MOUNTAIN-PLAINS CONSORTIUM

RESEARCH BRIEF | MPC 23-500 (project 593) | July 2023

Probabilistic Modeling of Landslide Hazards to Improve the Resilience of Transportation Infrastructure

the ISSUE

Prediction of landslides and their potential impacts on infrastructure is a challenging problem due to variability and uncertainty in hydroclimatic variables and soil and hillslope properties. This research aims to quantify this uncertainty by developing a probabilistic model for landsliding and applying it to current and future climate scenarios.

the RESEARCH

We used Landlab, a Python-based toolkit for landscape modeling, to perform Monte Carlo simulations with an infinite slope stability model to make spatially explicit calculations of the probability of landslide initiation. The soil moisture input to the landslide model is from the Equilibrium Moisture from Topography, Vegetation, and Soil (EMT+VS) Model, which downscales coarse-resolution soil moisture by incorporating the dependence of soil moisture on topographic, vegetative, and soil characteristics. We used the model to identify the key landscape characteristics that influence slope failures. We simulated landslide susceptibility over a 1,333-square-kilometer area of the Colorado Front Range that experienced more than 1,300 landslides during an extreme storm in 2013. These results were compared with a deterministic model to evaluate the performance of our probabilistic approach. We then changed the vegetation input to the model to reflect potential conditions of a warmer climate and explored how landslide susceptibility may shift spatially in the future.

In conjunction, we developed a simple landslide runout model to investigate whether topographic controls can be used to predict landslide termination. The runout model, which utilizes a critical slope for a stopping criterion, was used to replicate observed landslide runout from the 2013 event.

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A University Transportation Center sponsored by the U.S. Department of Transportation serving the Mountain-Plains Region. Consortium members:

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Project Title

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the FINDINGS

The probabilistic landslide initiation model predicted 79.6% of the mapped landslides from the 2013 storm. This outperformed the deterministic model, which captured only 42% of observed landslides, supporting the use of the probabilistic model. Most (66%) of predicted landslides occurred on south-facing slopes where trees are less abundant. After incorporating climate change, the model predicted an increase in the areas susceptible to landslides and a shift to more instability on north-facing slopes.

Our calibrated runout model outperformed the commonly used angle-of-reach approach, suggesting that topographic controls provide plausible initial estimates of runout endpoints.

the IMPACT

Probabilistic modeling of landslide initiation allows us to quantify potential landslide risk across the landscape, given uncertain input data. Our study suggests that vegetation changes due to climate change could result in major shifts in the people and infrastructure susceptible to landslides in the Colorado Front Range.

Our method of using critical slope and slope persistence to predict runout endpoints is a promising opportunity for landslide hazard mapping at large spatial extents.

For more information on this project, download the Main report at https://www.ugpti.org/resources/reports/details.php?id=1127

For more information or additional copies, visit the Web site at www.mountain-plains.org, call (701) 231-7767 or write to Mountain-Plains Consortium, Upper Great Plains Transportation Institute, North Dakota State University, Dept. 2880, PO Box 6050, Fargo, ND 58108-6050.