BEYOND SURFACE DEFORMATION: FEM-PINN INVERSION OF LANDSLIDES FROM INSAR

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IN THIS PRESENTATION

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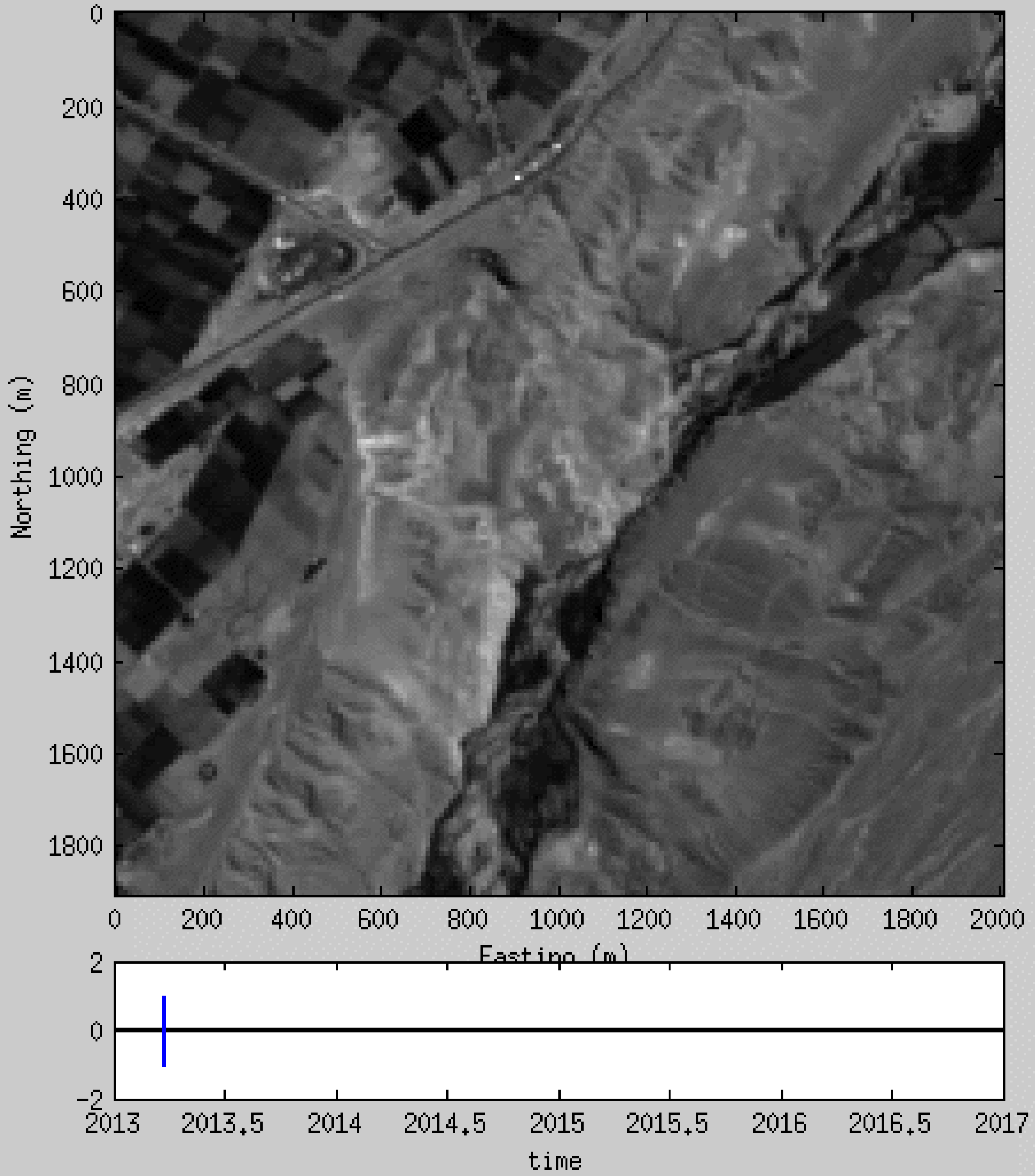
LANDSLIDES



Source: Lacroix, https://www.isterre.fr/

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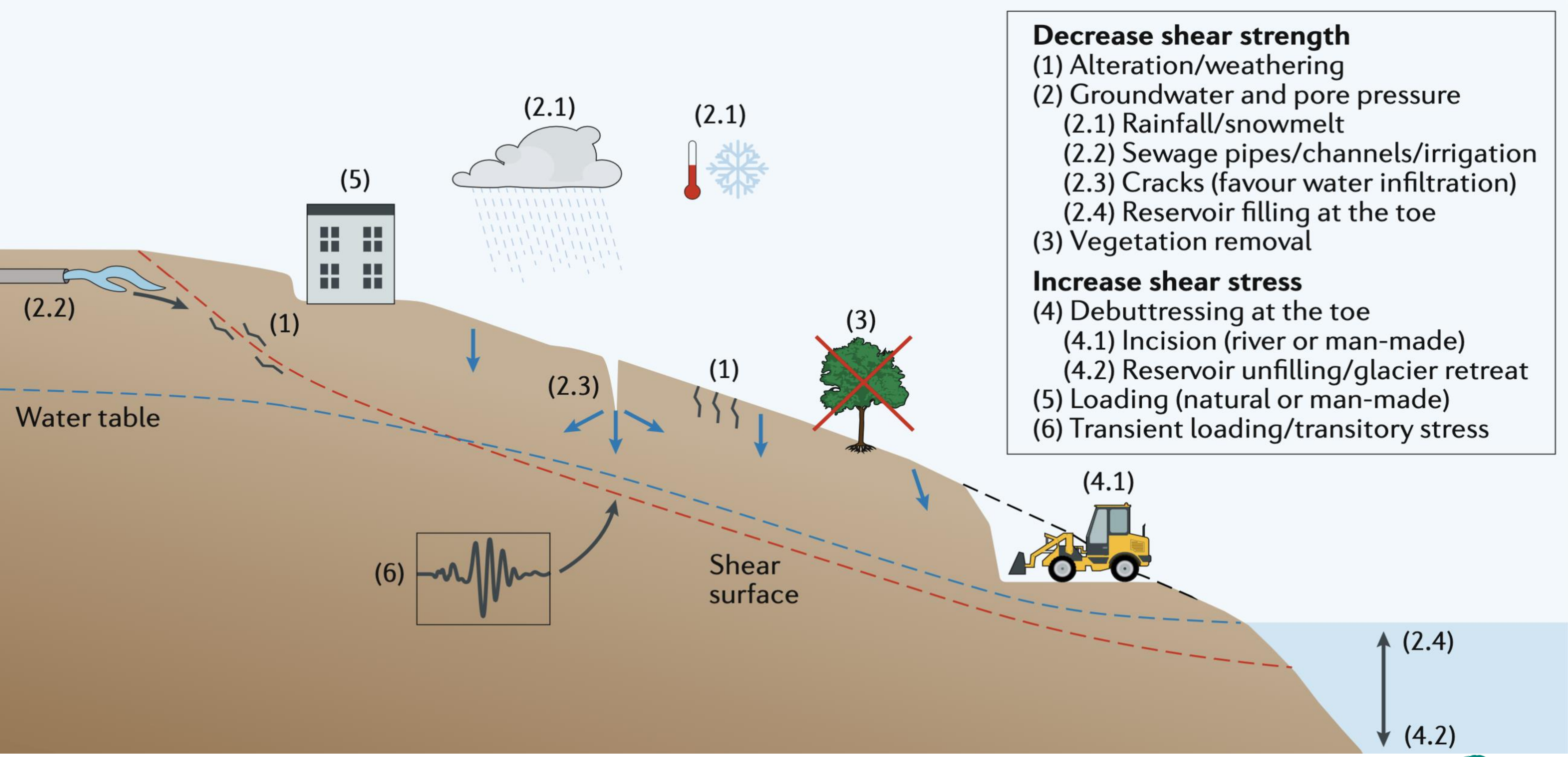

