manejo e conservação do solo: módulo erosão

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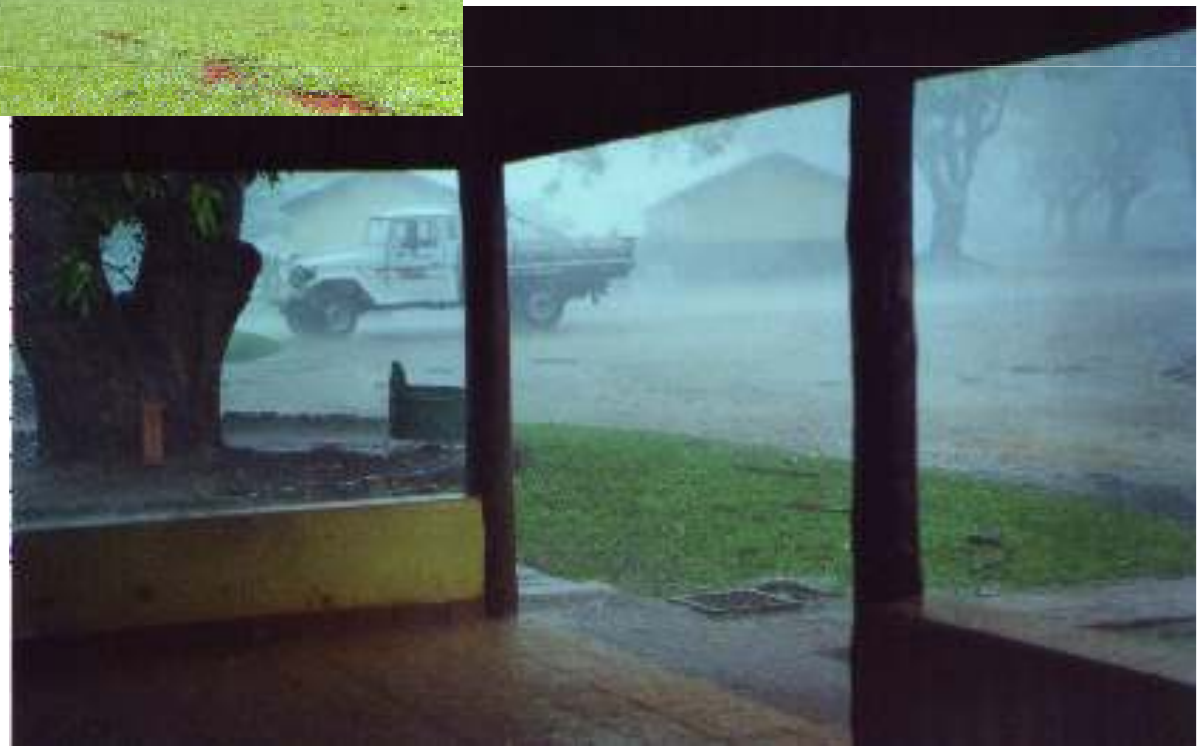


The theory: spherical drop on a rigid surface

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:

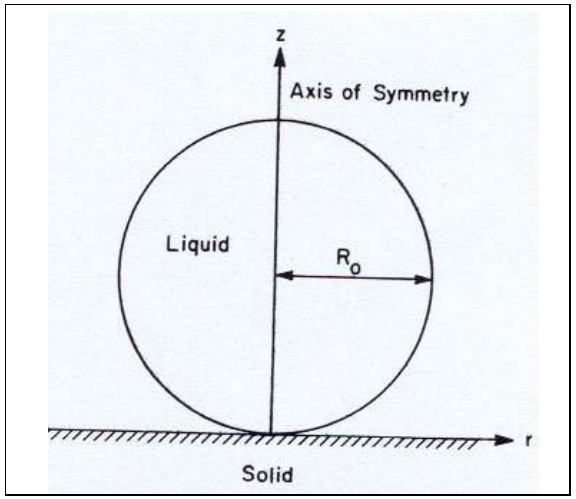
$$\frac{\partial \vec{V}}{\partial t} + \nabla \circ \left(\vec{V}\vec{V} \right) = \frac{-1}{\rho} \nabla P$$

Continuity equation

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

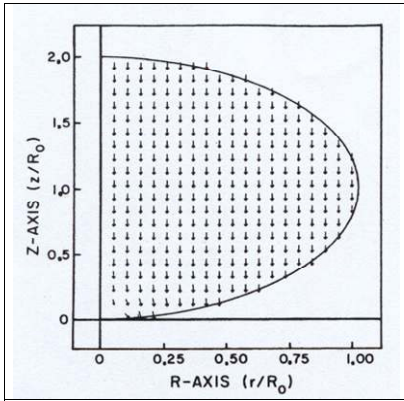
Where:

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

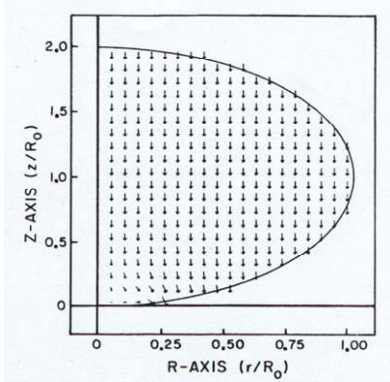


The problem domain

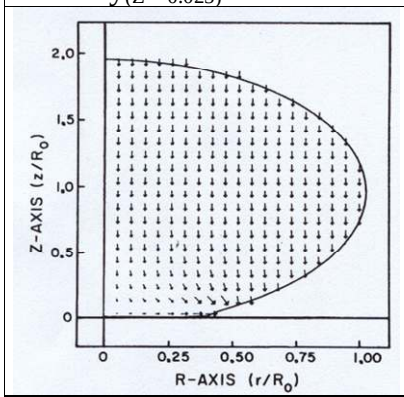
The time history of velocity:
Raindrop of 4 mm traveling at 10 m s^{-1}
(fall velocity normalized to 1)



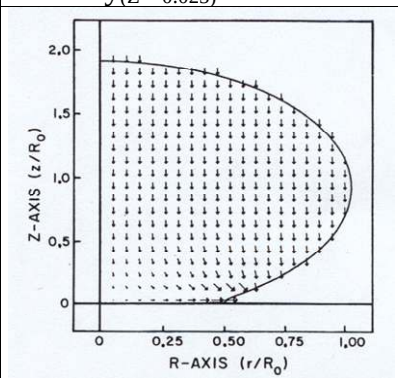
Time: 0.4 µ s
Velocity$_{(Z = 0.025)}$ = 0.26 to 1.09



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

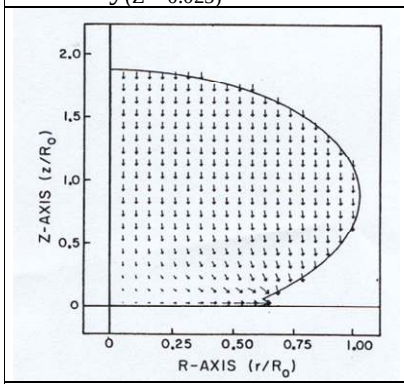


Time: 4.8 µ s
Velocity$_{(Z = 0.025)}$ = 0.13 to 1.59

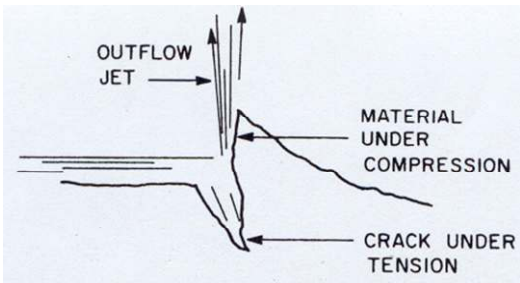


Time: 10.6 µ s
Velocity$_{(Z = 0.025)}$ = 0.11 to 2.01

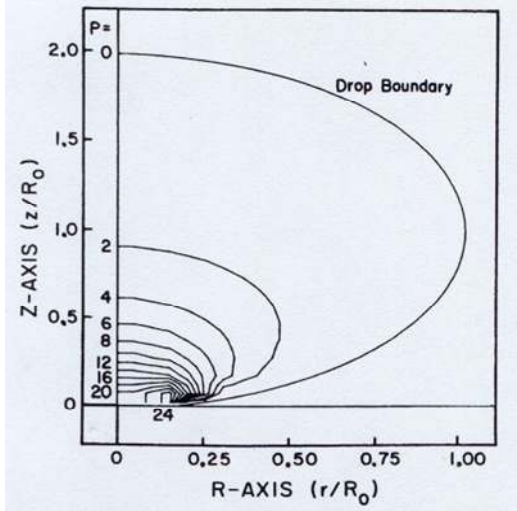
High speed lateral jet stream:
•large shearing stress at the surface
•tensile failure on surface irregularities



