Supplement information for

Spatially distributed water content thresholds for rainfall-induced landslide initiation

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S1 Methodological framework

The basin-wide analysis is represented in Fig. S1, which describes the entire framework. It is conducted over Homogeneous Soil Units (HSUs), where each unit is defined by a unique combination of slope and hydro-mechanical soil properties. By grouping areas with similar physical behavior, HSUs reduce spatial and computational complexity while preserving the dominant controls on slope stability. The depicted framework refers a constant depth to the potential failure plane and is therefore applicable where this assumption is valid.

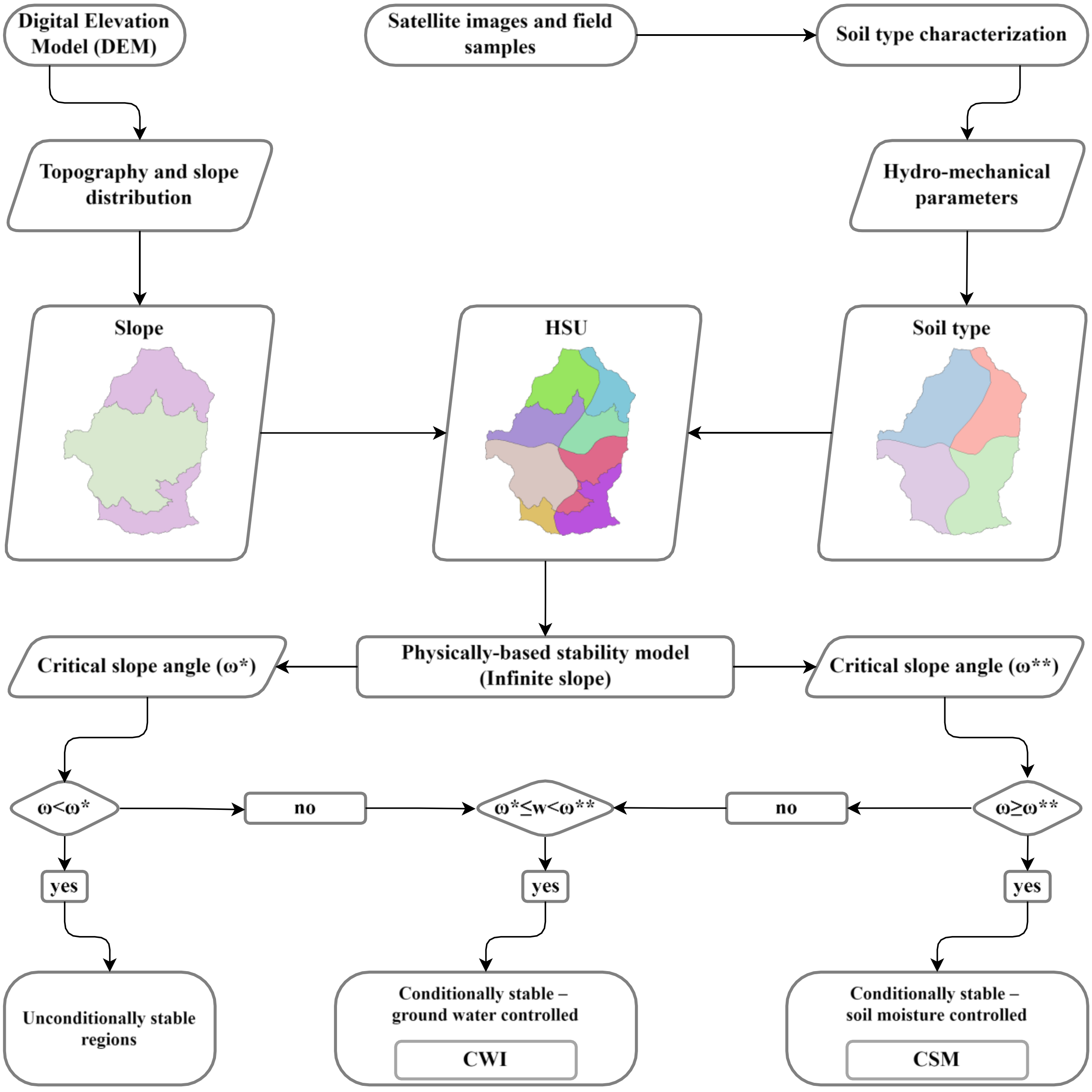

Figure S1: Flowchart of the presented methodology adopted to delineate the stability regions in terms of Critical Wetness Index (CWI) and Critical Soil Moisture (CSM) at basin scale, with the definition of Homogeneous Soil Units (HSU).

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S2 Metrics for model assessment and calibration

Model performance is evaluated using the Receiver Operating Characteristic (ROC) curve and associated metrics, including the Area Under the Curve (AUC) and Youden's J index (Youden, 1950). These metrics provide a robust framework for assessing the ability of the model to correctly classify stable and unstable areas.

The evaluation is based on a confusion matrix comprising:

- True Positives (TP): areas correctly identified as landslides
- False Negatives (FN): landslide areas incorrectly identified as stable
- True Negatives (TN): areas correctly identified as non-landslides
- False Positives (FP): stable areas incorrectly identified as landslides

From these variables, the sensitivity and specificity are calculated according to the following statistical relationships (Eq. S1 and S2):

$$\text{Sensitivity} = \frac{\text{TP}}{\text{TP} + \text{FN}} \tag{S1}$$

$$\text{Specificity} = \frac{\text{TN}}{\text{TN} + \text{FP}} \tag{S2}$$

The ROC curve is then generated by plotting sensitivity (True Positive Rate, TPR) against 1 − specificity (False Positive Rate, FPR) across varying cohesion. Youden's J statistic serves as a scalar proxy for the ROC curve by identifying the point of maximum vertical distance from the chance line (null-hypothesis diagonal representing random classification behavior) in TPR vs FPR space. The Youden's J index is defined as (Eq. S3):

$$\text{Youden's J} = \text{Sensitivity} + \text{Specificity} - 1 \tag{S3}$$

Youden's J parameter synthesizes the overall discriminatory power of the model; a higher Youden's J indicates superior model performance in distinguishing between two classes. In this context, it is employed to quantify the model's efficacy in accurately discriminating between stable and unstable areas. To construct the confusion matrix, a reference landslide inventory is rasterized to match the spatial resolution of the basin-level CWI and CSM maps. The CWI and CSM outputs are then converted into binary classes representing landslide and non-landslide conditions. To adopt a conservative classification approach, all conditionally stable areas are categorized as landslides, as they indicate zones with the potential to fail if the corresponding CWI or CSM thresholds are exceeded.

S3 References

Youden, W. J.: Index for rating diagnostic tests, Cancer, 3, 32–35, https://doi.org/10.1002/1097-0142(1950)3:1<32::AID-CNCR2820030106>3.0.CO;2-3, 1950.