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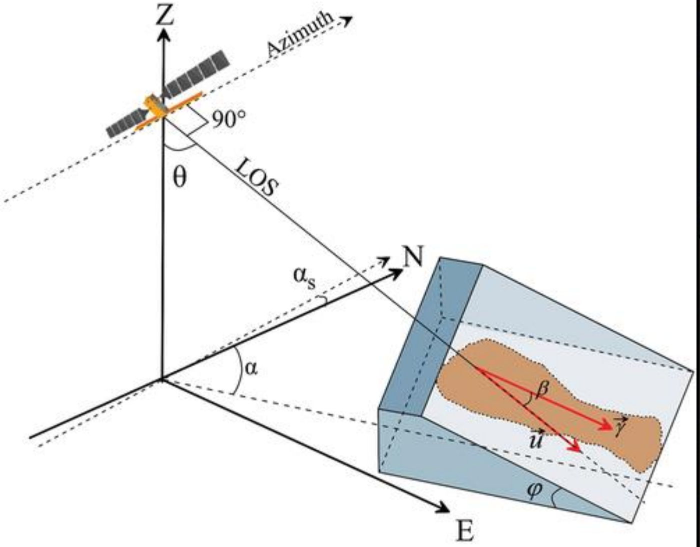
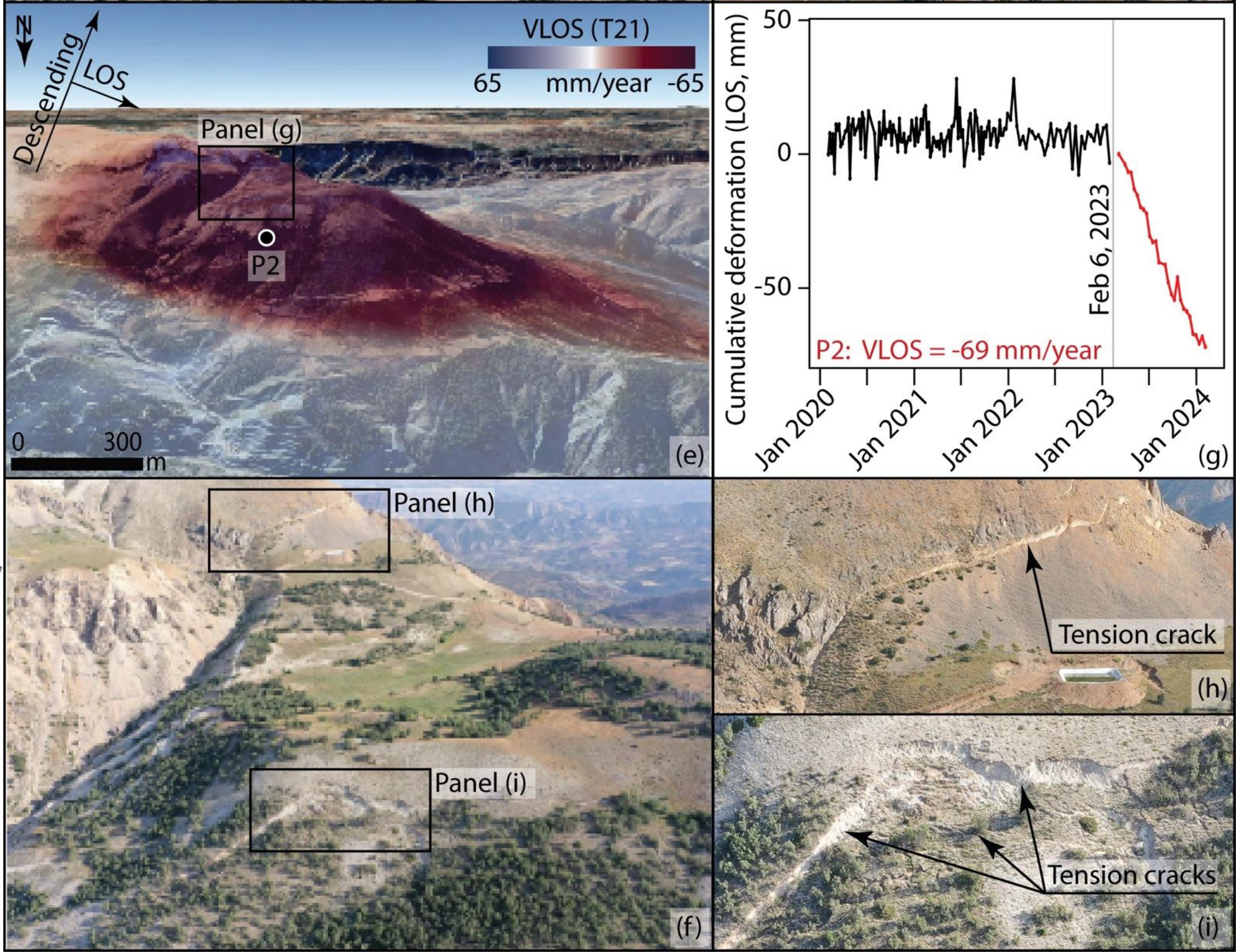
Source: Lacroix et al., (2020)

