Bern University of Applied Sciences

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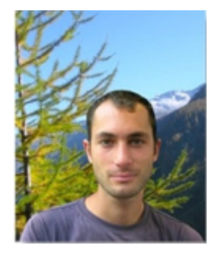
INTERPRAEVENT
2016 – Lucerne, Switzerland

Living with natural risks

Influence of forest structure on the mitigation of shallow landslides: a case study in St. Antönien (Switzerland)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Root reinforcement is recognized as an important factor for the stabilization of shallow landslides. Field studies revealed that the root distribution has a high temporal and spatial variability influenced by numerous factors, of which local ecological conditions and tree species composition are of highest importance.

Additionally, forest structure, mainly the diameter and position of trees, determines the spatial distribution of roots. Consequently, quantitative methods adapted for an assessment at hillslope scale are required to better understand the effects of forest structure and corresponding distribution of root reinforcement on slope stability. Moreover, it must be considered that root reinforcement contributes with different mechanisms to slope stability (Fig 1, Schwarz et al., 2015, JGR).

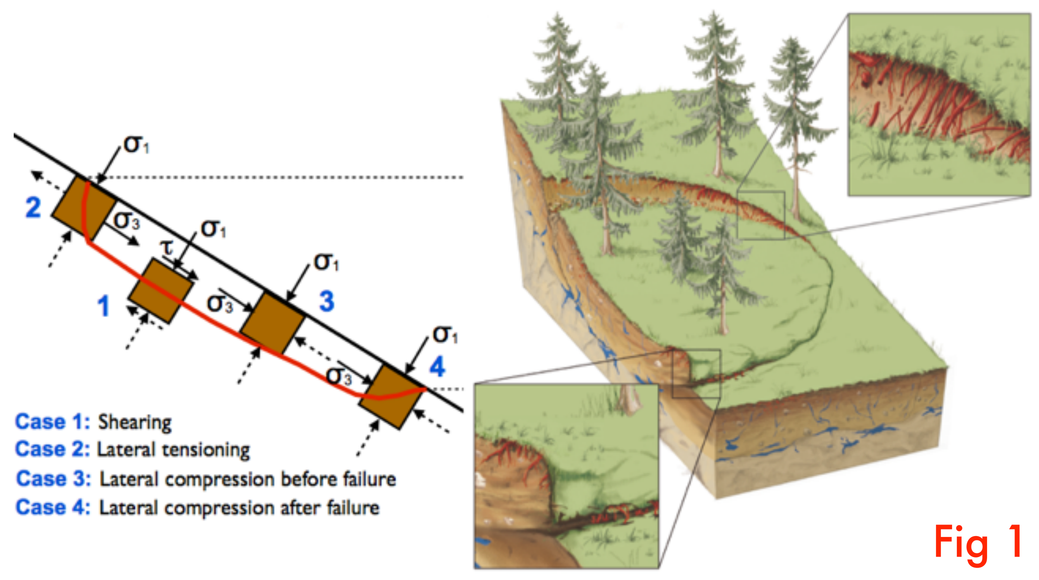

Fig 1

The objective of this work is to apply state of the art methods for the quantification of root reinforcement at hillslope scale and to analyse the influence of forest structure on slope stability combining statistical and physical models.

Flowcharts of methods — Fig 2

- **Field data** on root distribution and pullout tests
- Root Bundle Model | Root Distribution Model
- Characterization of forest structure with **FINT**
- Calculation of root reinforcement distribution
- Physically based model **SlideforMAP**
- Statistical analysis
- Results (e.g. Map protective function of forest)

Landslides dataset 2005, DEM, ...

The study area is located on a south-east exposed hillslope in St. Antönien (Eastern part of Switzerland) (Fig 3, Moos et al., 2016, ESPL). In 2005, a heavy rainfall event triggered numerous shallow landslides in the area. Shortly afterwards a detailed landslide inventory was compiled by Rickli et al. (2008). In addition to the 2005 landslides sites in forest , a set of control sites without landslide activity served as reference. The random determination of the control sites was based on two variables dictated by the landslide sites: slope angle and tree coverage.

