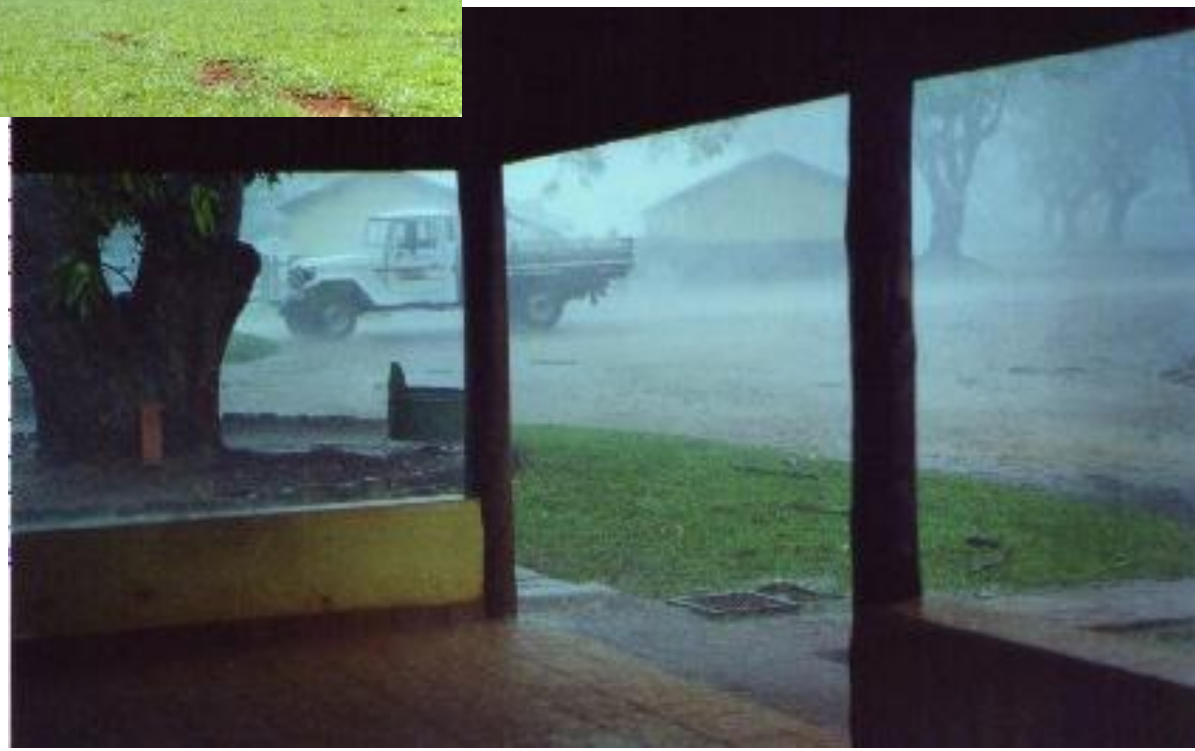
manejo e conservação do solo: módulo erosão

gerd sparovek (lso/esalq)

gerd@usp.br

segundo semestre de 2011



The theory: spherical drop on a rigid surface

Huang, C.; Bradford, J.M.; Cushman, J.H. (1982) A numerical study of raindrop impact phenomena: the rigid case. **Soil Science Society of America Journal** 46: 14-19.

- **Use techniques of material engineering that study high speed liquid-solid impact phenomena (turbine blades, airplane wings, and windows).**
- **Mechanistic approach rather than 'black box' as usual in agriculture.**
- **Calculated the compressive stress from the impact and the shearing stress from the lateral jetting.**

Basic fluid dynamic equations:

Momentum or Navier-Stokes equation:

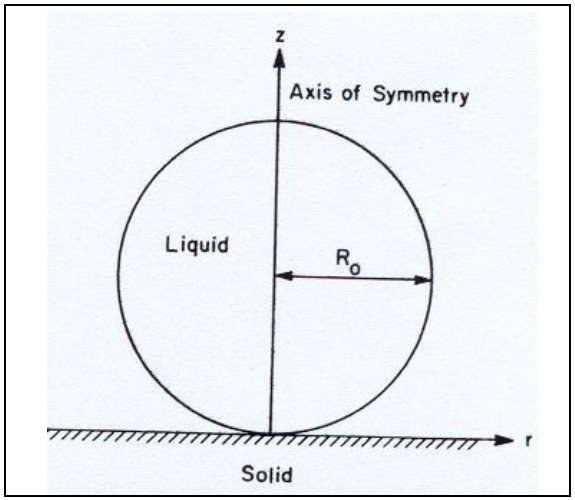
$$\frac{\partial \vec{V}}{\partial t} + \nabla \circ \left(\vec{V}\vec{V} \right) = \frac{-1}{\rho} \nabla P$$

Continuity equation

$$\nabla \circ \vec{V} = 0$$

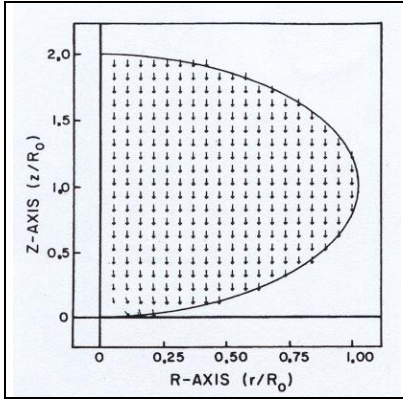
Where:

$\vec{V}$	velocity vector
P	pressure
ρ	density of the liquid
t	time
$\nabla\circ$	divergence operator
∇	gradient operator

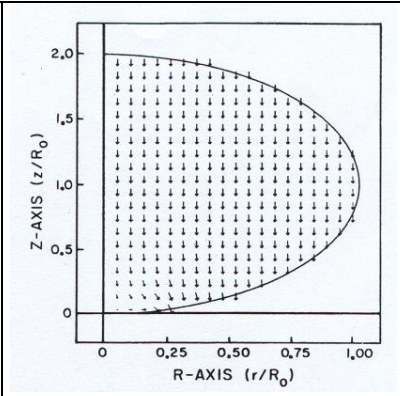


The problem domain

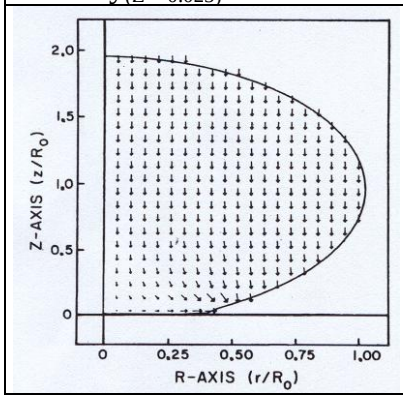
The time history of velocity:
Raindrop of 4 mm traveling at 10 m s^{-1}
(fall velocity normalized to 1)



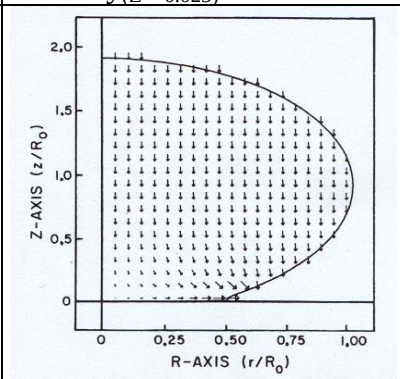
Time: 0.4 μ s
Velocity$_{(Z = 0.025)}$ = 0.26 to 1.09



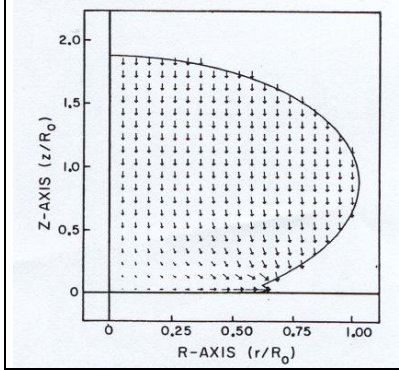
Time: 0.8 μ s
Velocity$_{(Z = 0.025)}$ = 0.19 to 1.56



