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Across-Scale Geomechanical Evaluation of Rain Intensity, Slope and Sand Type on Post-Wildfire Mudflow Composition and Onset Mechanisms

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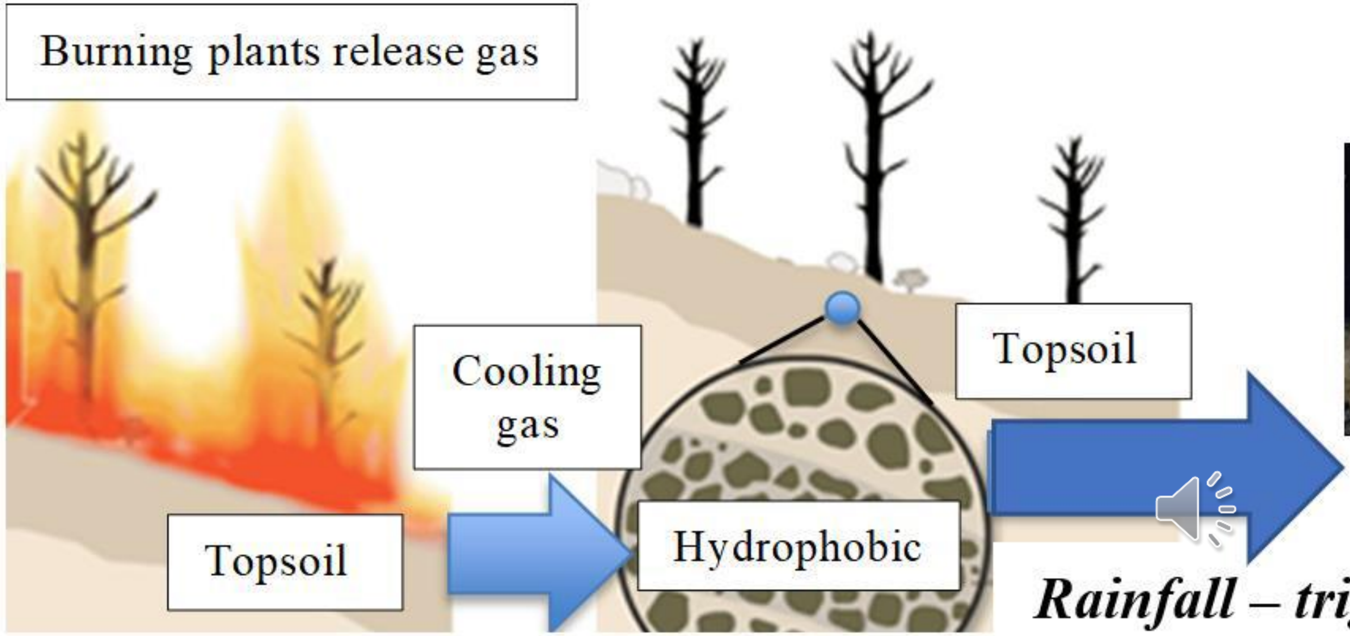
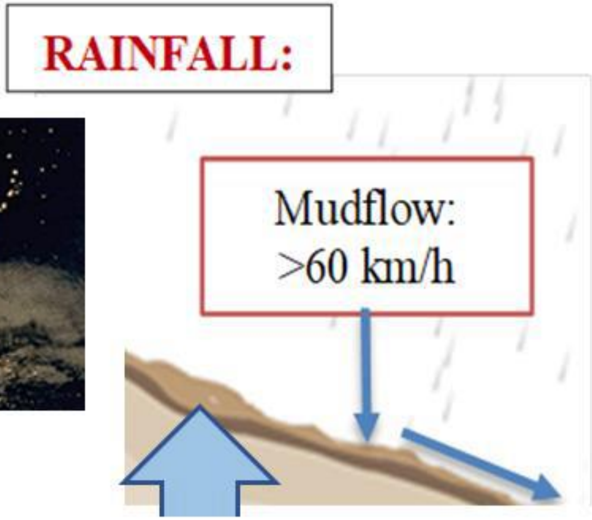
Presentation Outline

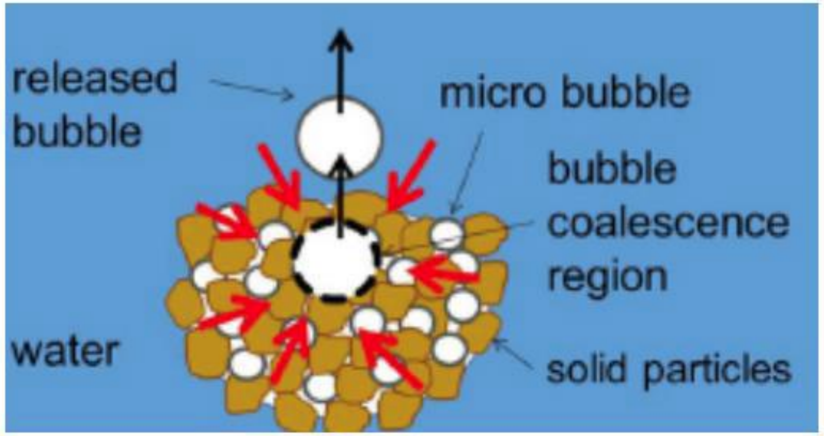
1. Background and motivation
2. Materials and Methods
3. Single raindrop experiments on different sands
4. Flume raining experiments
5. Mudflow composition
6. Air capturing inside of the mudflow
7. Conclusions

Background and Motivation





Rainfall – triggers mudflows, but are soil particles and water the only components?