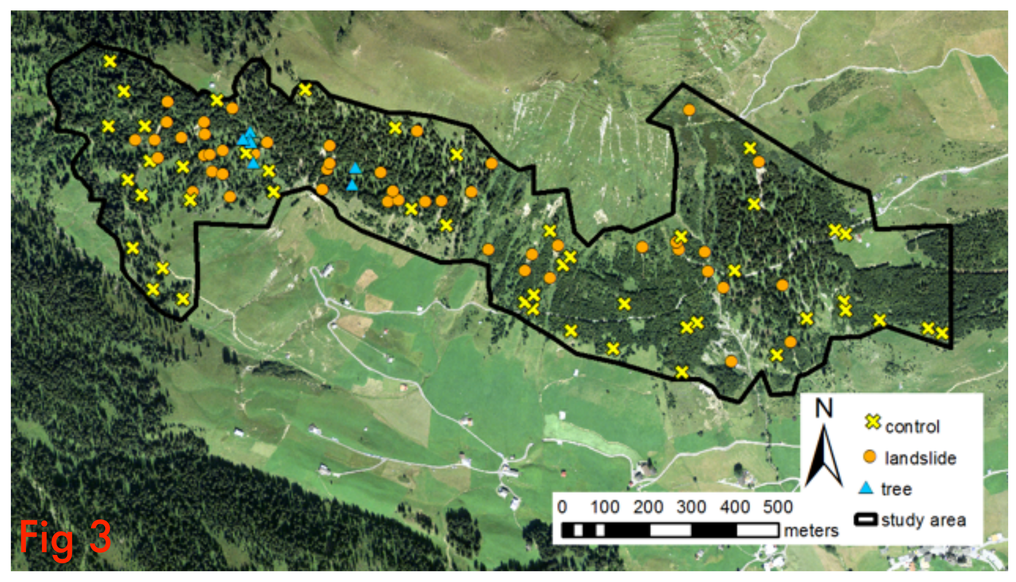

Fig 3


Fig 4

The root distribution was recorded in soil pits at regular distances (Fig 4) from 7 tree stems. In a first step, the results served to calibrate the root distribution model of Schwarz et al. (2010, ESPL) which, in a second step, described the root distribution for a large set of tree diameters (DBH) and distances from tree stems. The physically based numerical Root Bundle Model (RBMw; Schwarz et al., 2013, HESS) finally calculated root reinforcement as function of tree dimension and distance from tree stem using field root pullout data for calibration (Fig 5). The resulting root reinforcement served as input parameter to assess the influence of forest structure on slope stability following two different approaches: 1) statistical analysis and 2) a physically based model.


Fig 5

The statistical analysis of the relations between landslide occurrence and potentially relevant explanatory variables (such as lateral root reinforcement, slope inclination, water logging, etc.) were analysed using logistic regression as well as recursive partitioning based on the R package "Random Forest". The root reinforcement of the nearest trees was approximated based on the modelled values of root reinforcement using a gamma distribution.

The physically based model SlideforMAP , an extension of the tool SlideforNET (slidefor.net), is based on a 3D force balance assuming an elliptical shape of the shallow landslide body (Schwarz et al., 2016, NZJF). Root reinforcement is implemented in the calculation by considering 1) the roots crossing at the upper margin of the landslide (lateral root reinforcement along the potential tension crack) and 2) the roots crossing at the basal shearing plane (basal root reinforcement). In order to account for the effects of lateral root reinforcement on different dimensions of shallow landslides, a Gamma probability function is used to describe the frequency-magnitude distribution of potential shallow landslide volumes following Malamud et al (2008, WRR). The resulting number of unstable landslides both with and without root reinforcement is used to quantify the stabilising effect of forest structure on shallow landslides. The position and dimension of the trees was derived from DHM and DEM datasets using the FINT tool (ecorisq.org).

The results of the statistical analysis show that a gap length of 20 m can be considered as a critical threshold for increased susceptibility to shallow landslides.

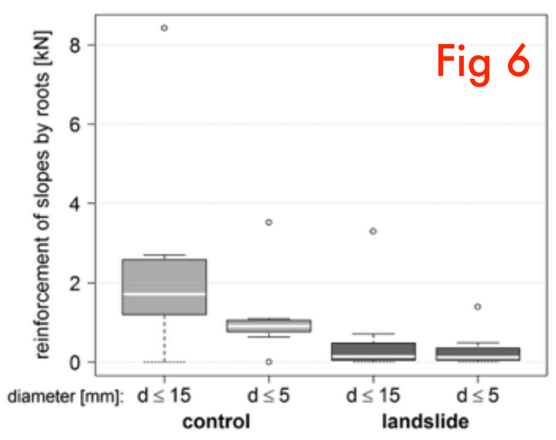

Fig 6

The calculated maximum of lateral root reinforcement of the five nearest trees to landslide and to control points are significantly different (Fig 6).

SlideforMAP can be used to visualize the spatial distribution of the protective effect of forest for a simulated 100 mm/h rainfall event without (Fig 7a) or with root reinforcement (Fig 7b). Such information may help to optimize the silvicultural measures and define where root reinforcement is effective in slope stabilization (Fig 7a- Fig 7b -> Fig 9).

