Case study from Swiss prealpine area (Emmental) from 2002 and 2005

Manfred Stähli [1], Christian Rickli [1], Jonas von Rütte [2],
Peter Lehmann [2] and many others

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[2] ETH Zürich, Soil and Terrestrial Environmental Physics

Foto: landwege.blogspot.ch

Short summary of the two events

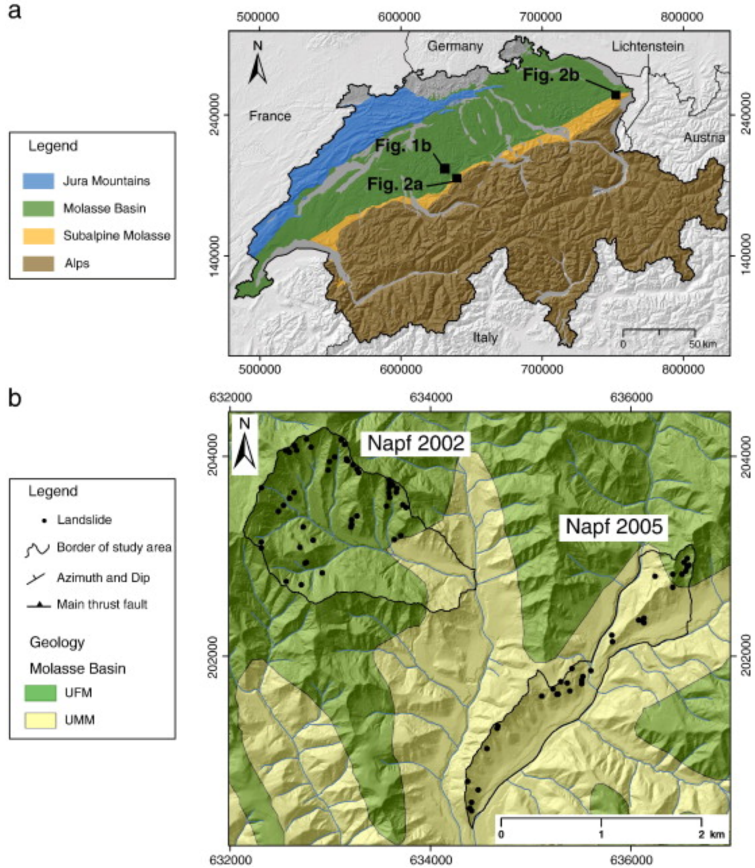
	15-16 July, **2002**	18-23 Aug., **2005**
Duration of rain-fall event:	3 hours	72 hours
Total amount of precipitation:	60 mm	241 mm
Number of observed landslides:	64	54

Geology:

- Molasse Basin
- Fluvial deposits of conglomerates and sandstones with intercalated marl layers

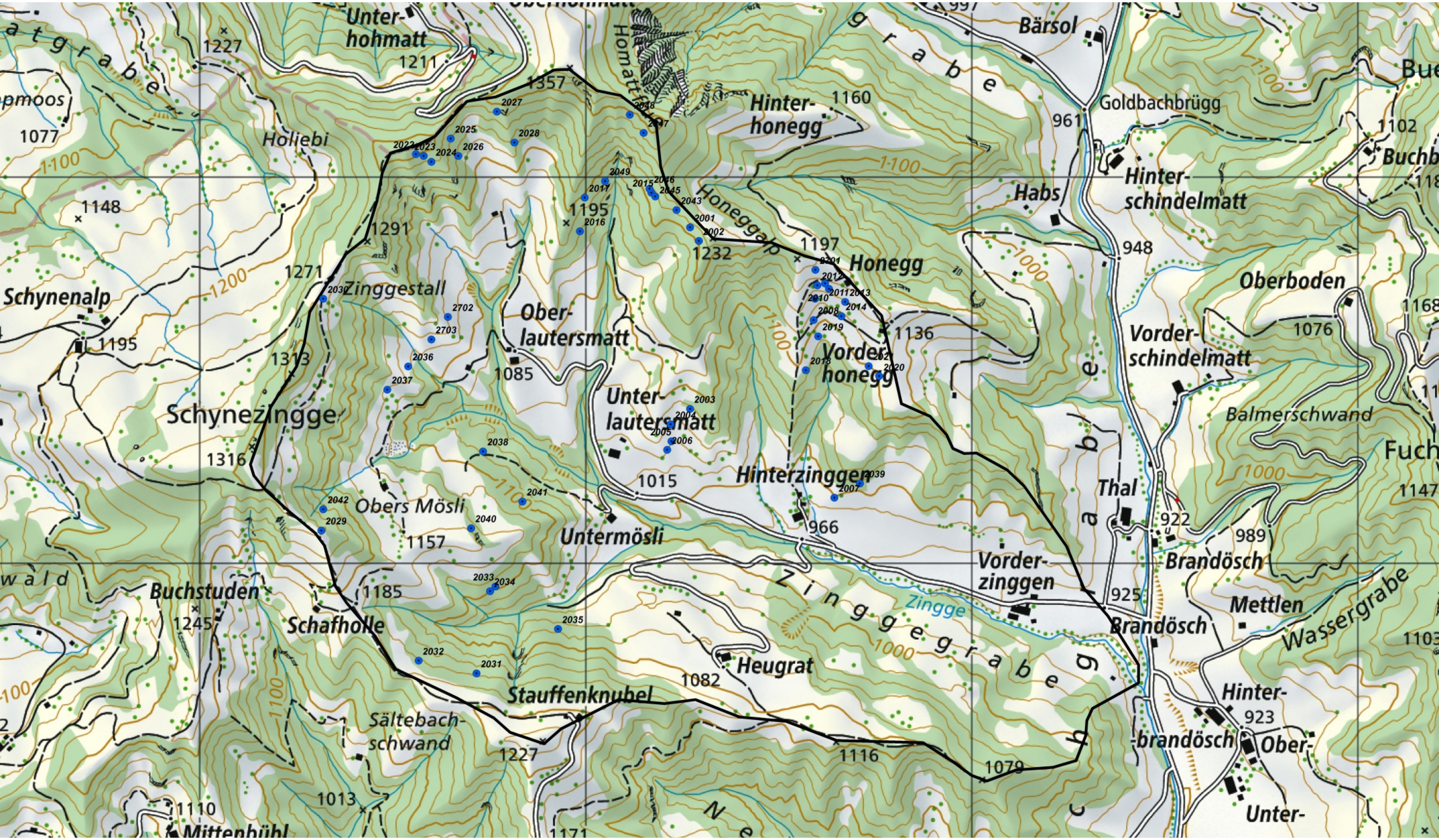
Area characteristics:

- Elevation: 800 – 1200 m a.s.l.
- Slope: 0 – 40º



From: von Ruette et al. 2011. Geomorphology,

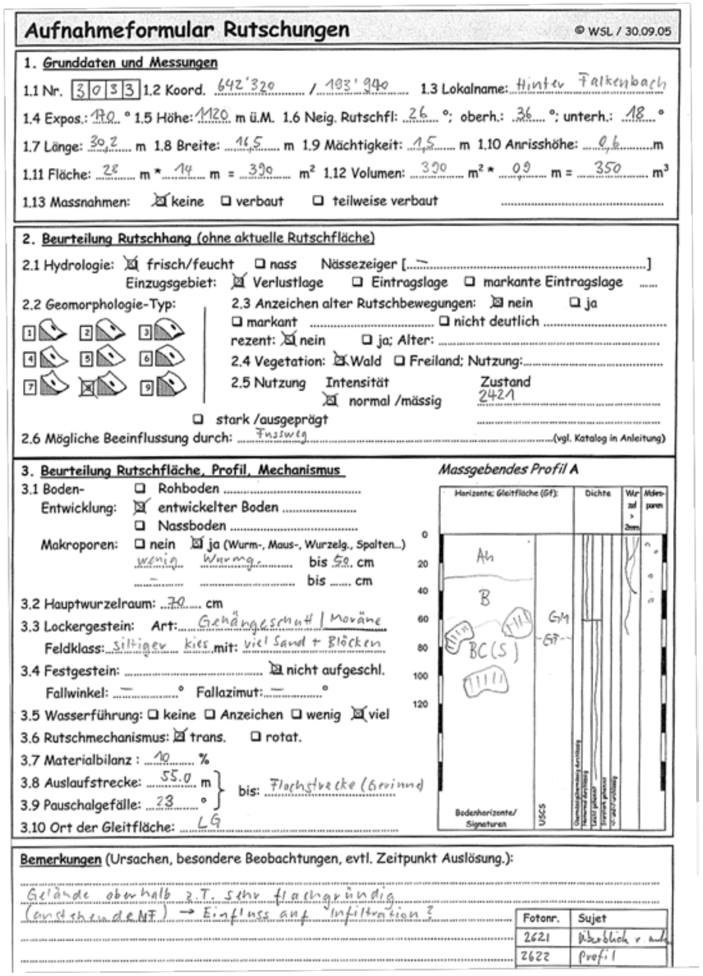
Observed landslides Napf (Zinggegrabe) 2002



Observed landslides Napf (Fankhausgraben) 2005

Inventory of shallow landslides

Assembled by Christian Rickli and co-workers (WSL)



Aufnahmeformular Rutschungen © WSL / 30.09.05

1. Grunddaten und Messungen

1.1 Nr. 3033 1.2 Koord. 642'320 / 193'940 1.3 Lokalname: Hinter Falkenbach

1.4 Expos.: 170 ° 1.5 Höhe: 1120 m ü.M. 1.6 Neig. Rutschfl: 26 °; oberh.: 36 °; unterh.: 18 °

1.7 Länge: 30,2 m 1.8 Breite: 16,5 m 1.9 Mächtigkeit: 1,5 m 1.10 Anrisshöhe: 0,6 m

1.11 Fläche: 28 m * 14 m = 390 m² 1.12 Volumen: 390 m² * 0,9 m = 350 m³

1.13 Massnahmen: ☒ keine ☐ verbaut ☐ teilweise verbaut

2. Beurteilung Rutschhang (ohne aktuelle Rutschfläche)

2.1 Hydrologie: ☒ frisch/feucht ☐ nass Nässezeiger [–]

Einzugsgebiet: ☒ Verlustlage ☐ Eintragslage ☐ markante Eintragslage

2.2 Geomorphologie-Typ: ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☒ 8 ☐ 9

2.3 Anzeichen alter Rutschbewegungen: ☒ nein ☐ ja

☐ markant ☐ nicht deutlich

rezent: ☒ nein ☐ ja; Alter:

2.4 Vegetation: ☒ Wald ☐ Freiland; Nutzung:

2.5 Nutzung Intensität ☒ normal /mässig ☐ stark /ausgeprägt Zustand 2421

2.6 Mögliche Beeinflussung durch: Fussweg (vgl. Katalog in Anleitung)

3. Beurteilung Rutschfläche, Profil, Mechanismus

3.1 Boden-Entwicklung: ☐ Rohboden ☒ entwickelter Boden ☐ Nassboden

Makroporen: ☐ nein ☒ ja (Wurm-, Maus-, Wurzelg., Spalten...)

wenig Wurmg. bis 50 cm

– bis ... cm

3.2 Hauptwurzelraum: 70 cm

3.3 Lockergestein: Art: Gehängeschutt / Moräne

Feldklass: siltiger kies mit: viel Sand + Blöcken

3.4 Festgestein: ☒ nicht aufgeschl.

Fallwinkel: – ° Fallazimut: – °

3.5 Wasserführung: ☐ keine ☐ Anzeichen ☐ wenig ☒ viel

3.6 Rutschmechanismus: ☒ trans. ☐ rotat.

3.7 Materialbilanz : 10 %

3.8 Auslaufstrecke: 55.0 m

3.9 Pauschalgefälle: 23 °

bis: Flachstrecke (Gerinne)