Gravity affects attachment of hydrophobic particles to ***air bubbles***

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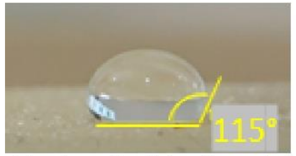
Materials and Methods

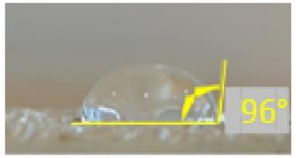
Materials:

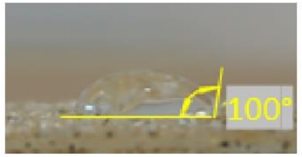
Fine Otawa Sand

Medium Sand

Coarse Sand





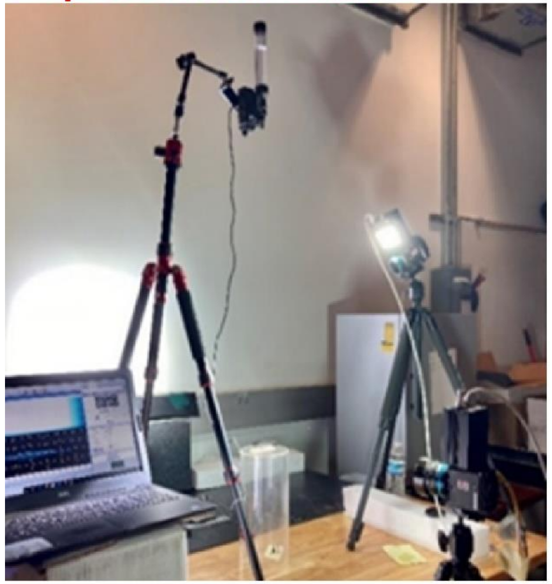


Hydrophobic Sand Contact Angles

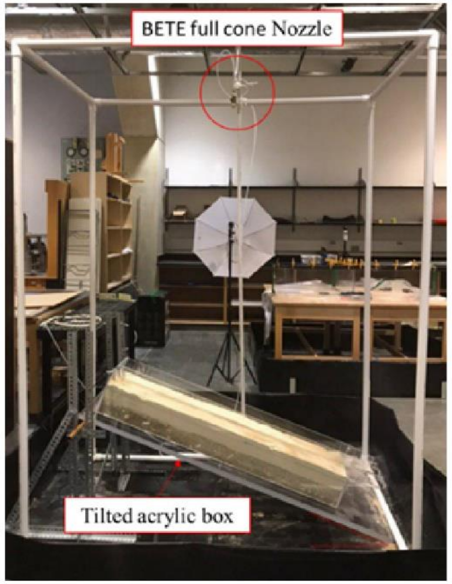
- Single drop experiments on flat and sloped surfaces
- Fine, medium and coarse sand: regular and hydrophobic
- Silane treated sand in laboratory to make surface hydrophobic

Soil	Contact angle (°)		Cu	Cc	D10 (mm)	D30 (mm)	D60 (mm)
	Regular	Hydrophobic					
Fine	60	115	1.50	0.90	0.15	0.18	0.23
Medium	38	100	1.67	1.01	0.28	0.37	0.47
Coarse	27	96	1.53	1.03	0.46	0.57	0.70

Experimental Scales:



Single Drop Experiments



Laboratory Raining Experiments

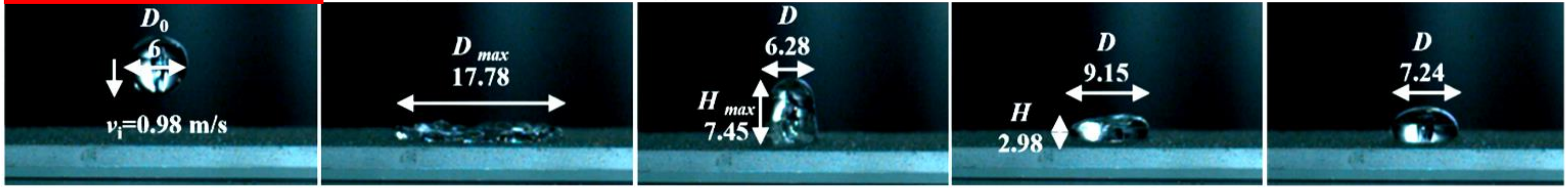
Large Environmental Outside Flumes

Upscaling:

1. Laboratory flume experiments with controlled raining intensity
2. Large outside flumes exposed to environmental conditions for 6 months