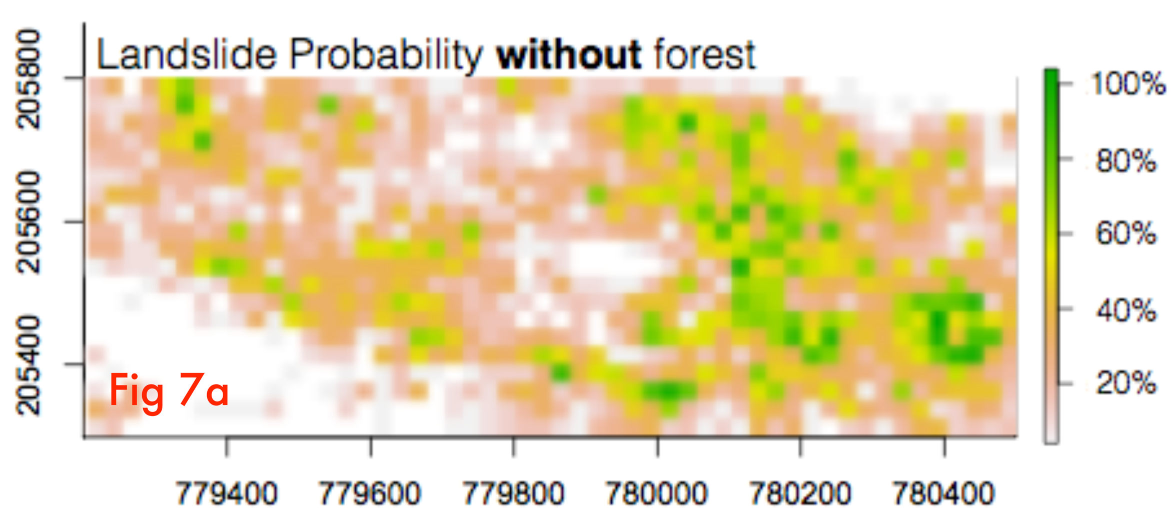

Fig 7a

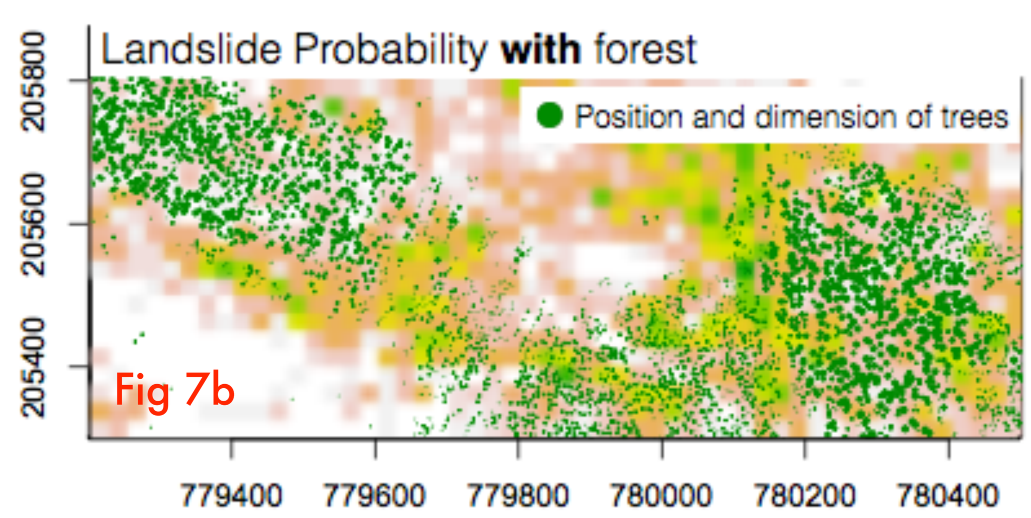

Fig 7b

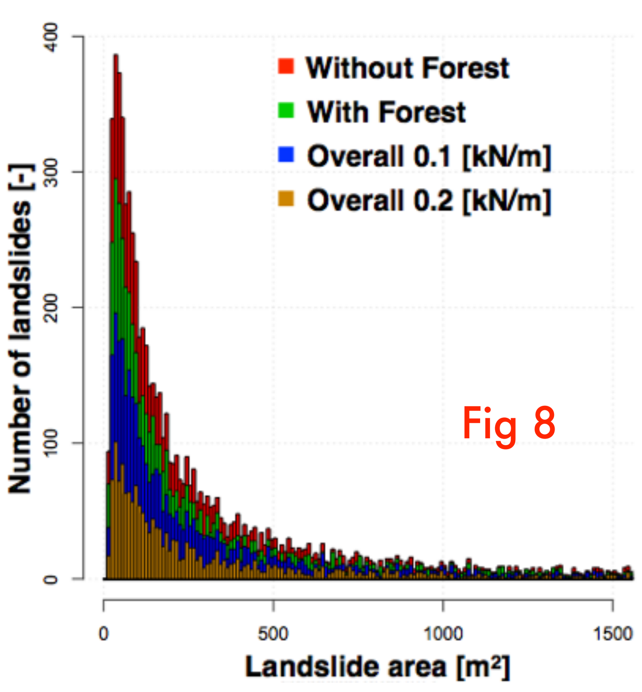

Fig 8

The results of the physically based model show that the efficiency of lateral root reinforcement depends on the dimension of the shallow landslides (Fig 8) and on the slope angle.