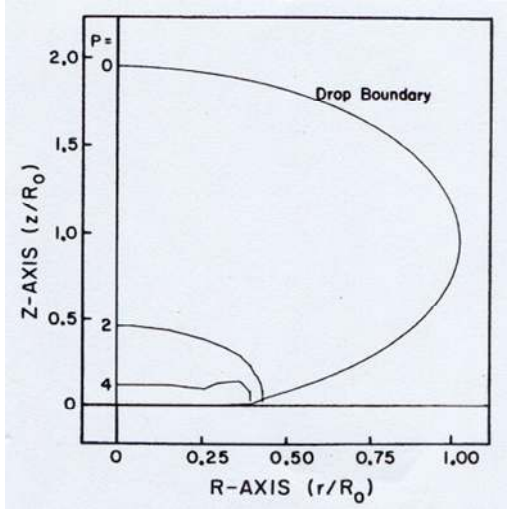
Time: 17.8 µ s
Velocity$_{(Z = 0.025)}$ = 0.17 to 1.88



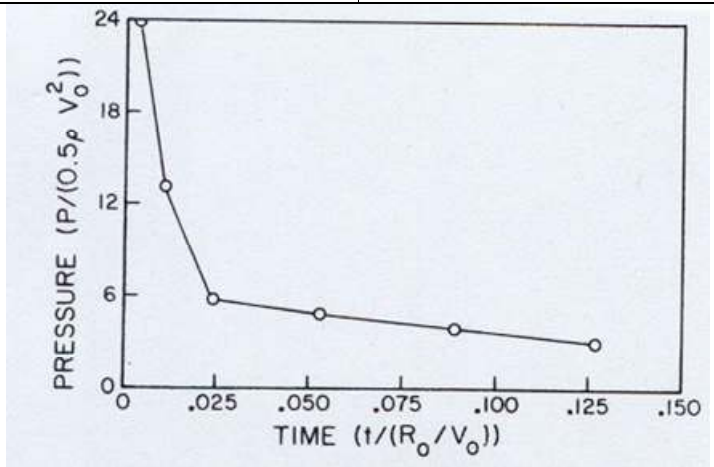
The time history of pressure:
Raindrop of 4 mm traveling at 10 m s^{-1}
(reference pressure = 50 kPa,
normalized to 1)



