Integrated statistical landslide susceptibility modelling: combining release and propagation

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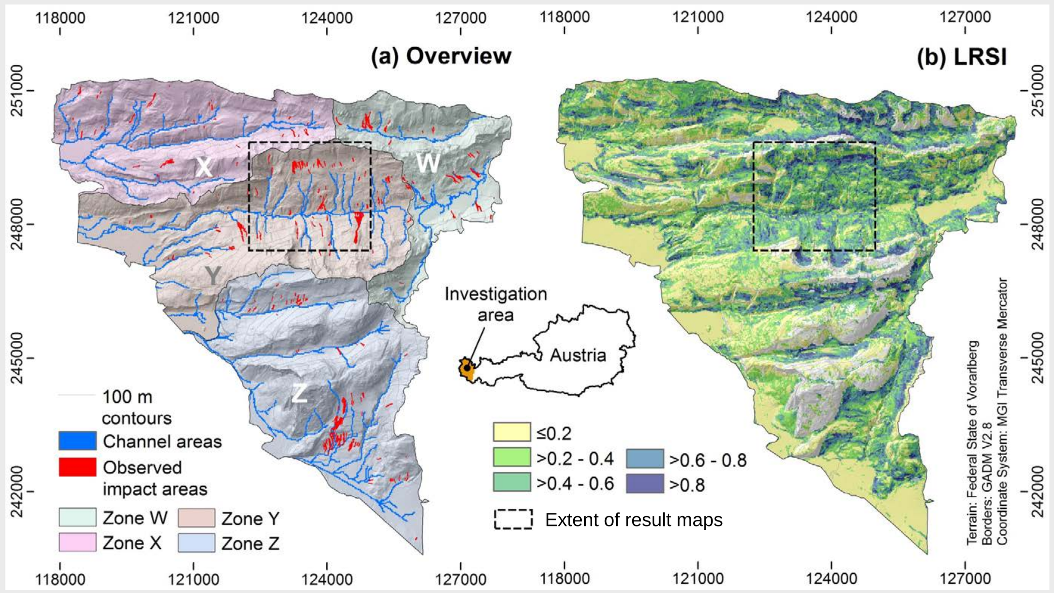
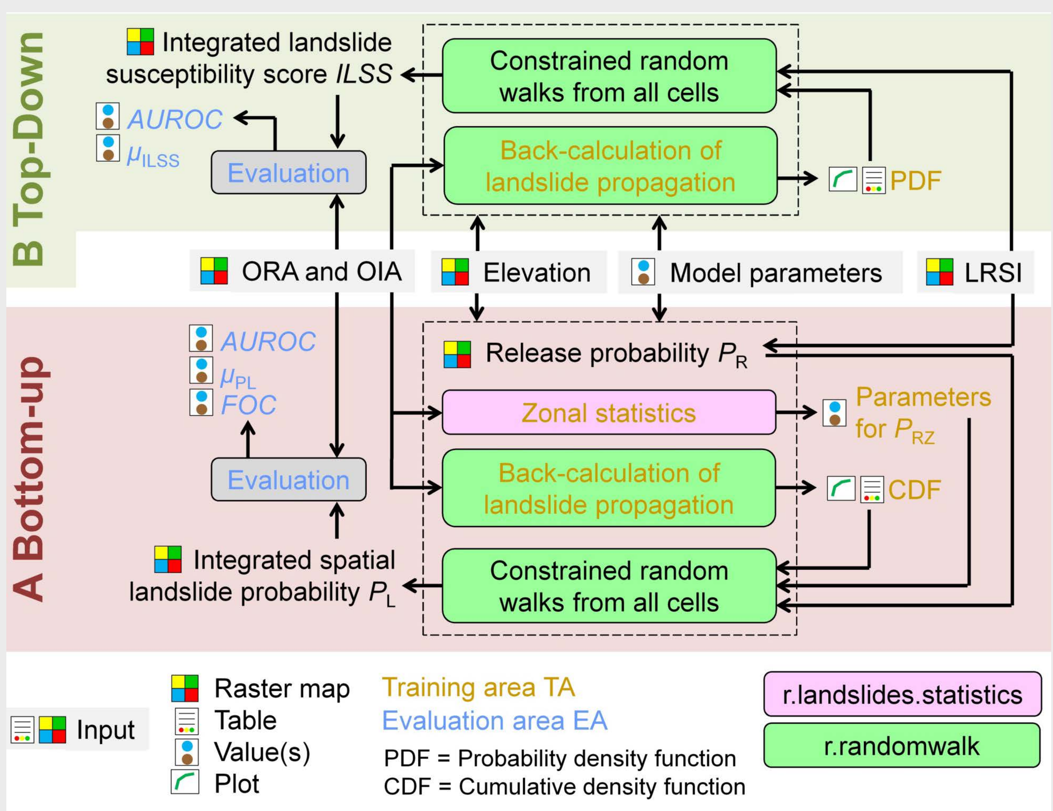
Statistical landslide susceptibility analyses have been conducted for many mountainous and hilly areas all around the world. The combination of statistically derived landslide susceptibility maps with conceptual runout models has yet been scarcely applied at broad scales. We compare two approaches to perform such a combination, and thereby critically reflect the related challenges.