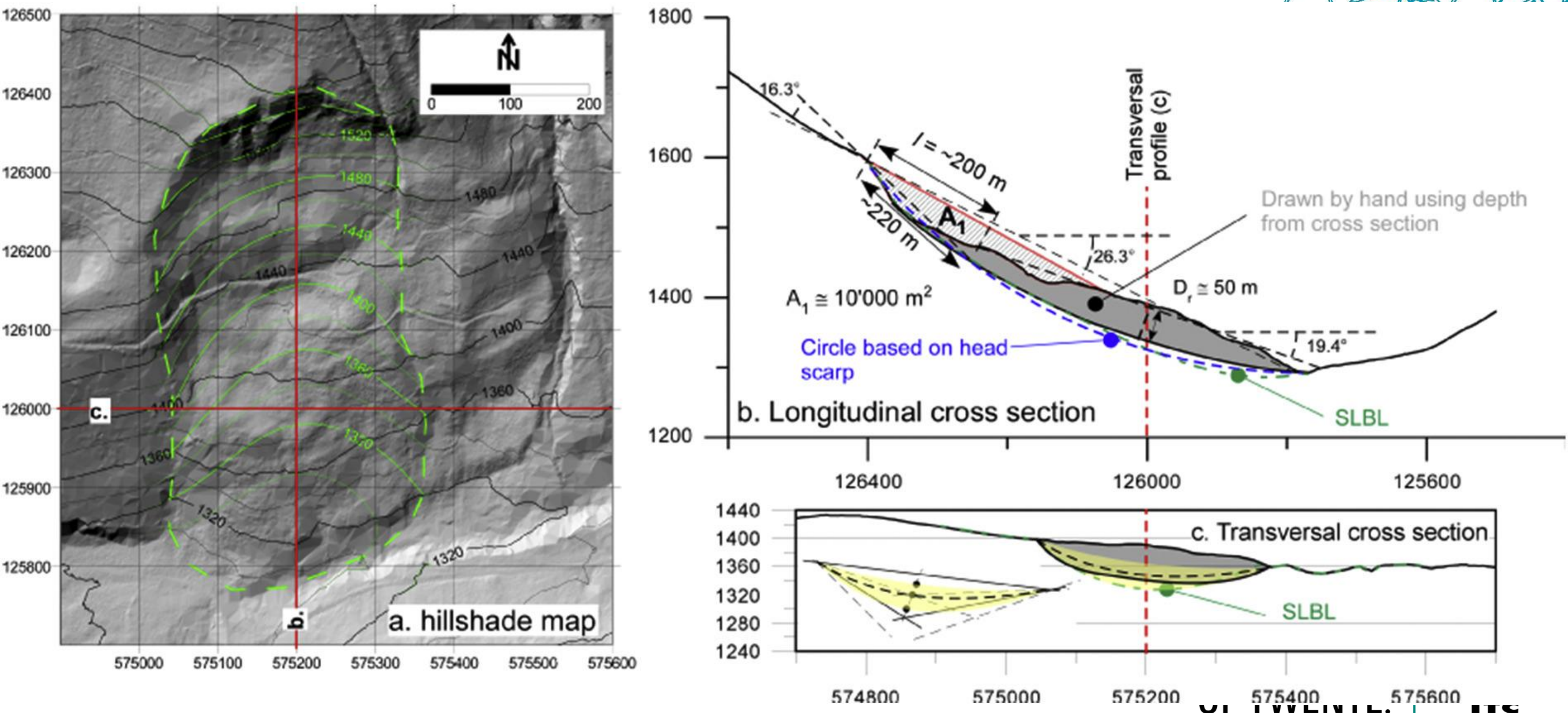
LANDSLIDES





Source: Dahal et al. (2025)

WHAT WE WOULD LIKE TO KNOW



Source: Jaboyedoff et al. (2020)

HOW TO INVERT THE FAILURE DEPTH, VOLUME, AND MECHANICS OF *SLOW-MOVING* LANDSLIDES ACCURATELY?

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FINITE ELEMENT FOR SLOPE STABILITY

INPUT PARAMETERS

Griffiths, D. V. & Lane, P. A. (1999). *Géotechnique* 49, No. 3, 387–403

Slope stability analysis by finite elements

D. V. GRIFFITHS* and P. A. LANE†

The majority of slope stability analyses performed in practice still use traditional limit equilibrium approaches involving methods of slices that have remained essentially unchanged for decades. This was not the outcome envisaged when Whitman & Bailey (1967) set criteria for the then emerging methods to become readily accessible to all engineers. The finite element method represents a powerful alternative approach for slope stability analysis which is accurate, versatile and requires fewer *a priori* assumptions, especially, regarding the failure mechanism. Slope failure in the finite element model occurs 'naturally' through the zones in which the shear strength of the soil is insufficient to resist the shear stresses. The paper describes several examples of finite element slope stability analysis with comparison against other solution methods, including the influence of a free surface on slope and dam stability. Graphical output is included to illustrate deformations and mechanisms of failure. It is argued that the finite element method of slope stability analysis is a more powerful alternative to traditional limit equilibrium methods and its widespread use should now be standard in geotechnical practice.

KEYWORDS: dams; limit equilibrium methods; numerical modelling; plasticity; slopes.

En grande majorité, les analyses de stabilité de pente menées dans la pratique continuent à utiliser les méthodes traditionnelles d'équilibre limite et des systèmes de tranches qui n'ont pratiquement pas changé depuis des dizaines d'années. Ce n'était pas le résultat envisagé quand Whitman et Bailey (1967) ont établi des critères pour que ces méthodes alors émergeantes puissent devenir facilement accessibles à tous les ingénieurs. La méthode d'éléments finis qui représente une alternative puissante pour les analyses de stabilité de pente, est exacte, polyvalente et demande moins d'hypothèses 'a priori', surtout en ce qui concerne les mécanismes de rupture. La rupture de pente dans le modèle à éléments finis se produit 'naturellement' à travers des zones dans lesquelles la résistance au cisaillement du sol est insuffisante pour résister aux contraintes tangentielles. Cet exposé décrit plusieurs exemples d'analyses de stabilité de pente utilisant les éléments finis et établit des comparaisons avec d'autres méthodes, comme l'influence d'une surface libre sur la stabilité d'une pente et d'une digue. Nous joignons une représentation graphique pour illustrer les déformations et mécanismes de rupture. Nous avançons que la méthode d'éléments finis pour analyser la stabilité des pentes constitue une alternative plus puissante aux méthodes traditionnelles d'équilibre limite et que son utilisation devrait maintenant devenir une pratique standard en géotechnique.

INTRODUCTION

Elasto-plastic analysis of geotechnical problems using the finite element (FE) method has been widely accepted in the research arena for many years; however, its routine use in geotechnical practice for slope stability analysis still remains limited. The reason for this lack of acceptance is not entirely clear; however, advocates of FE techniques in academe must take some responsibility.

Practising engineers are often sceptical of the need for such complexity, especially in view of the poor quality of soil property data often available from routine site investigations. Although this scepticism is often warranted, there *are* certain types of geotechnical problem for which the FE approach offers real benefits. The challenge for an experienced engineer is to know which kind of problem would benefit from a FE treatment and which would not.

In general, linear problems such as the prediction of settlements and deformations, the calculation of flow quantities due to steady seepage or the study of transient effects due to consolidation are all highly amenable to solution by finite elements. Traditional approaches involving charts, tables or

Manuscript received 28 May 1998; revised manuscript accepted 8 December 1998. Discussion on this paper closes 3 September 1999; for further details see p. ii.

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PROBABILISTIC NUMERICAL METHOD

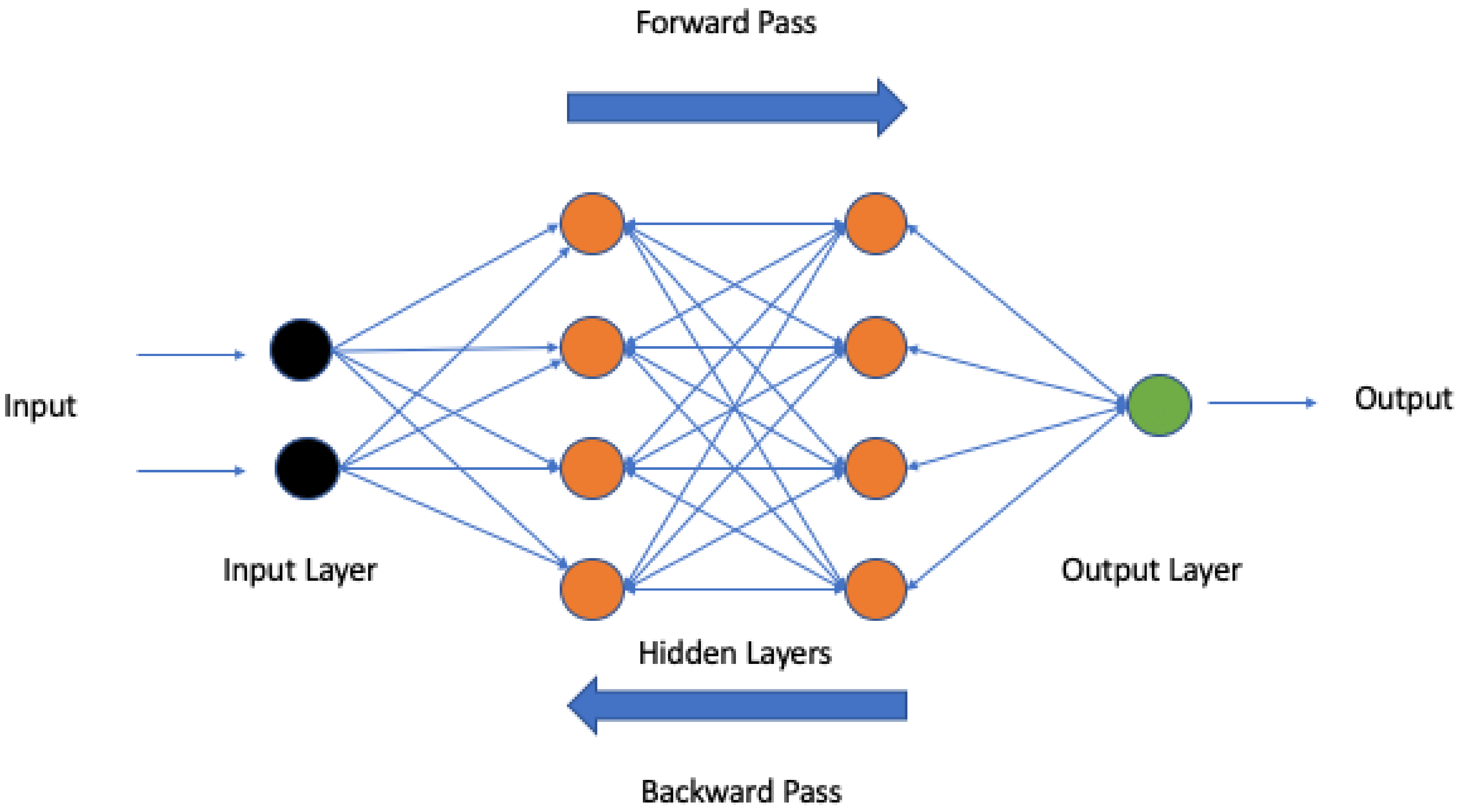
The Random Finite Element Method (RFEM) in Slope Stability Analysis

