.

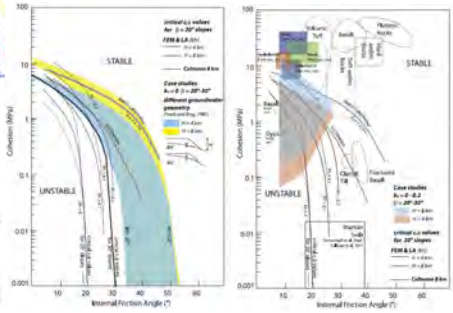

Figure 2. *Results for the critical c-φ' relationship together with previous estimates, the prediction of Culmann's model and the properties of reference geological materials.*

C. 3-D plot of dimensionless area and cohesion, friction angle and horizontal seismic coefficient

In Figure 3 three selected 3-D curves for k_h=0, k_h=0.1 and k_h=0.2 are plotted on the three planes as solid black curves. As seismic load increases, the 3-D line shifts to the upper-right area of the plot, but its geometrical characteristics remain approximately the same.

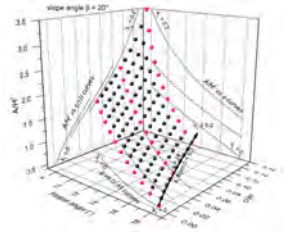

Figure 3. *3-D plot showing the complex relationship among A/H^2, φ, c/γH and k_h.*

CONCLUSIONS

- The results indicate a strong weakening of the mechanical properties of the rocks in VM.
- Probably the landslides in VM were very much favoured by the presence of impact craters prior to the creation of the valley itself.

EFFECT OF SEISMIC ACTION ON FISSURED SLOPES

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INTRODUCTION

A set of analytical solutions applying the upper bound theorem and the pseudo-static approach was derived for the assessment of the stability of homogeneous c, φ slopes manifesting vertical cracks and subject to seismic action [1]. The failure mechanisms assumed are 2D single wedge rigid rotational mechanisms with cracks of either known or unknown depth or location (**Figure 1**). Here are presented the results of a comprehensive parametric analysis carried out based on numerical limit analyses and displacement-based finite-element analyses with strength reduction technique.

Figure 1. *Failure mechanism.*

RESULTS

STABILITY FACTOR

- Charts providing the stability factor for fissured slopes subject to both horizontal and vertical accelerations for any combination of c, φ and β.

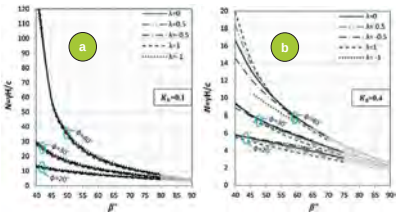

Figure 2. *Stability factor versus slope inclination for the most unfavourable crack scenario for a) K_h=0.1 and b) K_h=0.4, with $\lambda=K_v/K_h$.*

YIELD SEISMIC COEFFICIENT

- For φ>30° the reduction in K_y due to cracks becomes more significant for increasing c.

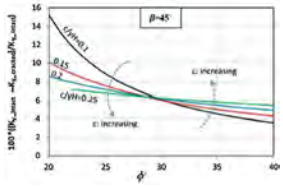

Figure 3. *Percentage of reduction in the yield acceleration due to the presence of the most unfavourable crack for the stability of the slope with λ=0 and β=45°.*

VALIDATION

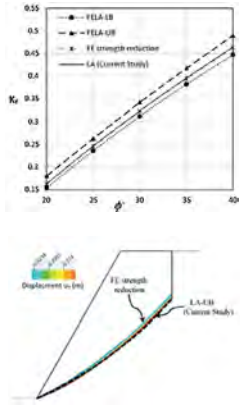

Figure 4. *Comparison between the analytical results and those obtained using FE-limit analysis and FE-displacement-based method using strength reduction technique (φ=20°, λ=0 and β=60°).*

SEISMIC DISPLACEMENTS

- Newmark's approach is used to compute the seismic induced displacements, assuming the presence of the most unfavourable crack in the slope.