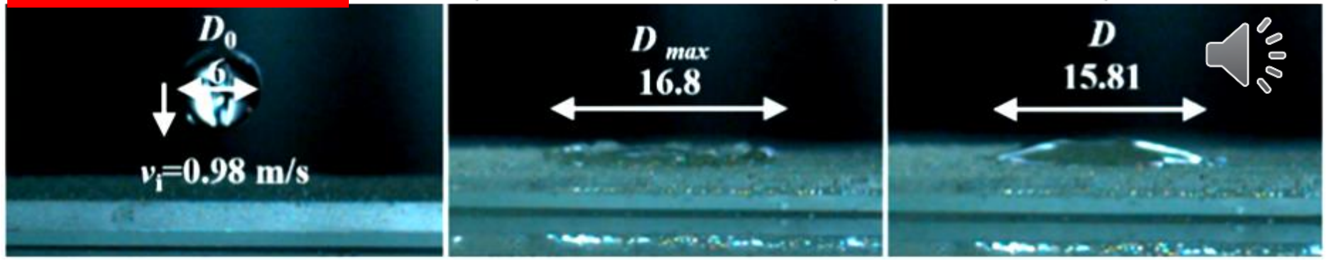
Single Raindrop Spread

Hydrophobic fine sand: Low impact 0.98 m/s velocity of a 6-mm drop



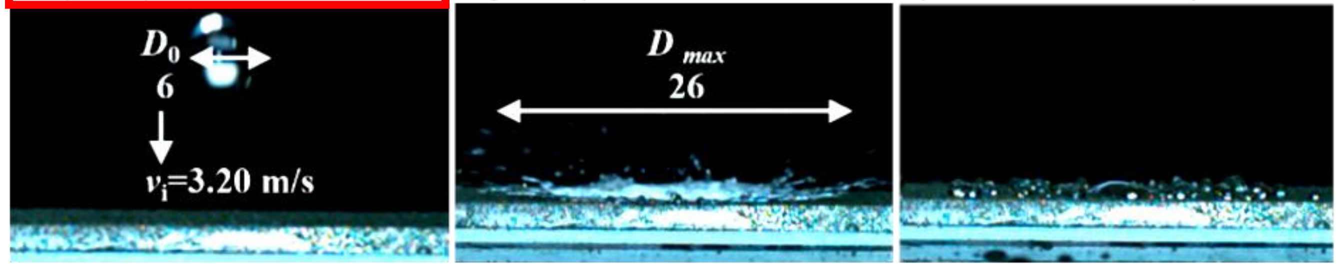
Impact | Max Spread | Rebound | Stabilization | Deposition

Regular fine sand: Low impact 0.98 m/s velocity of a 6-mm drop



Impact | Max Spread | Deposition

Hydrophobic fine sand: High impact 3.2 m/s velocity of a 6-mm drop

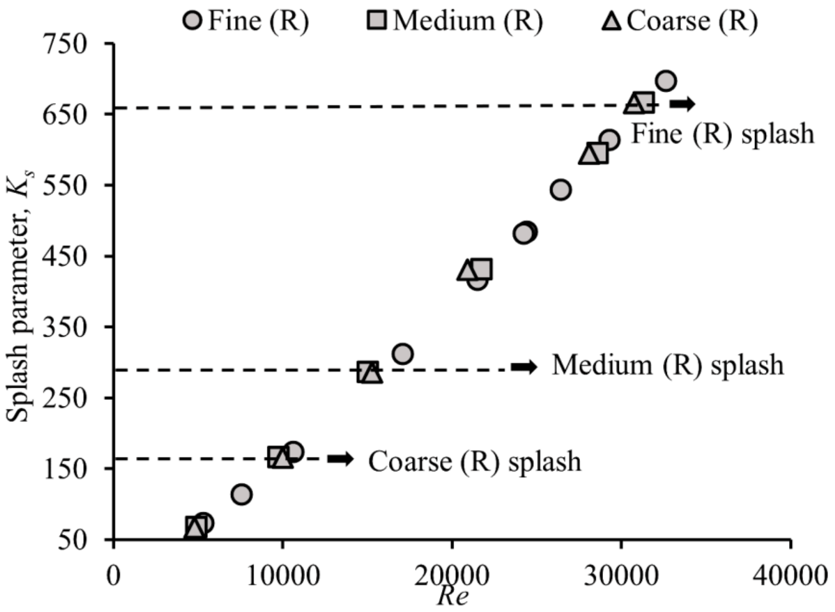


Impact | Max Spread | Detachment

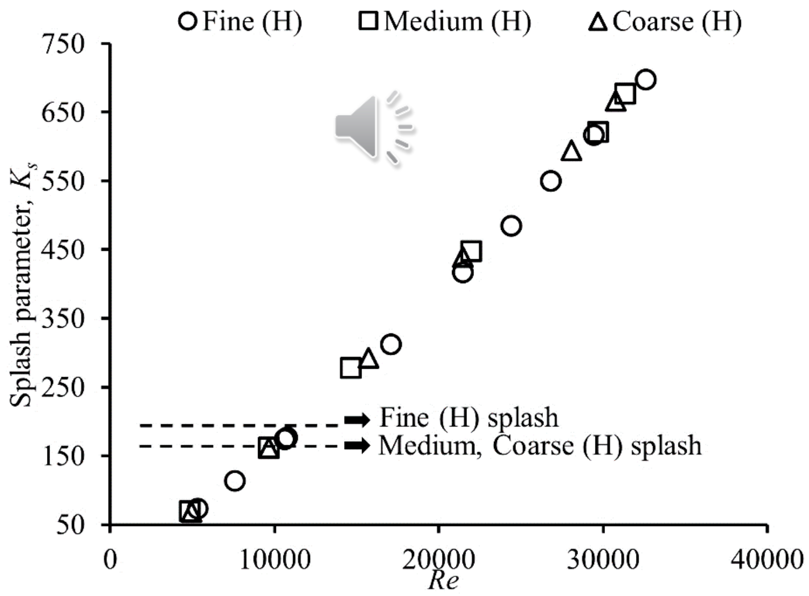
- Sand type and hydrophobicity change drop post-impact behavior
- Drop remains static and spread on regular sands
- Drop spread increases on hydrophobic surfaces and is not sensitive to grain size
- Drop retracts and bounces of hydrophobic sand surfaces at higher impact velocities

Single Raindrop Splash

- Splash threshold is lower for hydrophobic than regular sand
- Regular sand: splash threshold depends on the grain size
- Hydrophobic sand: the splash threshold is insensitive to the sand surface roughness



Regular sand



Hydrophobic sand

$$Re = \frac{\rho v D}{\eta} \quad \text{(Eq.1)}$$

$$We = \frac{\rho v D^2}{\sigma} \quad \text{(Eq.2)}$$

$$K_s = We^{1/2} Re^{1/4} \quad \text{(Eq.3)}$$

Re=Reynolds number
We =Weber number
ρ=liquid density
D=drop diameter
η=liquid dynamic viscosity
σ=liquid surface tension
v=velocity
K_s=splash parameter

