Landslide Hazard Assessment

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- Secretary of ISSMGE Joint Technical Committee on Landslides (JTC1), Member of ASCE “Technical Committee on Embankments, Dams and Slopes”, and Turkish Chamber of Civil Engineers (IMO) Geotechnical Council

OUTLINE

- Introduction
- Examples and Typical Characteristics of rainfall triggered landslides
- Landslide Mechanism
- Parametric numerical study
- Laboratory model tests to determine the triggering rainfall intensity-duration
- Landslide hazard assessment

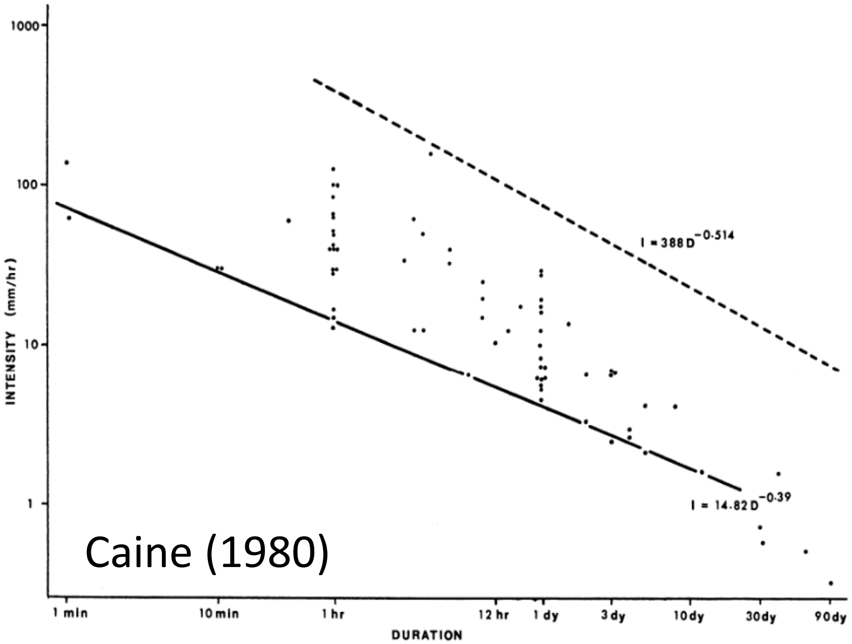

22/09/2010

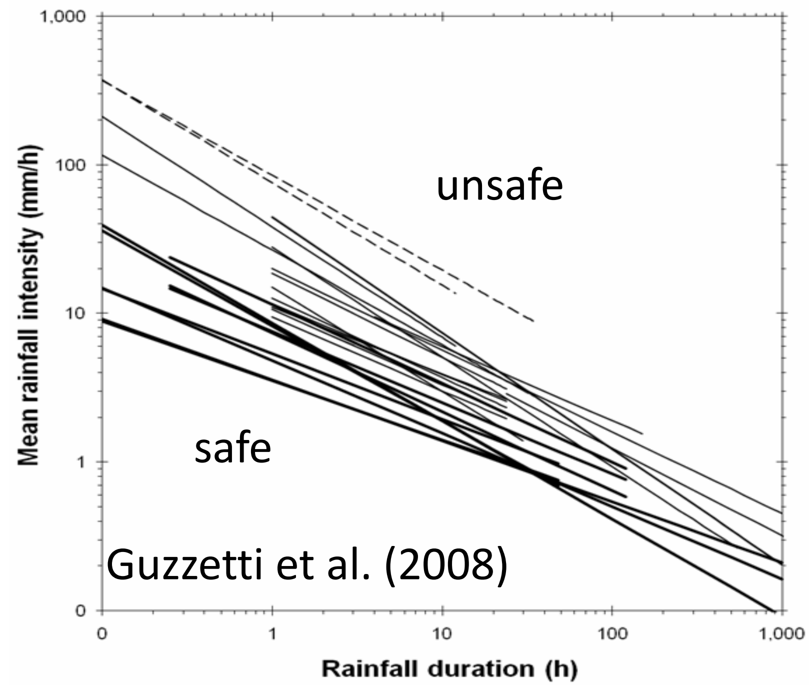

22/09/2010

Typical characteristics

- Their triggering factor is rainfall
- They are generally 2-5 m deep
- They occur on steep slopes
- They can be classified as “fast landslides”
- Ground water table is well below the ground surface, soils are unsaturated initially
- Residual soils (decomposition or rock in-place): sandy, silty
- Translational or rotational slides

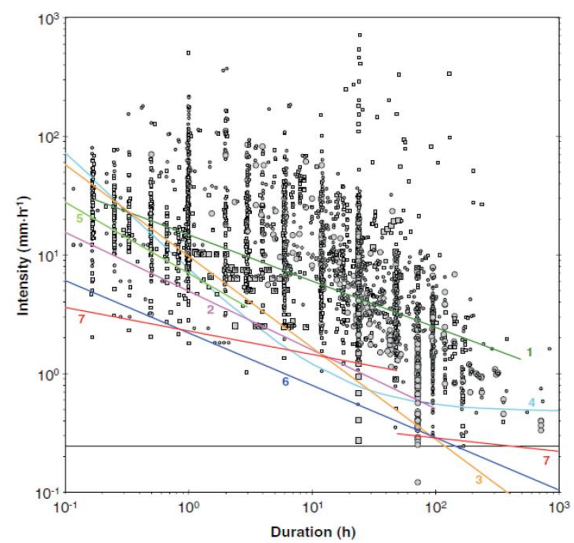
For early warning systems statistical rainfall intensity-duration (I-D) thresholds have been proposed in the literature.





They are affected by

- Availability, completeness
- Bias of records
- Not considering the mechanism of landslide

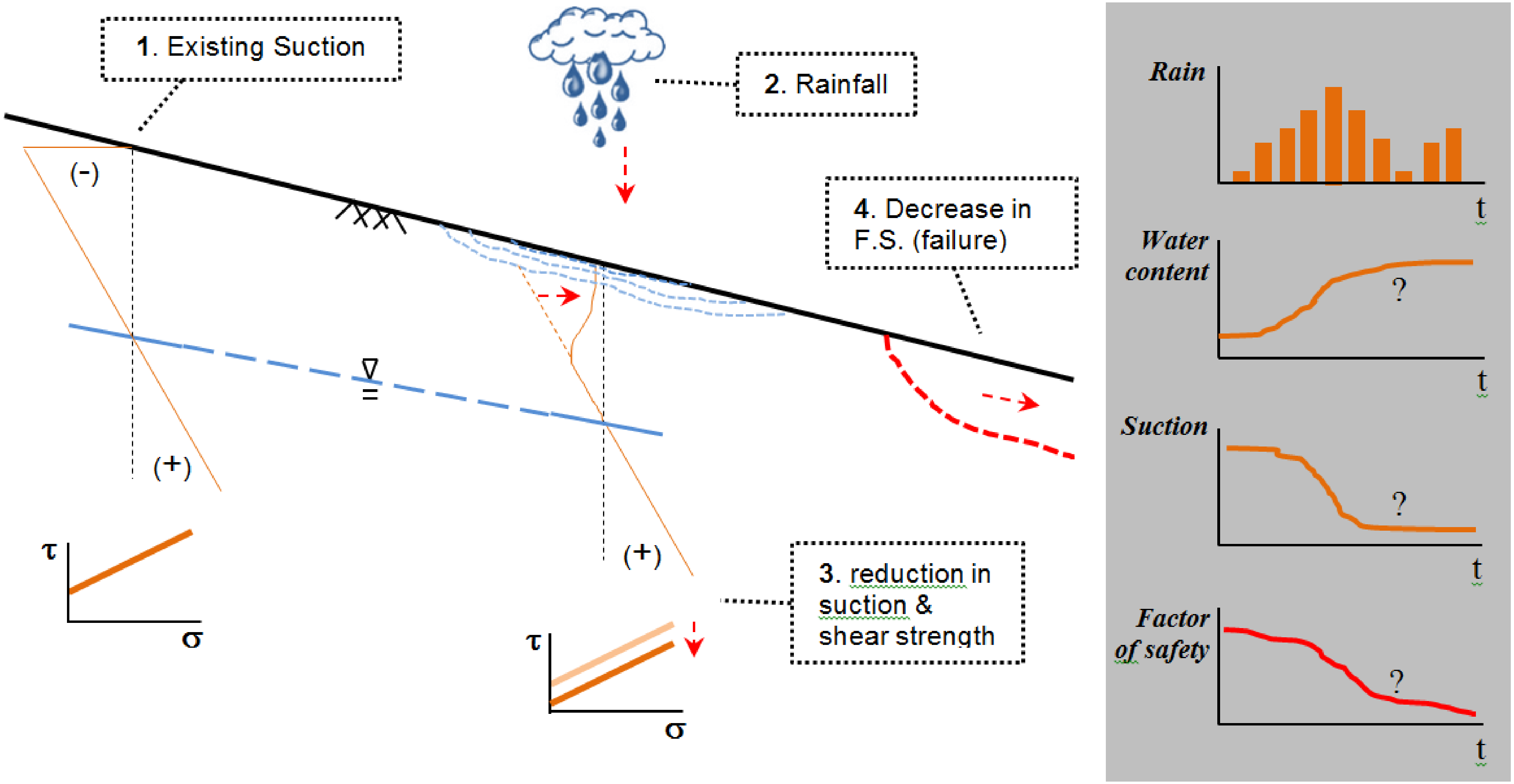


Objective of the research

to develop a physically-based model for prediction of rainfall triggered landslides (i.e. determine triggering rainfall intensity-duration threshold),

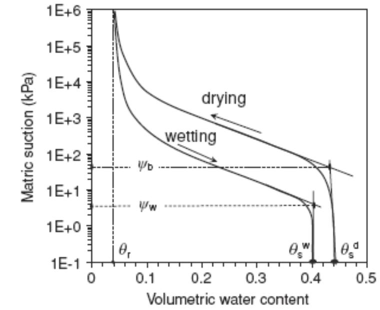
to lead toward an early warning system taking into account the physical mechanism of the problem.