D.V. Griffiths* and Gordon A. Fenton†

* Division of Engineering, Colorado School of Mines, U.S.A.
† Department of Engineering Mathematics, Dalhousie University, Canada

Abstract The paper investigates the probability of failure of a cohesive slope using both simple and more advanced probabilistic analysis tools. The influence of local averaging on the probability of failure of a test problem is thoroughly investigated. In the simple approach, classical slope stability analysis techniques are used, and the shear strength is treated as a single random variable. The advanced method, called the random finite element method (RFEM), uses elasto-plasticity combined with random field theory. The RFEM method is shown to offer many advantages over traditional probabilistic slope stability techniques, because it enables slope failure to develop naturally by "seeking out" the most critical mechanism. Of particular importance in this work, is the conclusion that simplified probabilistic analysis, in which spatial variability is ignored by assuming perfect correlation, can lead to unconservative estimates of the probability of failure. This contradicts the findings of other investigators using classical slope stability analysis tools.

NEURAL NETWORK



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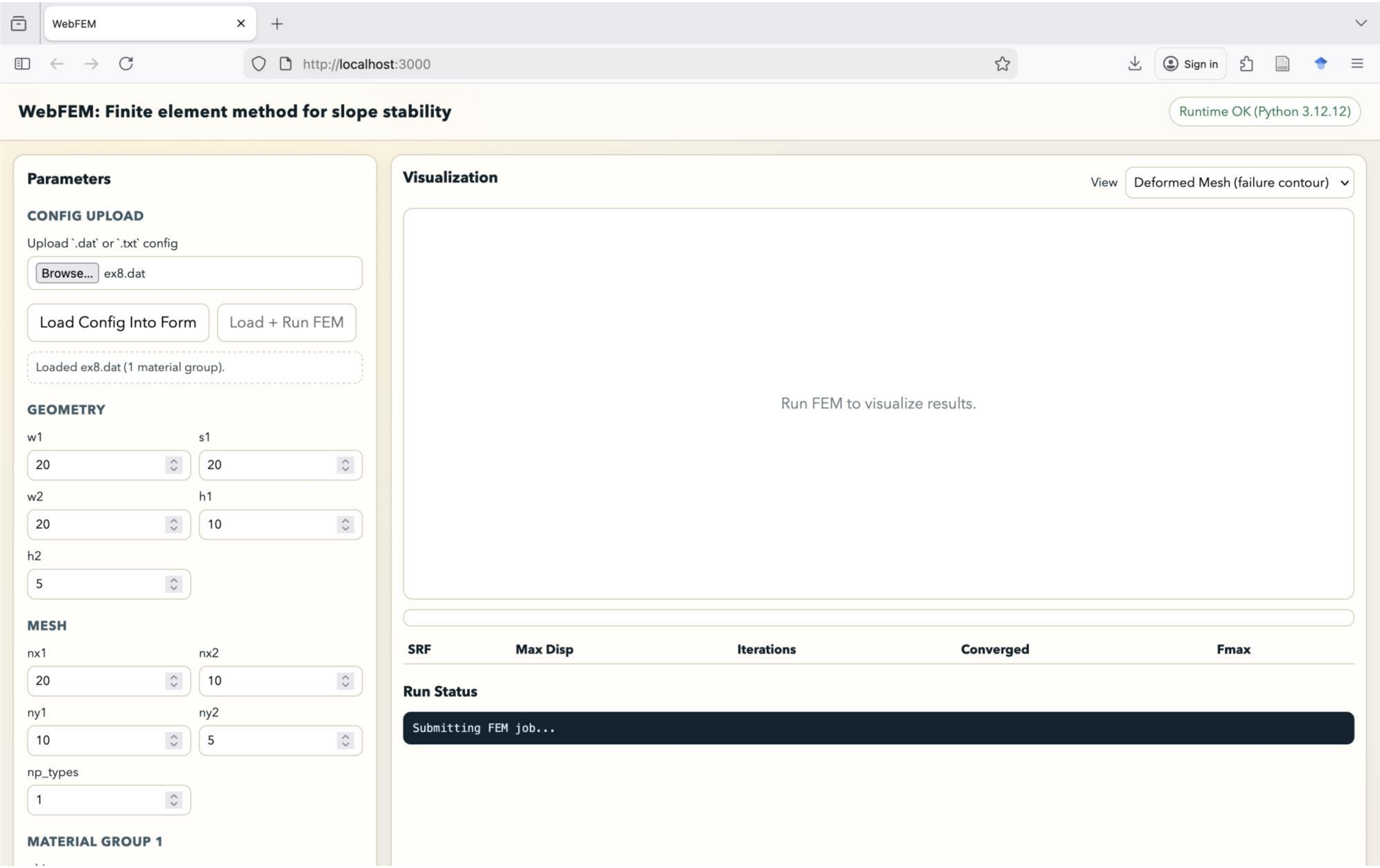
FINITE ELEMENT FOR SLOPE STABILITY



FINITE ELEMENT FOR SLOPE STABILITY

WebFEM

http://localhost:3000

Sign in

WebFEM: Finite element method for slope stability

Runtime OK (Python 3.12.12)

Parameters

CONFIG UPLOAD

Upload `.dat` or `.txt` config

Browse... ex8.dat

Load Config Into Form | Load + Run FEM

Loaded ex8.dat (1 material group).