Time: 0.8 µ s



Time: 4.8 µ s



Maximum pressure vs time

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

Soil shear stress: 2 to 20 kPa

11:01

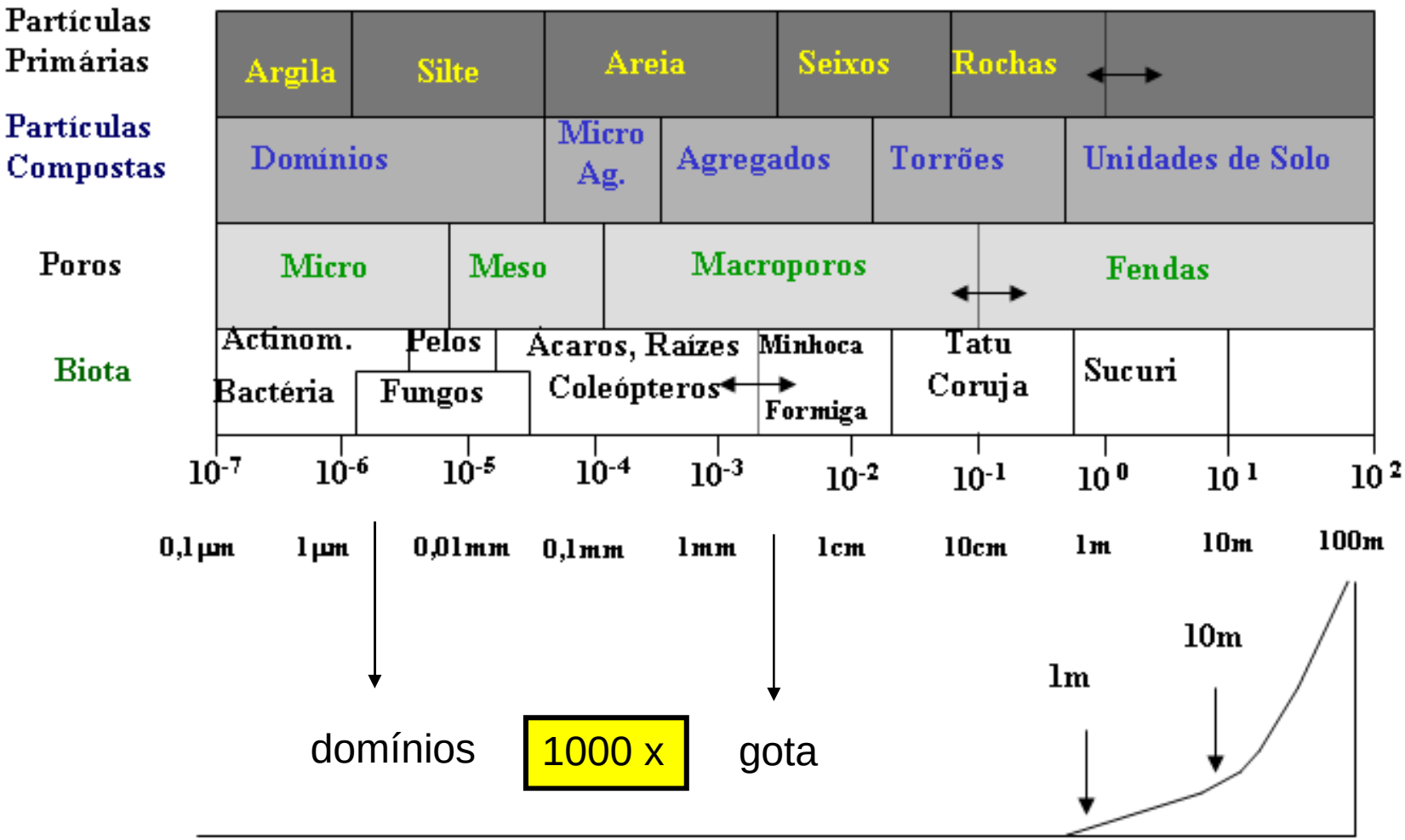
TECHNOS
11:02
MODE
SET

TECHNOS
11:12

TECHNOS
12:02

TECHNOS
2:02
START
MODE

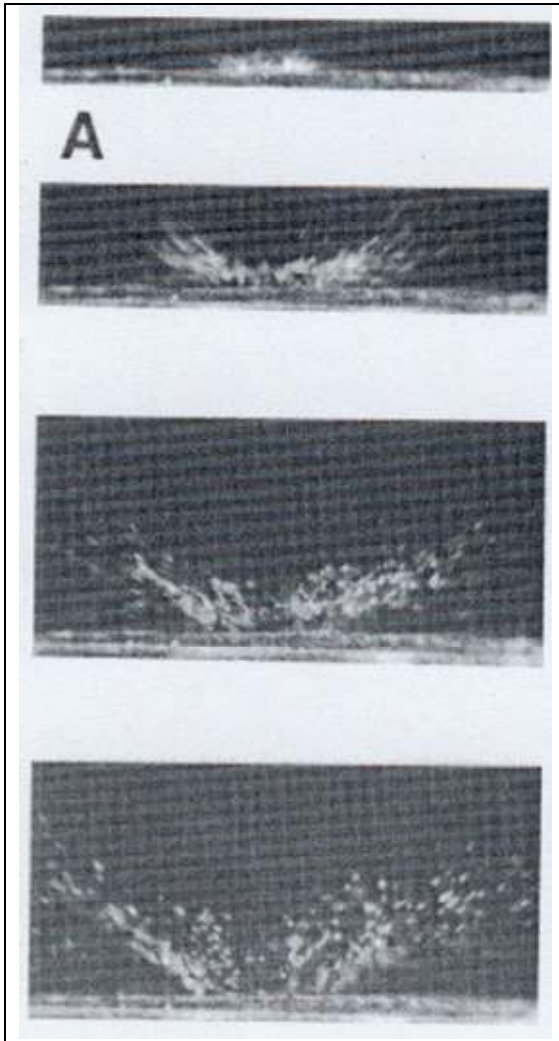
TECHNOS
4:02
MODE

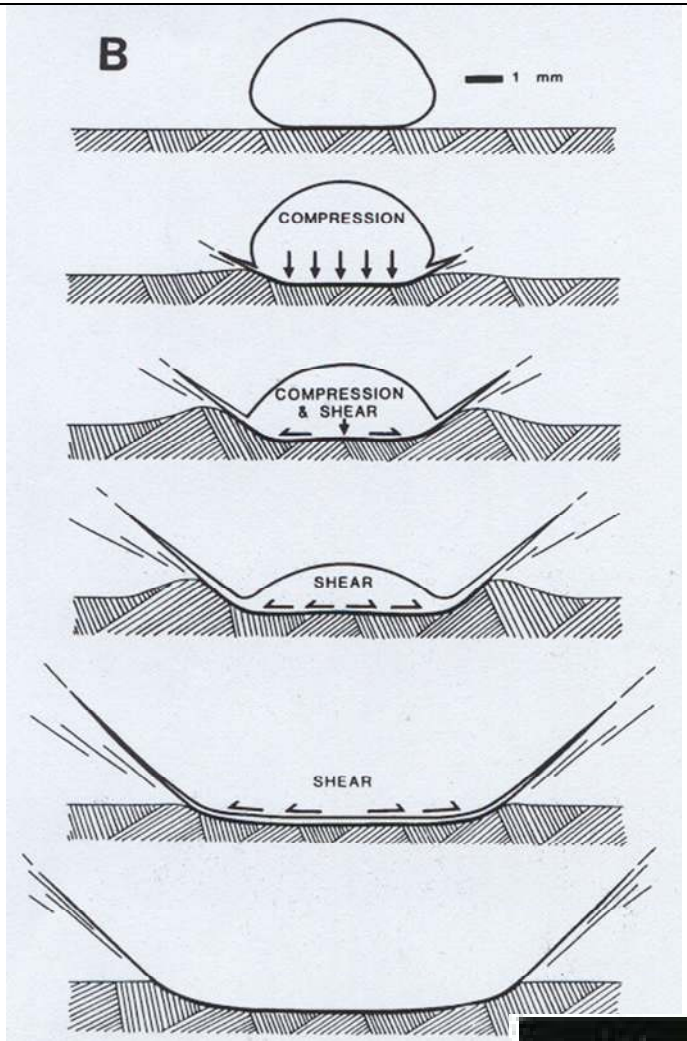

Partículas Primárias
Argila
Silte
Areia
Seixos
Rochas
Partículas Compostas
Domínios
Micro Ag.
Agregados
Torrões
Unidades de Solo
Poros
Micro
Meso
Macroporos
Fendas
Biota
Actinom.
Pelos
Acaros, Raízes
Minhoca
Tatu
Coruja
Sucuri
Bactéria
Fungos
Coleópteros
Formiga
10-7
10-6
10-5
10-4
10-3
10-2
10-1
100
101
102
0,1µm
1µm
0,01mm
0,1mm
1mm
1cm
10cm
1m
10m
100m
1m
10m
domínios
1000 x
gota