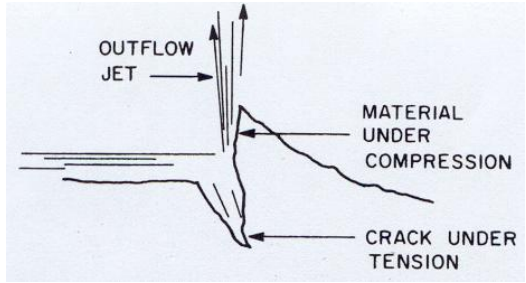
Time: 4.8 μ s
Velocity$_{(Z = 0.025)}$ = 0.13 to 1.59



Time: 10.6 μ s
Velocity$_{(Z = 0.025)}$ = 0.11 to 2.01

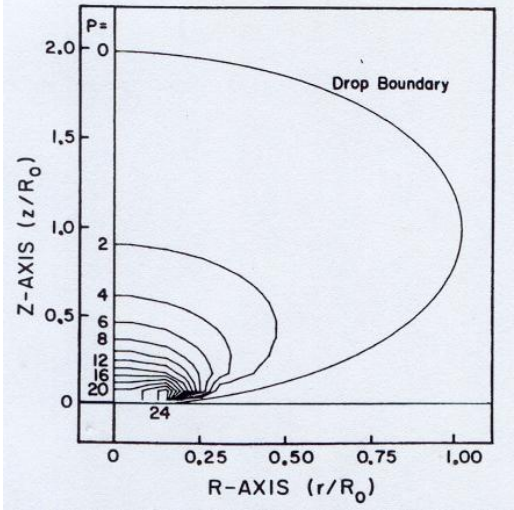


Time: 17.8 μ s
Velocity$_{(Z = 0.025)}$ = 0.17 to 1.88

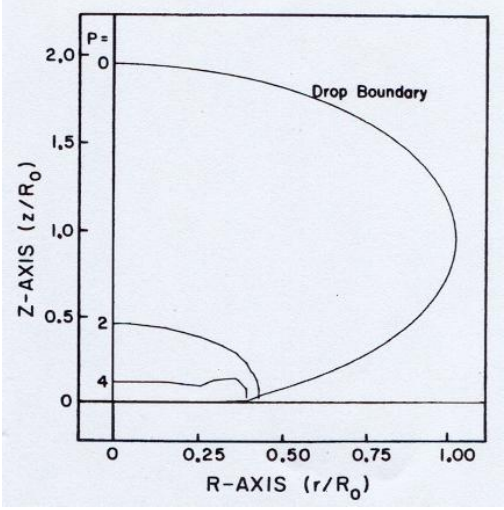


High speed lateral jet stream:
•large shearing stress at the surface
•tensile failure on surface irregularities

The time history of pressure:
Raindrop of 4 mm traveling at 10 m s^{-1}
(reference pressure = 50 kPa,
normalized to 1)

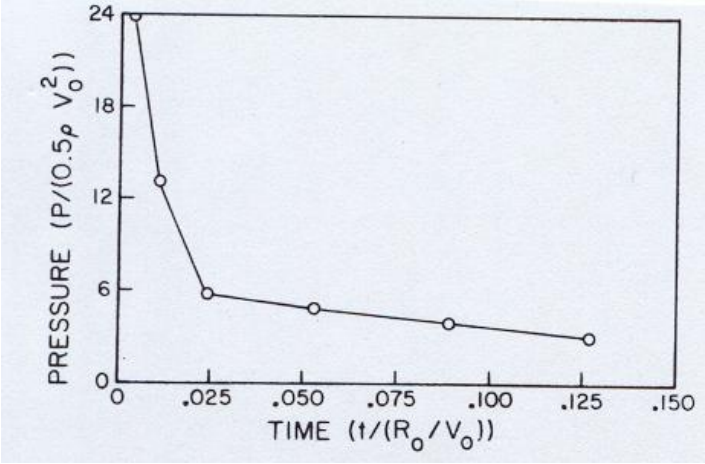


Time: 0.8 µ s



Time: 4.8 µ s

High initial pressure:
extremely high (1,200 kPa) pressure
at the very instant of impact
high capacity to deform plastic
surfaces



