Trees as hillslope debris flow brakers

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In Switzerland, **shallow landslides** and hillslope debris flows cause high levels of infrastructure damage, closures of important infrastructure, evacuations and sometimes fatalities every year. **A protective forest** can prevent the release of such landslides. There is often evidence in the transit and deposition area of hillslope debris flows that the forest also has a protective effect there. However, this has rarely been investigated so far.

Therefore, the goals of this project were :

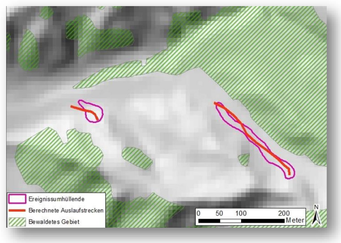
1. to quantify the protective effect of forests in the transit and deposit area of landslides;
2. to identify the most important forest structure parameters determining the protective effect;
3. to transfer these parameters into a protective forest management guideline (NaiS system, in the area of transit and deposition);
4. to demonstrate the protective effect of the forest against hillslope debris flows in the transit and deposition area based on an evaluation of risk for two case studies.

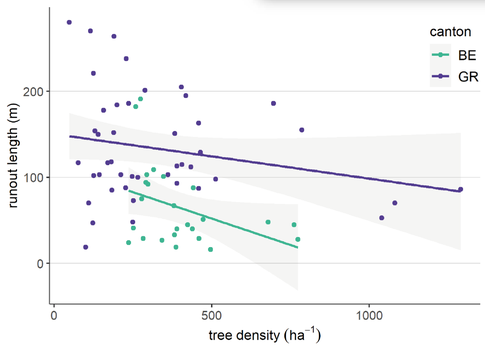
Conclusions

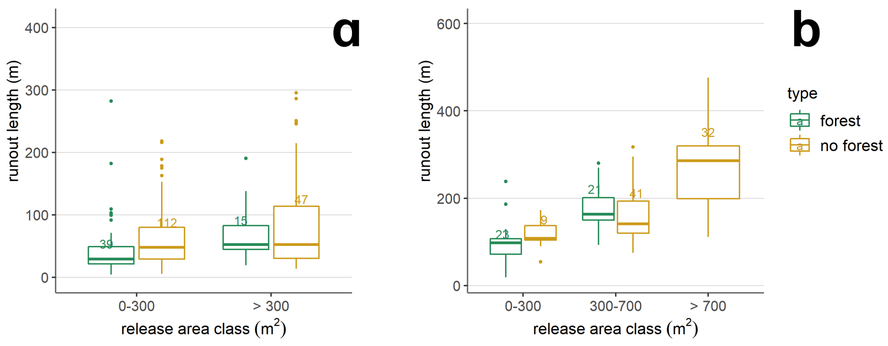
- The forest **has a braking effect** on the runout route, **especially for smaller landslide events.**
- According to the analyzed landslide events, this braking effect is **mainly influenced by the number of trunks.**
- A well-structured stand **with a high stem number**, and occasional **large diameters**, offers ideal protection against hillslope debris flows in the transit area.
- The results of the laboratory tests indicate that the braking effect of different forest structures (dense, open, with gaps) is given in comparison to a situation without forest, whereby it decreases with increasing water content.
- For slope debris flow with a release volume of approx. 900 m^3, the runout distance can be reduced by approx. 20% and its velocity by approx. 11% by the braking effect of a forest with 300 trees/ha and a mean DBH of approx. 36 cm.
- According to the case studies, the risk-reducing effect of forest in the transit area of a hillslope debris flow with a release volume of about 200 m^3 can range between CHF 1000/year for a municipal road and CHF 6,500/year for a highway.
- The negative effect of forests in the transit area of a hillslope debris flow still needs to be investigated.