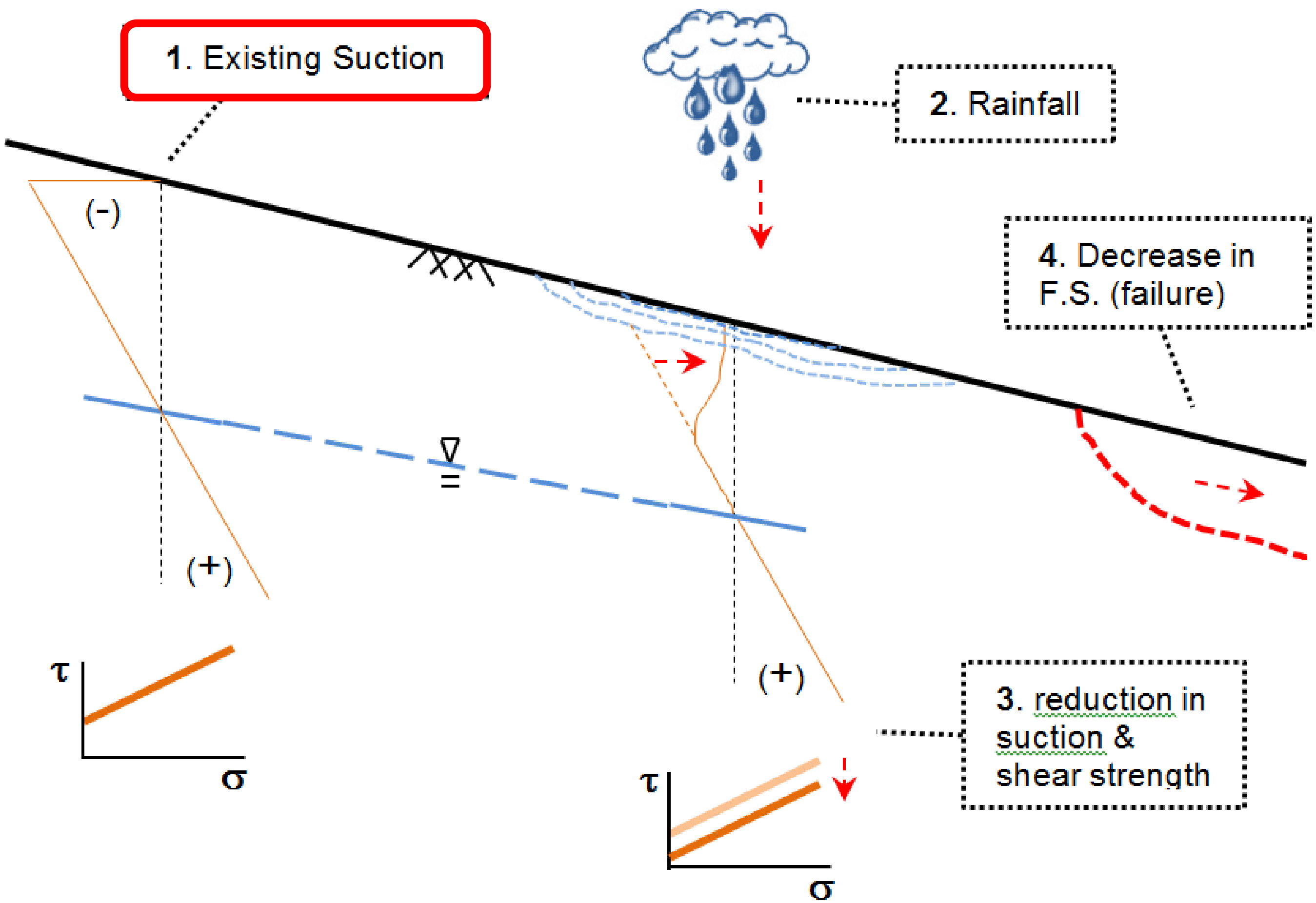
The mechanism

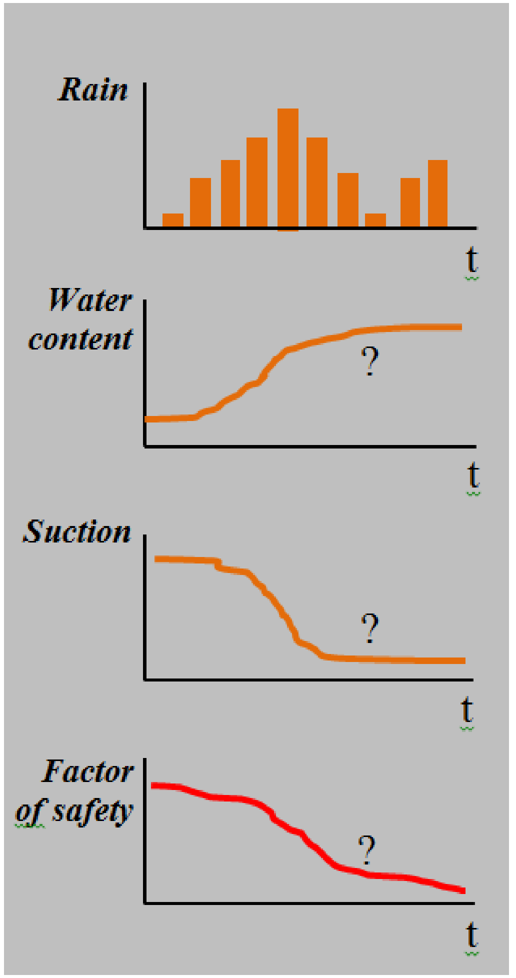


The mechanism

Soil Water Characteristic Curve (SWCC)

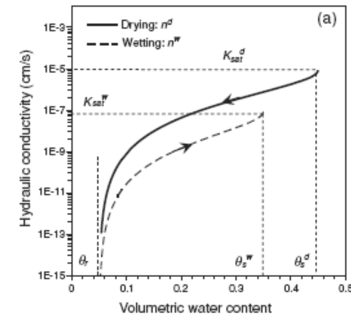


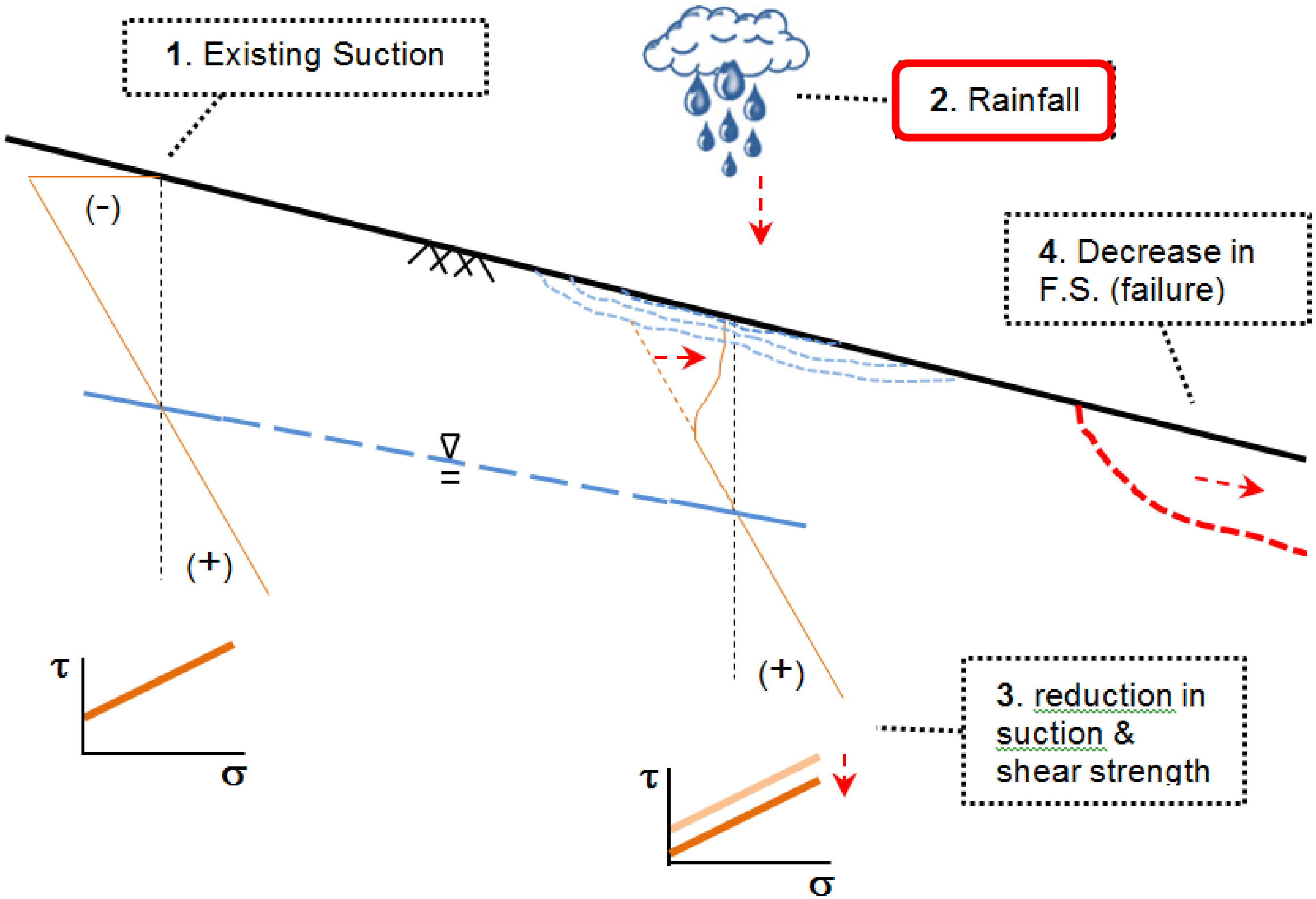


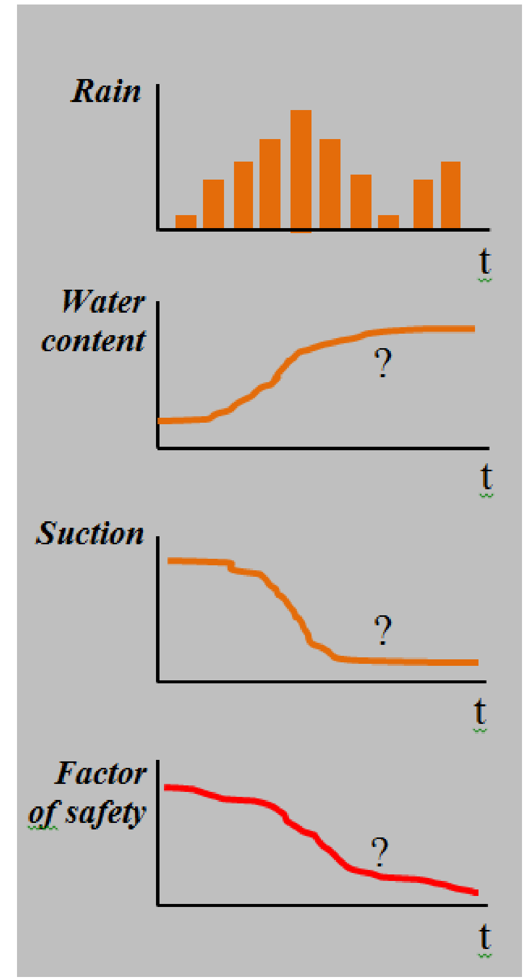


The mechanism

Hydraulic conductivity Function (HCF)