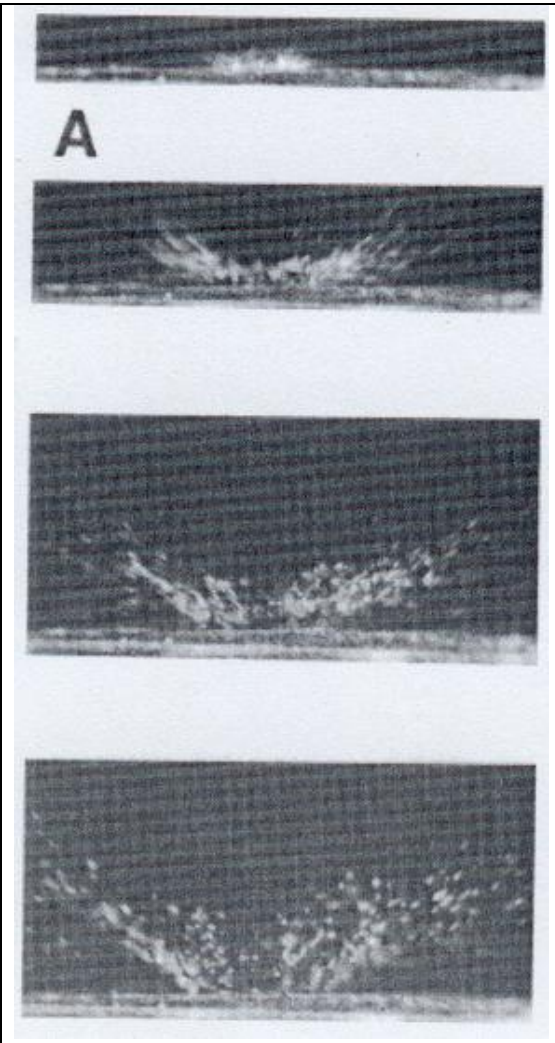
Maximum pressure vs time

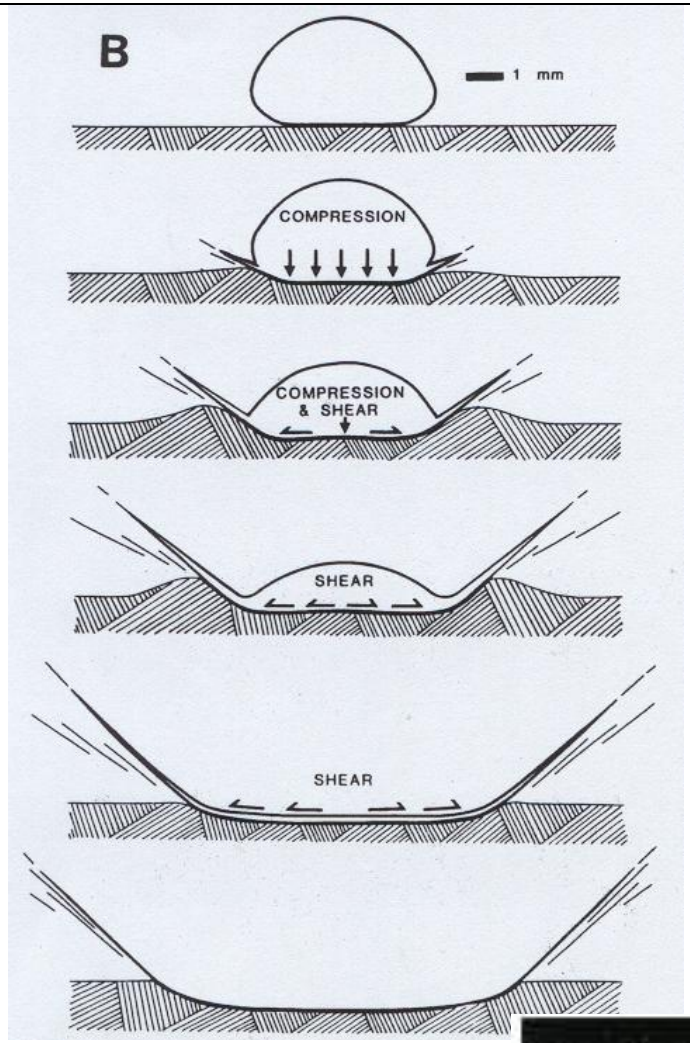
Soil shear stress: 2 to 20 kPa

The practice: high speed photography of drops impacting soil

Al-Durrah, M.M.; Bradford, J.M. (1982) The mechanism of raindrop splash on soil surfaces**. Soil Science Society of America Journa**l 46: 1086-1090.