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



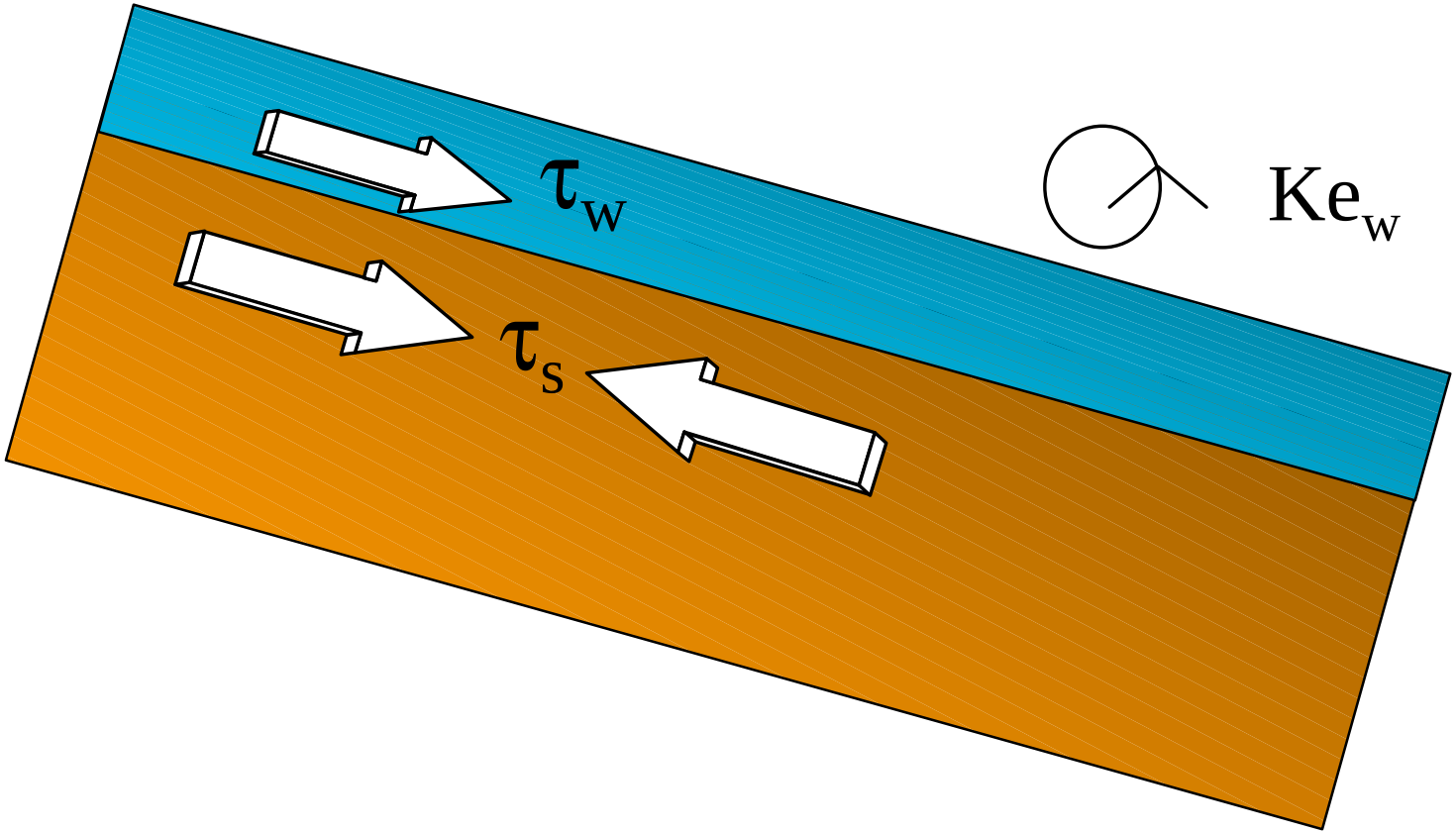


low shear strength τ = 2.6 kPa

Water velocity ≈ 0.5 - 1.0 m s^{-1} (Ke_w)

Laminar flow water shear stress ≈ Pa (τ_w)

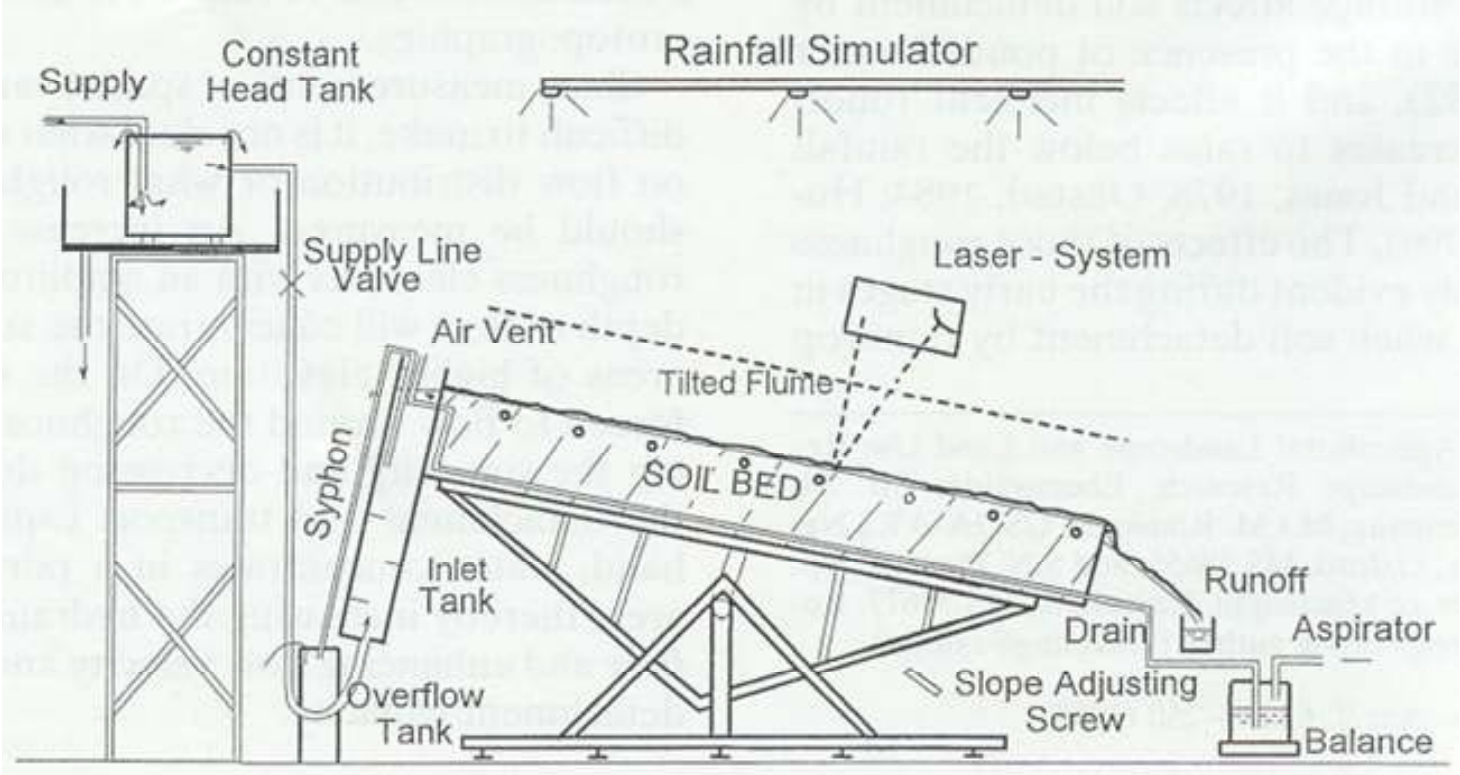
Soil strengths ≈ kPa (τ_s)