Methods & Results

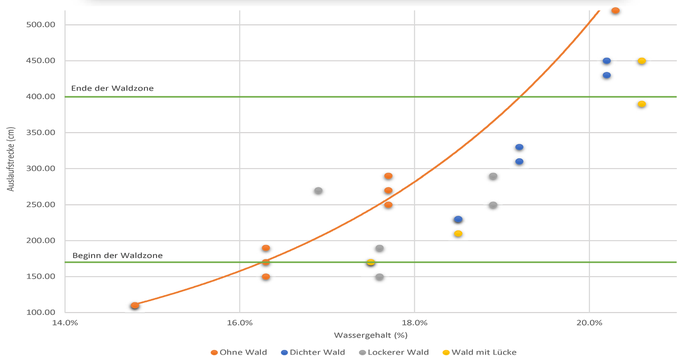
1. Field Surveys and event analyse





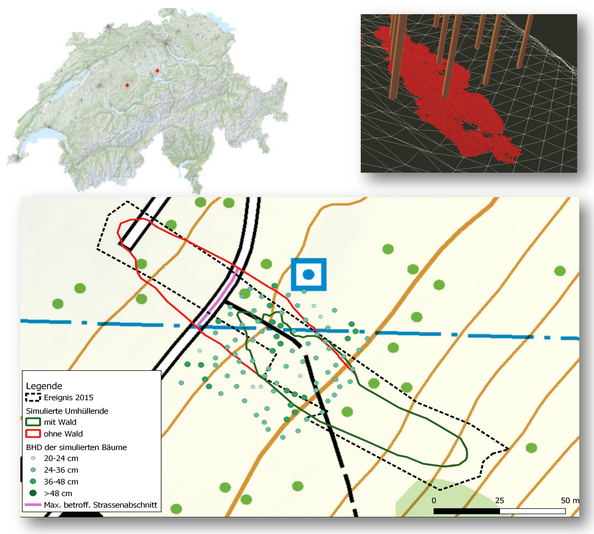


2. Lab. experiments



Correlation between water content (*Wassergehalt [%]*) and run-out distance (*Auslaufstrecke [cm]*) for the ramp experiments with the different forest situations : without forest, dense forest, loose forest and forest with gap. The orange trend curve serves as a reference for the situation without forest.

3. Simulation and Risk Calculation



Parameter for the risk calculation :
Probability of occurrence (1/Return Period) : [0.01; 0.033]
Daily car traffic (-) : [100; 10'000]
Maximum allowed speed (km/h) : [60; 80]
Basic infrastructure cost (CHF/m) : [5'000; 9'500]
Probability of rear-end collision (-): [0.05; 0.15]

Szenario	Jährlichk.	λ	SE	R_{direkt}	$R_{Auffahr}$	R_{Infra}	R_{Gesamt}	$R_{Ind\text{-}Todesfall}$	R_{Red}
ohne Wald	100	0.3	0.3	20	29	165	214	2.2E-7	(47%)
mit Wald	100	0.1	0.2	5	29	80	114	1.5E-7	100
ohne Wald	100	0.3	0.3	1'513	87	314	1'913	7.3E-8	(68%)
mit Wald	100	0.1	0.2	367	87	152	606	2.1E-8	1'307
ohne Wald	30	0.1	0.2	59	97	967	1'122	7.1E-7	(100%)
mit Wald	30	0	0	0	0	0	0	0	1'122
ohne Wald	30	0.1	0.2	4'430	290	1'836	6'557	2.1E-7	(100%)
mit Wald	30	0	0	0	0	0	0	0	6'557

Variation of the risk calculations with intensity based on pressure:
Locations : Root (1st and 2nd Scenario); Trub (3rd and 4th scenario)
Jährlichk. = Return period; X = lethality of the persons in the vehicle;
SE = damage sensitivity of the road infrastructure; R_{direct} = risk of direct hit;
$R_{Auffahr}$ = risk of rear-end collision; R_{Infra} = damage to the infrastructure; R_{Gesamt} = total risk;
$R_{Ind\text{-}Todesfall}$ = individual fatality risk;
R_{Red} = risk reduction (total risk without forest - total risk with forest).
All risks as well as the risk reduction, except individual fatality, are given in (CHF/year). All other variables are unitless.

Statements for the new NaiS-profile requirement for landslides

- The effect on the range and intensity of hillslope debris flows can be significant but **depends strongly on the fluidity of the soil material**.
- The relevant forest structure parameters for the braking effect in the transit area of hillslope debris flows are **the stem number and the DBH**. A stem number of at least 300 trees/ha with DBH values of at least 20 cm, a mean DBH > 36 cm, seem ideal.
- The water content and the cohesion of the material as well as the size of the release volume and the steepness of the transit area play an important role.
- The **forest structures that optimally protect** against hillslope debris flows in the transit and deposition area **are similar to those required in the release area**. In addition, large gaps in the release area as well as in the transit area have a negative effect on the protective effect.

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