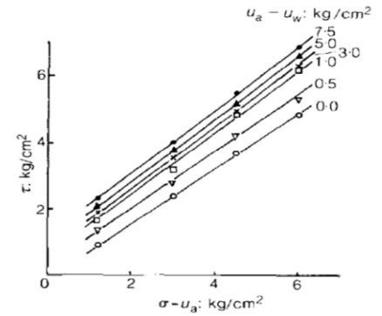


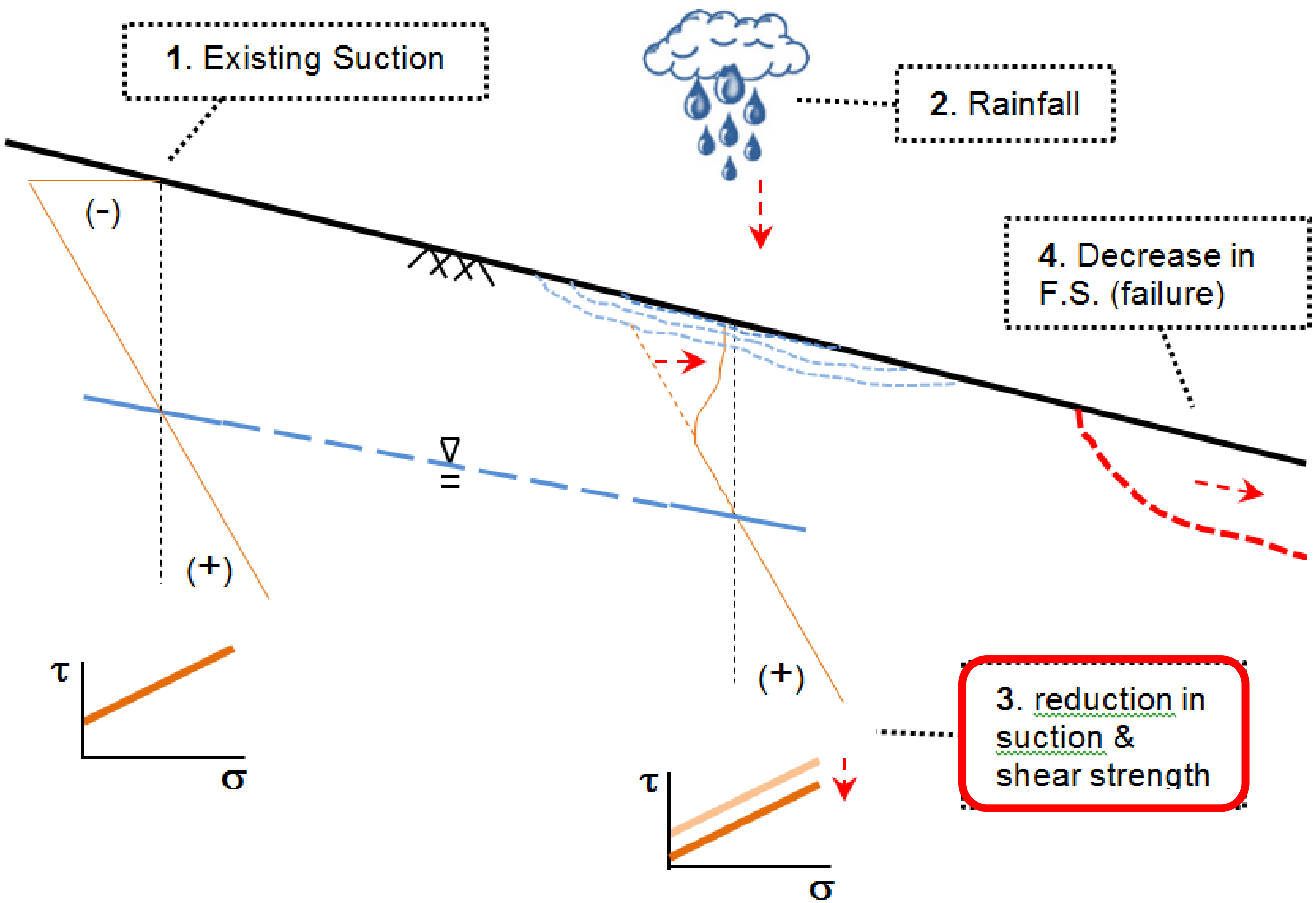


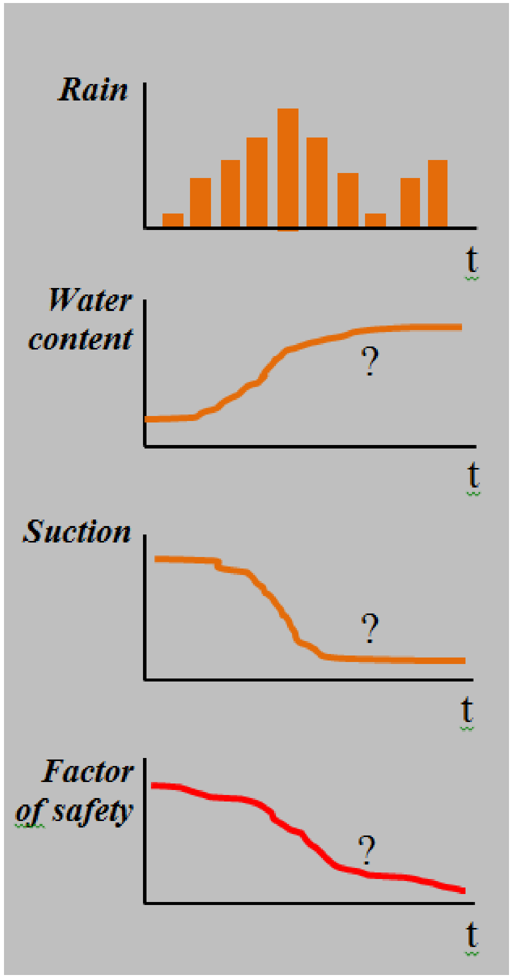


The mechanism

Unsaturated Shear Strength

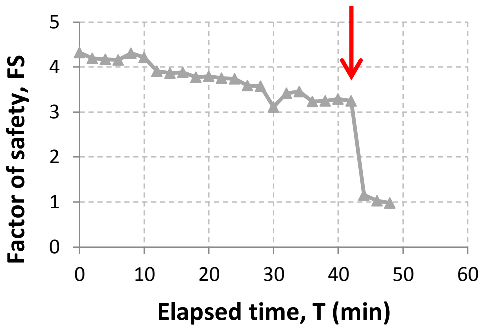


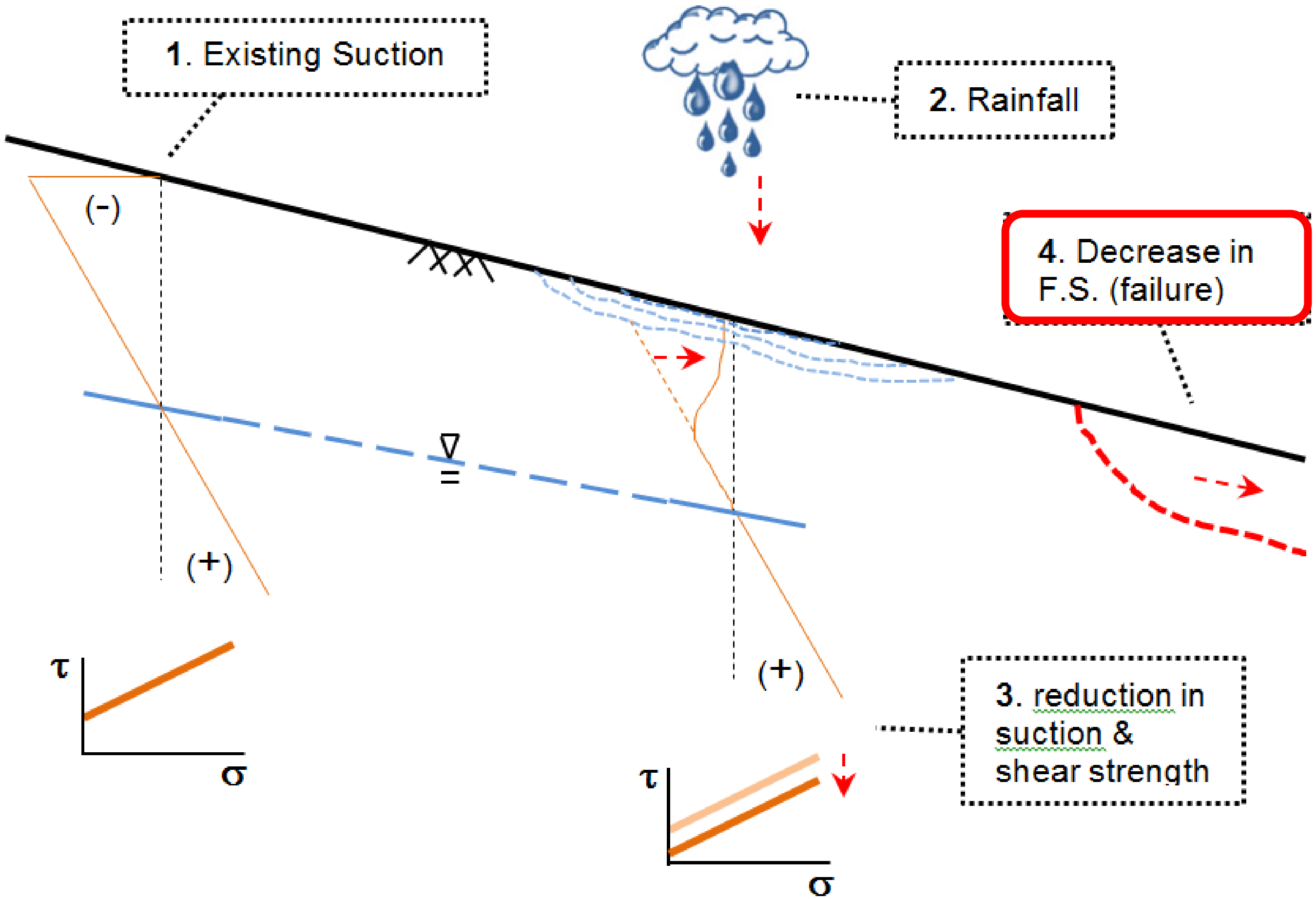


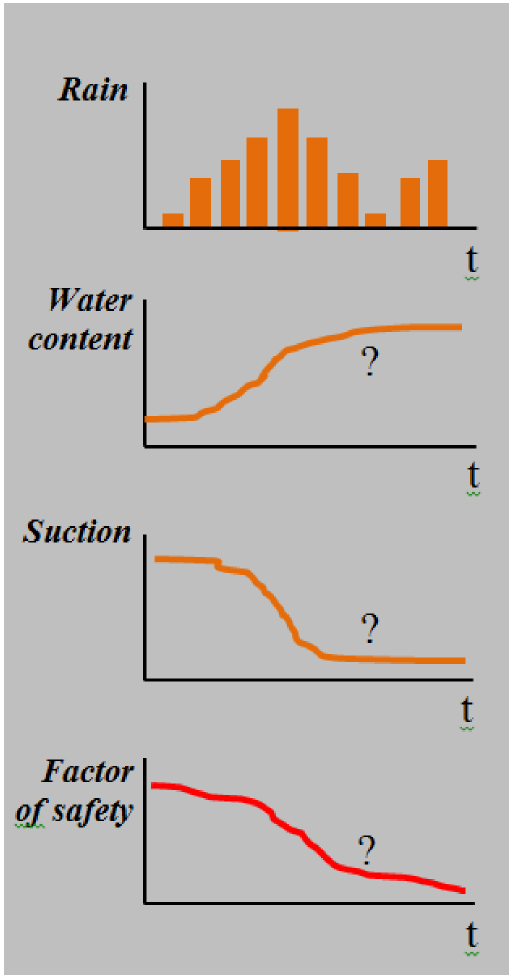


The mechanism

Numerical Simulations







Numerical study → A parametric study (changes in soil properties on I-D)

How SWCC can affect unsaturated seepage and slope stability?

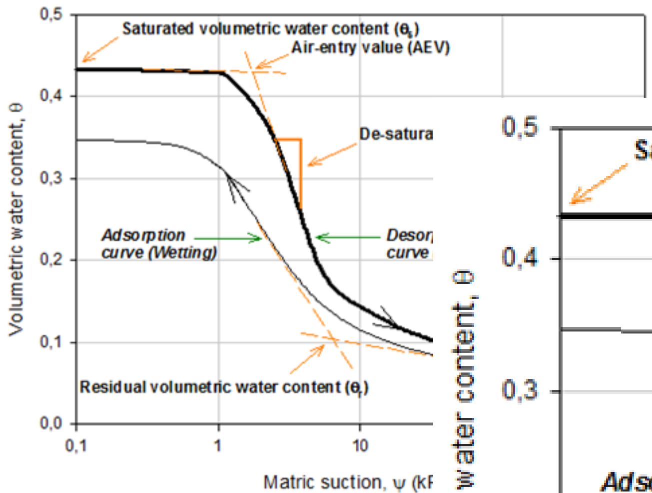
Gradation ⟹ **AEV**

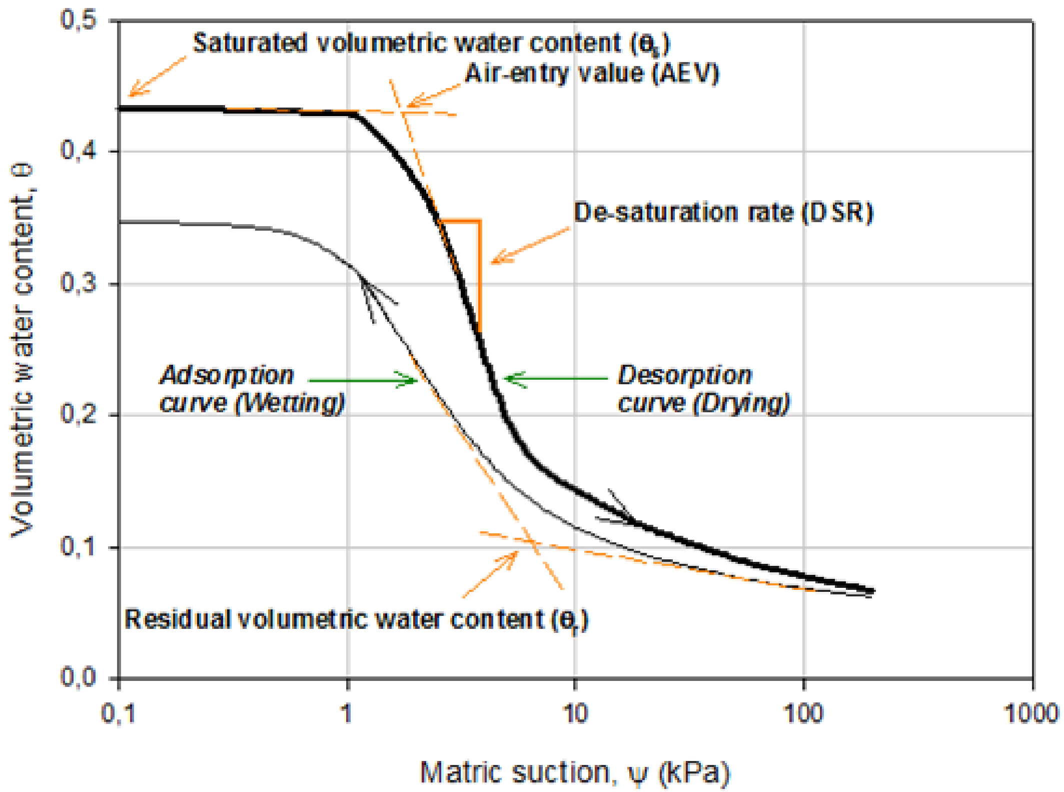
(a soil with a higher AEV is a finer grained soil)