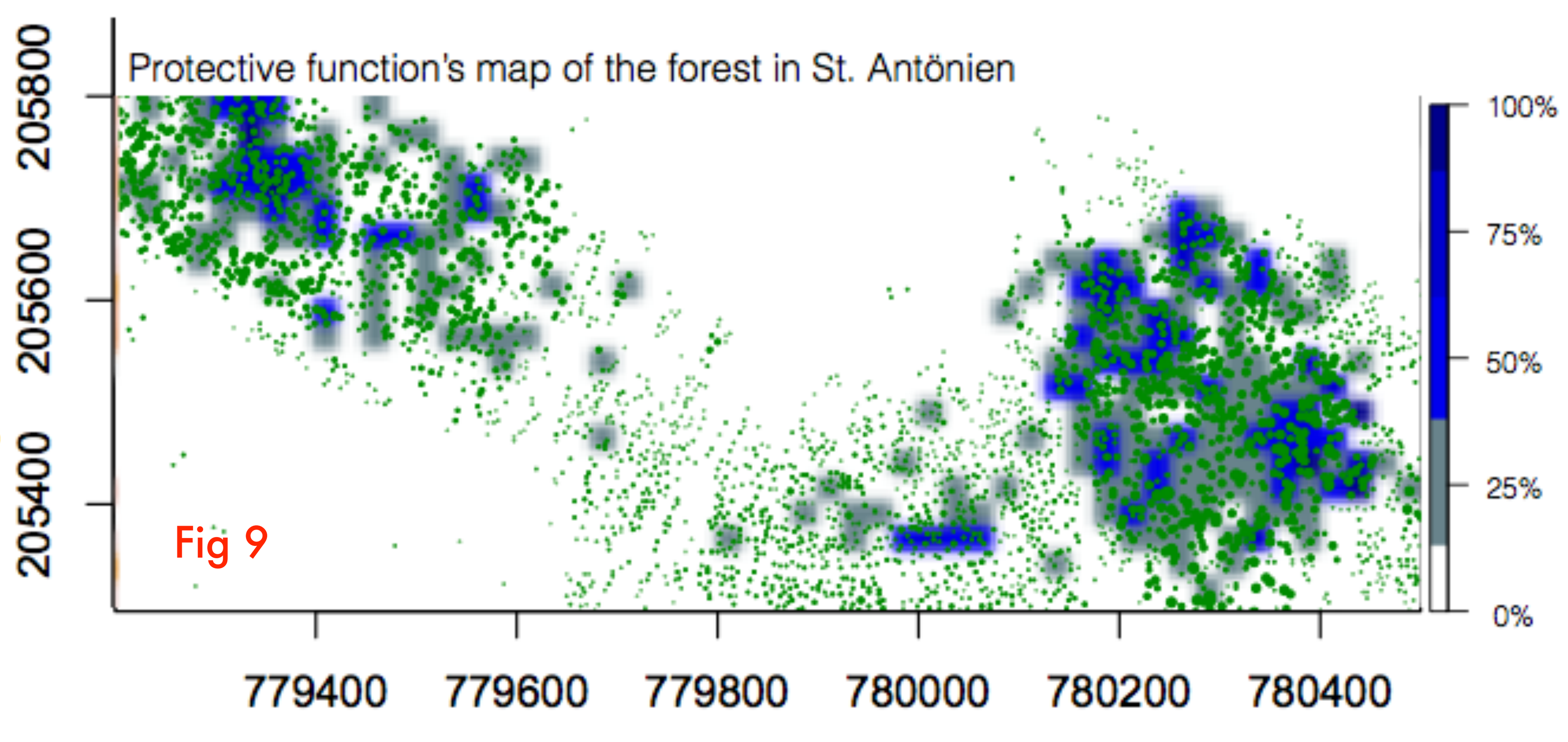

Fig 9

The results indicate that forest structure in addition to terrain and hydrological features substantially influences slope stability in spruce dominated mountain forest landscapes. Landslide susceptibility is decreased in forests with smaller distances from trees. therefore is a detailed characterization of spatial root reinforcement distribution important.

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