EGU European Geosciences Union 2020 | Online

SlideforMap – a regional scale probabilistic model for shallow landslide onset analysis and protection forest management

Berner Fachhochschule
Haute école spécialisée bernoise
Bern University of Applied Sciences

Feiko van Zadelhoff
Luuk Dorren
Massimiliano Schwarz

contact: Feiko.vanzadelhoff@bfh.ch

SlideforMap Overview

Purpose

- predict shallow landslide susceptibility
- Quantify the influence of protection forest regarding shallow landslide hazard
- Regional scale

Why yet another Landslide prediction model?

- Probabilistic parametrization to encompass mountain soil heterogeneity
- Root reinforcement implemented on a tree basis

SlideforMap

Calculations

- Probabilistic
- 100.000s – 10.000.000s randomly located landslides (RLL)
- RLL surface area distribution based on gamma fit on a shallow landslide inventory
- Factor of Safety calculated per RLL

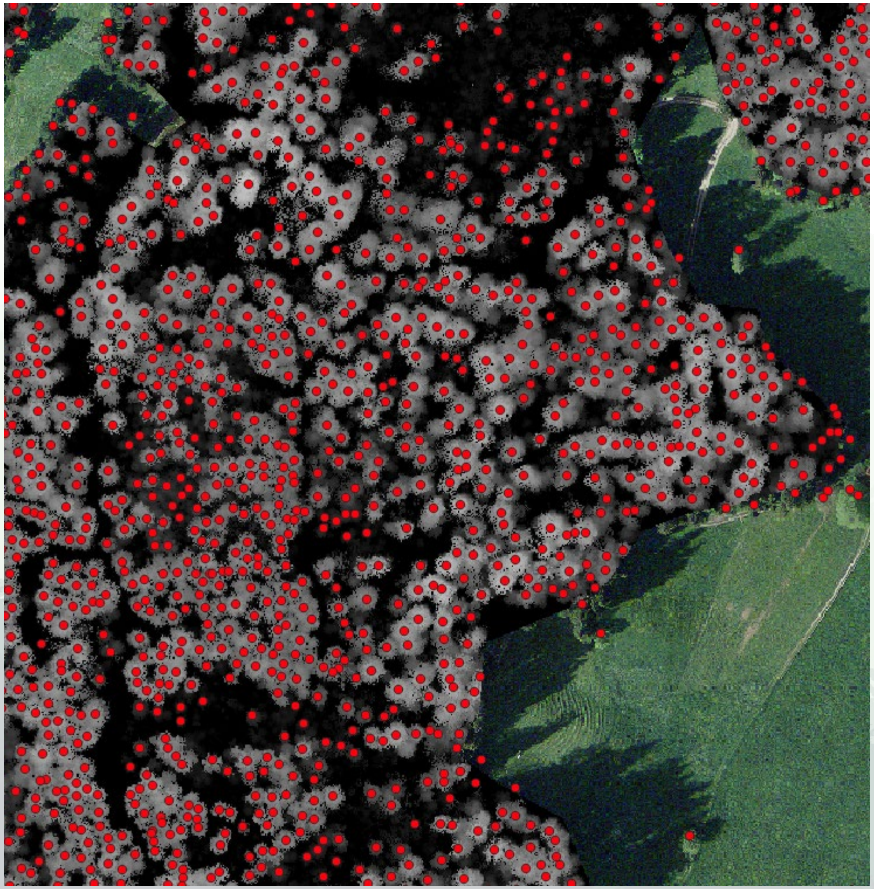
SlideforMap

Input

- DTM & DSM
- Topographic wetness index (TWI) or flow accumulation raster
- A representative landslide inventory

