How soil roughness affects runoff and sediment production ?

Chi-Hua Huang, Frédéric Darboux

How Soil Roughness Affects Runoff and Sediment Production?

Chi-hua Huang
USDA-ARS
National Soil Erosion Research Lab
West Lafayette, Indiana, USA

Frederic Darboux
INRA Orleans - Science Du Sol
FRANCE

- **Soil erosion is a surface boundary process occurring in a multiple range of spatial and temporal scales.**
- **Spatial and temporal variability in erosion is caused by the combined effects of variable surface conditions, hillslope positions and rainfall pattern.**

"A proper quantification of soil erodibility should include the transient surface boundary effects"

Evolving Concepts in Soil Erodibility:

-- Soil erodibility = Fn (soil properties, surface condition, ….)

-- Change in surface condition causes spatial and temporal variations in soil erosion.

-- Soil erodibility controls the dominant erosion process.

Surface Conditions Affecting Erosion:

- Microtopography or surface roughness.
- Seepage and hillslope hydrology.
- Macroporosity and bulk density.
- Wet consolidation.
- Drying and cracking due to shrinkage.
- Prior rain history.
- Freeze and thaw cycle.
- Biological activities and plant materials.

Seepage/drainage effects on erosion

Topography (macro/micro) and Erosion

- Erosive forces on the surface are controlled by topography.
- Changes in surface topography reflect the dominant erosion processes on the surface.
- Dissipation of flow energy is caused by surface roughness and treated as a residual term in energy balance.
- Microtopography affects both soil erodibility and erosivity.
- Both surface and sub-surface hydrology are controlled by topography (at all scales).

Why interested in studying soil roughness?

- "Single-valued roughness index"
- "Roughness decay with rain"

Untangling the Myth of Soil Roughness

Quiz 1:

Will rainfall increase or decrease soil roughness?

Quiz 2:

Will an increased soil roughness increase or decrease soil erosion?

Current erosion models predict a reduced sediment production with an increased soil roughness

Assumptions: *Fully submerged flow*
Flow depth >> roughness height
Roughness elements dissipate flow energy

In partially inundated flow, soil microtopography can either converge or diverge the surface flow, hence cause both increased and decreased erosion at the same time but at different locations on the surface.

Hypothesis:

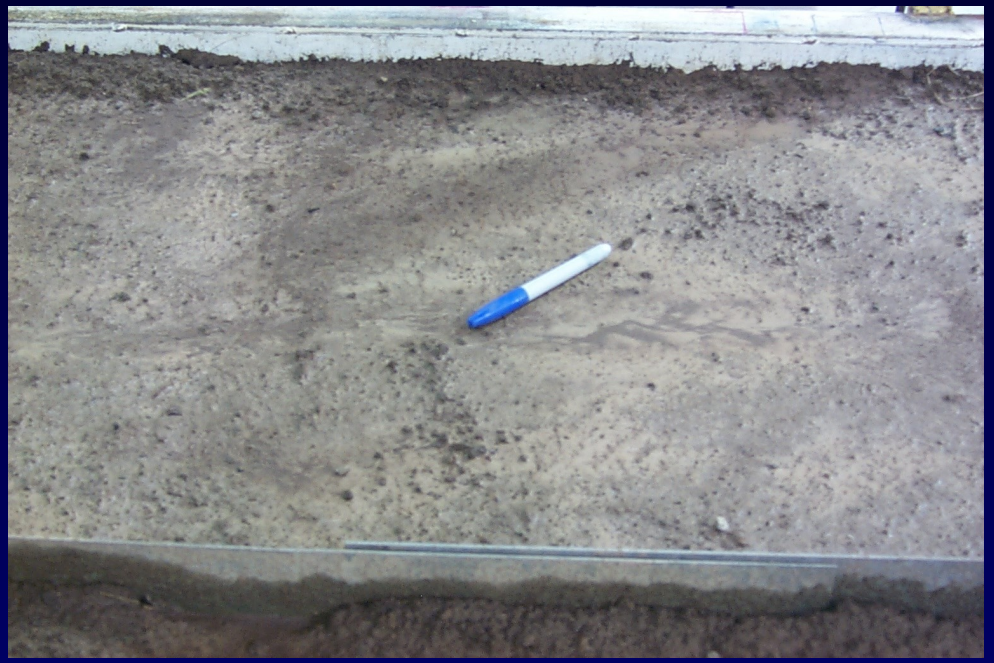
Surface depressions and mounds may affect runoff and sediment production differently