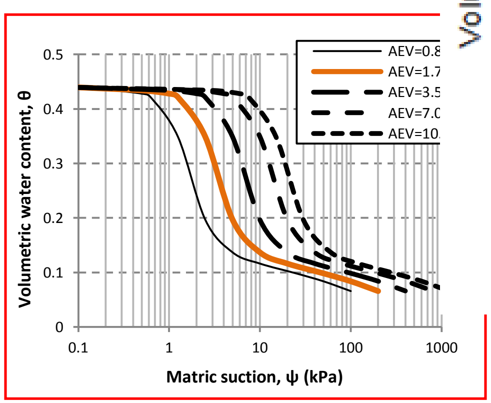
⟹ θ_s

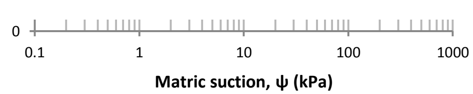
⟹ **DSR**

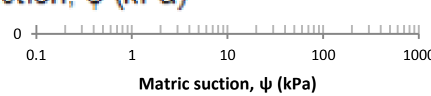
⟹ θ_r

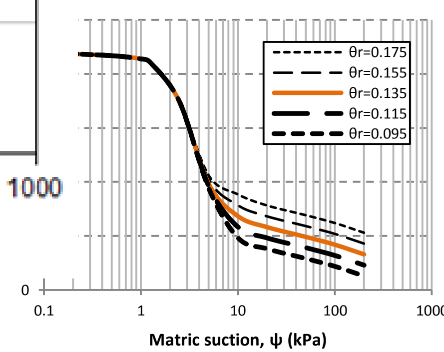






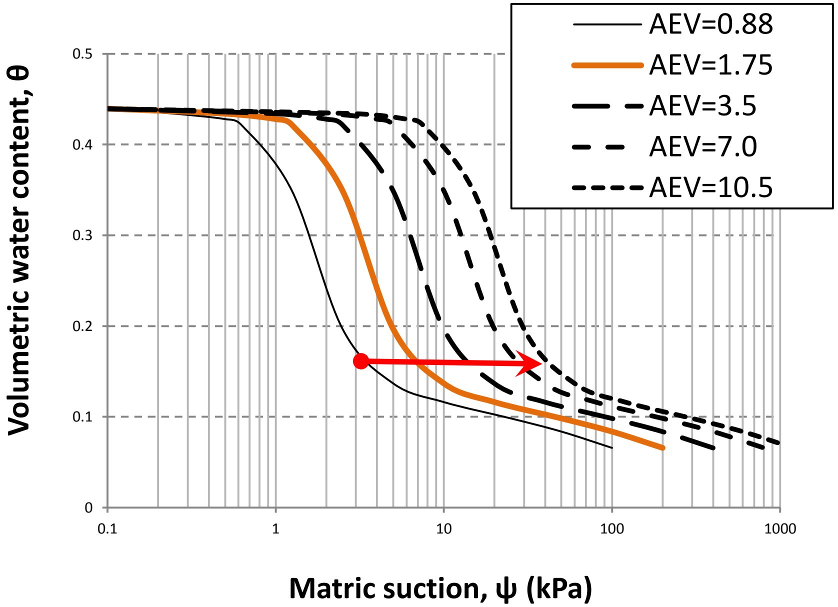


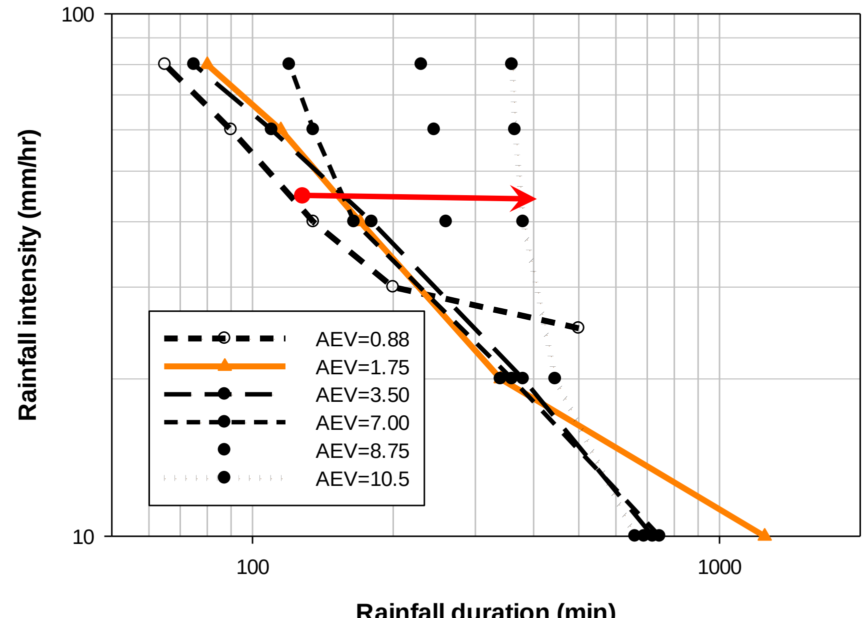


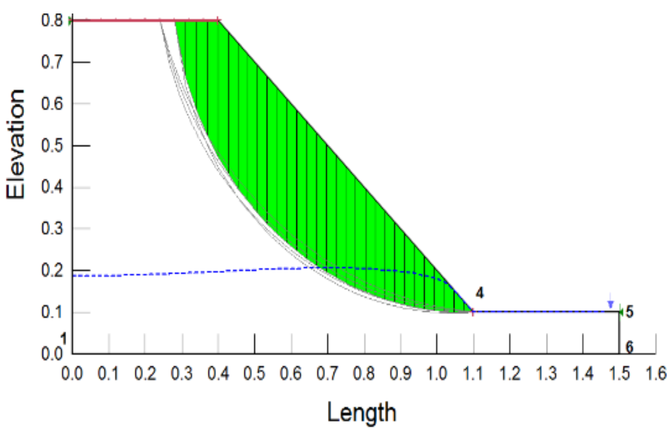


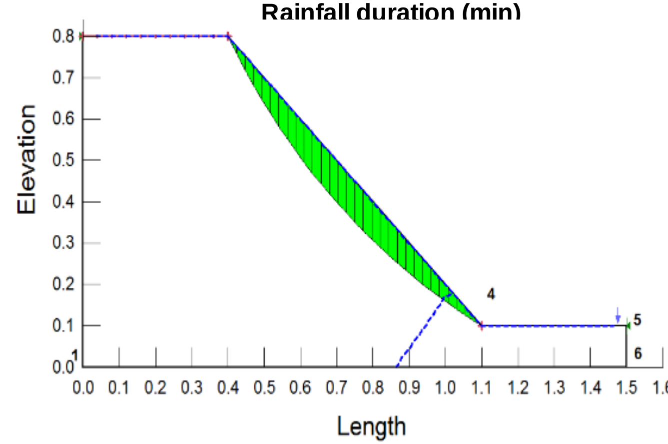
Numerical study → A parametric study (changes in soil properties on I-D)

Soil gradation was found to be the most important factor that can cause significant changes in location and shape of the I-D thresholds.









Kenanoglu, Ahmadiadli, Huvaj, Toker (2016) Computers and Geotechnics

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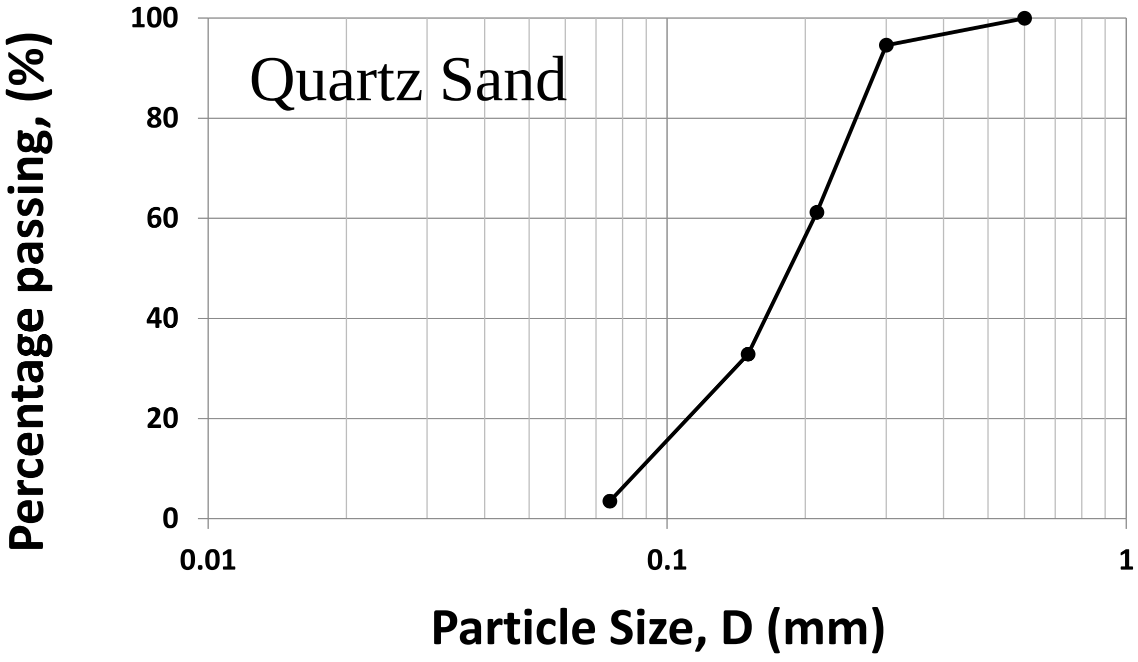
Laboratory model tests

