NH3.7 Space and time forecasting of landslides

ENVISAGING POST-EARTHQUAKE SNOWMELT-INDUCED SHALLOW LANDSLIDES UNDER CLIMATE CHANGE

Srikrishnan Siva Subramanian (1), Xuanmei Fan (1), Ali. P. Yunus (1), Theo van Asch (1), Qiang Xu (1) and Runqui Huang (1)

(1) State Key Laboratory of Geohazard Prevention and Geoenvironment Protection (SKLGP), Chengdu University of Technology, Chengdu, Sichuan, China - 610059
Summary of our main research aspects on geo-hazards and their evolution at different temporal scales

Co-seismic Phase | Post-seismic short-medium term | Long-term
---|---|---
Wenchuan earthquake
Triggering and development of co-seismic geo-hazards
- Mapping, spatial distribution patterns
- Initiation and failure mechanism analyses
- Evaluation of runout characteristics
- Formation and failure of co-seismic landslide dams

Post-seismic landslides and debris flows
- Case studies and inventory
- Initiation and runout: mechanisms and modelling
- Observations and modelling of changing rainfall threshold
- Risk management and mitigation (including structural and non-structural measures)

Post-seismic landslides and their hazard assessment
- Spatial and temporal evolution
- Controls on the post-earthquake geo-hazards evolution
- Hazard, risk assessment and reconstruction strategies

Long-term impact of strong earthquakes
- Weathering related post-seismic landsliding
- Sediment cascade and yield after a strong earthquake
- Long-term landscape evolution: the mass balance problem

---

Fan et al., 2019
*Review of geophysics, 57*

- Quantification of post-earthquake landslide evolution in time, space and in magnitude. The challenge is to analyze the controlling factors for the post-seismic landslide evolution. Developing integrated physically-based landslides and debris flow simulation models. The present generation of numerical models are poorly suited for post-earthquake settings.
Envisaging post-earthquake snowmelt-induced shallow landslides under climate change
Srikrishnan Siva Subramanian (1), Xuanmei Fan (1), Ali. P. Yunus (1), Theo van Asch (1), Qiang Xu (1) and Runqui Huang (1)
(1) State Key Laboratory of Geohazard Prevention and Geoenvironment Protection (SKLGP), Chengdu, Sichuan, China

Model development: A sequentially coupled catchment-scale numerical model for snowmelt-induced soil slope instabilities

Siva Subramanian S, Fan X…Xu Q….Huang et al., (JGR: Earth Surface, 2020)

* Predominant hydrological and geo-mechanical processes in cold regions

©2020 American Geophysical Union.

Simplified account of below-freezing temperature on hydro-mechanical-behaviour for catchment-scale slope stability assessment.

©2020 American Geophysical Union.
Model testing and validation:

Envisaging post-earthquake snowmelt-induced shallow landslides under climate change
Srikrishnan Siva Subramanian (1), Xuanmei Fan (1), Ali. P. Yunus (1), Theo van Asch (1), Qiang Xu (1) and Runqui Huang (1)

(1) State Key Laboratory of Geohazard Prevention and Geoenvironment Protection (SKLGP), Chengdu, Sichuan, China

(a) Landslide polygons
- Catchment
- Coseismic shallow soil slides
- Coseismic landslides

(b) Lithology
- Massive Mudstone
- Andesite
- Sandstone and Mudstone
- Sandstone
- Mudstone and Sandstone
- Andesite and pyroclastics
- Siltstone
- Hard sandstone
- Hard siltstone
- Mudstone

(c) Landslide polygons
- Snowmelt-induced landslides

(d) Depth of coseismic landslide deposits (m)
- 3

Soil Depth (m)
- High: 3.0
- Low: 1.5
Envisaging post-earthquake snowmelt-induced shallow landslides under climate change

Srikrishnan Siva Subramanian (1), Xuanmei Fan (1), Ali. P. Yunus (1), Theo van Asch (1), Qiang Xu (1) and Runqui Huang (1)

(1) State Key Laboratory of Geohazard Prevention and Geoenvironment Protection (SKLGP), Chengdu, Sichuan, China