GEOMETRY

w1: 20
s1: 20
w2: 20
h1: 10
h2: 5

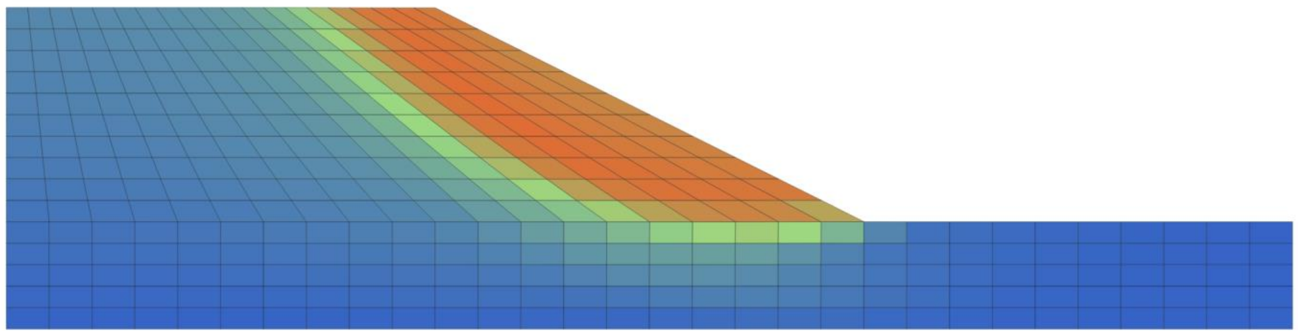
MESH

nx1: 20
nx2: 10
ny1: 10
ny2: 5
np_types: 1

MATERIAL GROUP 1

Visualization

View: Deferred Mesh (failure contour)



disp_mag

min: 1.943e-5 | max: 2.603e-2

Trials executed: **6** | Status: **Failure detected** | Critical SRF: **1.6000**

SRF	Max Disp	Iterations	Converged	Fmax
1.00	1.711e-2	10	true	4.377e-2
1.20	1.890e-2	17	true	5.946e-2
1.40	2.123e-2	33	true	8.266e-2
1.50	2.298e-2	67	true	8.080e-2

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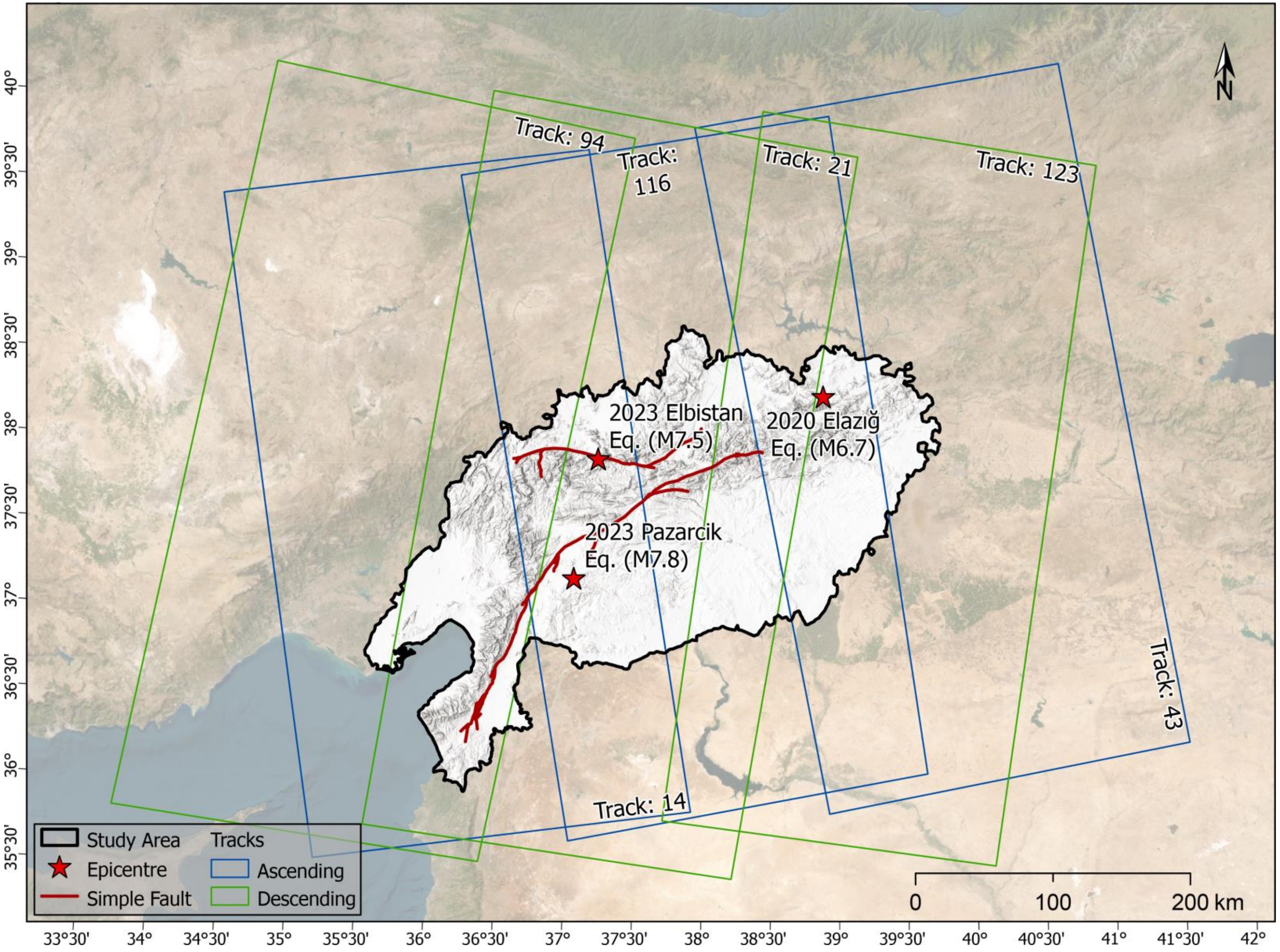
INVERSION WITH NN: STUDY AREA



Source: Dahal et al. (2025)

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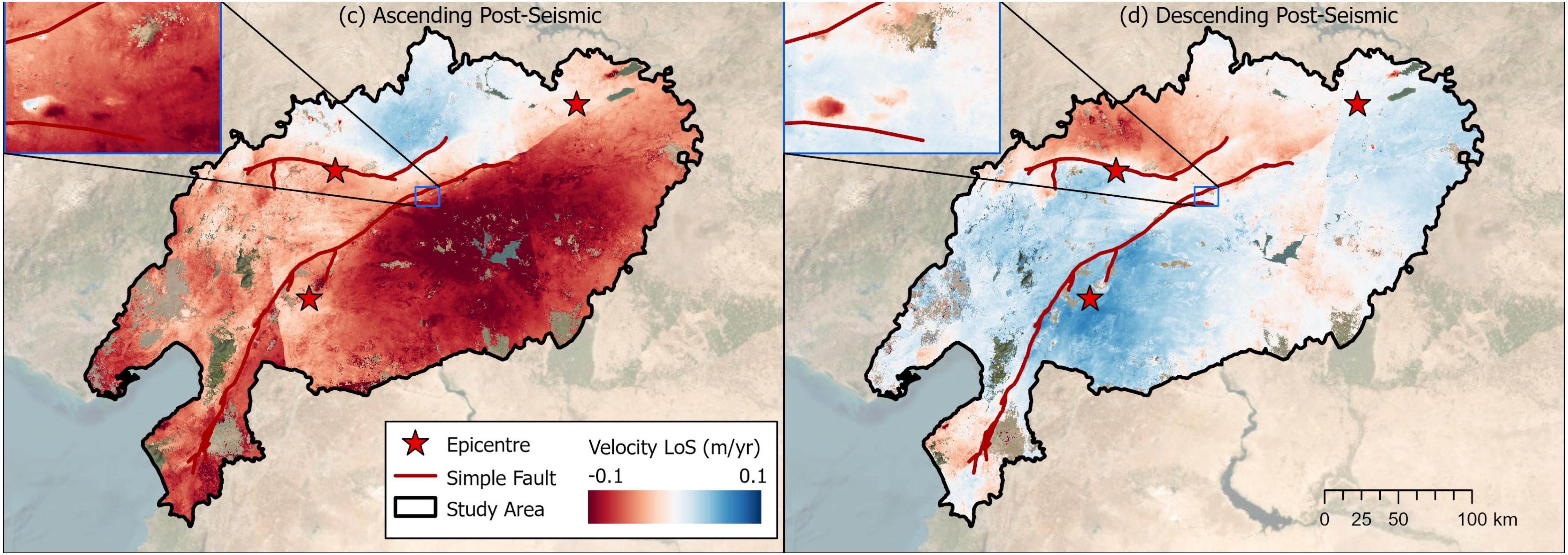