Trees

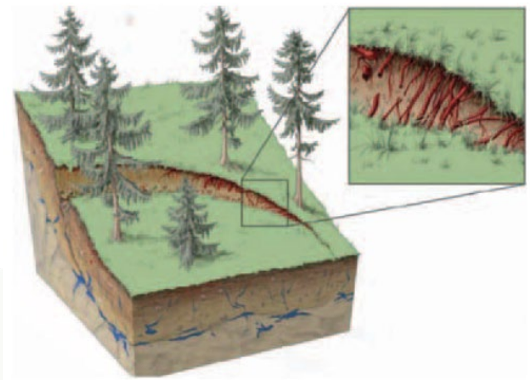
Summarized Workflow

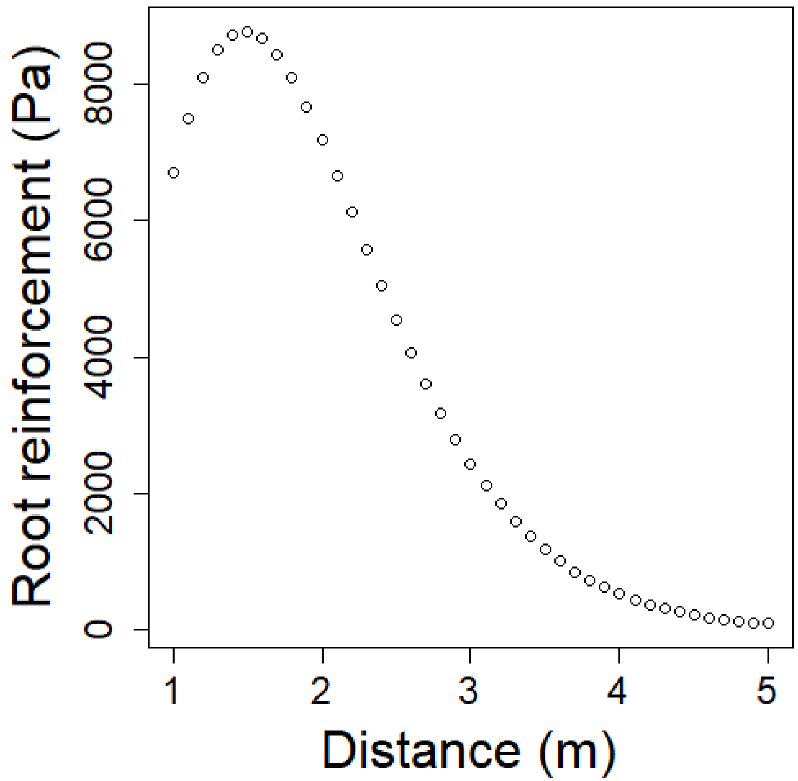


- DSM minus DTM
- Resample
  (1 m. res.)
- Gaussian filter
  (kernel = 3, st. dev. = 2)
- Find Local Maxima and
  extract height
- DBH = 0.0125 * height

Lateral Root reinforcement

$$RR_{lat}\,(DBH, Distance) = 50 \cdot DBH \cdot \gamma[\alpha,\beta]\,\frac{Distance}{0.01 * DBH * 18.5}$$





α and β: shape and scale parameters of the gamma distribution.

$\alpha = 5$
$\beta = 15$

Moos et al., 2015
Picea Abies (Spruce)

Basal root reinforcement

$RR_{bas} = RR_{lat} * \gamma[\alpha,\beta]$ (Soil Depth)

$\alpha = 3.1$
$\beta = 12.57$

Moos et al., 2015

Picea Abies (Spruce)

Vegetation Weight

- Trees assumed as cones
- Density assumed of 700 kg/m^3
- Weight equally distributed over root extent

Hydrology

TOPmodel (Beven & Kirkby, 1979)

$$\text{TWI} = \ln\left(\frac{A_{catchment}}{\tan(Slope)}\right)$$

$$w = \frac{P}{T} * \text{TWI}$$

w = Fraction of a cell that is saturated i.e. position of groundwater table (-)
P = Precipitation (m/s)
T = Soil Transmissivity (m^3/s)
TWI = Soil Transmissivity (m/s)