Single Raindrop on Slope

Regular Fine Sand


Impact


Spreading


Rebound, Sliding


Arrest

Hydrophobic Fine Sand


Impact

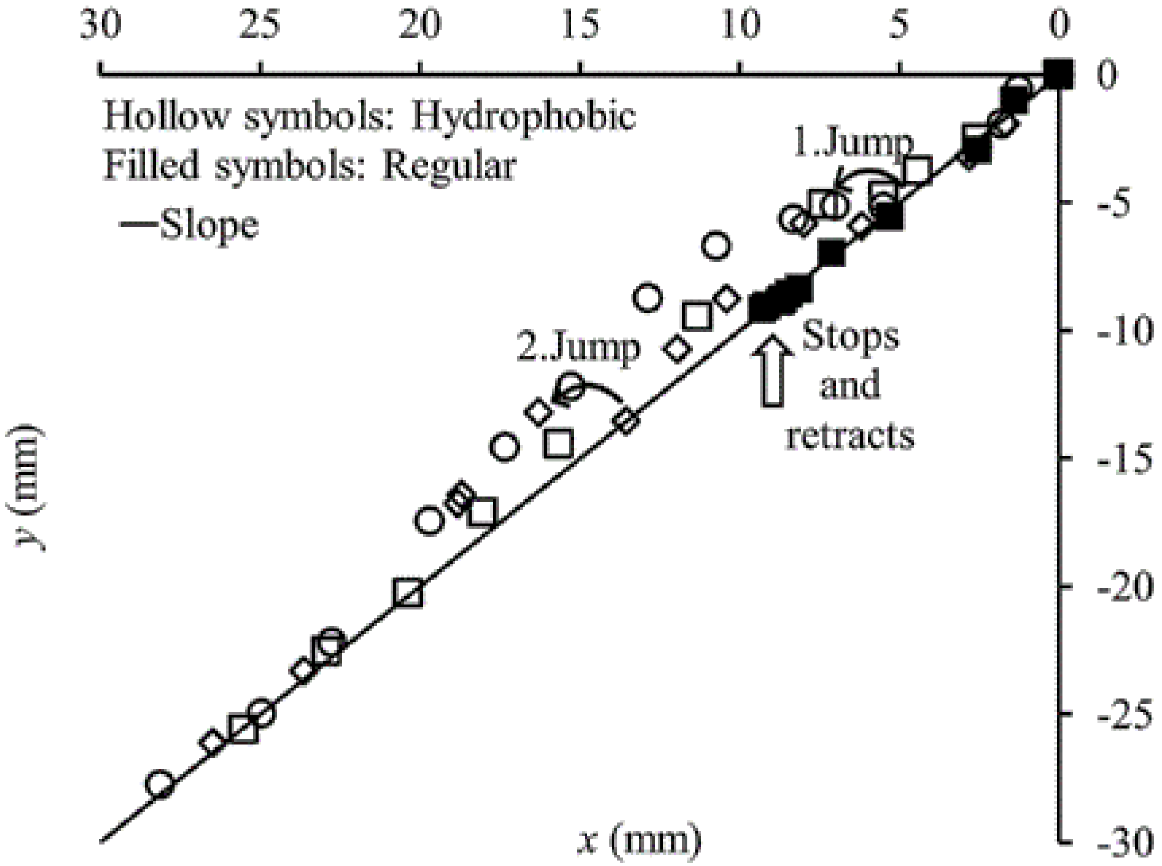

Spreading


Rebound, Sliding


Tail Formation


Jump


Rolling and Sliding



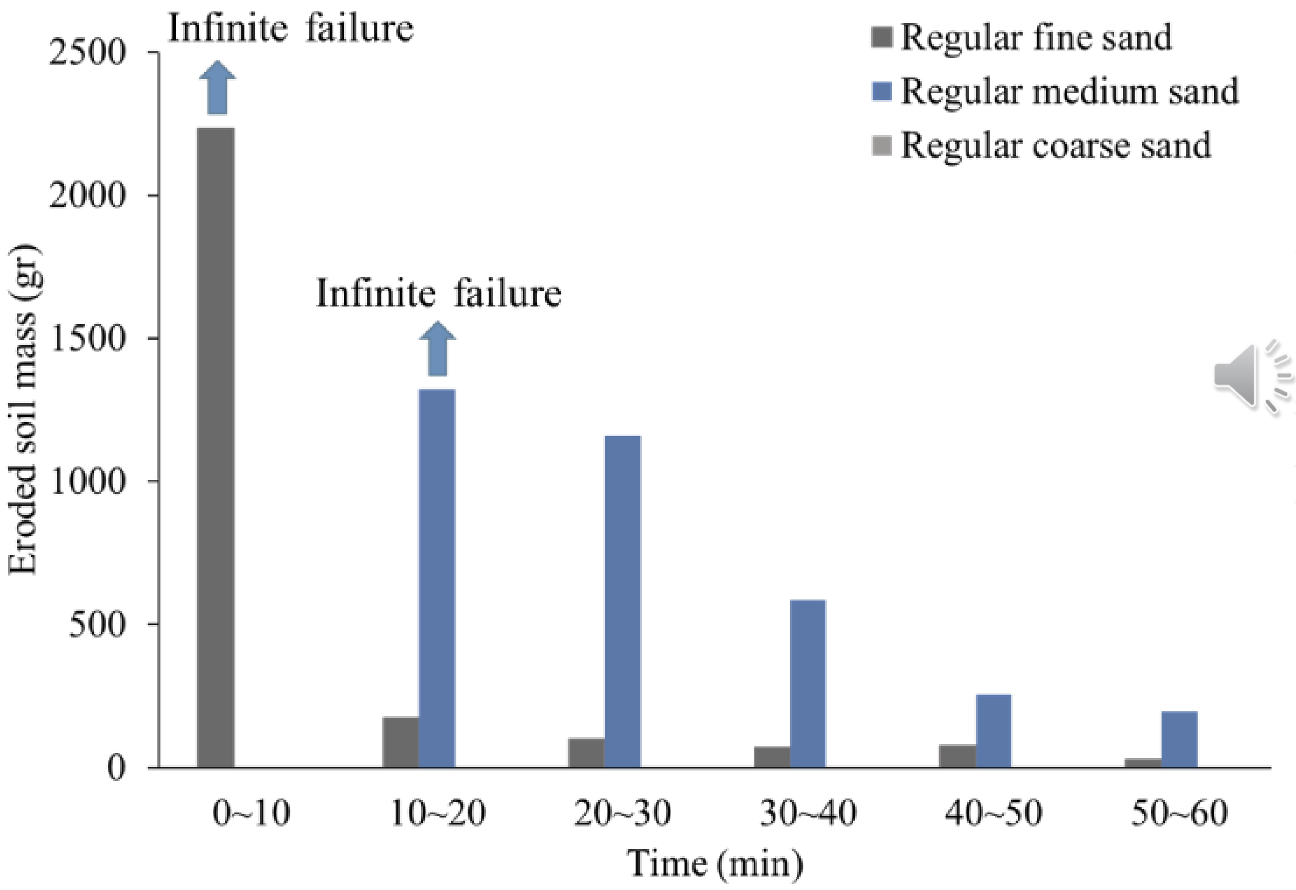
Drop falling on 45° slope with impact velocity of 0.98 m/s