Image and Data Source: Dahal et al. (2025)

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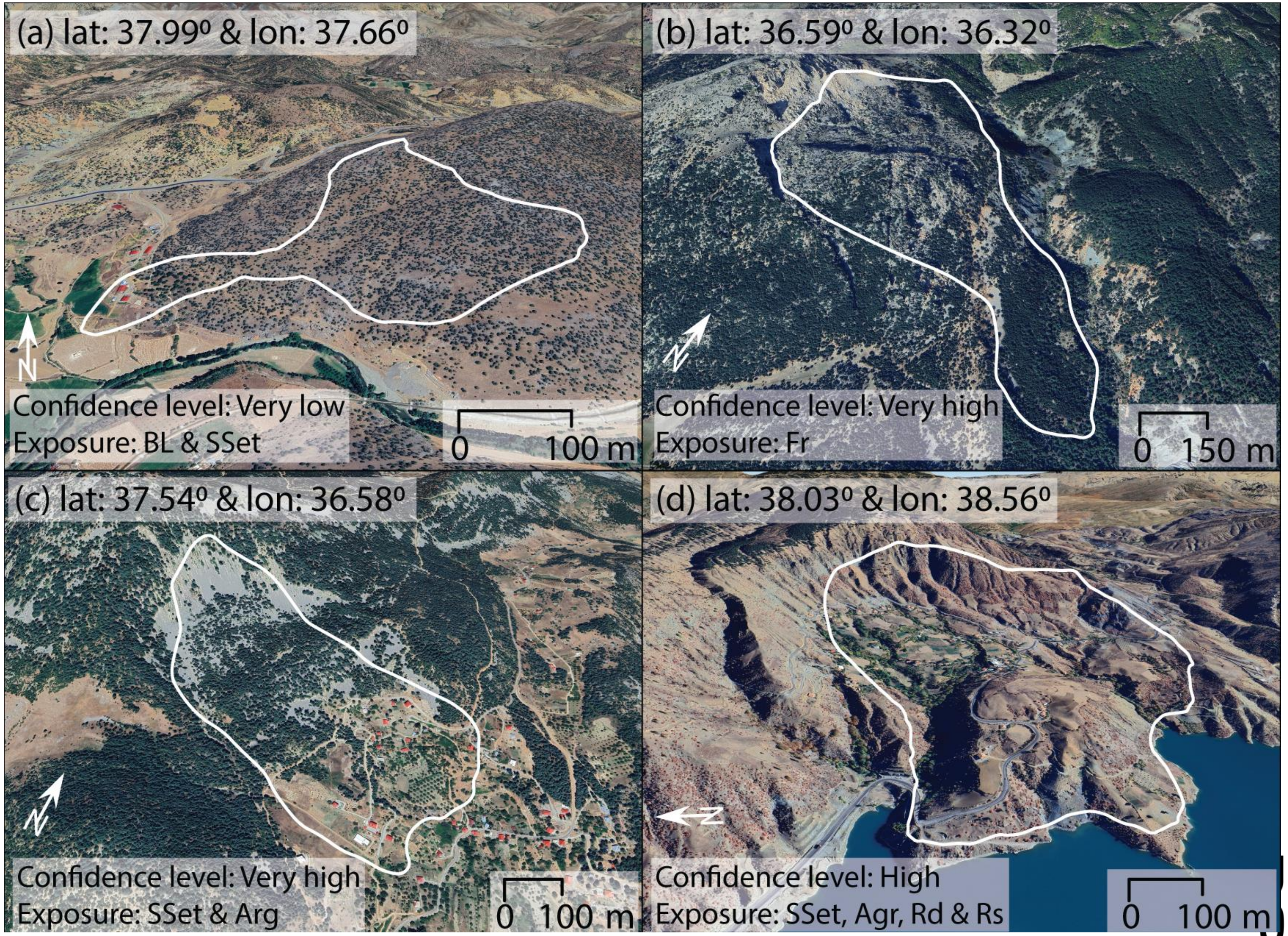

Image and Data Source: Dahal et al. (2025)

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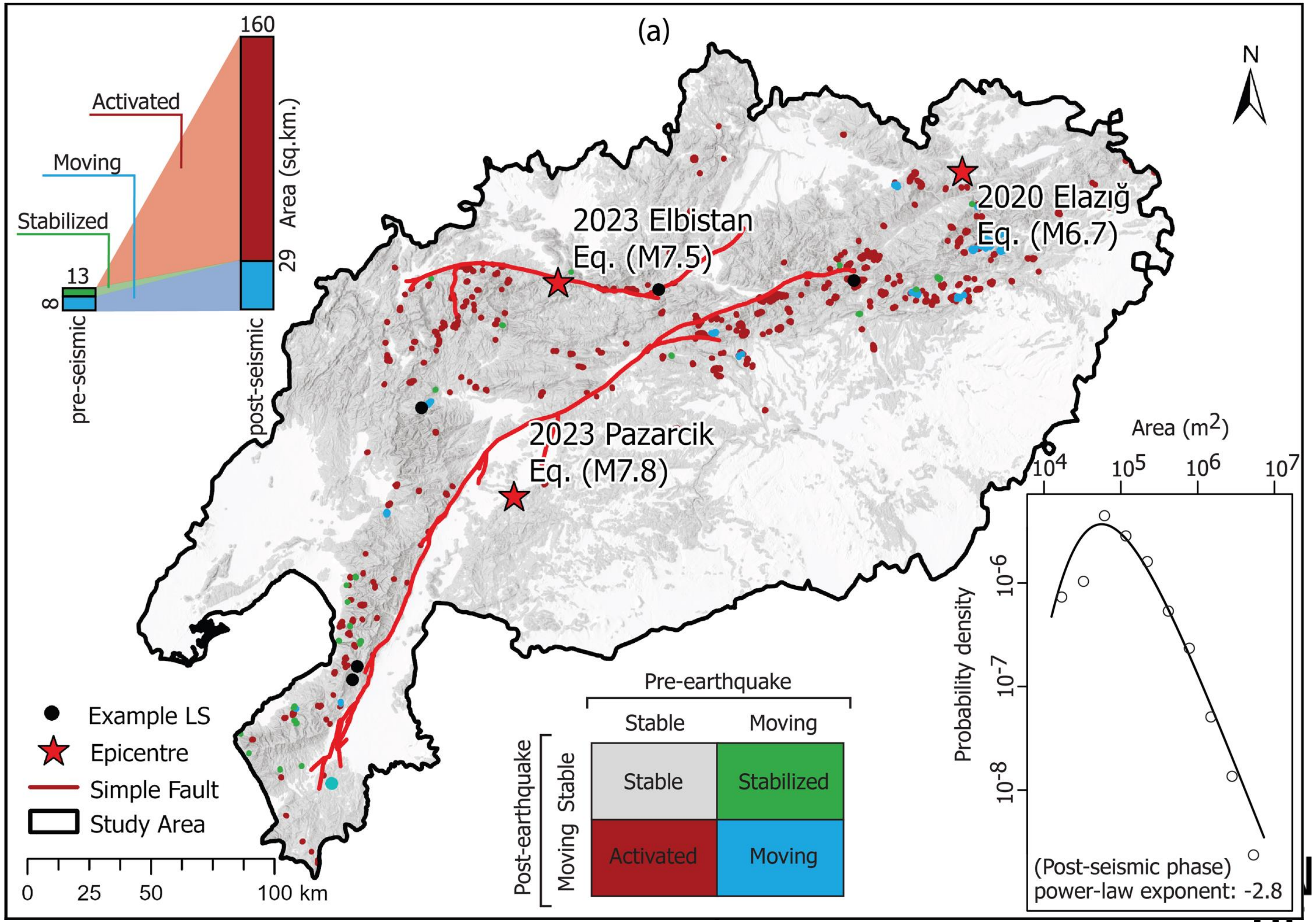