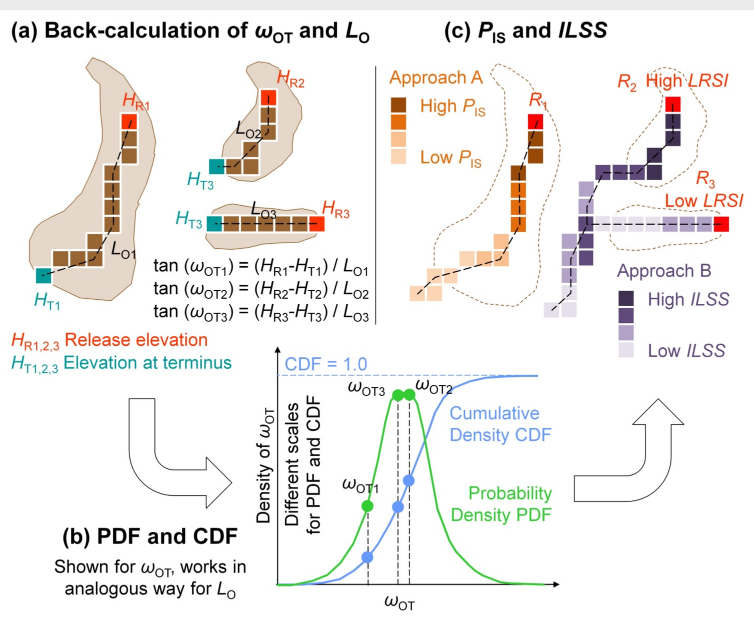


The Schnepfau study area with zones W-Z alternatively used for training and evaluation, and the landslide release susceptibility index (*LRSI*)



Work flow of the integrated landslide susceptibility analysis, with the approaches A and B

Landslide propagation: derivation and application of density functions for the derivation of P_{IS} and *ILSS*



Study area

Surroundings of **Schnepfau** in Vorarlberg, western Austria: a comprehensive inventory of shallow landslides that have developed into hillside debris flows was mapped by the Geological Survey of Austria, using Airborne Lidar data and aerial images.

Study design and methods

A landslide release susceptibility index (*LRSI*) map is computed using logistic regression for those areas free of rocks, where shallow landslides can occur. This map is used as the basis for the further analyses. Our approaches employ the density functions (pdf and cdf) of the **angles of reach and/or travel distance** of the observed landslides, and use a constrained random walk approach for downslope routing of mass points (r.randomwalk):

A

Bottom-up approach: for each GIS raster cell, the probability that landslide release is observed anywhere in its catchment is computed from the pixel-based release susceptibilities and the catchment area. This zonal release probability is then multiplied with the probability that the same pixel is reached by a landslide released in its catchment.

B

Top-down approach: for each cell, a number of random walks proportional to the release susceptibility is started. Each random walk proceeds until a given angle of reach is met. This angle of reach is probabilistically derived from the pdf, separately for each random walk. Each time a GIS raster cell is impacted by a random walk, its susceptibility score is increased by 1.

Results and discussion

The spatial patterns of the resulting maps are largely similar among A and B. However, whereas A produces a spatial probability at the cost of a high level of spatial blurring of the release information, B results in a qualitative score which retains the signal of the release susceptibility and performs better in terms of empirical adequacy than the probability yielded with A. Visually, both maps are comparable and dominated by the effects of landslide runout rather than by those of the release. We recommend using the approach B – yielding a score – for semi-quantitative spatial overviews, whereas the approach A is still needed as the basis of quantitative risk analyses. The table below shows the *AUROC* (area under ROC curve) and *FOC* (factor of conservativeness) values associated to each experiment. A1 and B1 use the cdf and pdf of the angle of reach, A2 and B2 of the travel distance, and A3 and B3 of a combination of both.

Experiment	With spatially varied *LRSI*		With constant *LRSI*	
	AUROC	*FOC*	*AUROC*	*FOC*
A1	0.713	1.75	0.738	1.87
A2	0.724	0.59	0.748	0.65
A3	0.637	0.41	0.664	0.47
B1	0.774	NA	0.700	NA
B2	0.824	NA	0.733	NA
B3	0.727	NA	0.593	NA

Our findings underline the importance of considering the propagation – and appropriately combining release and propagation models – when analyzing the susceptibility of a given area to long-runout-landslides. The most suitable approach depends on the purpose of the study.