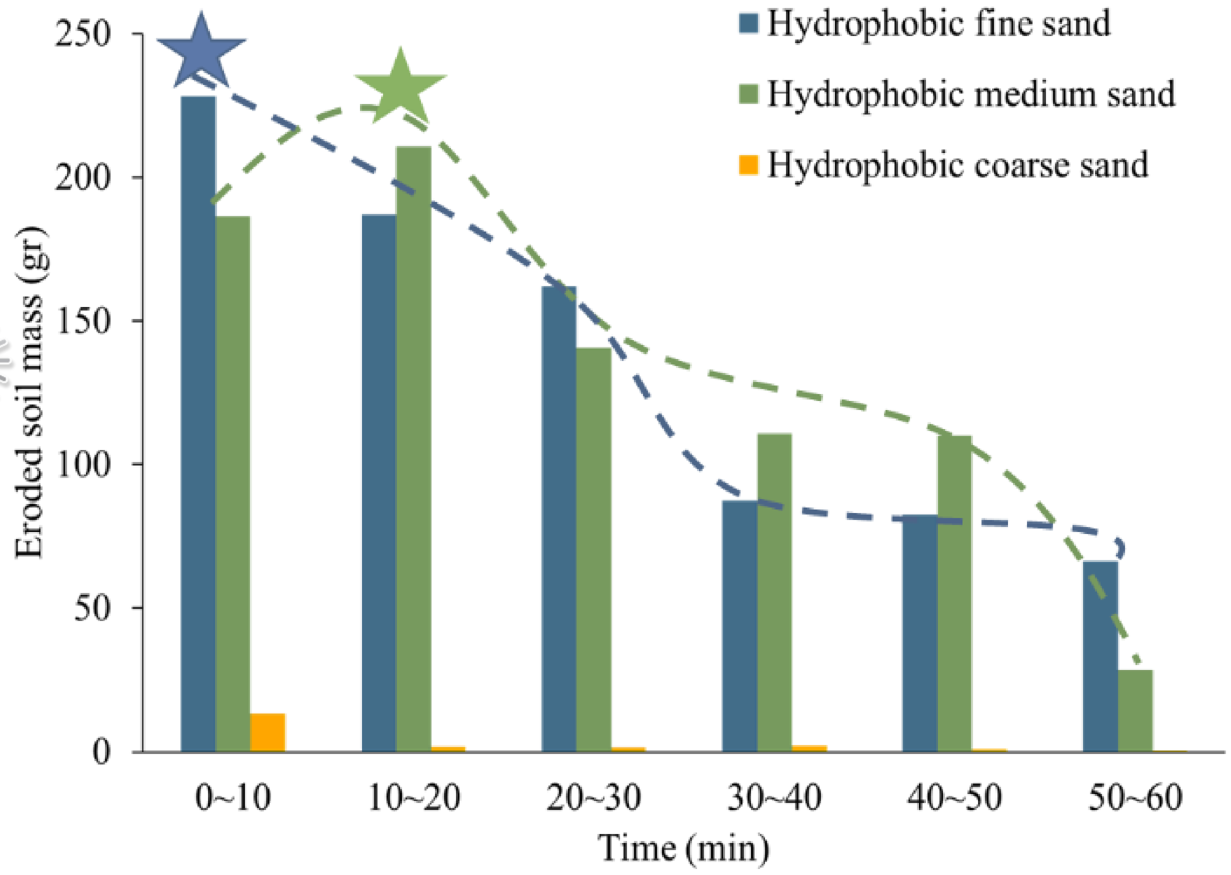
Erosion Under Rain Experiments

60 mm/h rain intensity, 30° slope

Erosion patterns on fine, medium, and coarse hydrophobic sand from left to right in the configuration