Research Methodology

Paired smooth vs rough surfaces (with depressions or mounds) compared

Soil erodibility adjusted by seepage and drainage control

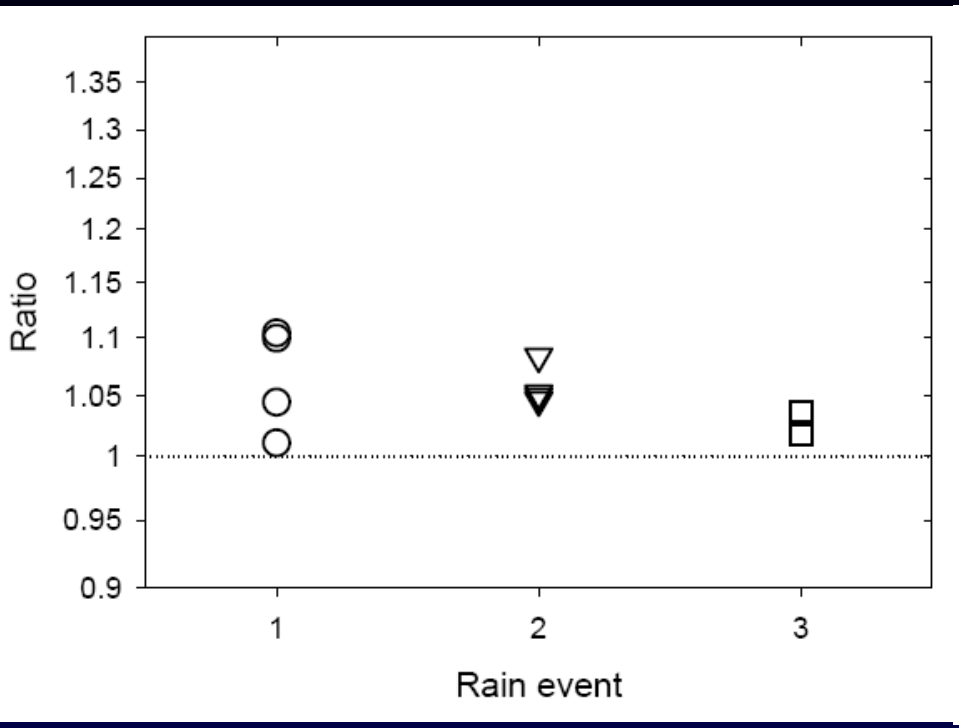
Erosivity changed by varying rainfall intensity and run-on (inflow from upslope feeder box)