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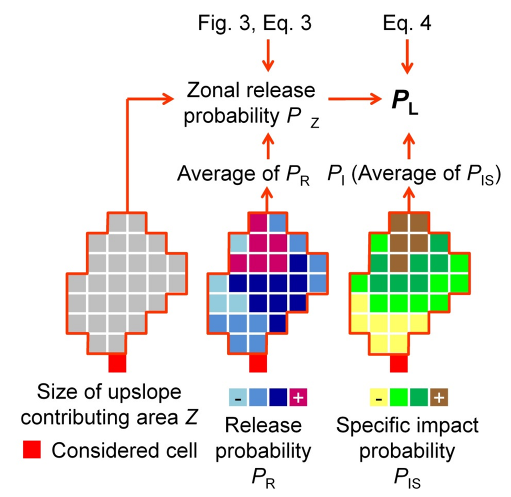
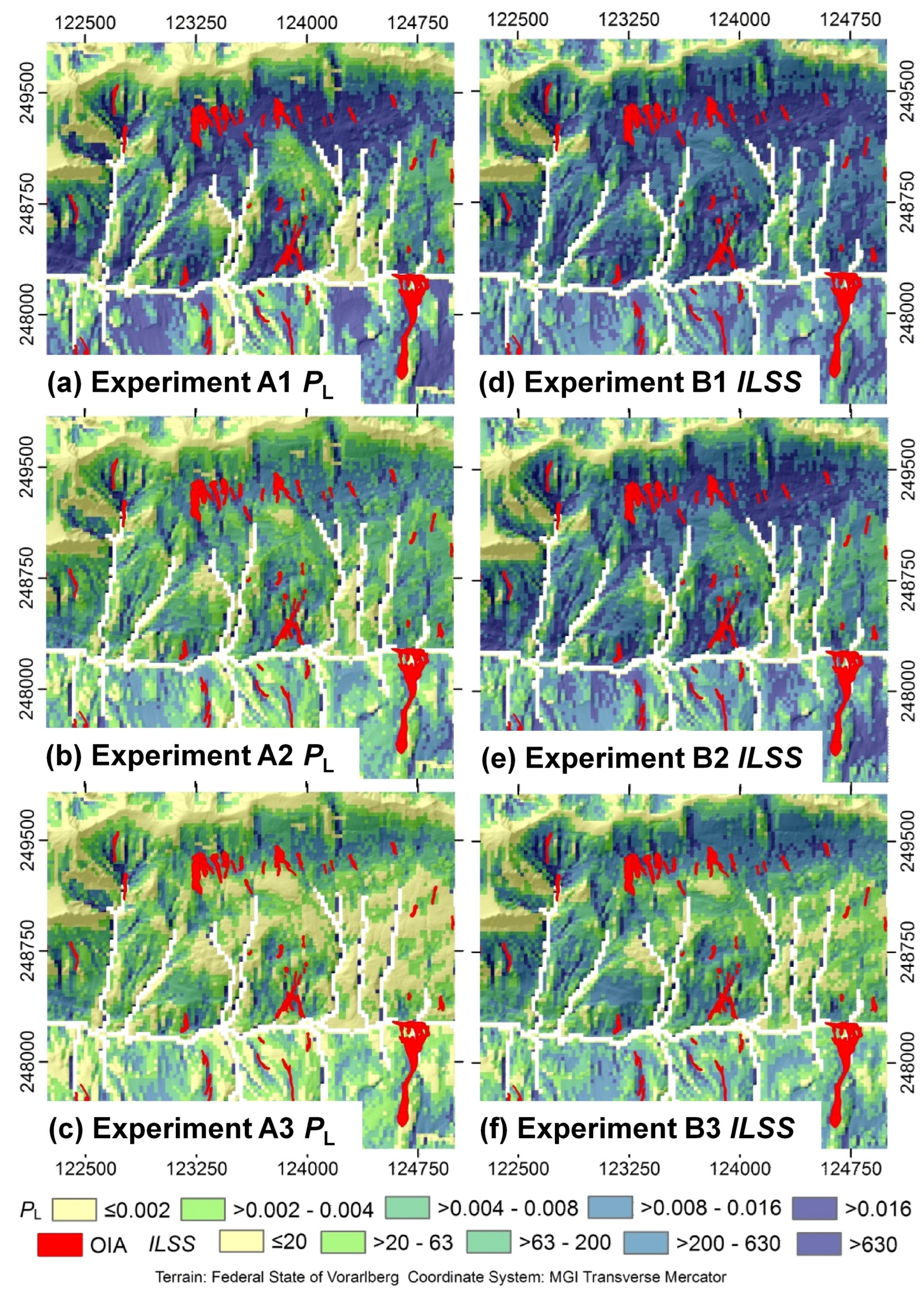


Approach A: the zonal release probability (P_Z) and its integration in the work flow



Integrated landslide probability P_L (a-c) and integrated landslide susceptibility score *ILSS* (d-f) for part of the study area and three stopping criteria applied to the random walks; OIA = observed impact area