3.10 Ort der Gleitfläche: LG

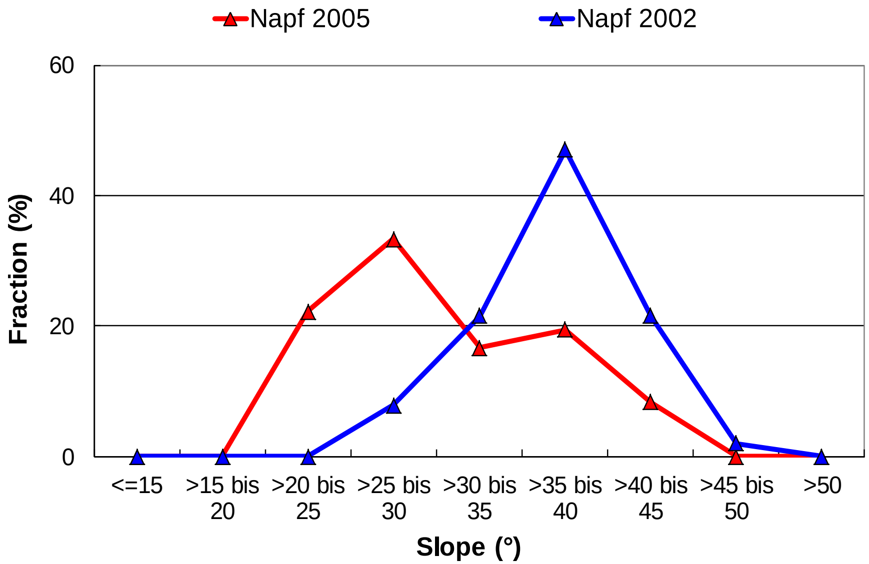
Massgebendes Profil A

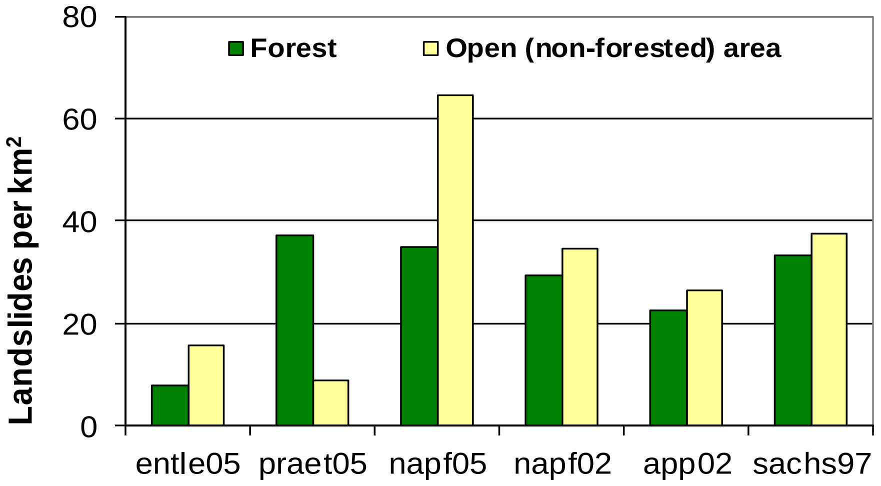
Bemerkungen (Ursachen, besondere Beobachtungen, evtl. Zeitpunkt Auslösung.):

Gelände oberhalb z.T. sehr flachgründig (anstehende NF) → Einfluss auf Infiltration?

Fotonr.	Sujet
2621	Überblick v. unten
2622	Profil

Template for characterizing each landslide





Spatial statistical modeling of shallow landslides

von Ruette et al. 2011, Geomorphology, 133: 11-22.

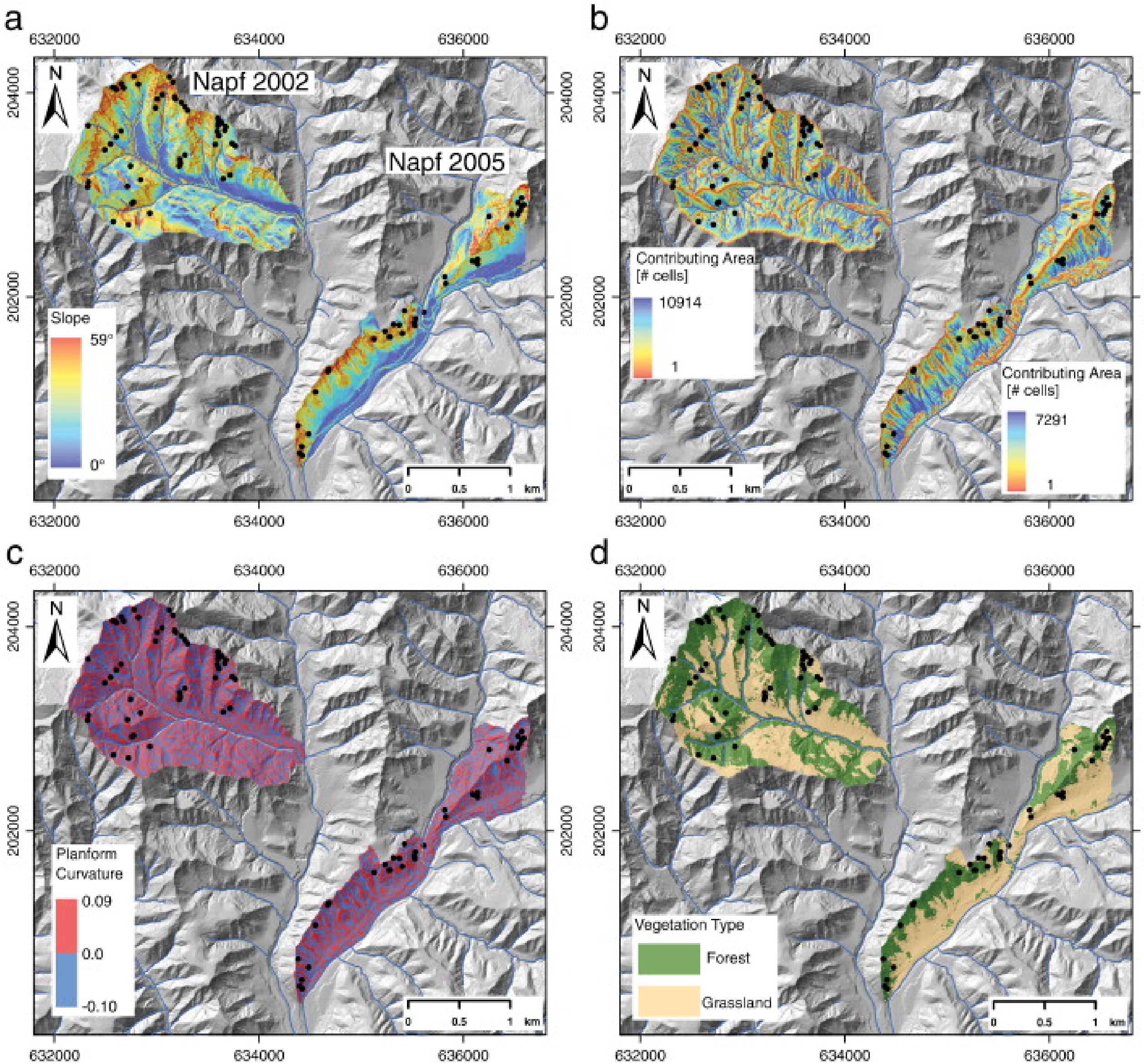
Method:

- Logistic regression model fitted to 2005
- Then applied to 2002

Question:

Transferability of statistical models?