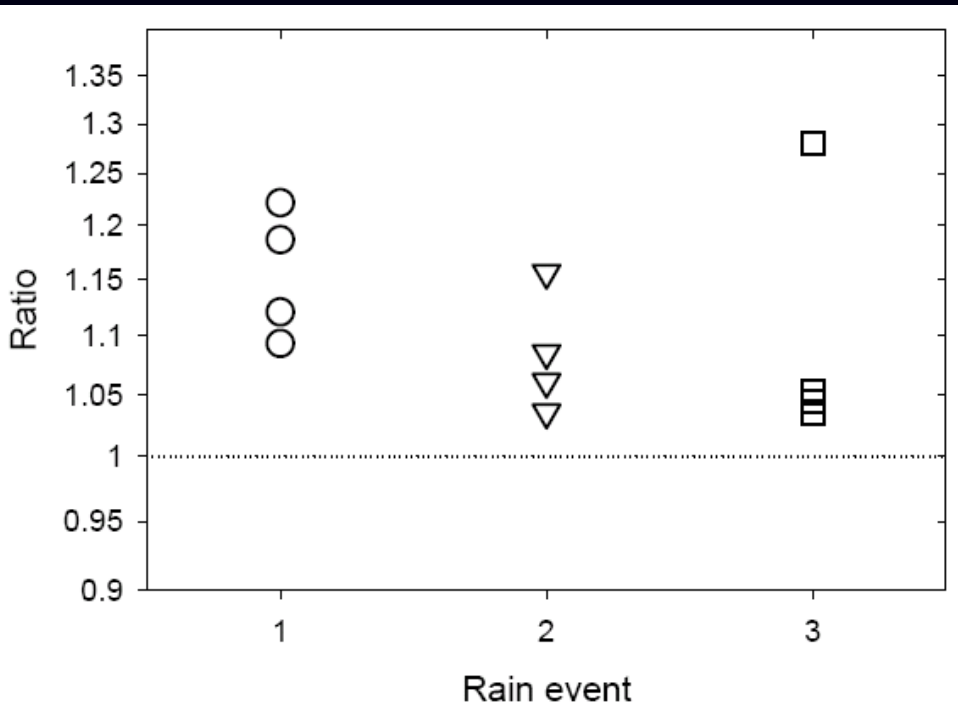


Time to Runoff Under Drainage Condition

Rain Event	Flat	With Depressions
Rain 1, Rep 1	6’ 05”	19’ 40”
Rep 2	5’ 15”	14’ 00”
Rep 3	2’ 40”	12’ 45”
Rep 4	3’ 30”	11’ 30”
Rain 2, Rep 1	2’ 00”	3’ 00”
Rep 2	1’ 40”	2’ 20”
Rep 3	1’ 10”	4’ 00”
Rep 4	1’ 30”	3’ 00”
Rain 3, Rep 1	1’ 45”	1’ 30”
Rep 2	--	--
Rep 3	1’ 00”	2’ 10”
Rep 4	--	--