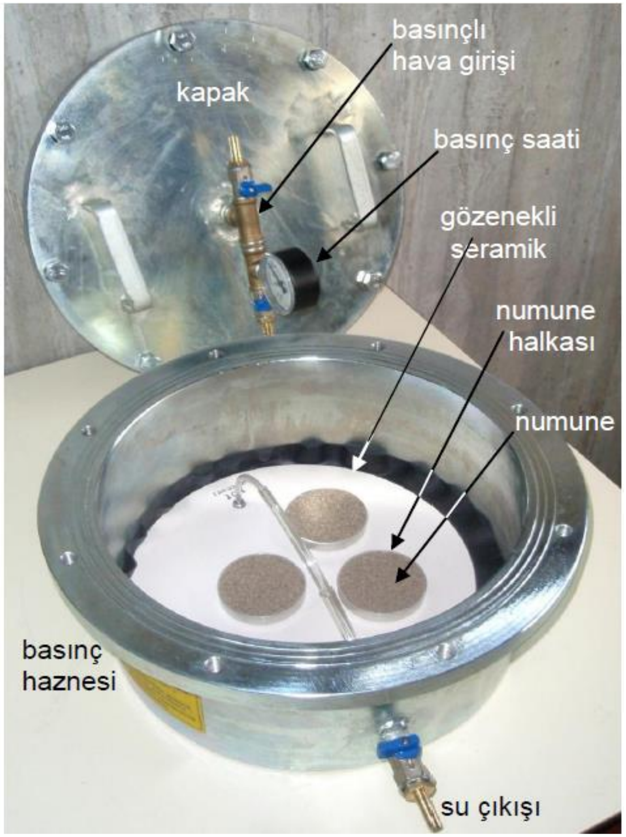


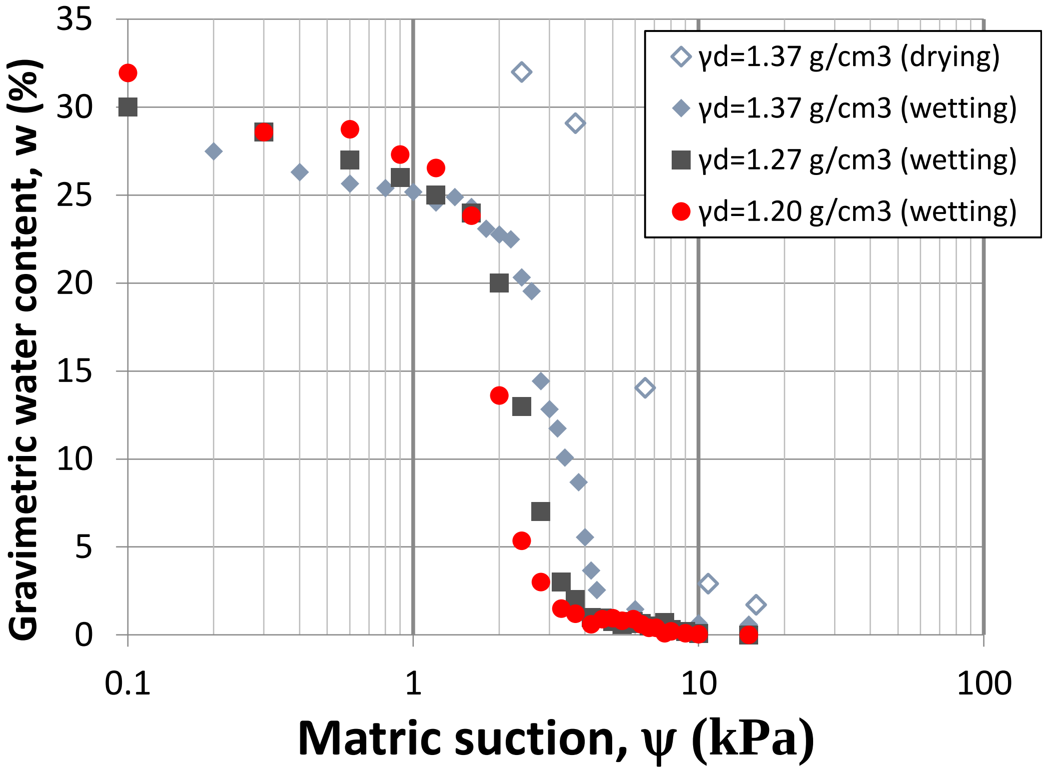
D_{10} (mm) :	0.09	PI (%) :	N.P.
D_{30} (mm) :	0.14	USCS Soil Class:	SP
D_{50} (mm) :	0.18	Gs :	2.663
D_{60} (mm) :	0.202	$\Upsilon_{d\,max}$:	1.648 g/cm^3
C_c :	1.08	$\Upsilon_{d\,min}$ * :	1.332 g/cm^3
C_u :	2.24	K_{sat} :	1.145e-6 m/sec

Laboratory works → material properties (SWCC)

- Hanging column setup (0-80 kPa)
- Pressure plate setup (50-1500 kPa)
- Capillary tube

were designed and manufactured at METU geotechnical laboratory.

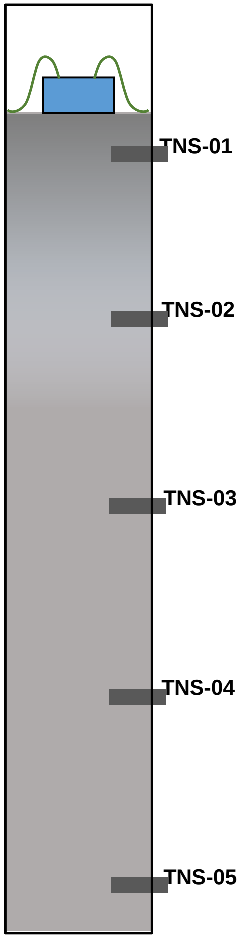


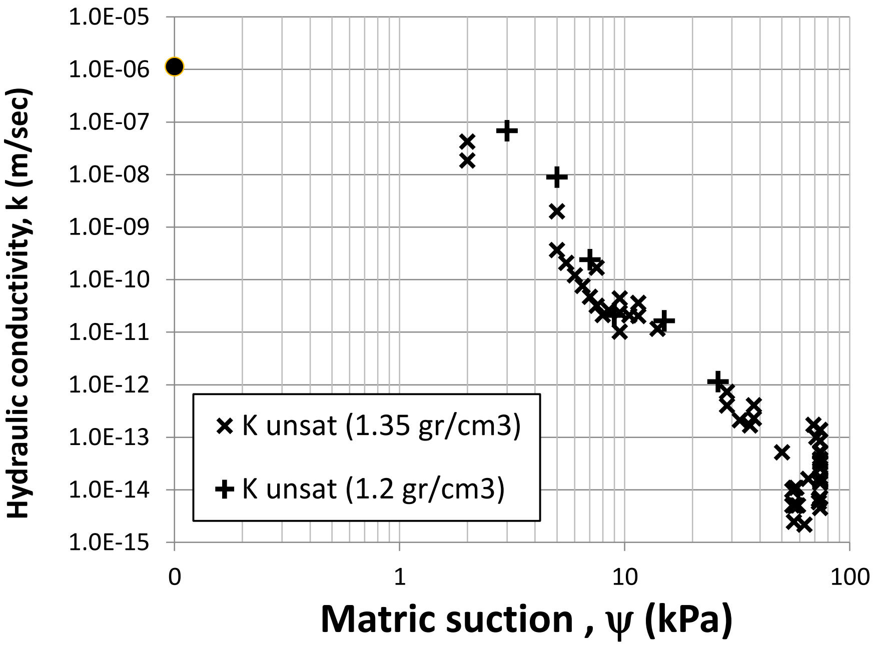


Laboratory works → material properties (HCF)

- Infiltration column setup (through dry medium)

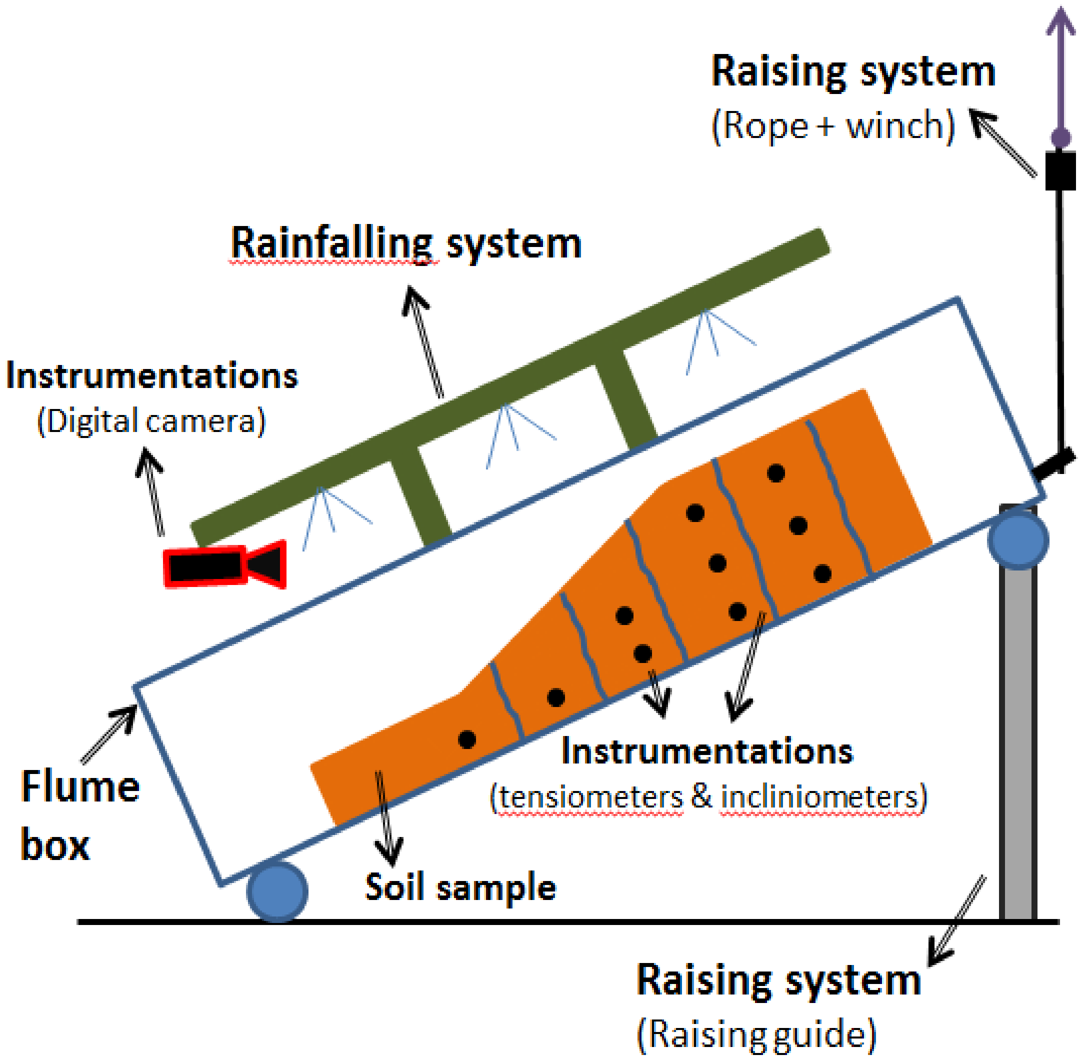
  was designed and manufactured at METU geotech. lab.

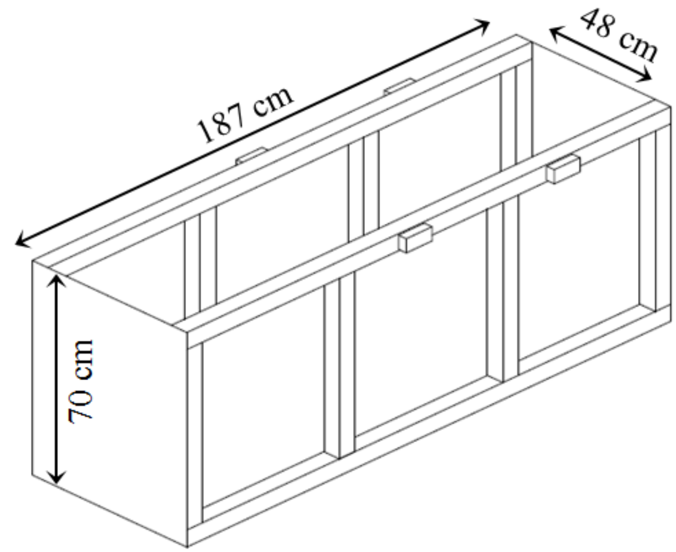




Laboratory works → flume model tests (setup)

A laboratory setup that includes a flume box, rainfall system and raising setup was designed by the author and manufactured for METU geotechnical laboratory.