Sand Type Effect on Erosion Rates





60 mm/h rain intensity, 30° slope

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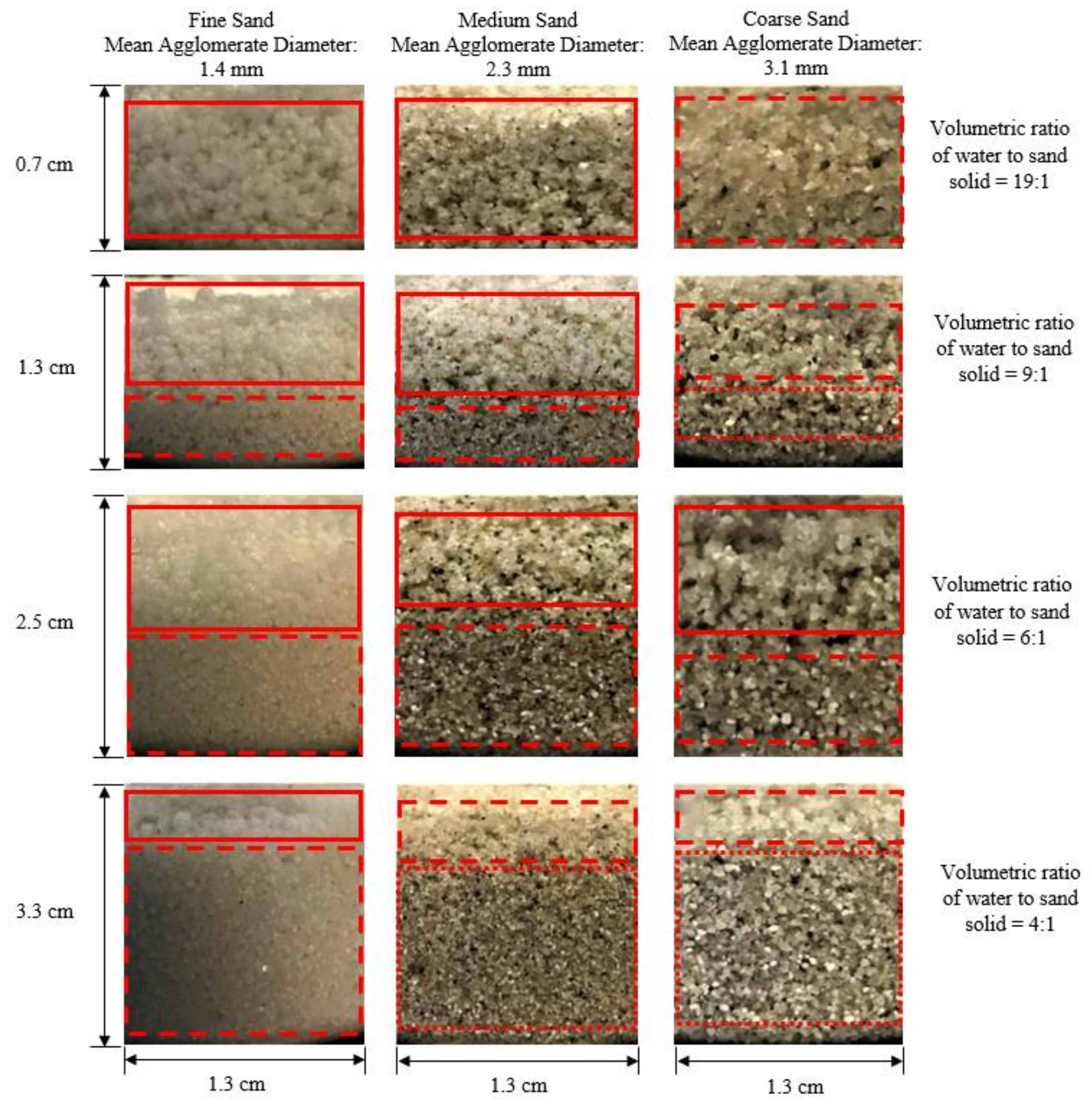
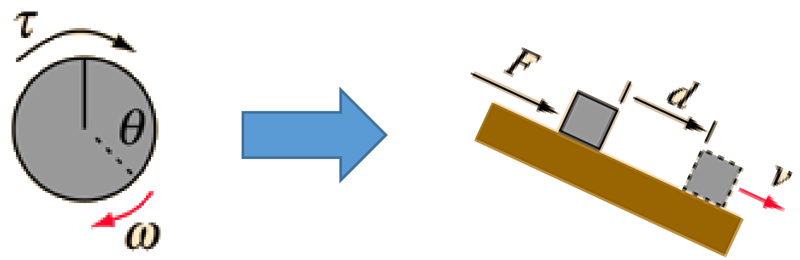
Mudflow Composition Experiments



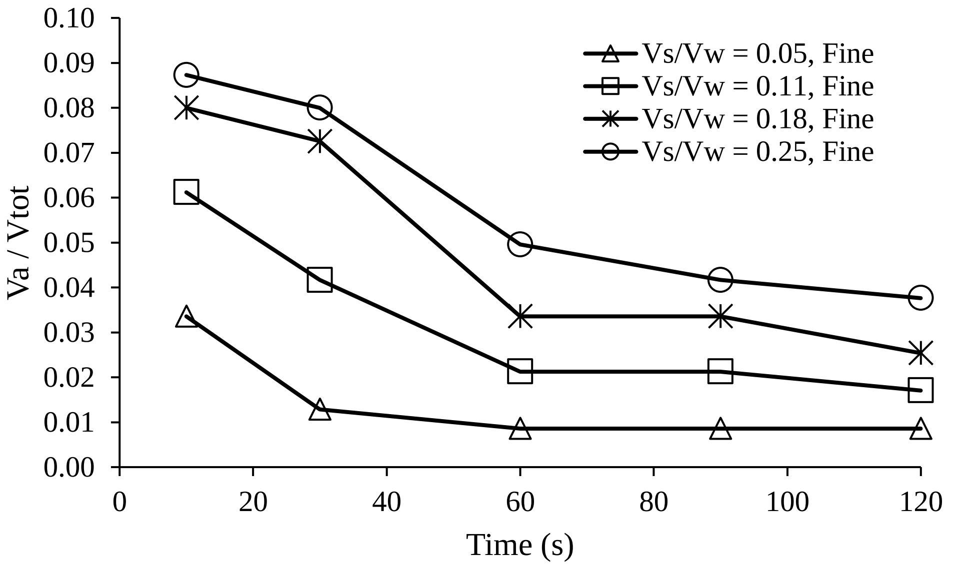
Mixing experiments with different blade rotation speeds to mimic downhill flow