Roughness, runoff and soil loss

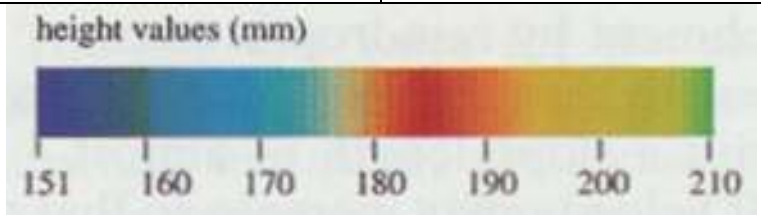
Helming, K., Römkens, M.J.M., Prasad, S.N. (1998) Surface roughness related processes of runoff and soil loss: a flume study. **Soil Science Society of America Journal** 62: 243-250.

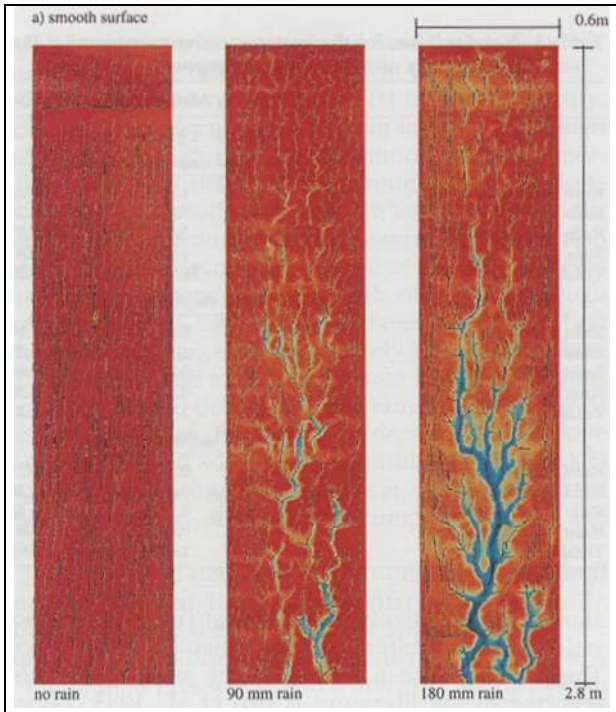
- Effect of roughness on spatial distribution of runoff and flow concentrations affecting the amount of soil loss.
- Rain simulation, 2.8 m flume, three roughness conditions (rough, medium and smooth) two slopes (2, 8 and 17 %).
- Roughness was calculated from DEM obtained from laser microrelief measurements.