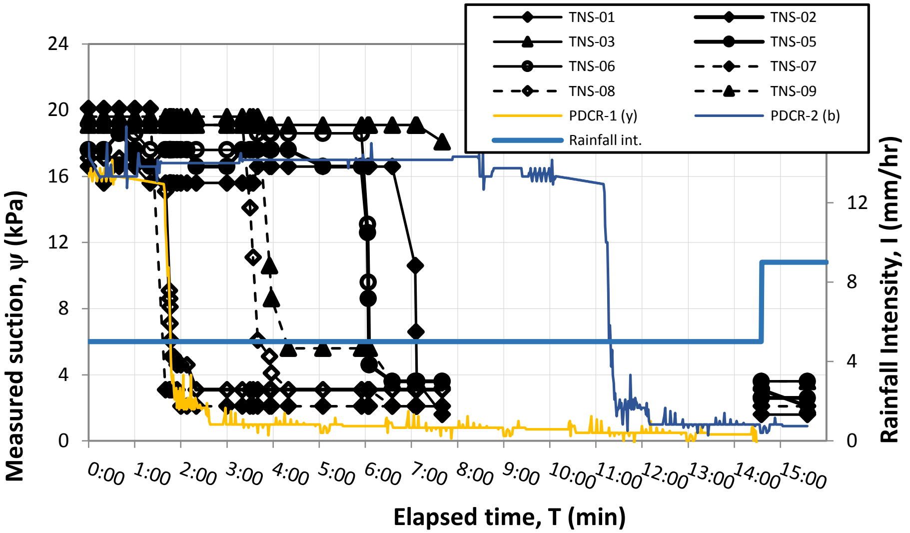


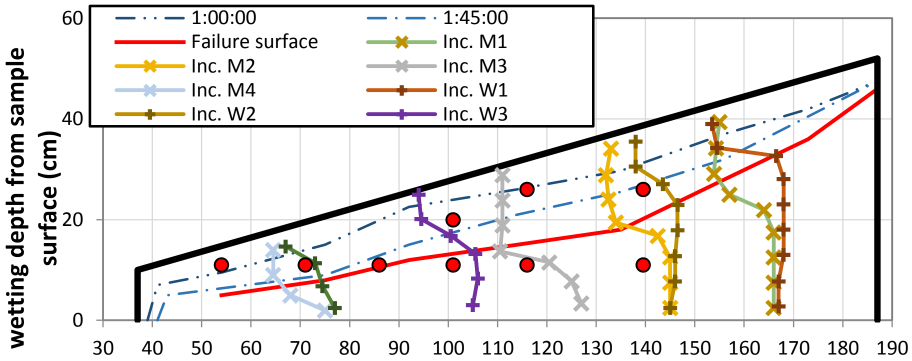


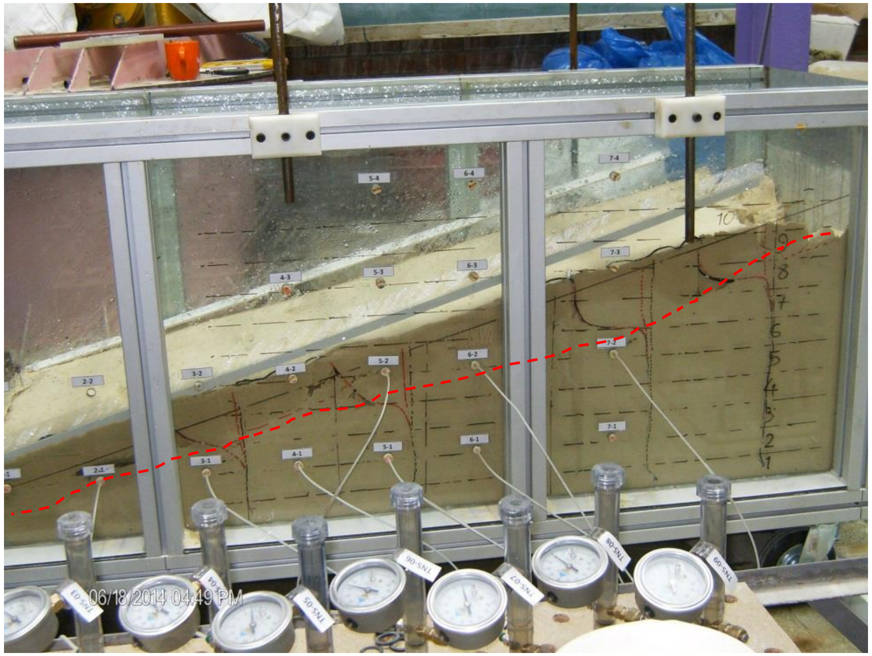
Laboratory works → flume model tests (sample preparation)

Laboratory works → flume model tests (test results)

- Tensiometers (suction-time)
- Wetting front
- Inclinometers
- Failure surface







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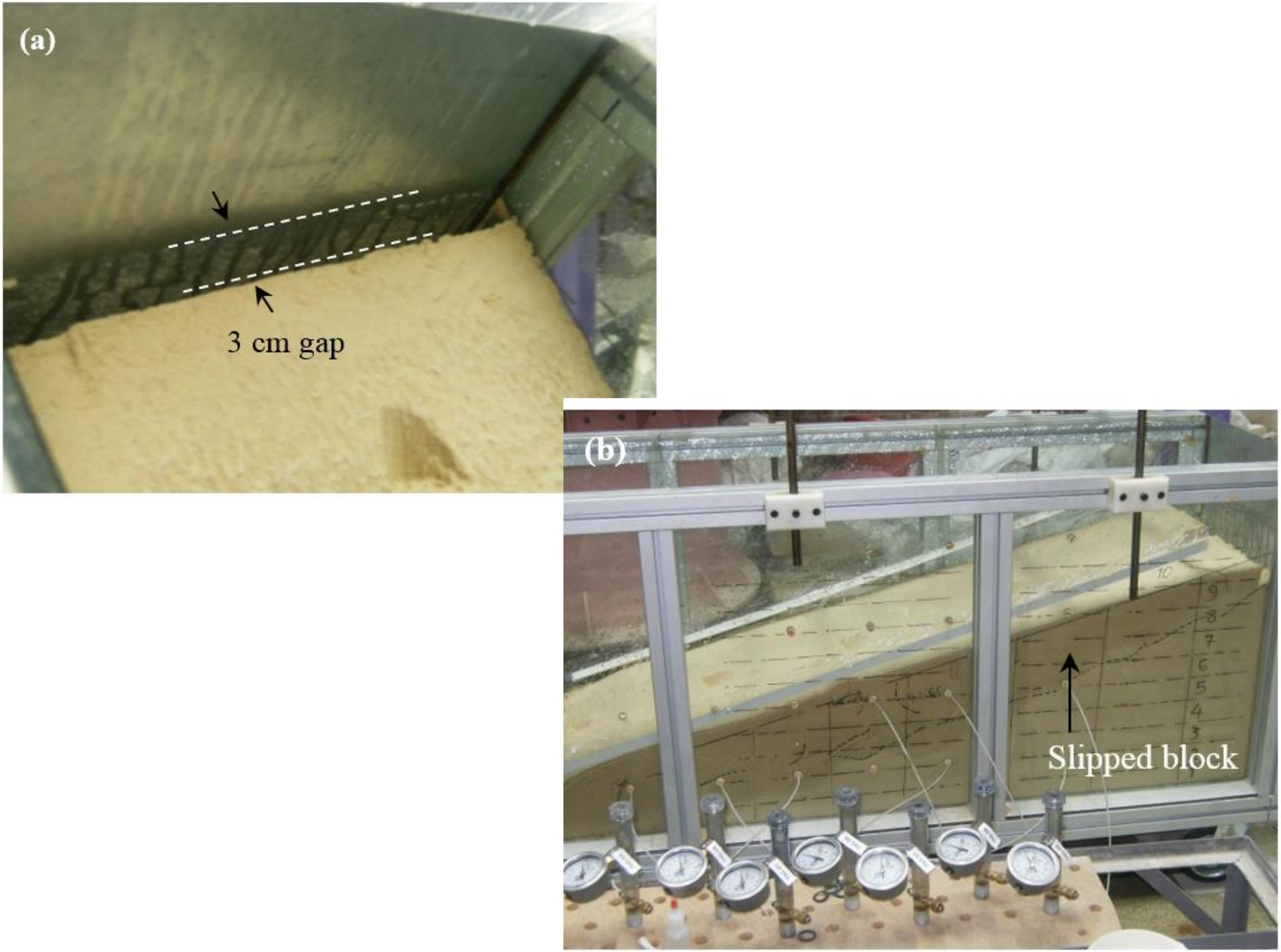
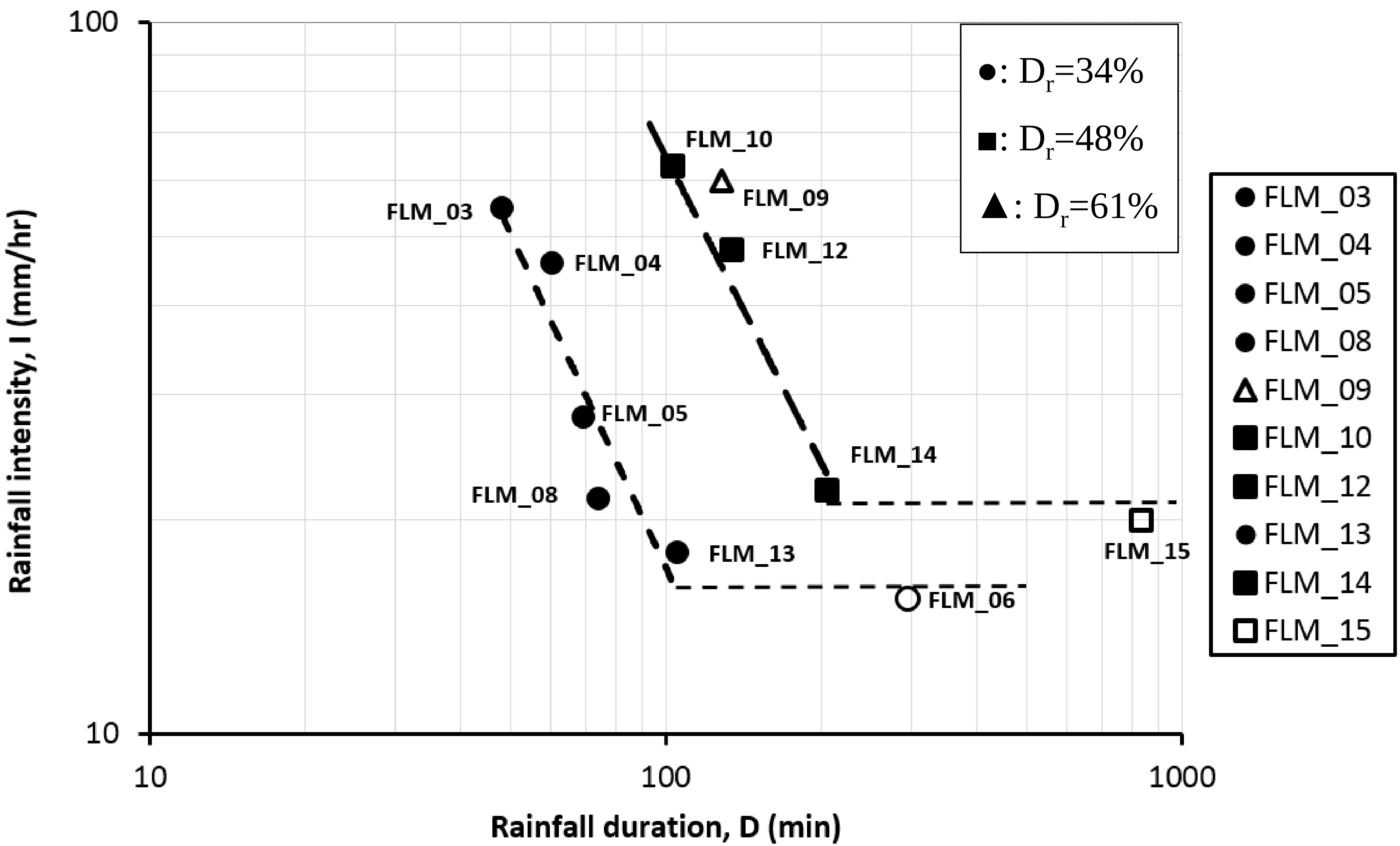