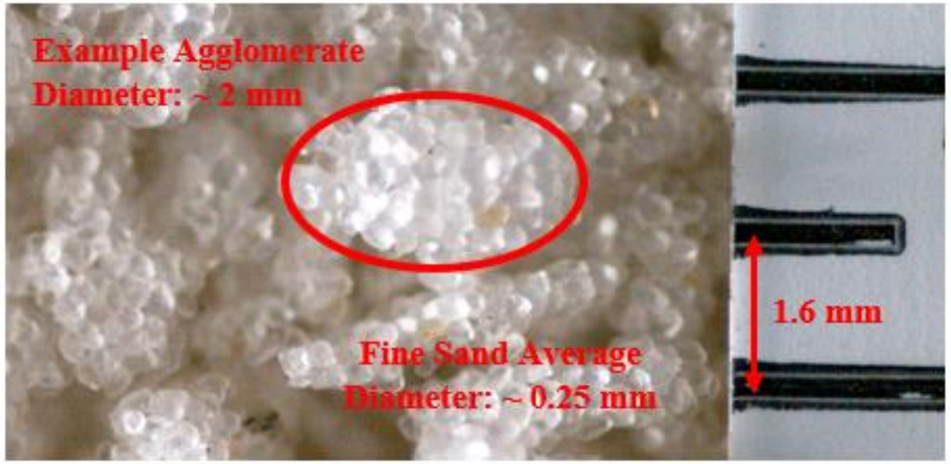


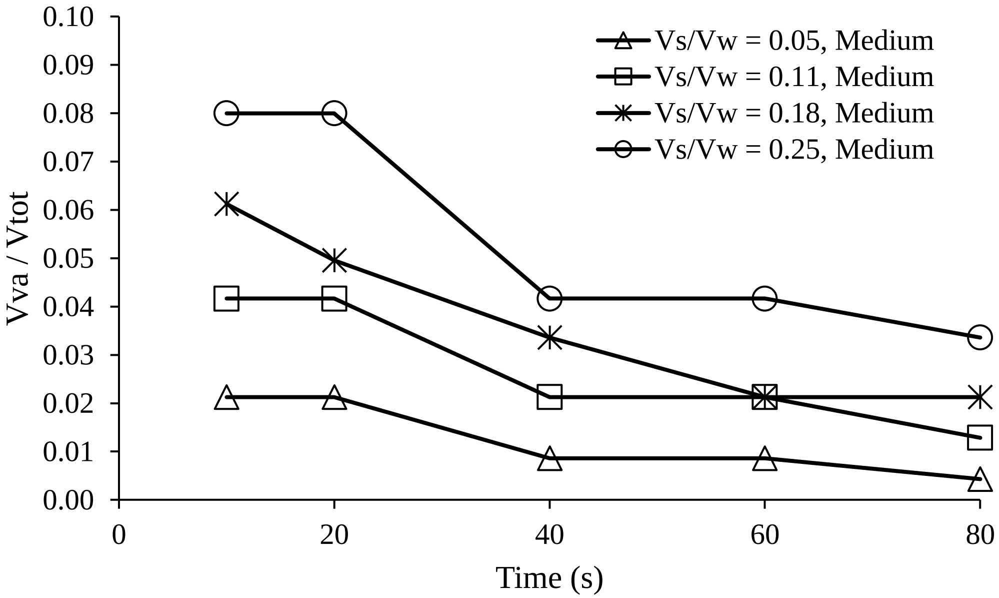
Mudflow mixture composition depends on sand type, air trapping, mixing speed and gravity

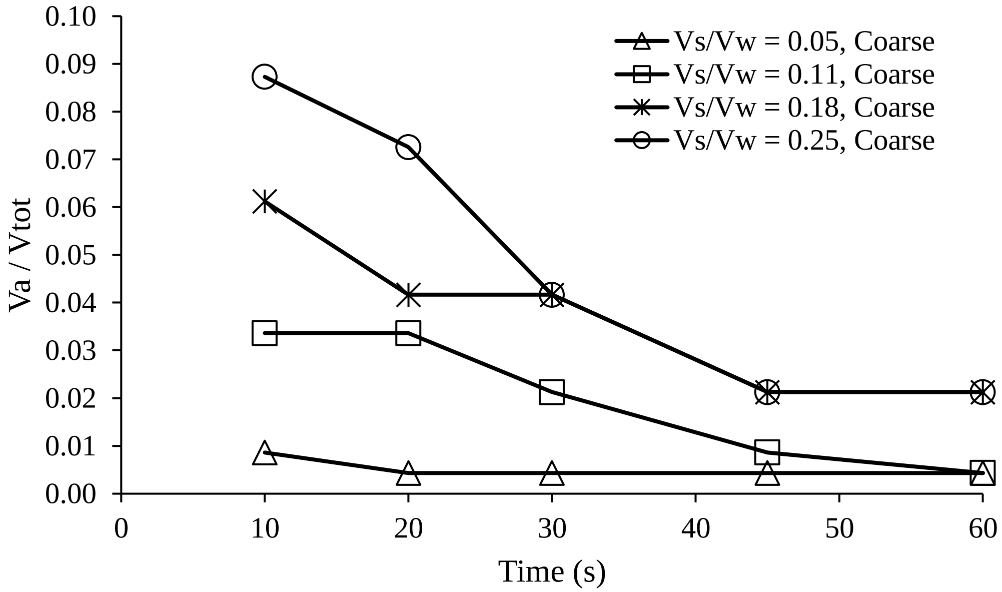
We assessed the conditions that affect amount of trapped air and agglomerate shapes and sizes