Maps of explanatory variables (10 m grid spacing)
(a) slope angle,
(b) contributing area,
(c) planform curvature,
(d) vegetation type.



WSL

Spatial statistical modeling of shallow landslides

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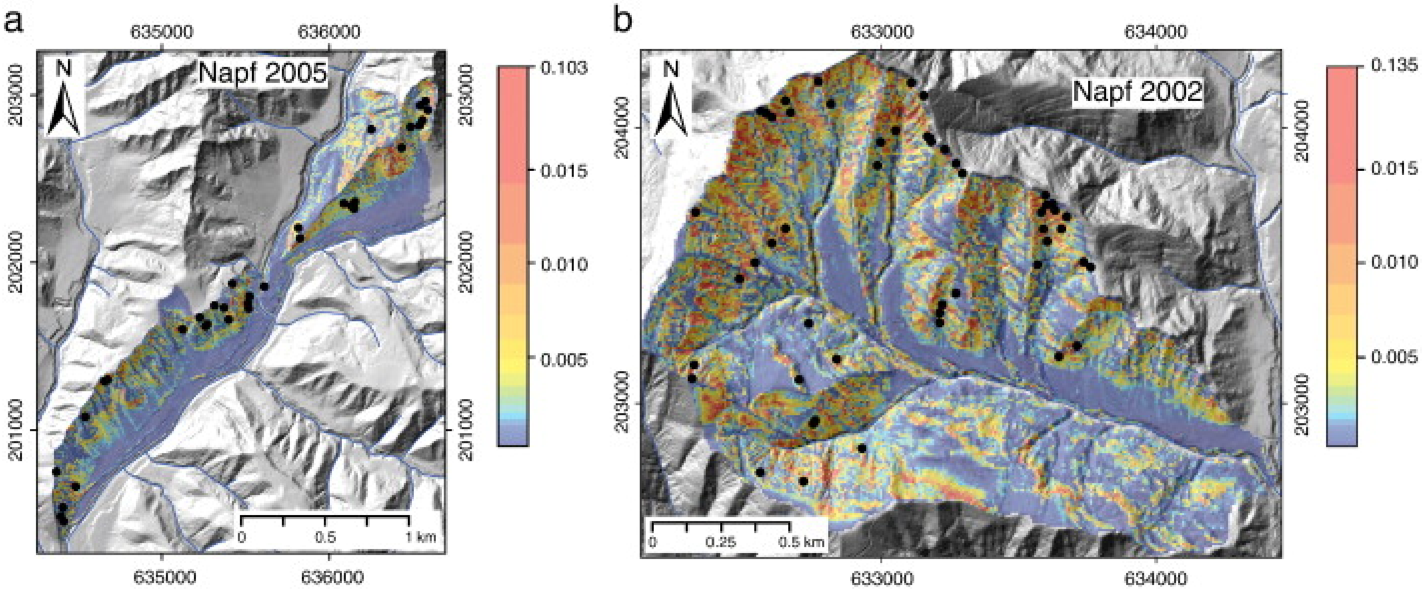
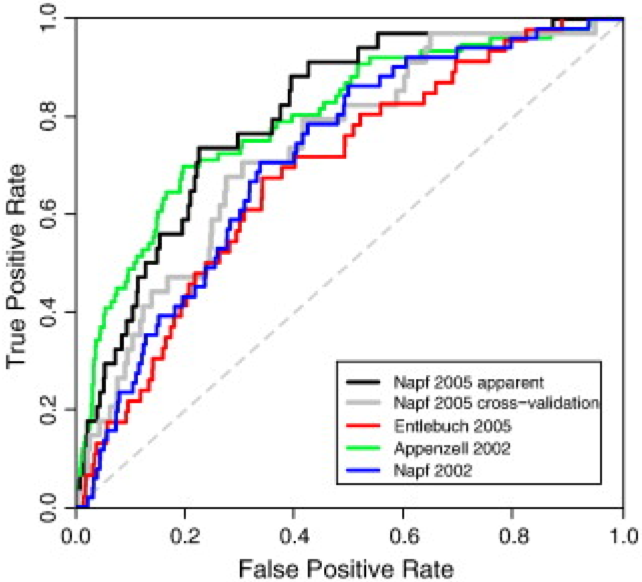
Results:



Susceptibility maps:
(a) Calibration study area Napf 2005.
(b) Validation study area Napf 2002.

Receiver Operating Characteristics (ROC) curves: Cross-validation AUC for Napf 2005 is 0.74 and the apparent AUC value is 0.80. For the Napf 2002 validation study areas, the AUC values were somewhat smaller (0.72)