(a)
3 cm gap
(b)
Slipped block

Rainfall Intensity-Duration thresholds



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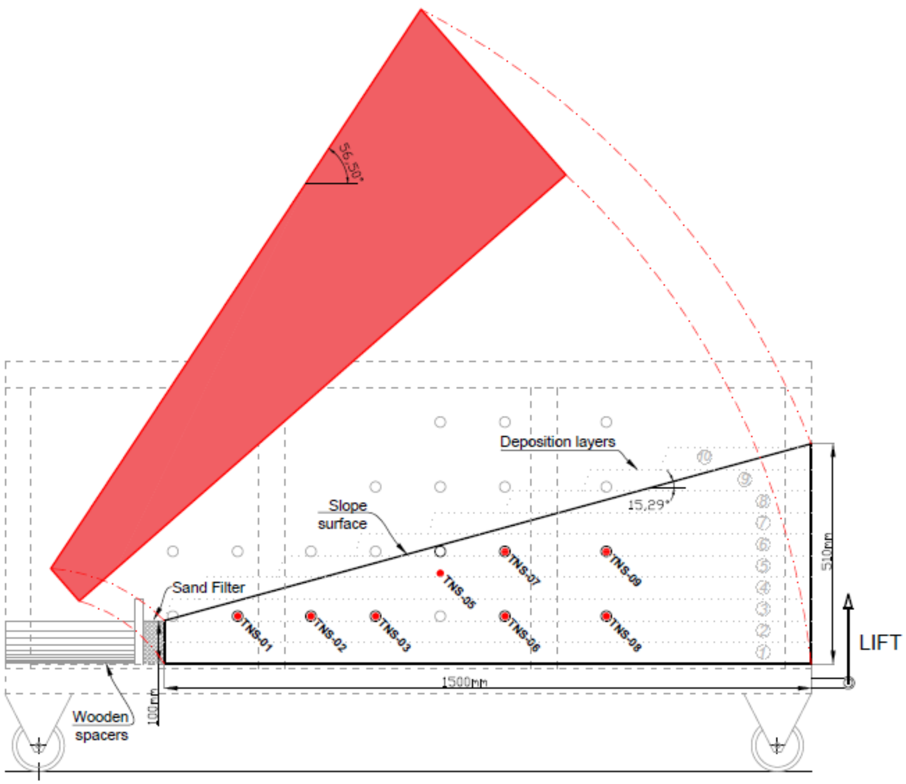
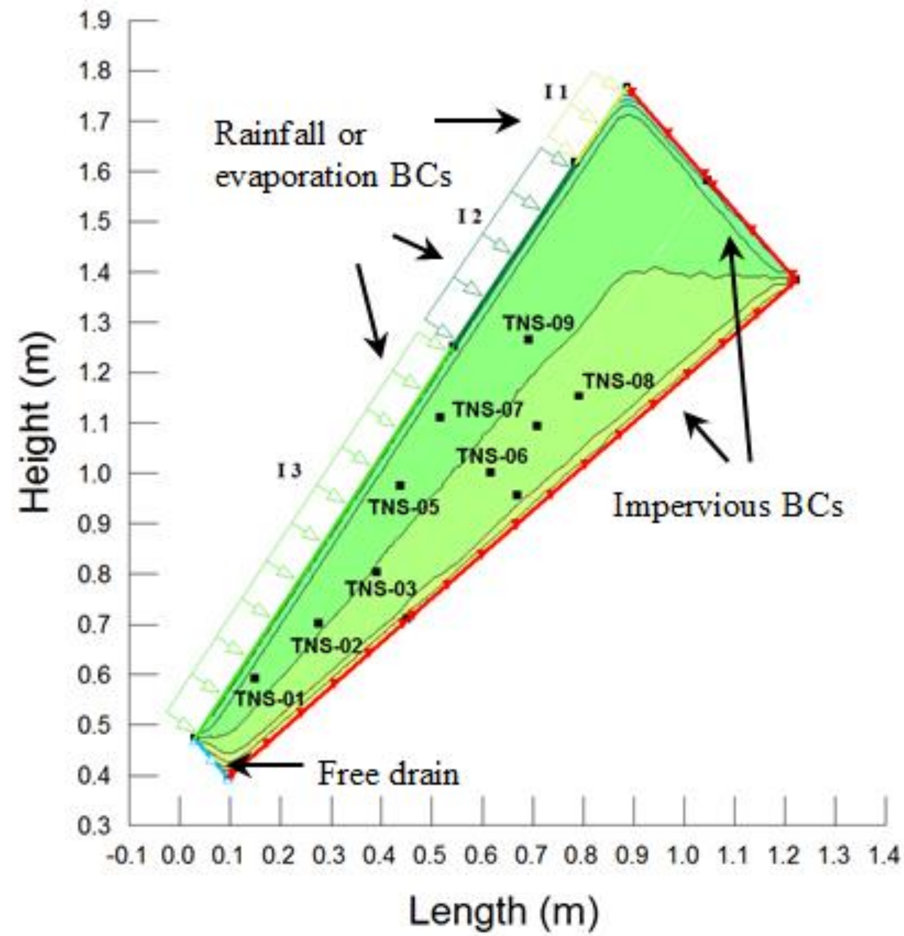
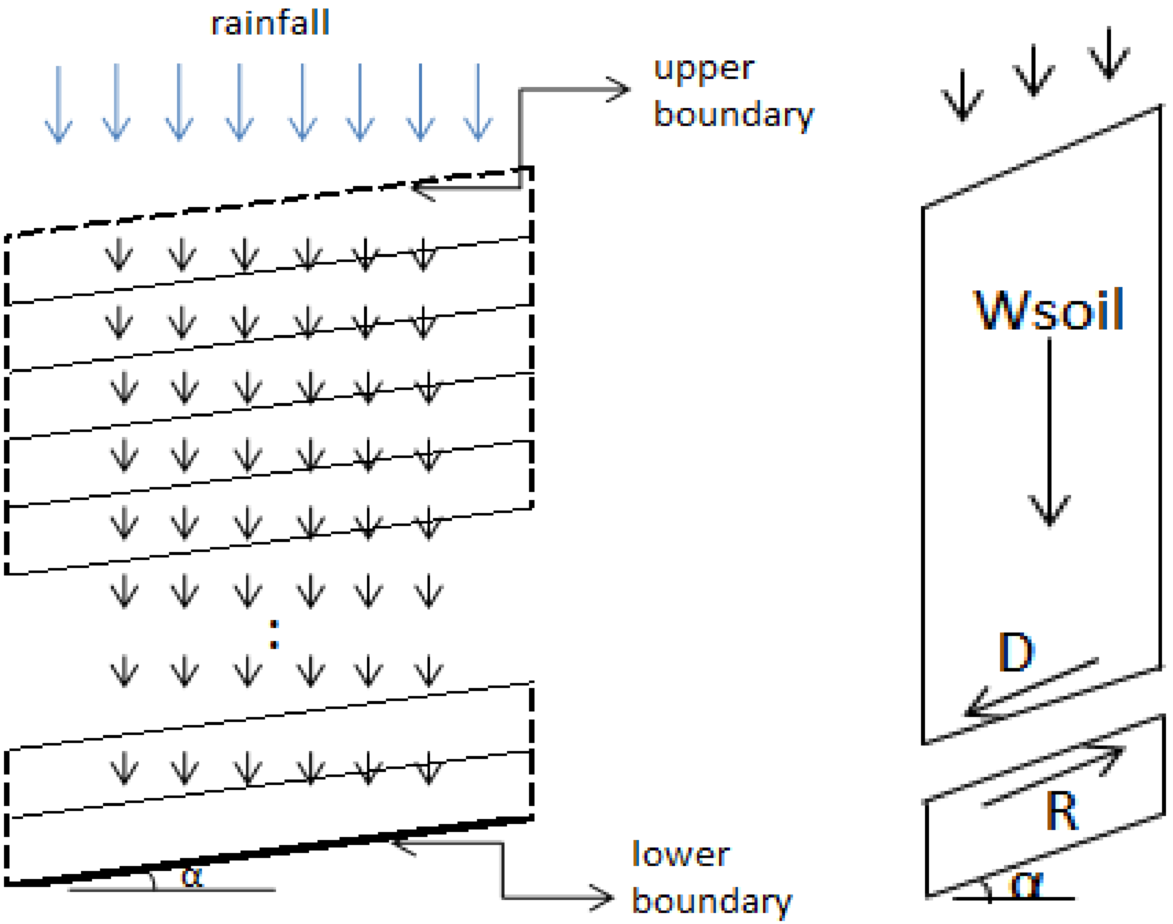
Numerical simulations → finite slopes (flume experiments)

- Geometry & Boundary Conditions





Numerical simulations → infinite slopes (MATLAB code)



at a given time

- Pore pressures
- Suction
- Unsat. Shear strength
- Factor of safety

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Currently, we are working on Landslide hazard assessment using:

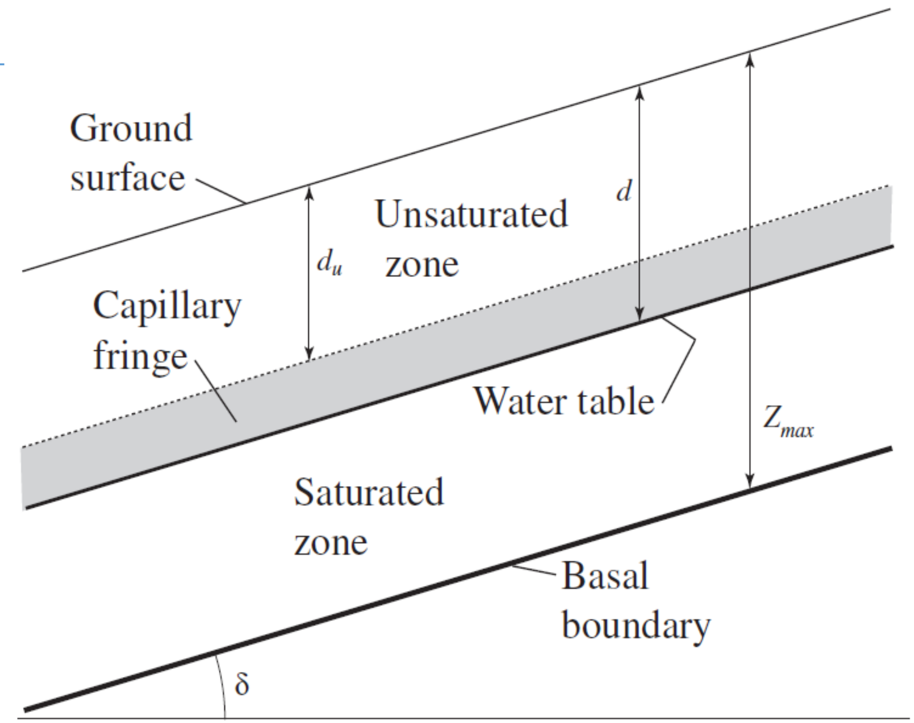
- **TRGRS** by USGS
- **SLIDE** model by Japanese researchers
- Our model

Ahmadiadli, TUBITAK post-doc funding

science for a changing world

TRIGRS—A Fortran Program for Transient Rainfall Infiltration and Grid-Based Regional Slope-Stability Analysis, Version 2.0

By Rex L. Baum, William Z. Savage, and Jonathan W. Godt



Engineering Geology 102 (2008) 85–98

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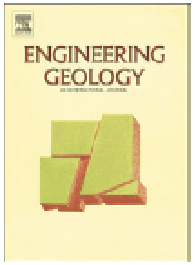

Guidelines for landslide susceptibility, hazard and risk zoning for land use planning

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on behalf of the JTC-1 Joint Technical Committee on Landslides and Engineered Slopes

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Harmonised approaches for landslide susceptibility mapping in Europe

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J.-P. Malet
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M. Van Den Eeckhaut
Institute for Environment and Sustainability, Joint Research Centre (JRC), European Commission, Ispra, Italy

- Among countries and even within any one country there is seldom uniformity in terminology and the results of the landslide zoning are often not precisely defined these maps have different accuracy and reliability.

- Maps are currently prepared using a variety of input data that can be either qualitative or quantitative.

- In some countries, the data required for an appropriate quantitative landslide hazard zoning are unavailable.

Landslide susceptibility zoning usually involves developing an **inventory of landslides** which have occurred in the past together with an assessment of the areas with a potential to experience landsliding in the future

There is no unique procedure capable of estimating the potential of failure of each type of landslide and its expected travel distance. In fact, the conditioning factors (i.e. slope angle, lithology, groundwater conditions,...) are specific for each landslide mechanism.

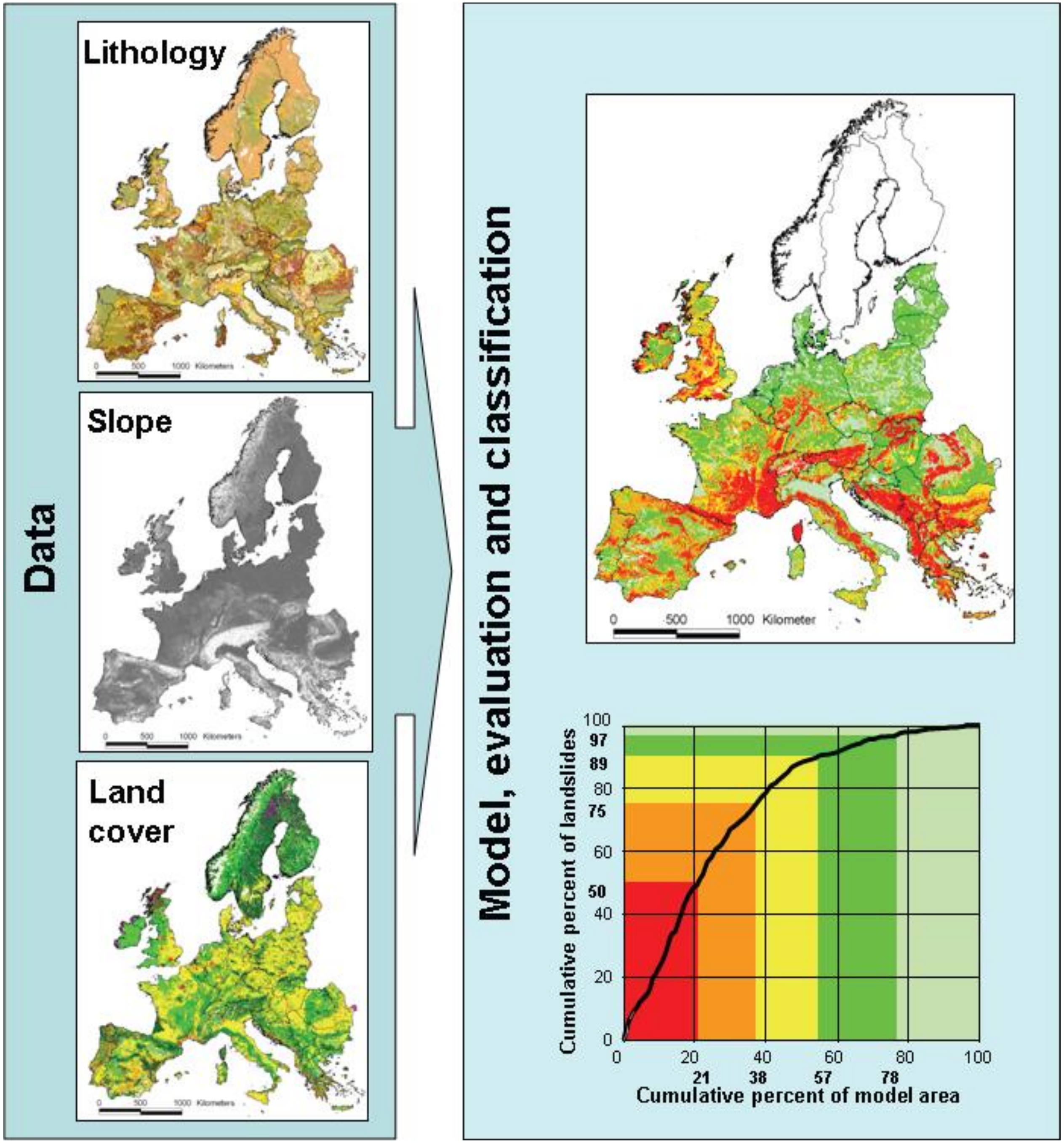
Because of this, it will often be necessary to assess separately susceptibility, hazard and risk, for the different types of landslides affecting the area (i.e. for rock falls, small shallow landslides and deep-seated large landslides) and to present the results in specific zoning maps as the recommendations or the statutory obligations to mitigate the risk might differ for the different landslide types. These maps may be combined onto one map.