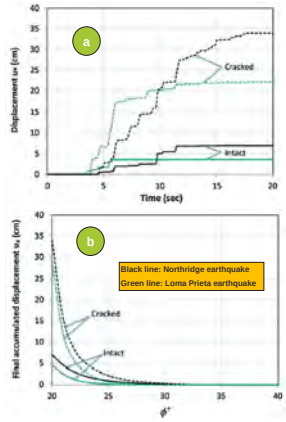

Figure 5. a) Horizontal displacement of the slope toe versus time (φ=20°, λ=0 and β=55°) and b) final accumulated displacement versus φ.

CONCLUSIONS

- The presence of cracks causes substantial reduction of the yield seismic coefficient for steep slopes of low φ.
- Depending on the slope characteristics, the induced displacements of a fissured slope can be significantly larger (up to five times) than those of an intact slope.
- Practioners can use the charts for an estimate of the destabilizing influence of the presence of cracks on the slope of interest for any level of prescribed seismic action.

REFERENCES

1. Utili, S. and Abd, A.H. (2016). On the stability of fissured slopes subject to seismic action. *International Journal for Numerical and Analytical Methods in Geomechanics*, 40(5): 785-806.

ACKNOWLEDGEMENTS

This work has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie Actions RISE 'GEO-RAMP' grant number 645665 .

MECHANICALLY STABILIZED EARTH TECHNOLOGY FOR PASSIVE PROTECTION OF AREAS PRONE TO LANDSLIDES

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Mechanically Stabilized Earth (MSE) technology is a flexible, well understood technology that allows the use of soil by adding discrete inclusions.

MSE technology, also called reinforced soil is being in use for over 50 years for applications ranging from walls, reinforced slopes, protection bunds, back to back walls incorporating steepened fascia with different possible facing finishes, a relative wide array of soils for backfill including lightened backfills, in-situ soils and even incorporating the use of modified soils or recycled materials.

Reinforced Earth® avalanche barrier, Seydisfjordur (Islande)

MSE for natural risks mitigation

MSE is currently in use for avalanche protection structures and for earthen embankments for rockfall protection.

Additionally, MSE technology is used as passive structures to protect against flows, lateral spreads and slides.

MSE is the prime system for the stabilization and mitigation of problematic slopes

Zmorth Project, Jammu & Kashmir, India

In the state of Jammu and Kashmir (Northern India), IL&FS Transportation Networks Limited is constructing an all weather road consisting of a 5km long bored tunnel.

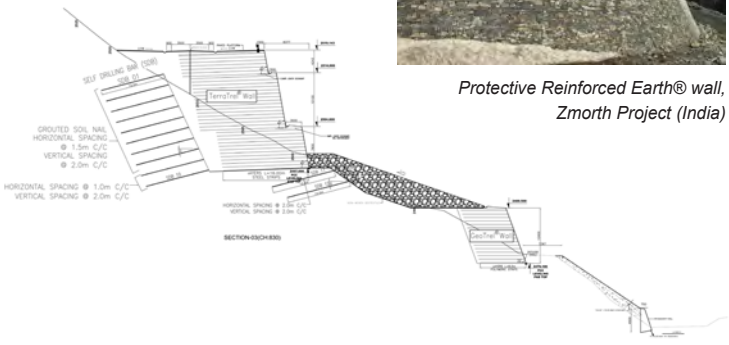
Reinforced Earth Company (RECo) India is involved in the project as a specialized subcontractor offering design, methods engineering, supply of materials and on-site technical assistance for in particular but not limited to slope stabilization and construction of ventilation tunnel approach roads.

For the project the upper slope has been stabilized and a portal platform has been created using soil nailing and a MSE structure with mineral facing to preserve some of the rugged natural look.

The lower slope has been stabilized using three tier structures. The toe of the hill cut has been proposed with stone masonry wall.

An additional MSE wall was designed at intermediate level to flatten the slope and to improve the stability of the structure.

Protective Reinforced Earth® wall, Zmorth Project (India)



Notes