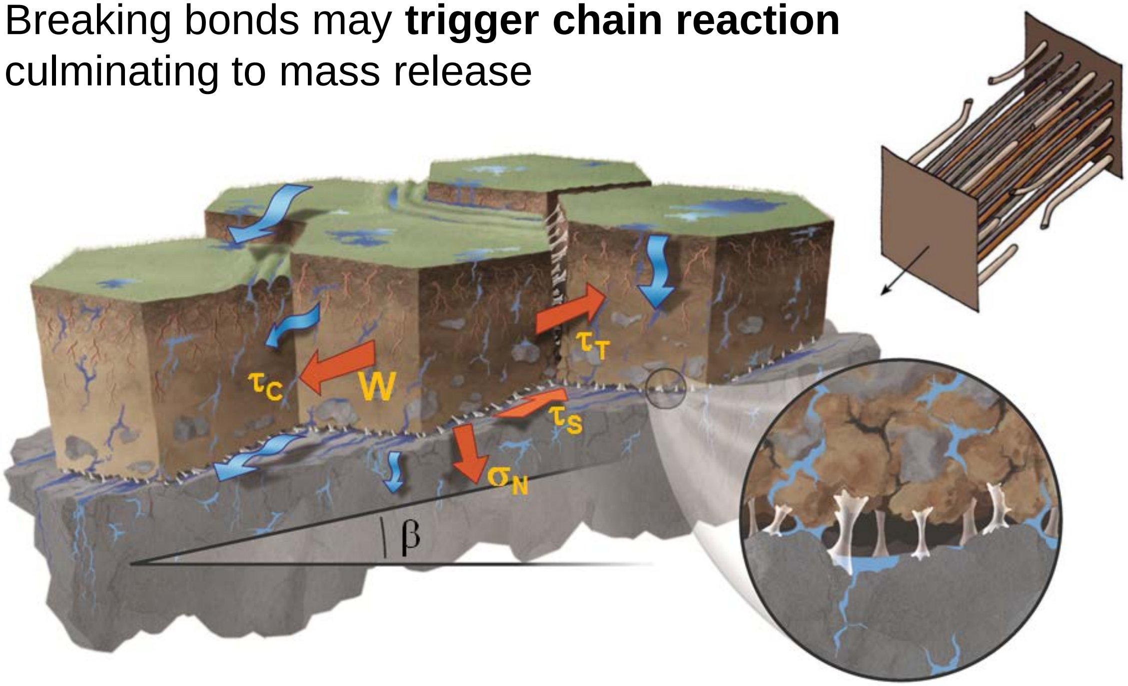
Numerical model STEP-TRAMM

Hydrology:

- Water **infiltration** into soil column
- **Subsurface flow** through soil matrix and fast flow along soil-bedrock interface
- **Surface runoff**

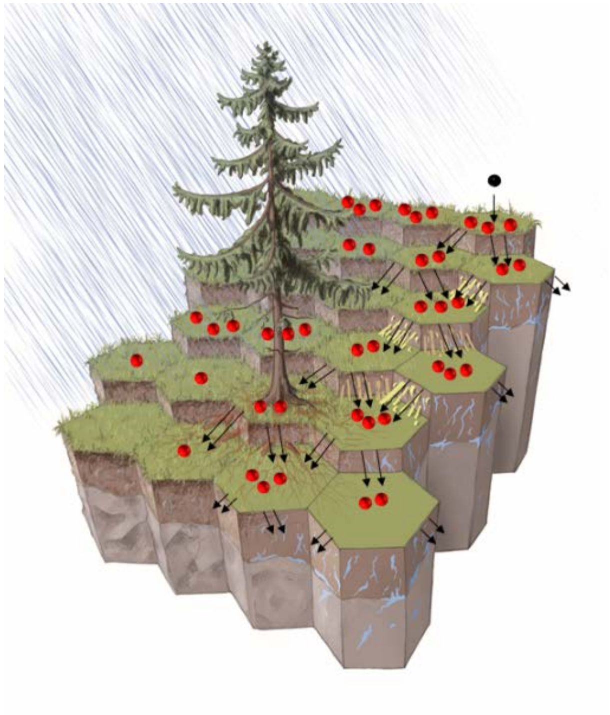
Soil Mechanics:

- Soil columns interconnected by **mechanical bonds** to bedrock and adjacent columns
- Breaking bonds may **trigger chain reaction** culminating to mass release



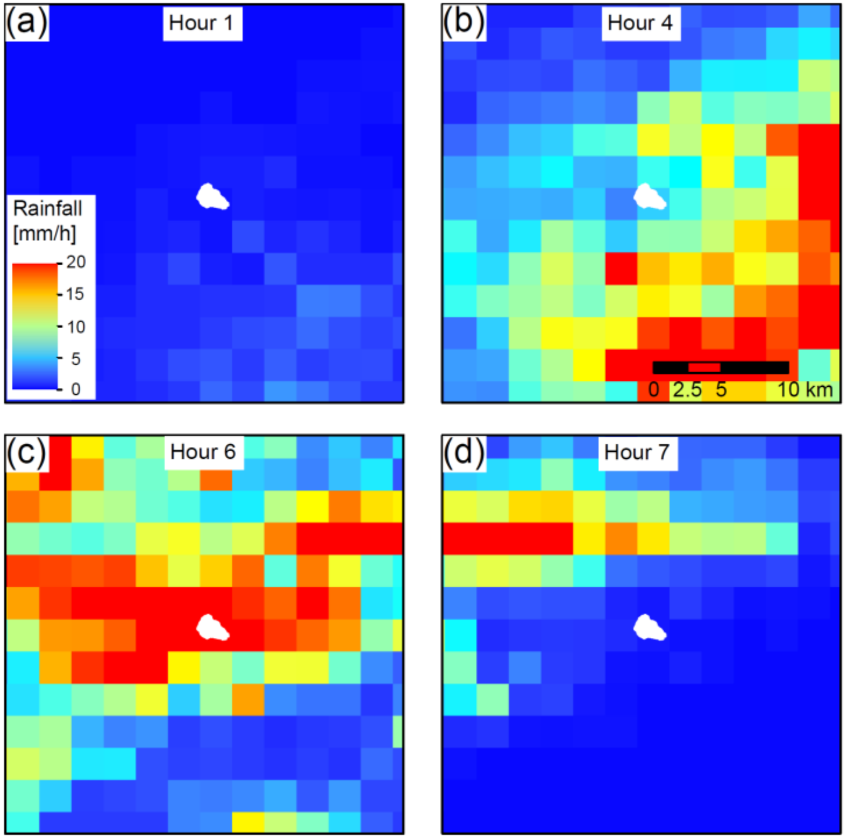
Lehmann and Or. 2012. Water Resources Research, 48, W03535.