Effect of Surface Depressions on Steady-state Runoff

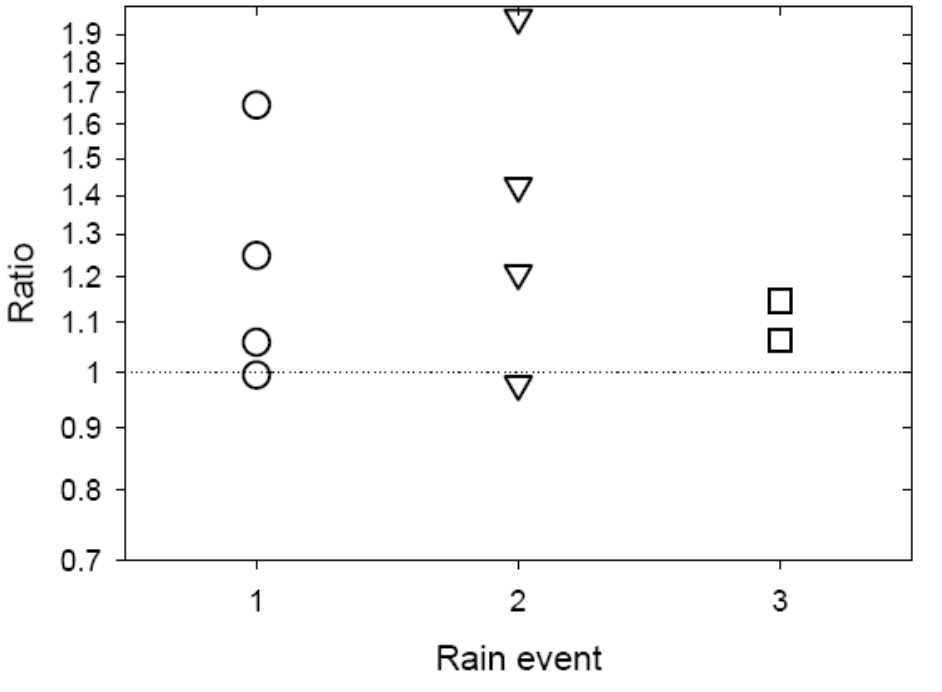


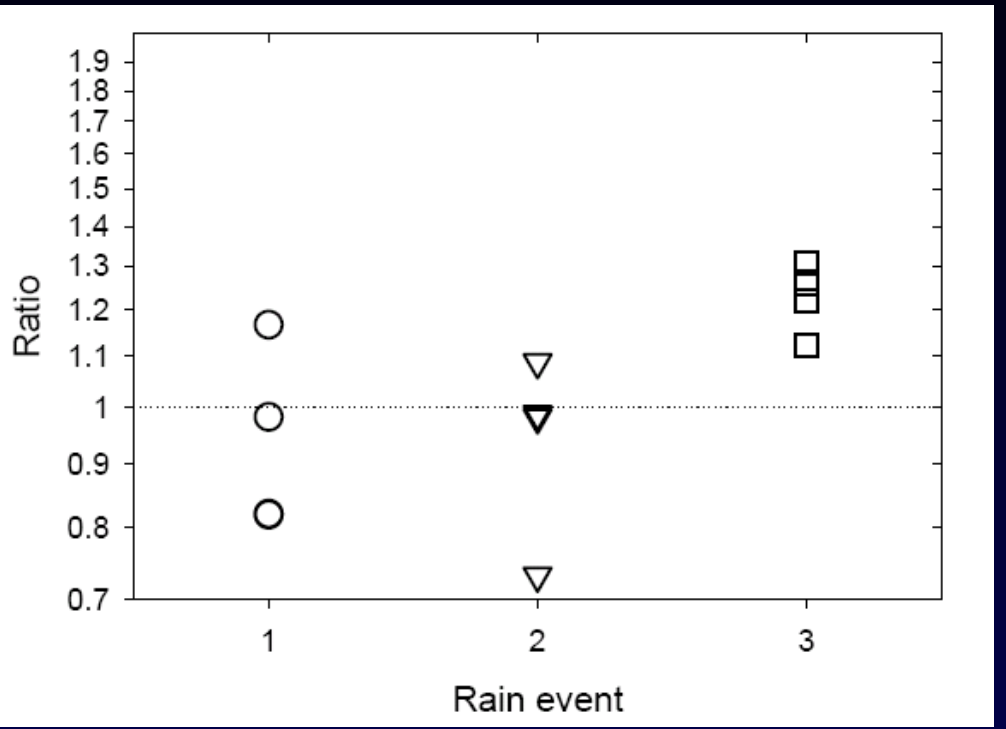


Drainage **Seepage**

Runoff Ratio = $\frac{\text{Runoff from surface with depressions}}{\text{Runoff from flat surface}}$

Effect of Surface Depressions on Sediment Discharge





Drainage **Seepage**

$$\text{Sediment Ratio} = \frac{\text{Sediment from surface with depressions}}{\text{Sediment from flat surface}}$$

Effect of Surface Mounds on Sediment Concentration

	Sediment Ratio	
Rain Intensity	Drainage	Seepage
48	1.12	0.82
72	1.18	0.91

$$\text{Sediment Ratio} = \frac{\text{Sediment flux from surface with mounds}}{\text{Sediment flux from flat surface}}$$

Soil Roughness Effects

Surface depressions delayed runoff initiation.

At steady state runoff, surface with depressions produced greater runoff.

There is a consistent trend for rough surfaces (both with depressions and mounds) to produce greater sediment under the drainage condition.

Under the seepage condition, the roughness effect in sediment yield is different for depressions and mounds when compared to flat surfaces:

Depressions:	Either increase or decrease
Mounds:	Mostly decrease

Soil Roughness Effects

Erosion reduction from soil roughness is only through delayed runoff from depressions.