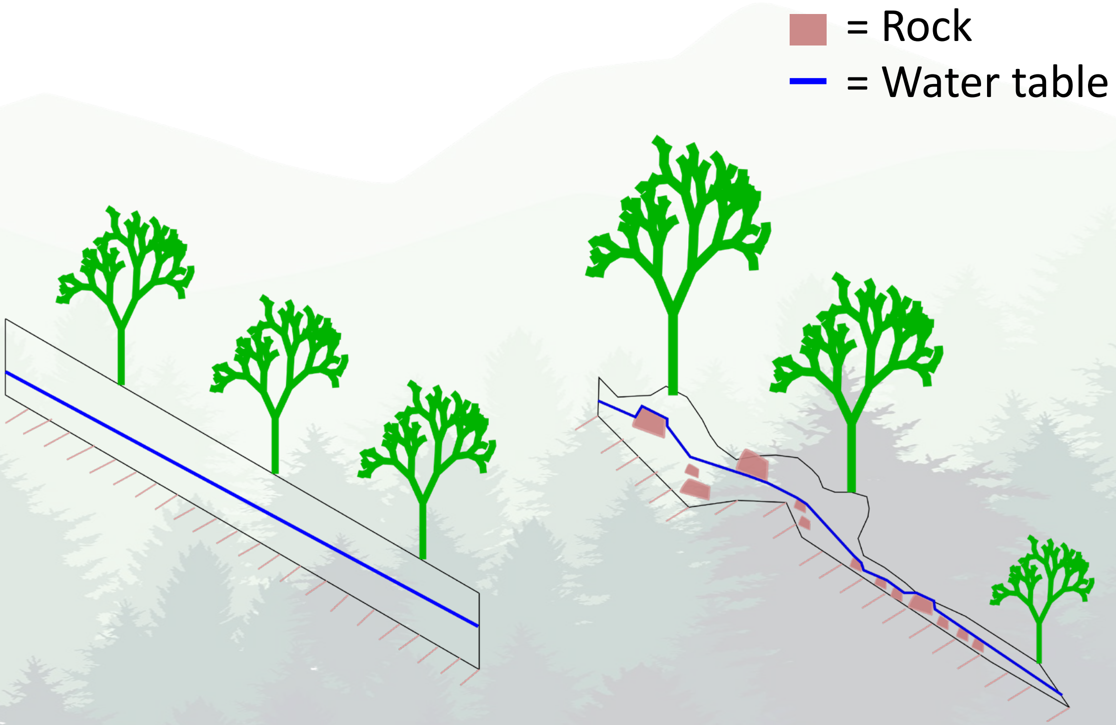
Assumed: steady state reached in short time due to macropore dominance in hydrology

The transmissivity is calibrated by assuming that
- Under a precipitation with a 100 year return period
- 25% of the area gets fully saturated (w=1)

Parametrization

Mountainous area -> Probabilistic rather than deterministic -> Picks from a normal distribution for the following parameters:

- Soil Depth (afterwards corrected on steep slopes)
- Soil Cohesion
- Angle of Internal Friction



Deterministic model vs. Mountainous reality

SlideforMap

Output

Each cell is touched by a large number of RLL

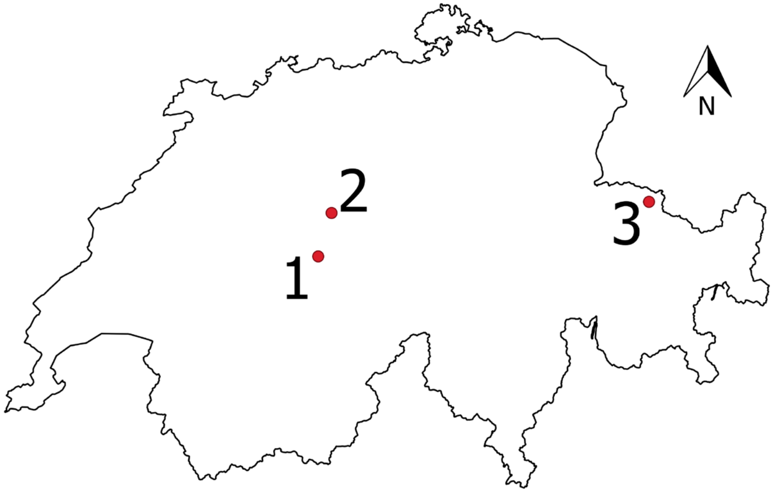
Per cell: The percentage of these slides that is unstable (FOS < 1)