- Incorporation of **strength threshold** leads to abrupt failure of mechanical bonds and chain reaction, determining attainment of criticality

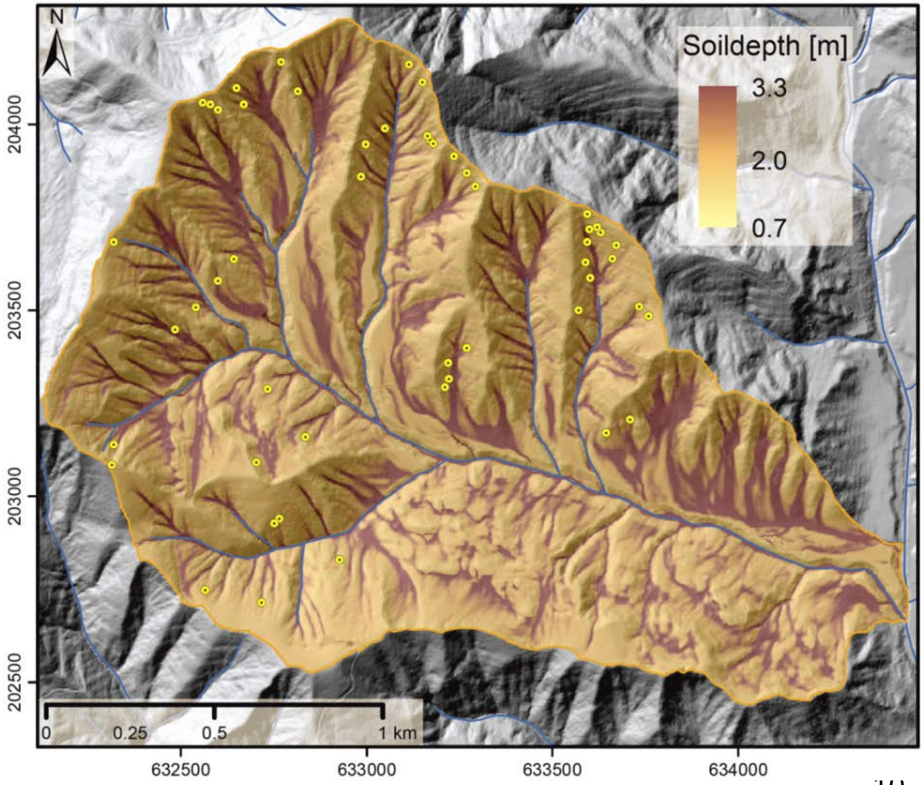


Application STEP-TRAMM model

Precipitation input: Radar precipitation dataset CH02H with hourly rainfall intensities (MeteoSwiss ©)



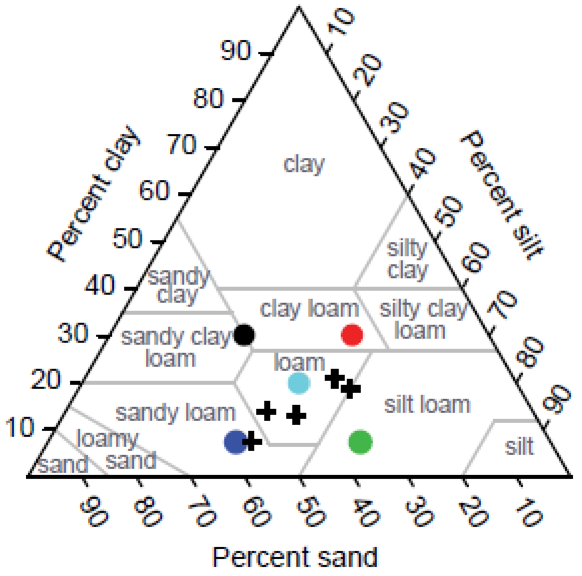
Soil depth distribution at catchment scale is evaluated with a steady-state model balancing soil production and erosive processes



Application STEP-TRAMM model

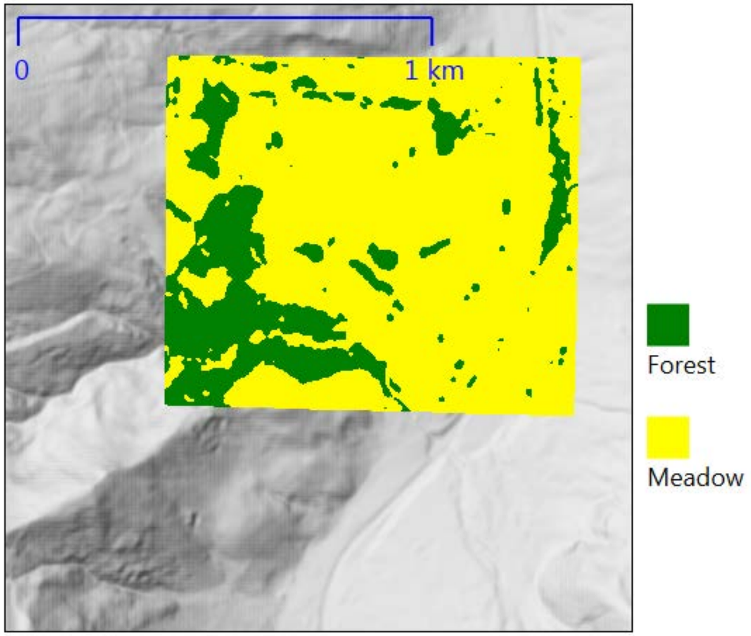
Soil properties:

- Few measured soil samples ( )
- Soil hydraulic functions deduced from database
- Varying initial soil water content