Implications

If the surface is dry or rainfall is insufficient to produce a full runoff, the delayed runoff from surface depressions will cause reduced total runoff, hence, total sediment yield from rough surfaces.

Once the depressions are filled, or under moist conditions, the net roughness effect becomes uncertain due to complex interactions between mounds and depressions as well as other factors affecting soil erodibility (for example, seepage vs. drainage).

Untangling the Myth of Soil Roughness

Quiz 1: Will rainfall increase or decrease soil roughness?

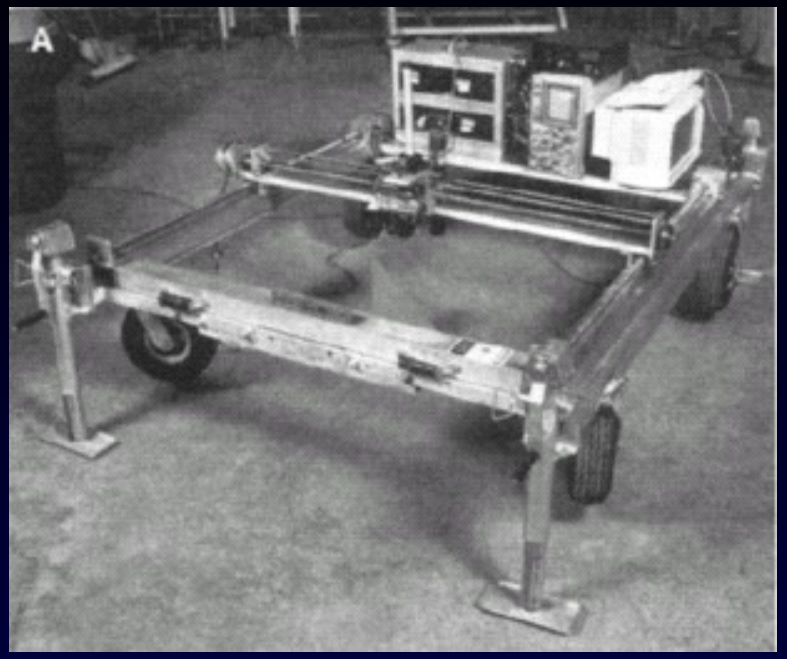
‘Eroded surfaces or landscape tend to be rough’