Output is:

Shallow landslide susceptibility under a certain precipitation event

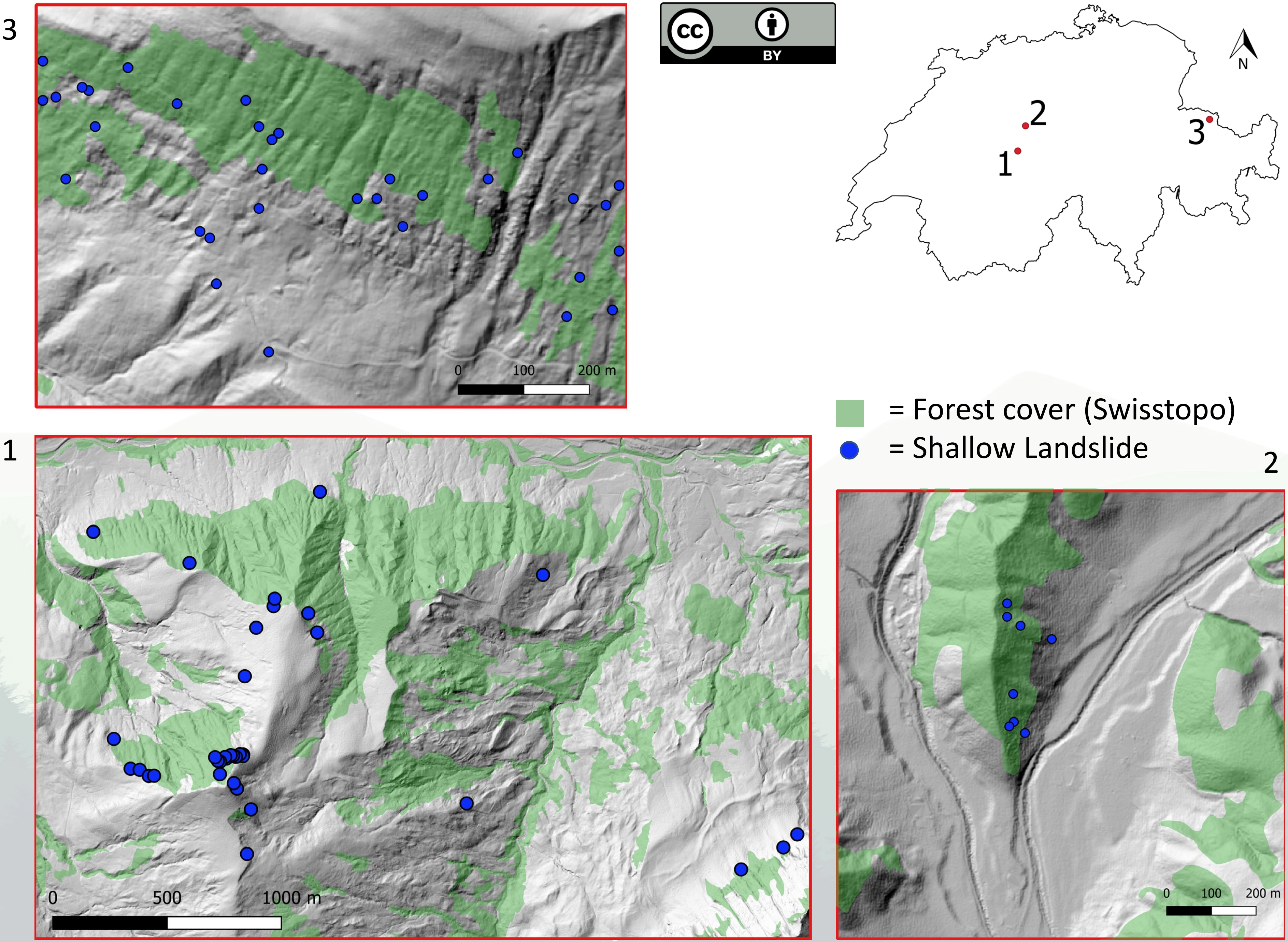
Test areas

Switzerland

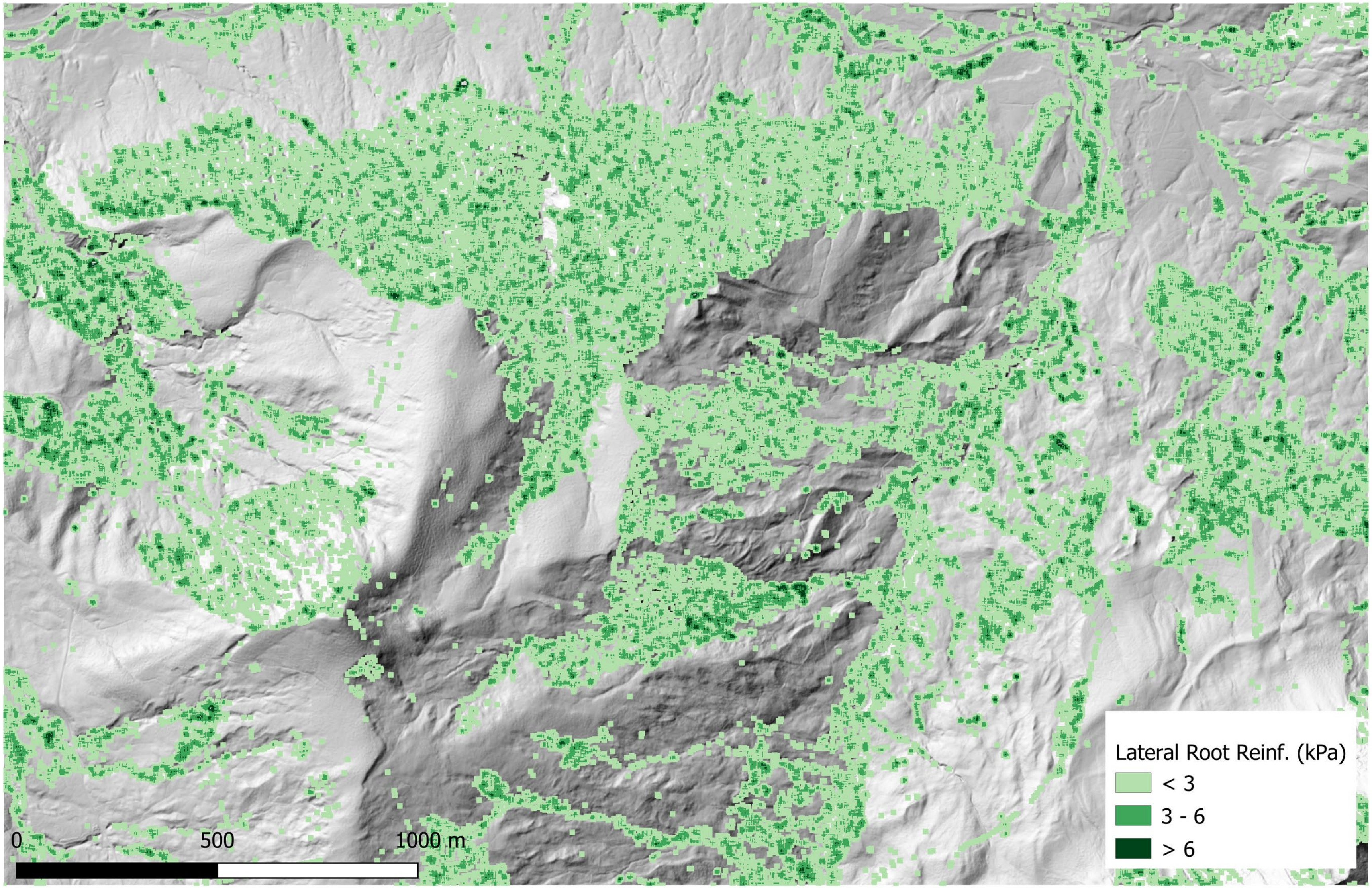