Image and Data Source: Dahal et al. (2025)

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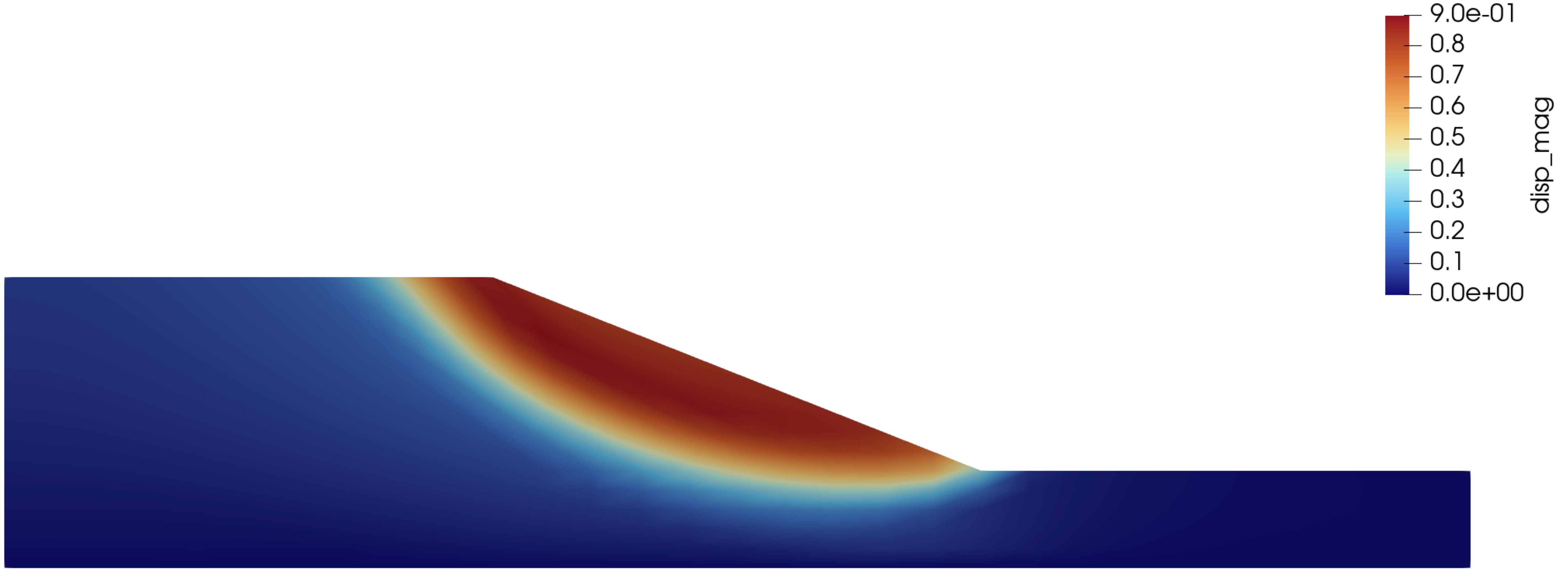
INVERSION WITH NN: RESULTING SAMPLE MESH



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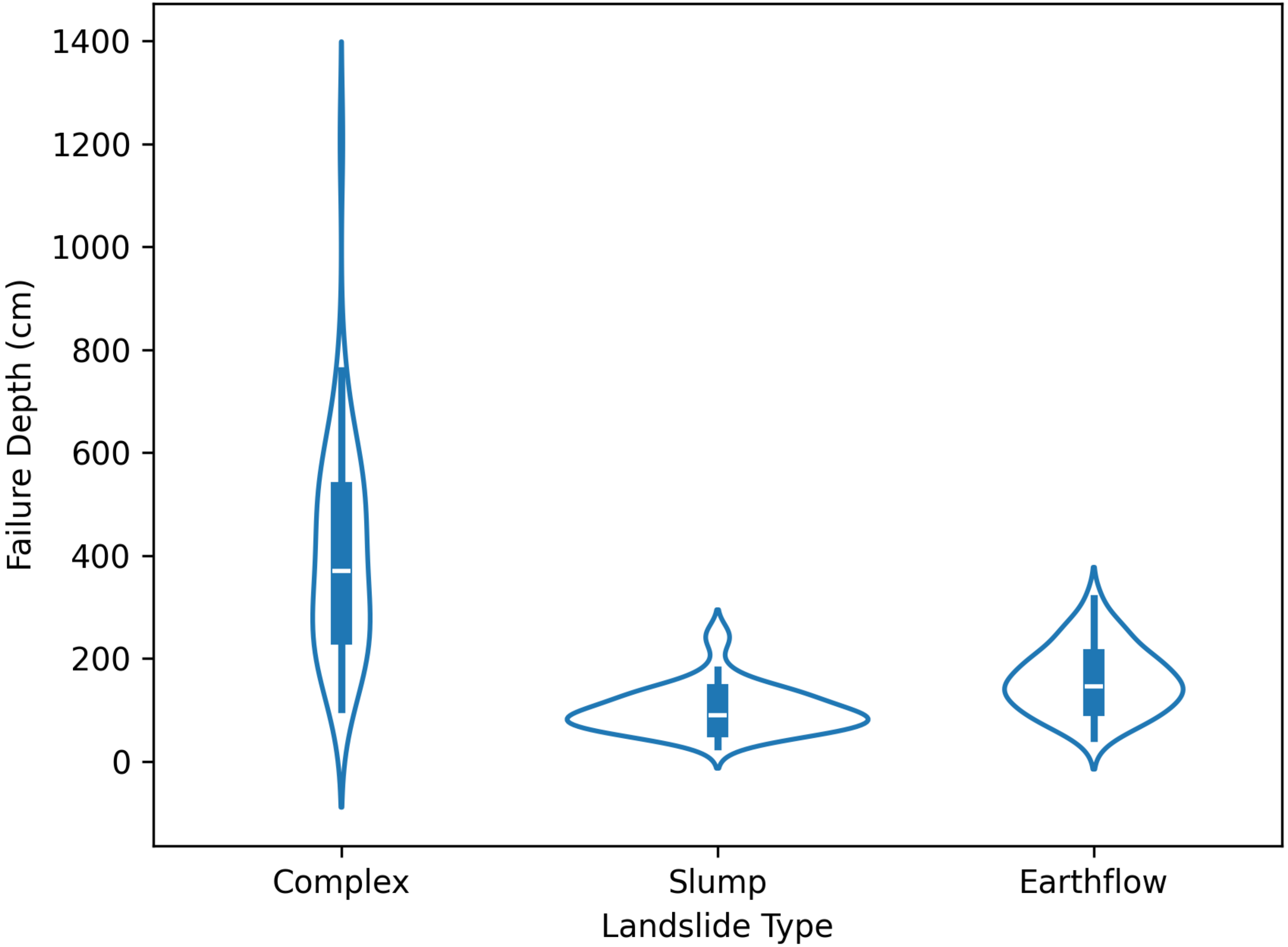
INVERSION WITH NN: DEPTH ESTIMATION