- High speed photography (2,000 frames s^{-1}) in laboratory study (rain tower with drops of 4.6 mm falling from 890 cm)
- Different soils varying shear strength by changing bulk density and matric potential in the range of ~ 1 to ~20 kPa
- Splash angle and relative velocity





low shear strength $\tau = 2.6$ kPa

TECHNOS
11:01

TECHNOS
1:02
MODE
RESET

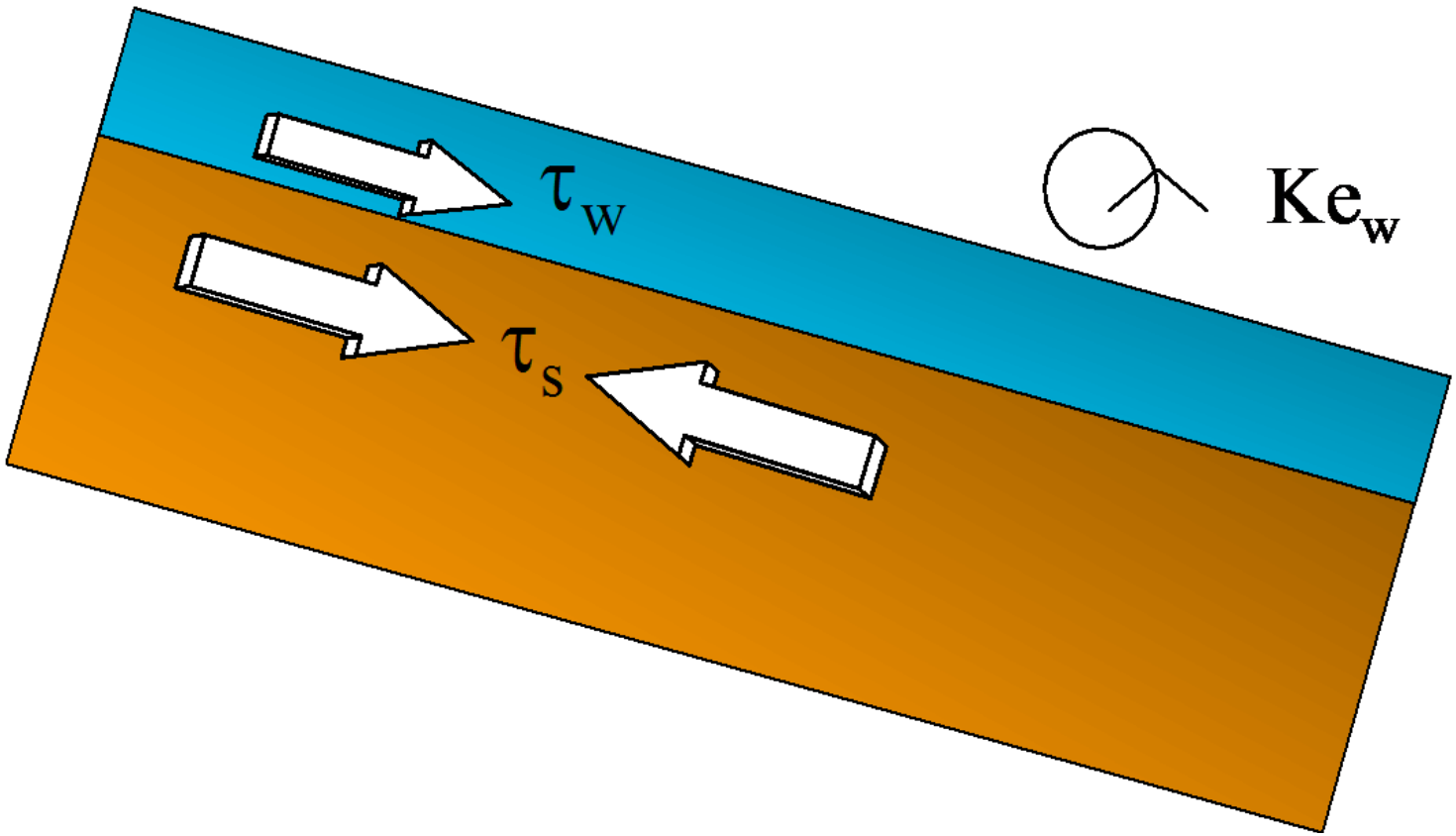
TECHNOS
11:12

TECHNOS
12:02

TECHNOS
2:02

TECHNOS
4:02
START
MODE

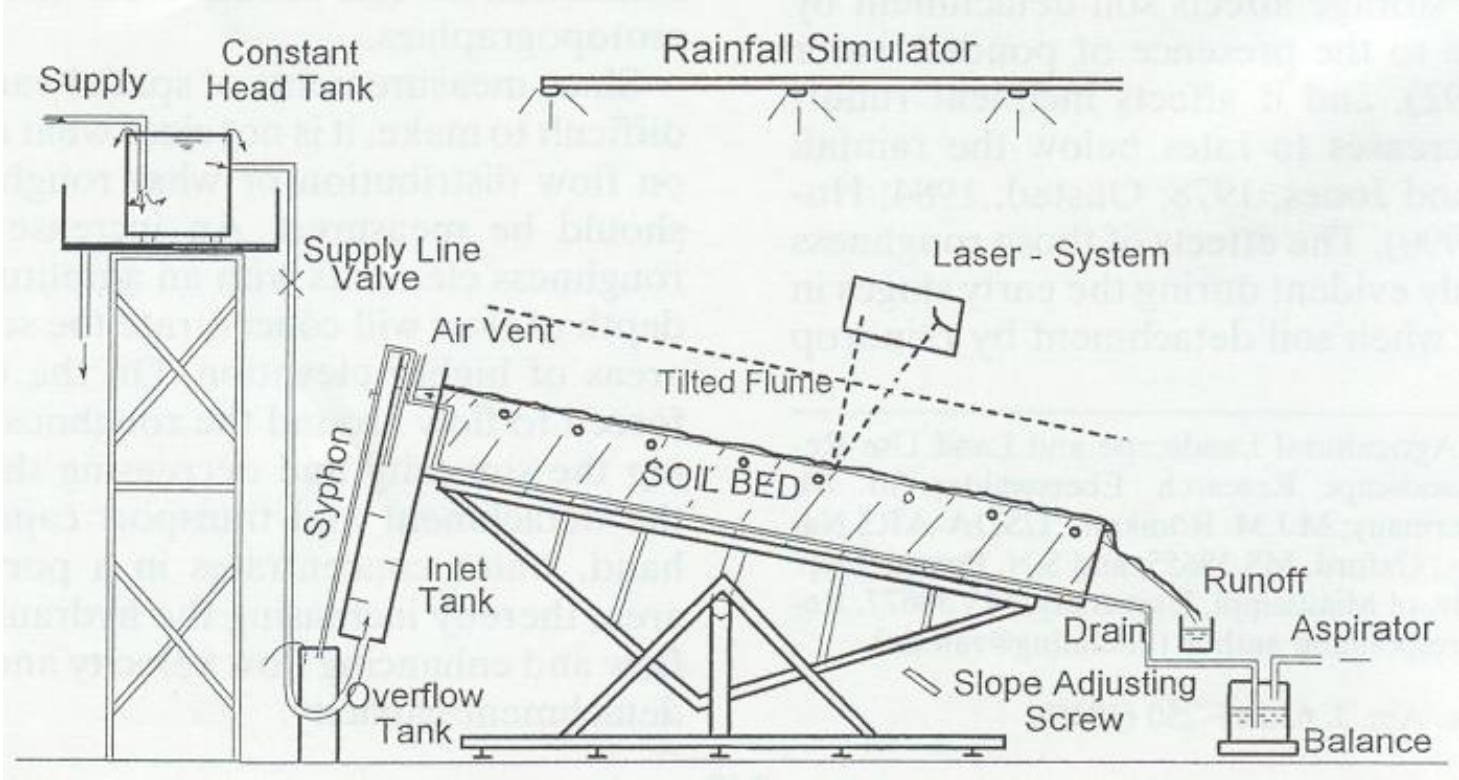
Water velocity ≈ 0.5 - 1.0 m s^{-1} (Ke_w)
Laminar flow water shear stress ≈ Pa (τ_w)
Soil strengths ≈ kPa (τ_s)