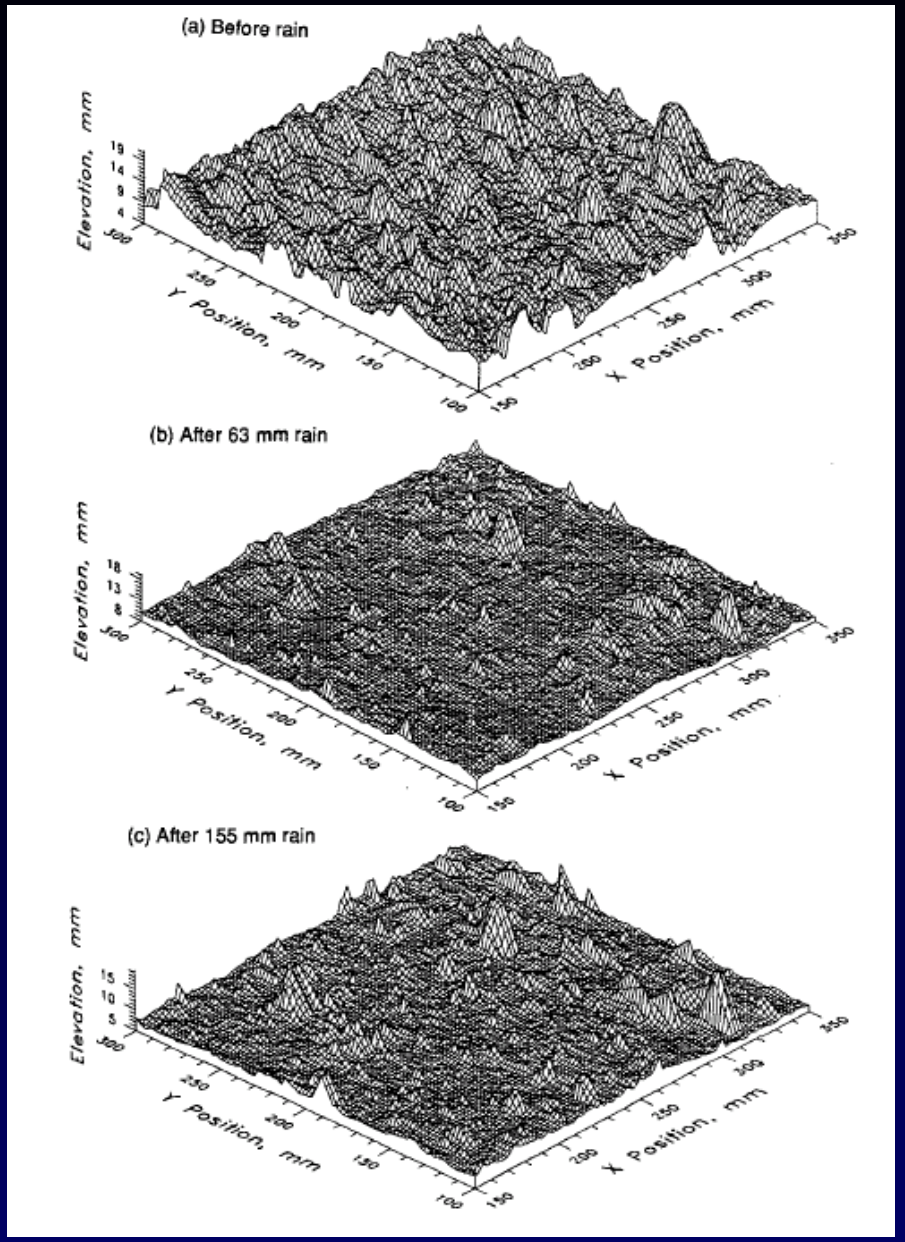
- high slopes with severe rill or gully erosion

‘Stable landscape tends to be smooth’

- low slopes or areas of deposition.

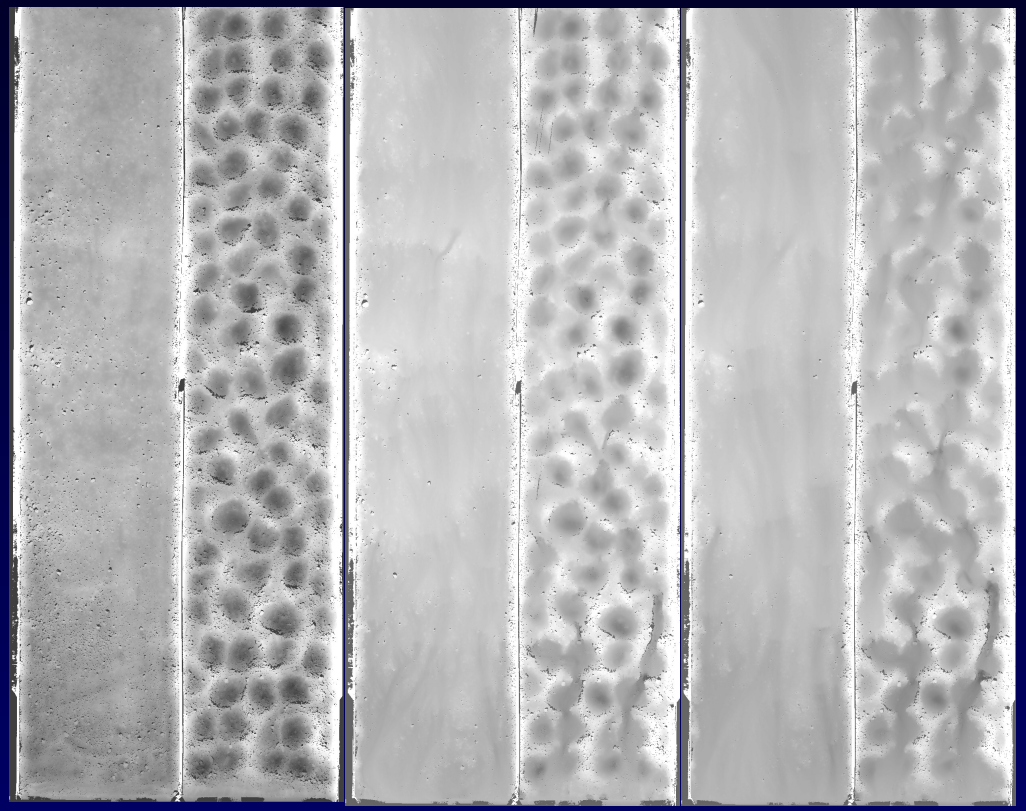
Measurement of surface roughness and its change