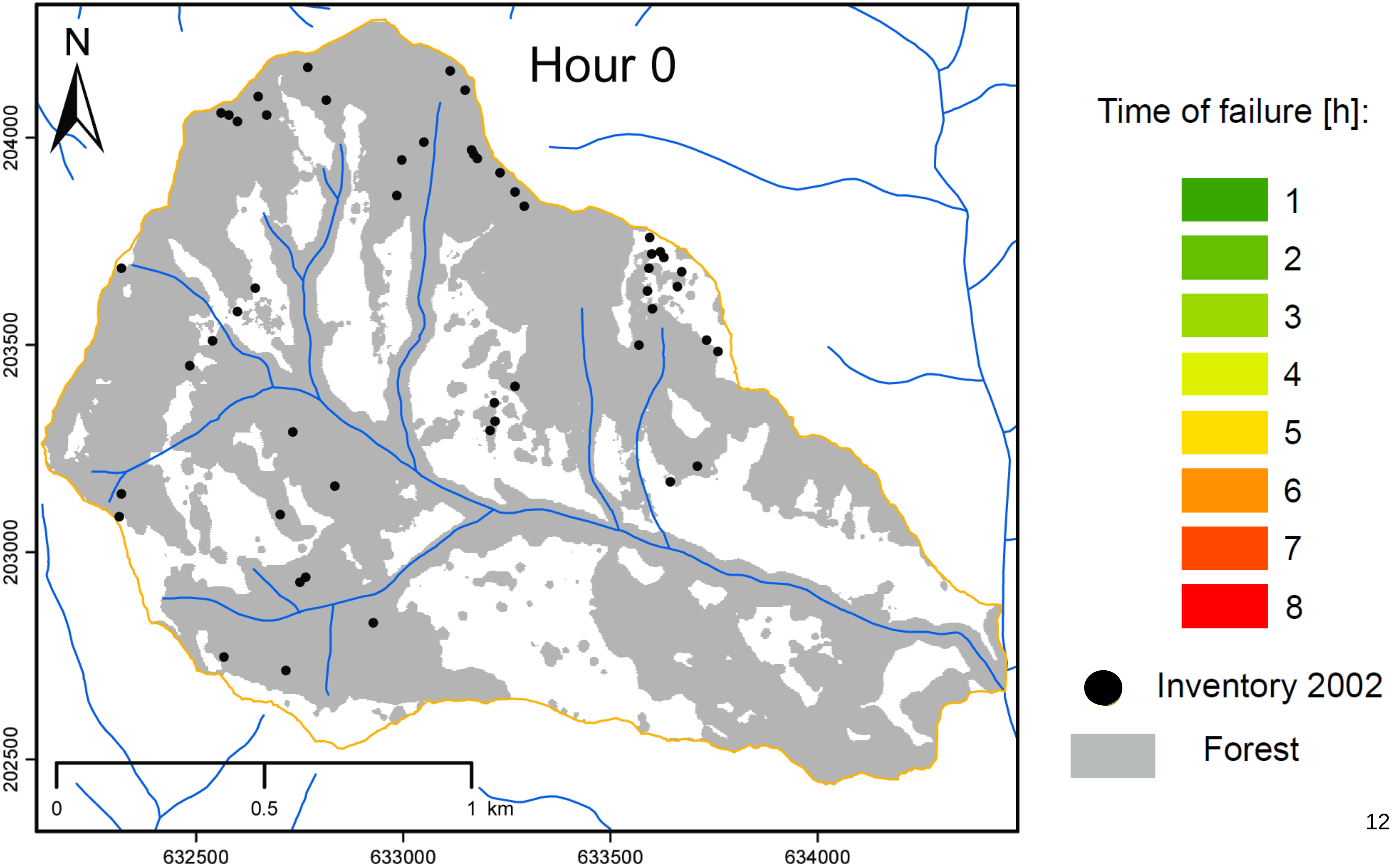


Vegetation:

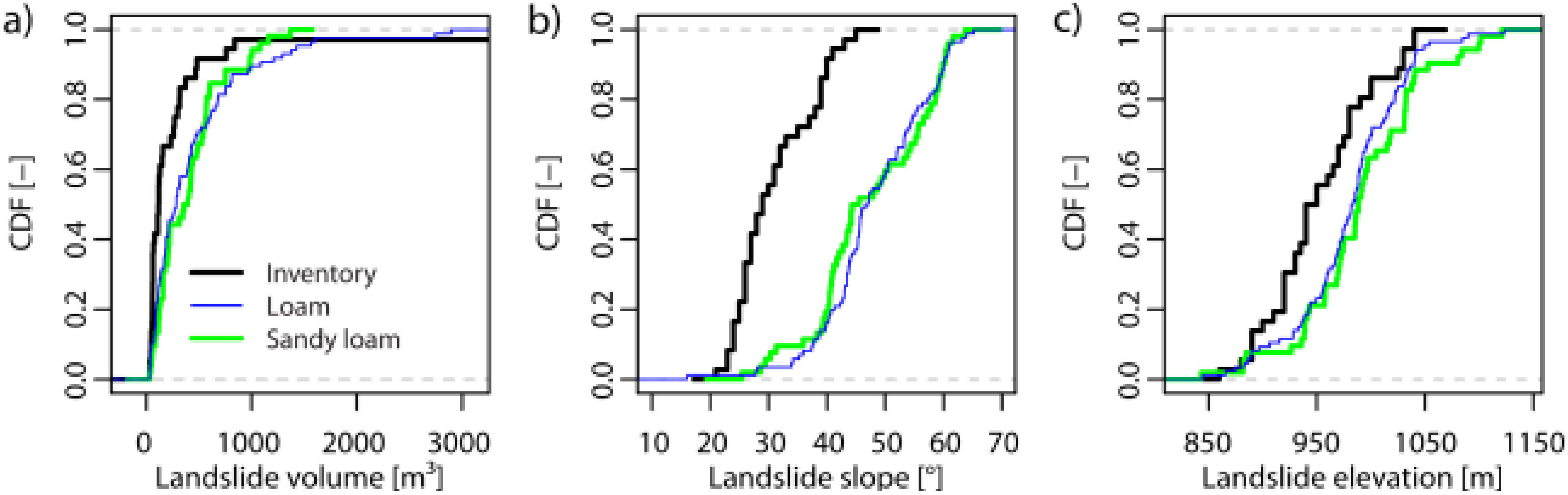
Binary map of forest and non-forest pixels (automatically derived from a Swiss-wide laser-scanning product of Swisstopo)