Study Area	Centre (WGS 84)	Size (km^2)	Elevation range (m.a.s.l)
1	7.81; 46.78	7.54	966 – 1753
2	7.90; 46.96	1.00	820 – 1016
3	9.80; 46.98	0.56	1542 – 2009

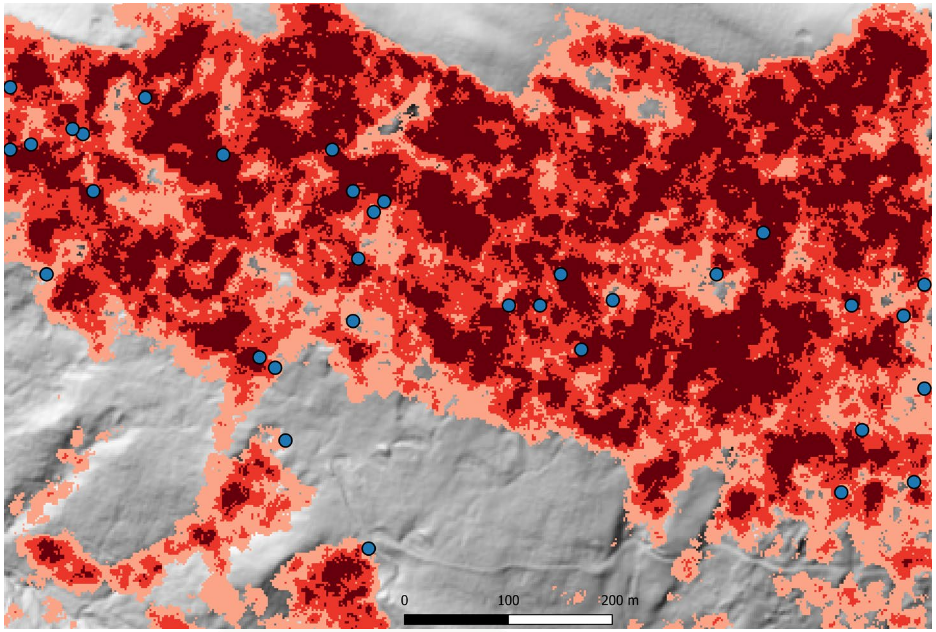
Landslide inventory from the Swiss Federal office of the environment (BAFU). 667 Shallow Landslides, 1997-2012


3
0
100
200 m
2
1
3
N
= Forest cover (Swisstopo)
= Shallow Landslide
1
0
500
1000 m
2
0
100
200 m