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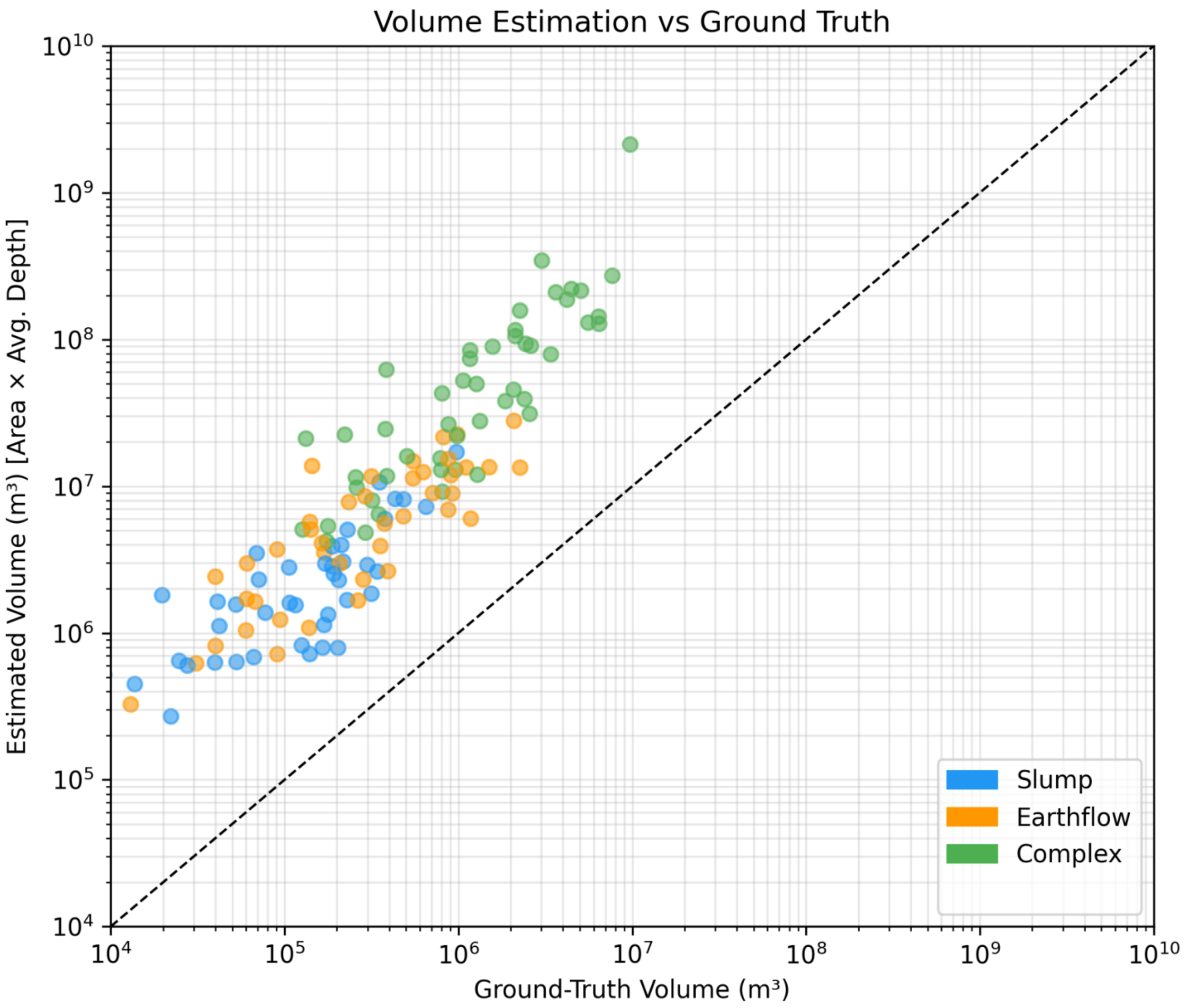
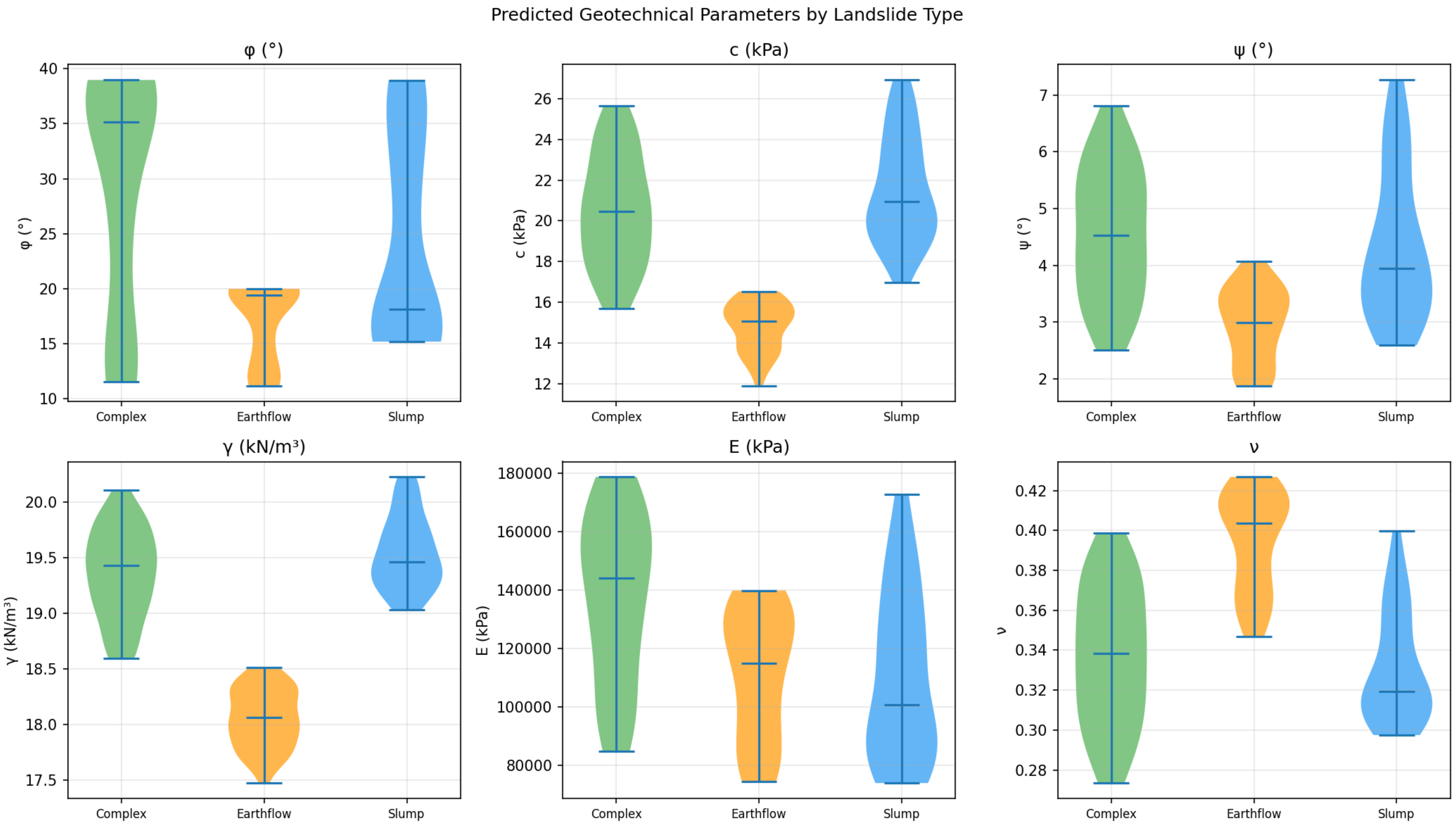
INVERSION WITH NN: VOLUME ESTIMATION



INVERSION WITH NN: PARAMETERS



FUTURE DIRECTIONS

- 3D Mesh Structures
- Real Topography
- Prediction at each nodes
- InSAR uncertainity ~ Model uncertainity

THANK YOU!