Simulation of the 2002-event

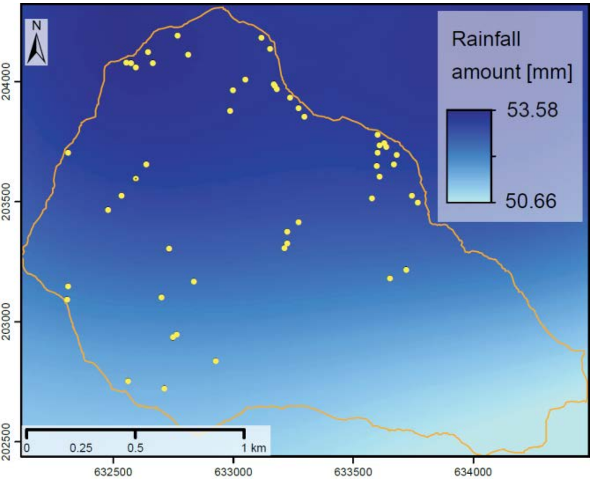


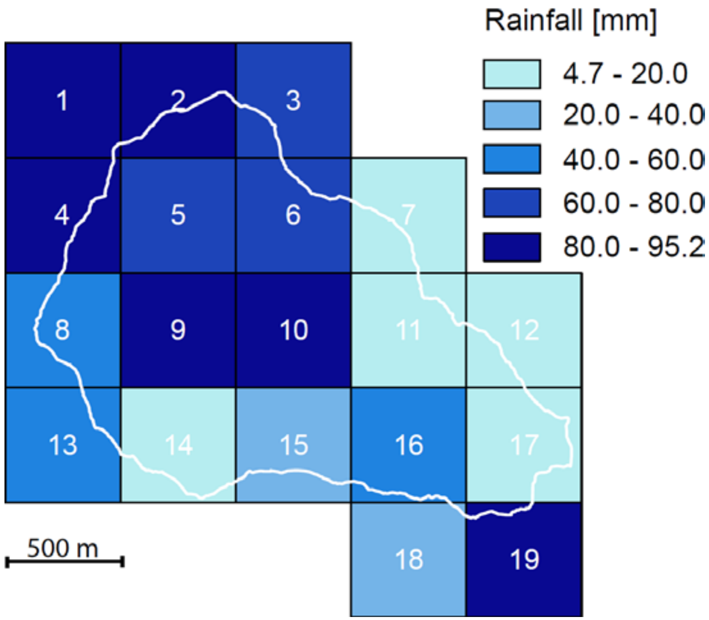
Comparison of simulated and maped landslides



Von Ruette et al. 2013. Water Resources Research,

Model sensitivity to precipitation input fields





Four categories of rainfall scenarios were generated with the constraint that total rainfall amount is 53 mm (rainfall amount of Napf 2002):

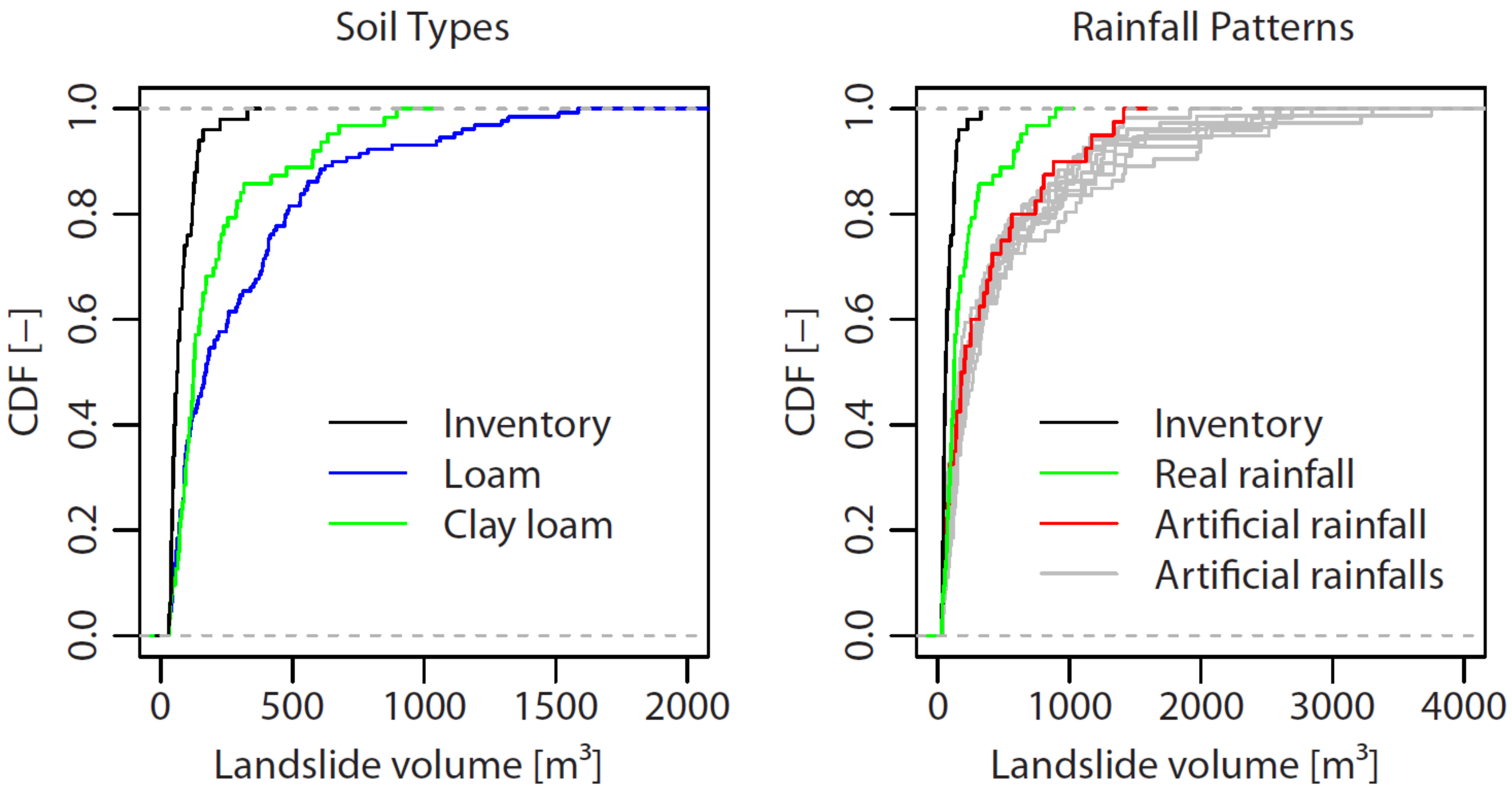
1. Real rainfall: radar data from 2002 event (spatially homogeneous, temporally heterogeneous)

2. Uniform rainfall: constant rainfall intensities and homogeneous rainfall distributions

3. Spatial heterogeneous rainfall: grid of 500 x 500 m2 cell size and random rainfall intensities with 8 h duration

4. Intermittent rainfall: grid of 500 x 500 m2 cell size and random rainfall intensities with 2 h duration (2 x 1 hour rainfall peaks)

Comparison of simulated and maped landslides



	# Landslides	Total volume [m^3]
Inventory	**51**	**4’019**
Artificial rainfall	40	14’480
Clay loam	63	12’700
Loam	130	39’500

Lessons learned from the modelling

- Advanced numerical model not able to simulate the **exact** location of shallow landslides

- However, it is useful for estimating timing, volumes and numbers of shallow landslides for a given catchment

- The simulated landslides are equally sensitive to selected soil properties and precipitation input fields.

Conclusions on case study Napf (2002 and 2005)

- Transferability of statistical, topography-derived landslide susceptability from one event to another ??
- Advanced hydro-mechanical modelling opens up for warnings based on precipitation radar and soil wetness.
- Raises many reflections on potential (ultimate) goals of an early warning system