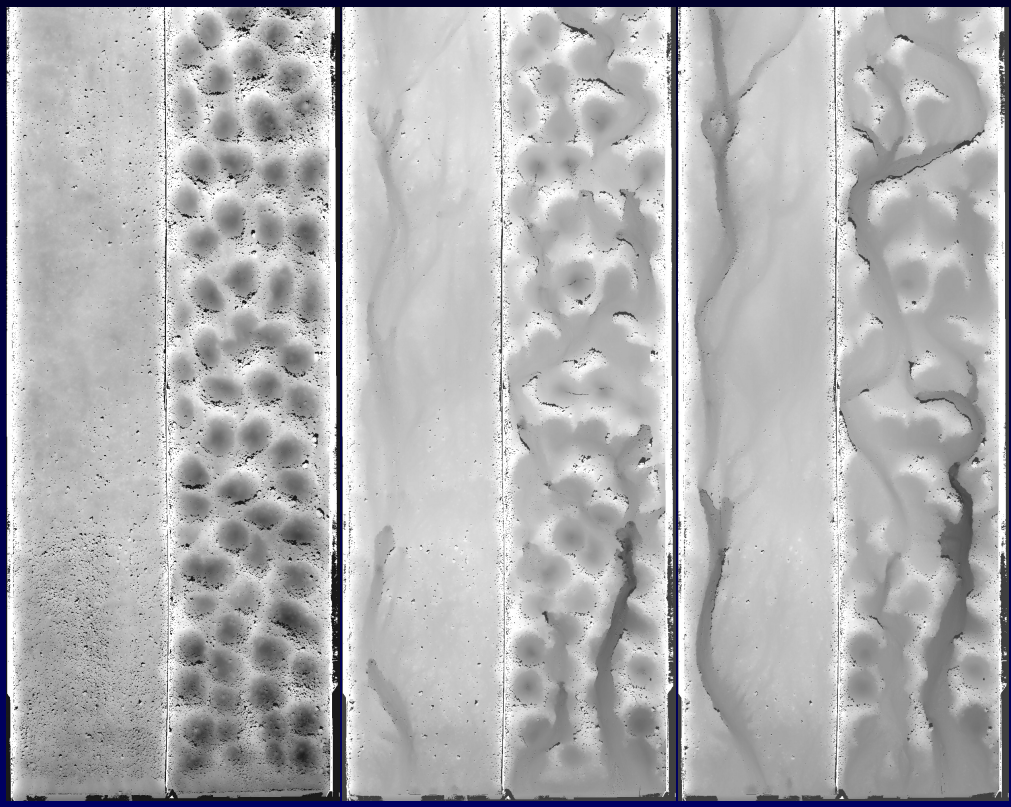


Will rainfall increase or decrease soil roughness?

Drainage Condition:_



Seepage Condition:_



Untangling the Myth of Soil Roughness

Quiz 2:

Will an increased soil roughness increase or decrease soil erosion?

I hope you know the answer by now. Otherwise, I will be happy to repeat this presentation!

Thank You