Landslide zoning mapping scales and their application

Scale description	Indicative range of scales	Examples of zoning application	Typical area of zoning
Small	<1:100,000	Landslide inventory and susceptibility to inform policy makers and the general public	>10,000 km^2 square kilometres
Medium	1:100,000 to 1:25,000	Landslide inventory and susceptibility zoning for regional development; or very large scale engineering projects. Preliminary level hazard mapping for local areas Preliminary level hazard mapping for local areas	1000–10,000 km^2 square kilometres
Large	1:25,000 to 1:5000	Landslide inventory, susceptibility and hazard zoning for local areas Intermediate to advanced level hazard zoning for regional development. Preliminary to intermediate level risk zoning for local areas and the advanced stages of planning for large engineering structures, roads and railways Preliminary to intermediate level risk zoning for local areas and the advanced stages of planning for large engineering structures, roads and railways	10–1000 km^2 square kilometres
Detailed	>5000	Intermediate and advanced level hazard and risk zoning for local and site-specific areas and for the design phase of large engineering structures, roads and railways	Several hectares to tens of square kilometres

Recommended descriptors for hazard zoning

Hazard descriptor	Rock falls from natural cliffs or rock cut slope	Slides of cuts and fills on roads or railways	Small landslides on natural slopes	Individual landslides on natural slopes
	Number/annum/km of cliff or rock cut slope	Number/annum/km of cut or fill	Number/km^2/annum	Annual probability of active sliding
Very high	>10	>10	>10	10^{-1}
High	1 to 10	1 to 10	1 to 10	10^{-2}
Moderate	0.1 to 1	0.1 to 1	0.1 to 1	10^{-3} to 10^{-4}
Low	0.01 to 0.1	0.01 to 0.1	0.01 to 0.1	10^{-5}
Very low	<0.01	<0.01	<0.01	$<10^{-6}$


Data
Lithology
0 500 1000 Kilometers
Slope
0 500 1000 Kilometers
Land cover
0 500 1000 Kilometers
Model, evaluation and classification
0 500 1000 Kilometer
Cumulative percent of landslides
100
97
89
80
75
60
50
40
20
0
0 20 40 60 80 100
21 38 57 78
Cumulative percent of model area

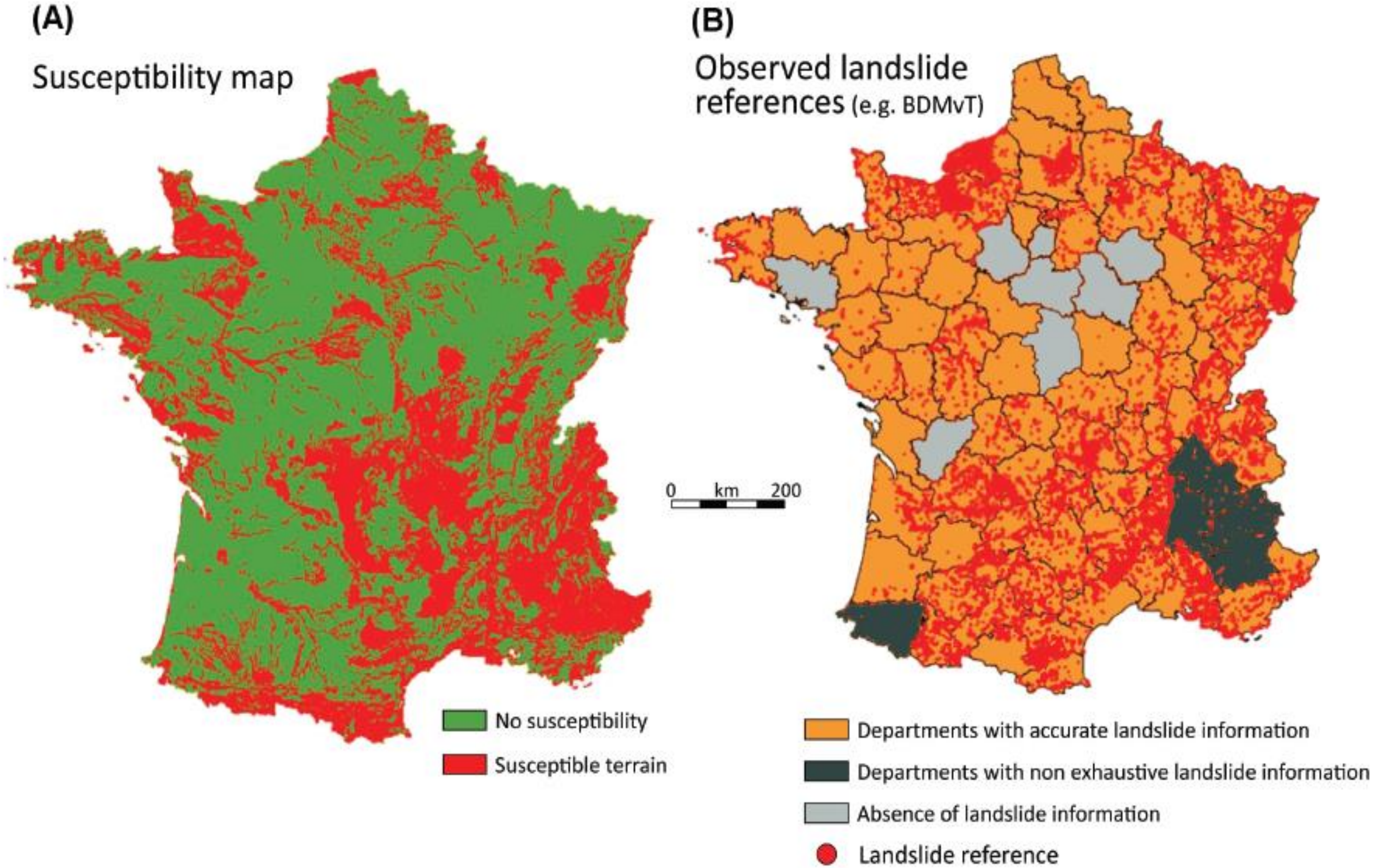


Figure 2. (A) Example of landslide susceptibility map for France according to the Tier 1 approach, showing two susceptibility classes; (B) Simplified landslide inventory map of France based on the BDMvT database, indicating the completeness of the database information for each department.

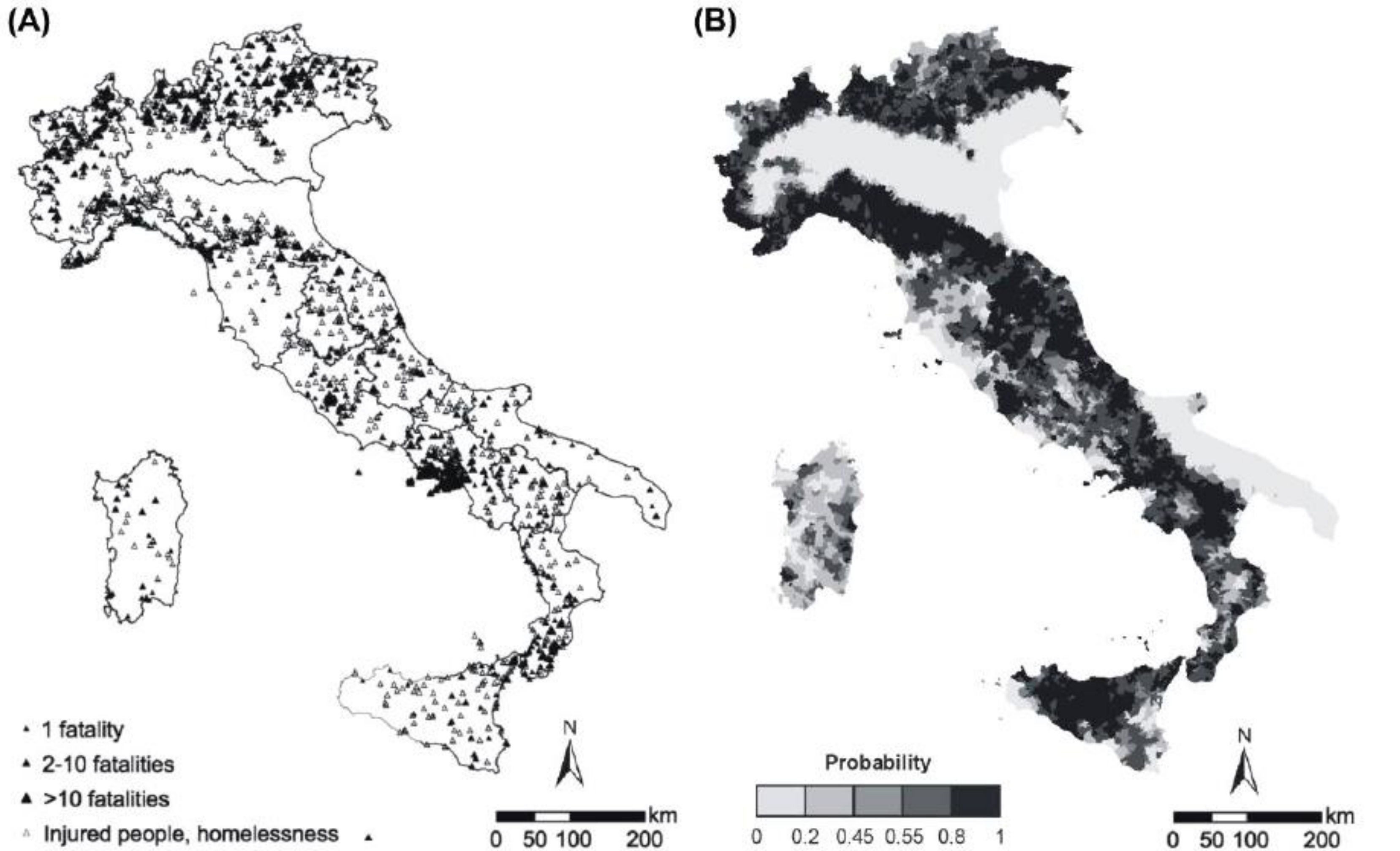


Figure 3. (A) Distribution of landslides with human consequences in Italy from AD 1279 to 2002. The size of the symbol indicates the intensity of the event: Small symbol: 1 dead or missing person; medium symbol, 2–10 deaths or missing persons; large symbol, more than 10 deaths or missing persons. Open symbols indicate sites where injured people, homeless people, or evacuated people were reported (Guzzetti et al. 2005a); (B) Landslide susceptibility map of Italy (Günther et al. 2008).