Roughness, runoff and soil loss

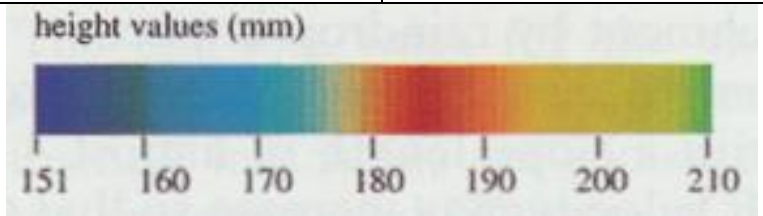
Helming, K., Römkens, M.J.M., Prasad, S.N. (1998) Surface roughness related processes of runoff and soil loss: a flume study. **Soil Science Society of America Journal** 62: 243-250.

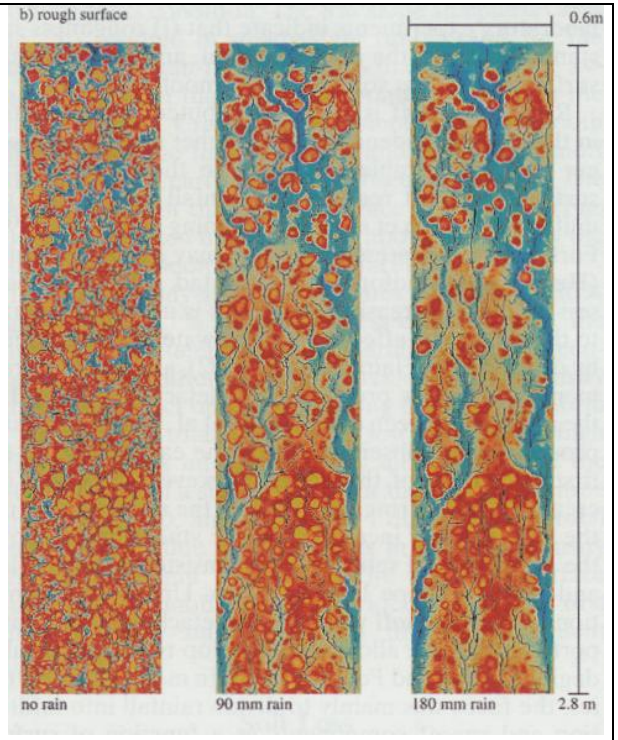
- Effect of roughness on spatial distribution of runoff and flow concentrations affecting the amount of soil loss.
- Rain simulation, 2.8 m flume, three roughness conditions (rough, medium and smooth) two slopes (2, 8 and 17 %).
- Roughness was calculated from DEM obtained from laser microrelief measurements.



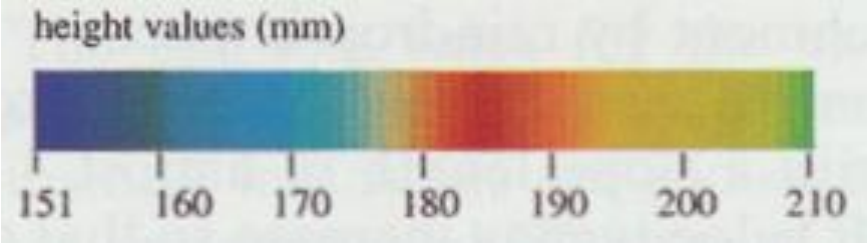
Adjustable flume, rainfall simulator, laser microrelief meter

smooth	rough





smooth		rough	
Slope	**Soil loss (kg m^{-2})**	**Slope**	**Soil loss (kg m^{-2})**
2%	0.56	2%	0.53
8%	3.31	8%	1.41
17%	9.38	17%	7.2



A erosão do solo: Processo

Desprendimento ->

Desagregação:

Forças de adesão e coesão em função da agregação do solo

Impacto da gota de chuva

Enxurrada

Transporte ->

Quantidade de energia disponível

Enxurrada

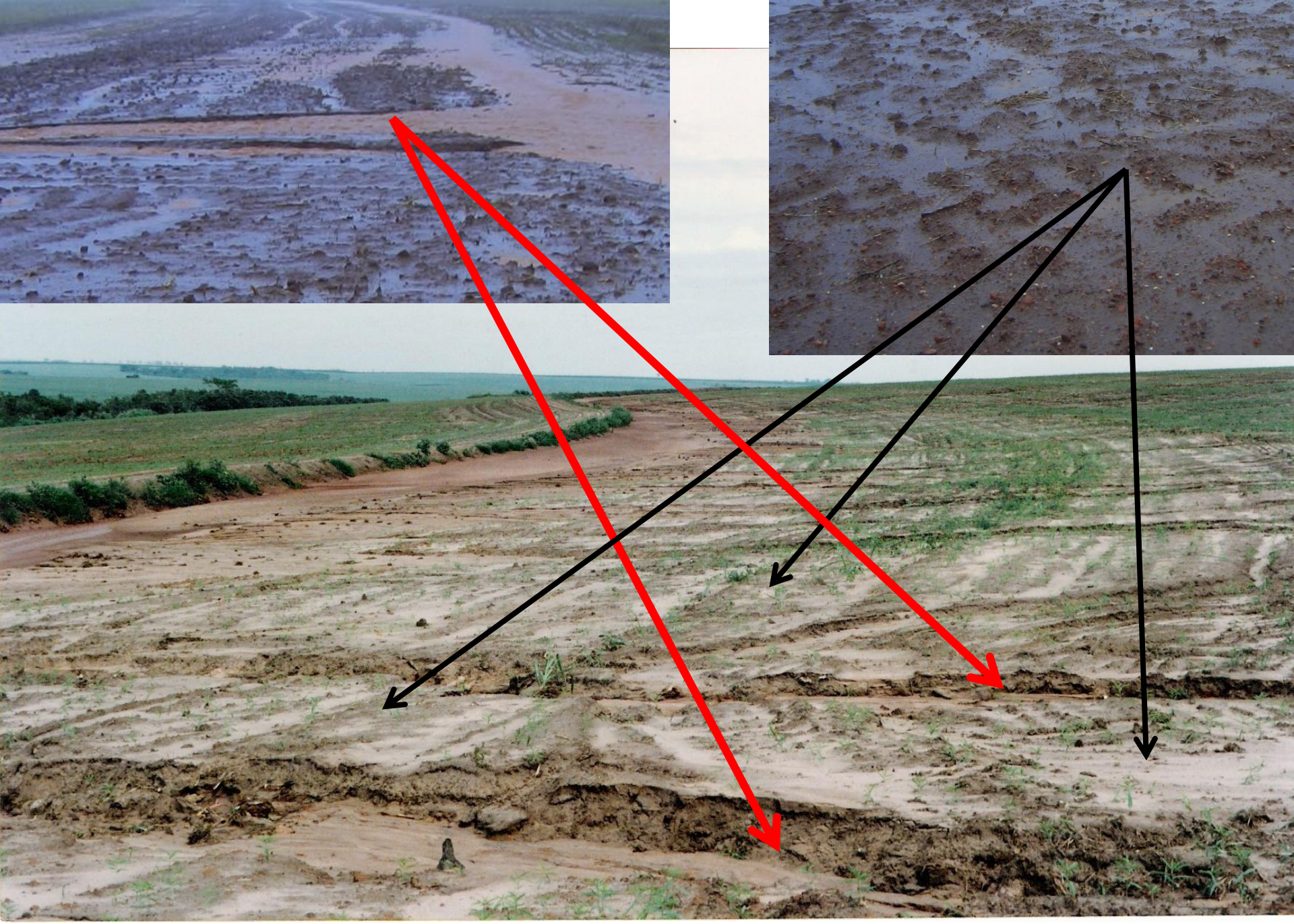
Deposição

Diminuição da quantidade de energia

A erosão do solo: **Formas**

Impacto da gota → Laminar → Muito seletivo

Enxurrada → Dispersa (não recorrente) → Sulcos

Enxurrada → Concentrada (recorrente) → Voçorocas efêmeras

Concentrada (recorrente) → Voçorocas permanentes