Example of modelled Lateral root reinforcement in Area 1



3



Event: P = 38 mm over one hour

Observed shallow landslides

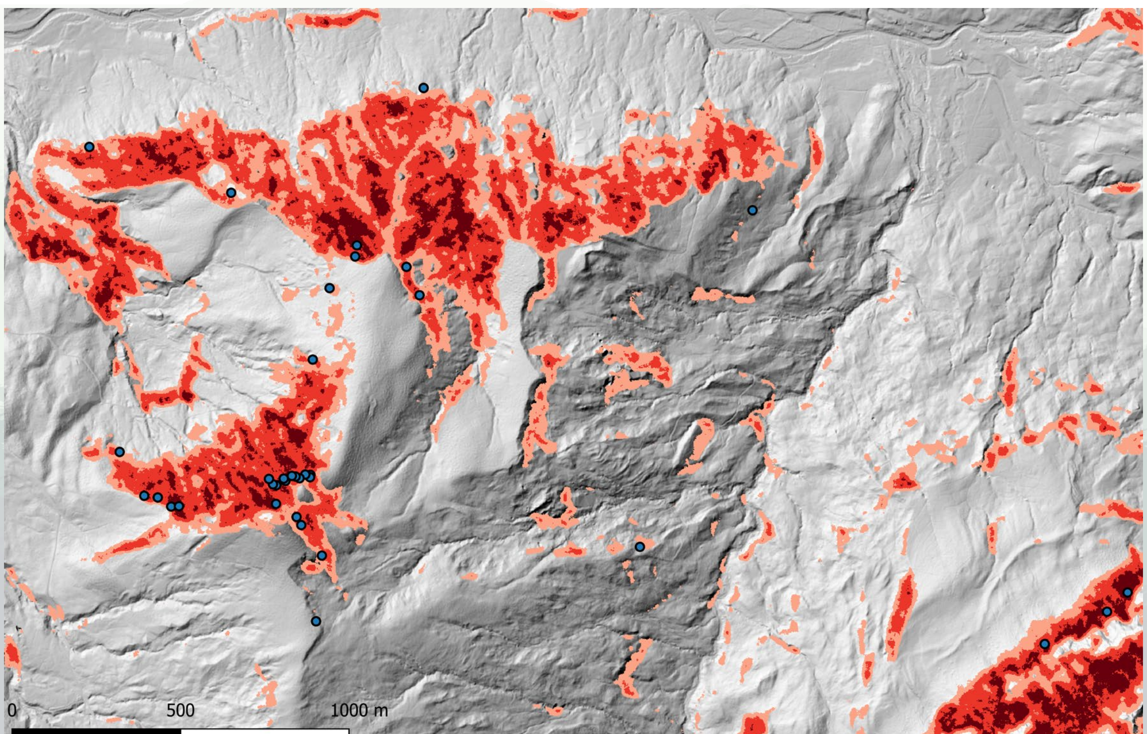
Shallow landslide susceptibility (-)

25 - 50 %

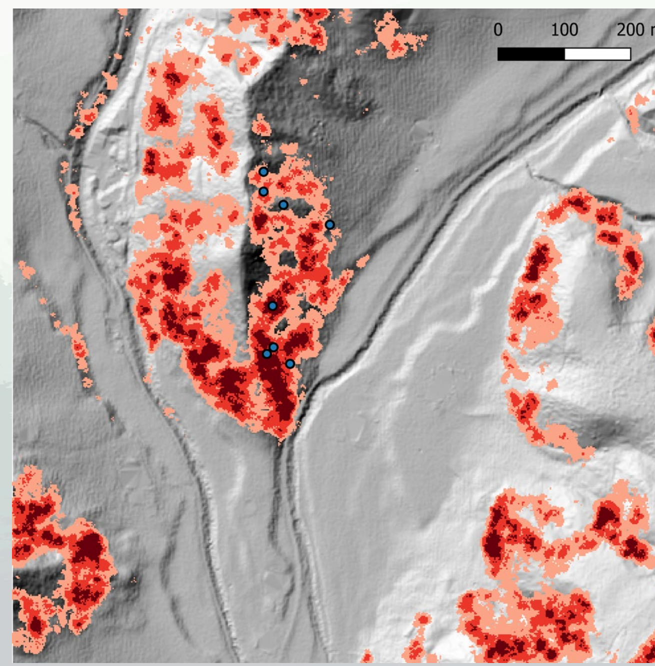
50 - 75 %

> 75 %

1



2



Sensitivity

Latin Hypercube Sampling (McKay et al. 1979)

On the fraction of RLL that are unstable.
Mean of 800 runs per test area, only significant variables shown

Variable	PRCC (importance of the variable)	Beneficial (+) or harmful (-) to stability
Lateral Root reinforcement	0.69	+
Precipitation event	0.67	-
Mean Angle of internal friction	0.61	+
Mean soil depth	0.40	-
Assumed saturated fraction	0.38	-
100 year precipitation intensity	0.33	-
Mean cohesion	0.24	+