- **True Positives**: 9
- **True Negatives**: 50
- **False Positives**: 21
- **False Negatives**: 20
- **Accuracy**: 59
- **Cohen’s Kappa**: 0.38
Improvements in the present snowmelt model for large scale applications

- Snowmelt water is estimated using the meteorological data according to the following relationship,

\[ SM = \Delta SWE - S \quad (1) \]

- SWE is calculated using snow density \((\rho_s)\) and snow depth \((h_s)\) through the following relationships,

\[ SWE = h_s \frac{\rho_s}{\rho_w} \quad (2) \]

Improved distributed model

\[ \lambda \Delta SWE = S + L_a - L_t + H + E + G \]

\[ + P - SWE(C\Delta T_s) \]

where \(\lambda\) is the latent heat of fusion \((3.35 \times 10^3 \text{kJ m}^{-3})\), \(\Delta SWE\) is the change in the snowpack’s water equivalent (m), \(S\) is the net incident solar radiation (kJ m\(^{-2}\)), \(L_a\) is the atmospheric long wave radiation (kJ m\(^{-2}\)), \(L_t\) is the terrestrial long wave radiation (kJ m\(^{-2}\)), \(H\) is the sensible heat exchange (kJ m\(^{-2}\)), \(E\) is the energy flux associated with the latent heats of vaporization and condensation at the surface (kJ m\(^{-2}\)), \(G\) is ground heat conduction to the bottom of the snowpack (kJ m\(^{-2}\)), \(P\) is heat added by rainfall (kJ m\(^{-2}\)) and \(SWE(C\Delta T_s)\) is the change of snowpack heat storage (kJ m\(^{-2}\)).

Envisaging post-earthquake snowmelt-induced shallow landslides under climate change

Srikrishnan Siva Subramanian (1), Xuanmei Fan (1), Ali. P. Yunus (1), Theo van Asch (1), Qiang Xu (1) and Runqui Huang (1)

(1) State Key Laboratory of Geohazard Prevention and Geoenvironment Protection (SKLGP), Chengdu, Sichuan, China

Statistics from long-term 1989 – 2019 (30 years) daily weather records from selected AMeDAS (Automated Meteorological Data Acquisition System) inside Niigata.
Envisaging post-earthquake snowmelt-induced shallow landslides under climate change
Srikrishnan Siva Subramanian (1), Xuanmei Fan (1), Ali. P. Yunus (1), Theo van Asch (1), Qiang Xu (1) and Runqui Huang (1)
(1) State Key Laboratory of Geohazard Prevention and Geoenvironment Protection (SKLGP), Chengdu, Sichuan, China

Modeling snowmelt-induced shallow landslides under boundary conditions from the past and presumed future

- Meteorological data was collected for 15 AMeDAS stations inside Niigata prefecture.
- Meteorological domain was set dividing the Niigata area into 15 zones.

Siva Subramanian S, Fan X….Xu Q,… Huang et al., (Manuscript under preparation)
Envisaging post-earthquake snowmelt-induced shallow landslides under climate change
Srikrishnan Siva Subramanian (1), Xuanmei Fan (1), Ali. P. Yunus (1), Theo van Asch (1), Qiang Xu (1) and Runqui Huang (1)
(1) State Key Laboratory of Geohazard Prevention and Geoenvironment Protection (SKLGP), Chengdu, Sichuan, China

10 mm increase in daily snowfall projected for Niigata region in Japan. Kawase et al., 2016 (Climatic Change 139:265–278)
➢ Space and probability forecasting of future snowmelt-induced landslides under increased and decreased melt rates and post-earthquake settings.

Over the Niigata region, landslide area increases under high snowmelt and exaggerated if follows an earthquake.
We developed a novel spatially distributed, a physically-based numerical approach to compute slope stability within a basin, explicitly considering the atmosphere-ground, hydrology, and mechanical interactions on a day to day time step.

Using this model, we envisaged future snowmelt-induced landslides under increased and decreased melt rates and post-earthquake settings.

The probability density curves of these future landslides suggest that under slower snowmelt rates, the occurrence probability of individual landslides remains the same, whereas, under rapid and increased snowmelt rates, the size-distribution of the landslides increase one magnitude and doubles if rapid snowmelt follows an earthquake.

Thank you for your kind attention!