Assessment of Trapped Air

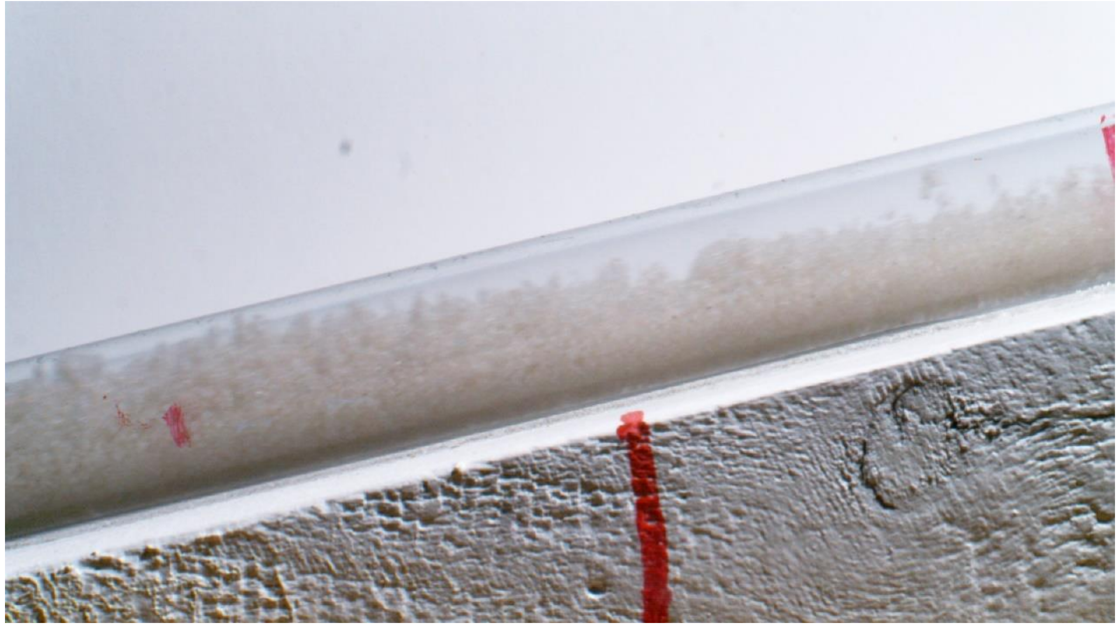




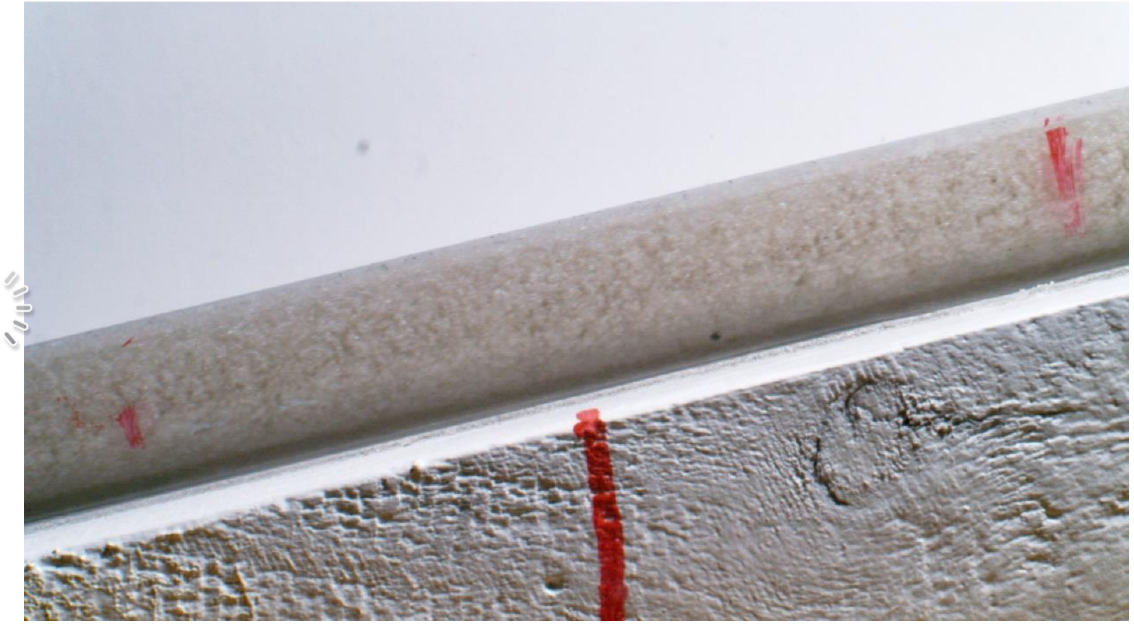




Mudflow Mixture Flow and Transport



Layered mixture flow and transport



Plug mixture flow and transport

Conclusions

- Wildfires induce hydrophobicity on soil grain surface, predominately on granular soils such as sands
- Across-scale experiments from a single drop impact towards raining experiments help better understand roles of different parameters on mudflow onset, flow and transport
- Soil surface dramatically affects a single drop post-impact behavior
- Drop rebounds, splashes and speeds down the hill more on finer sand compared to coarser sand, and hydrophobicity enhances it
- Water overflow and sand erosion is boosted with hydrophobicity and smaller grain size
- Environmental experiments reveal cascading response of the burned surface, once an initial rain induced post-erosion channels on surface, less intensive rains yielded enhanced sand erosion and water overflow
- Surface morphology is constantly changing and affects erosion risk for the subsequent rain event

Thank you for your attention!

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