Validation

AUC

Model / Inventory	TRUE	FALSE
TRUE	True positive (TP)	False negative (FN)
FALSE	False positive (FP)	True negative (TN)

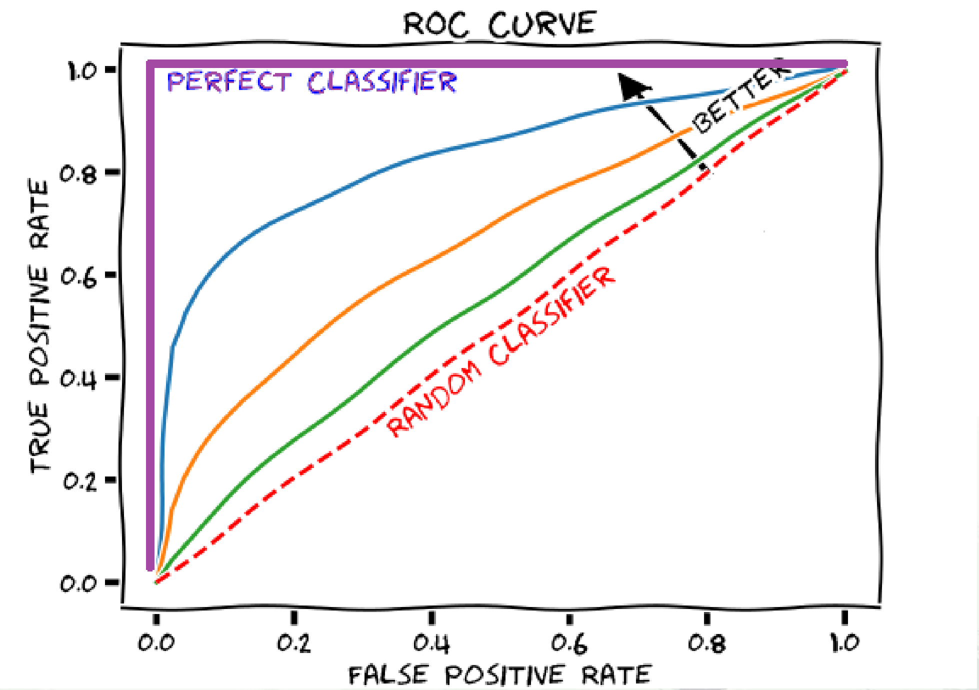


Figure by: Rachel Draelos, Machine learning and medicine

Study Area	Mean AUC
1	0.84
2	0.84
3	0.63

- SlideforMap enables us to predict the effect of different protection forest management techniques, different planting techniques, the influence of forest fires on slope stability and maybe many more applications

Future

- Improvement in the hydrological approach

- Improvement in validation

  somehow make it independent of the topography of the study area, suggestions are welcome

- Differentiate tree species

References

- Beven, K. J., & Kirkby, M. J. (1979). A physically based, variable contributing area model of basin hydrology. *Hydrological Sciences Bulletin*, *24*(1), 43–69. https://doi.org/10.1080/02626667909491834
- McKay, M. D., Beckman, R. J., & Conover, W. J. (1979). Comparison of three methods for selecting values of input variables in the analysis of output from a computer code. *Technometrics*, *21*(2), 239-245.
- Moos, C., Bebi, P., Graf, F., Mattli, J., Rickli, C., & Schwarz, M. (2016). How does forest structure affect root reinforcement and susceptibility to shallow landslides? *Earth Surface Processes and Landforms*, *41*(7), 951–960. https://doi.org/10.1002/esp.3887
- Schwarz, M., Giadrossich, F., & Cohen, D. (2013). Modeling root reinforcement using a root-failure Weibull survival function. *Hydrology and Earth System Sciences*, *17*(11), 4367–4377. https://doi.org/10.5194/hess-17-4367-2013