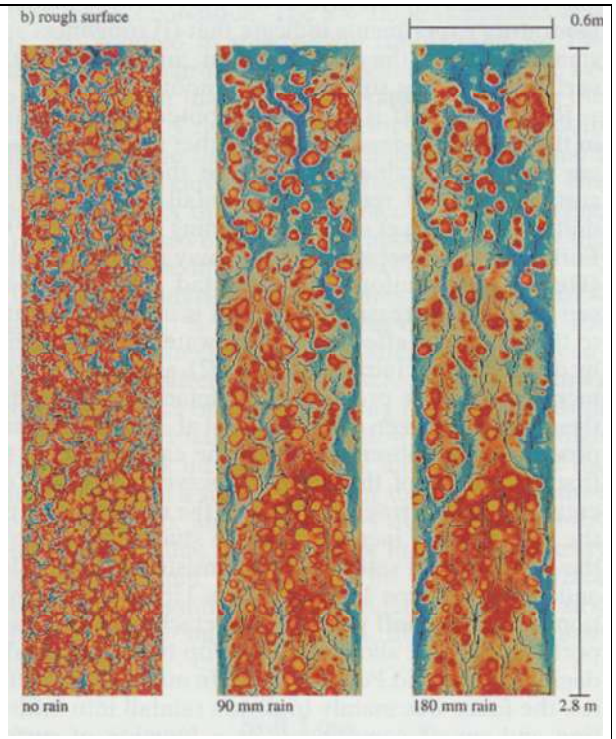


Adjustable flume, rainfall simulator, laser microrelief meter

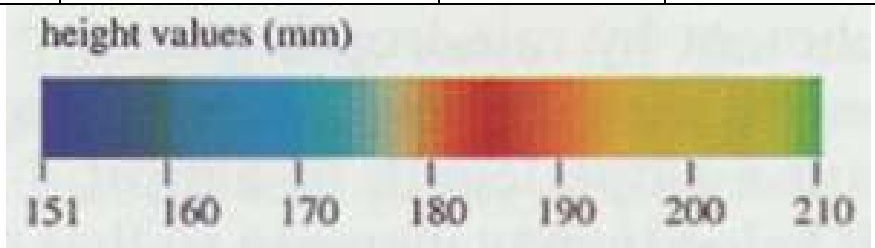
smooth	rough



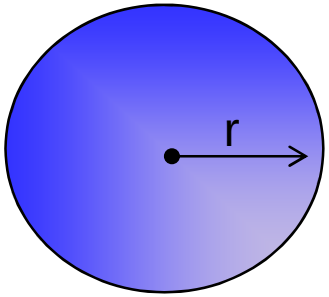


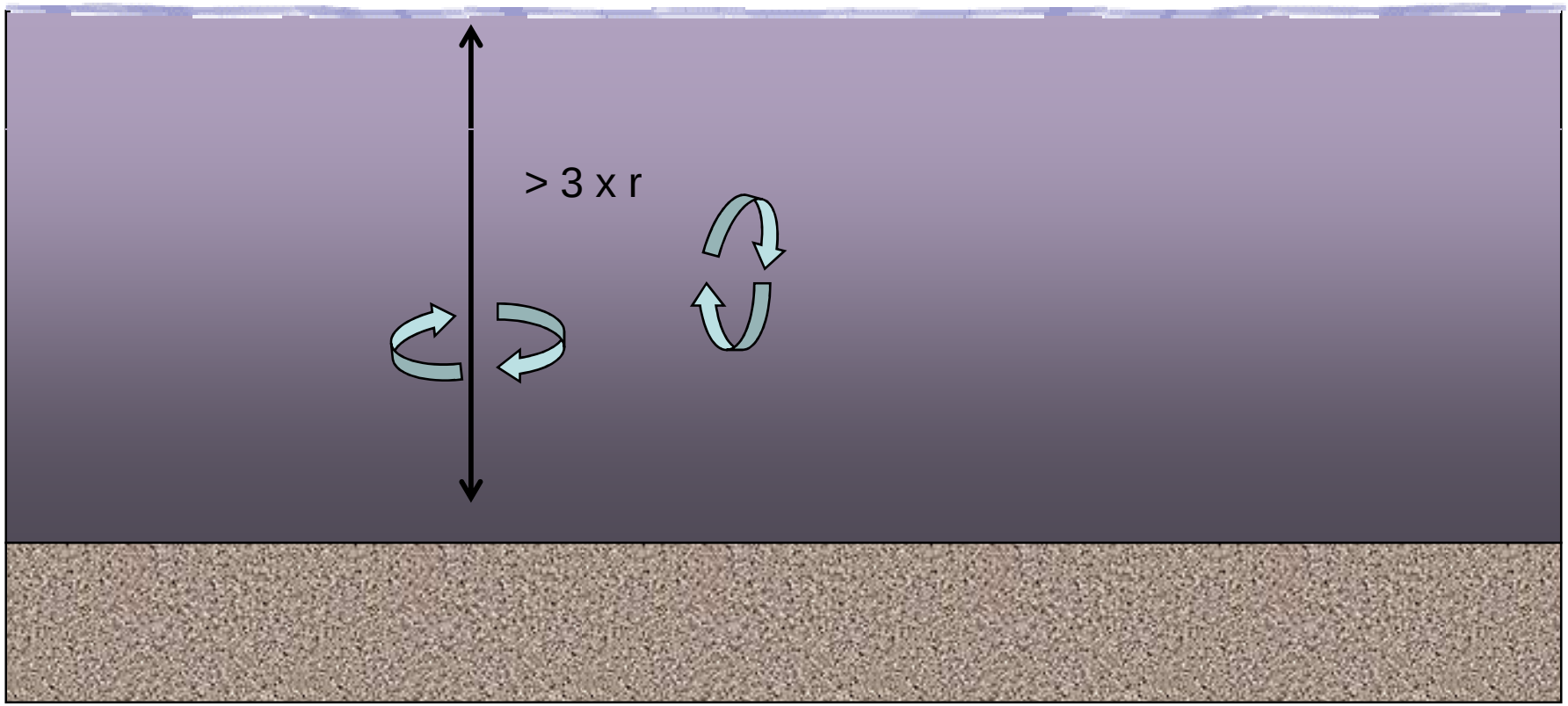


smooth		rough	
Slope	**Soil loss (kg m^{-2})**	**Slope**	**Soil loss (kg m^{-2})**
2%	0.56	2%	0.53
8%	3.31	8%	1.41
17%	9.38	17%	7.2



Capacidade de transporte





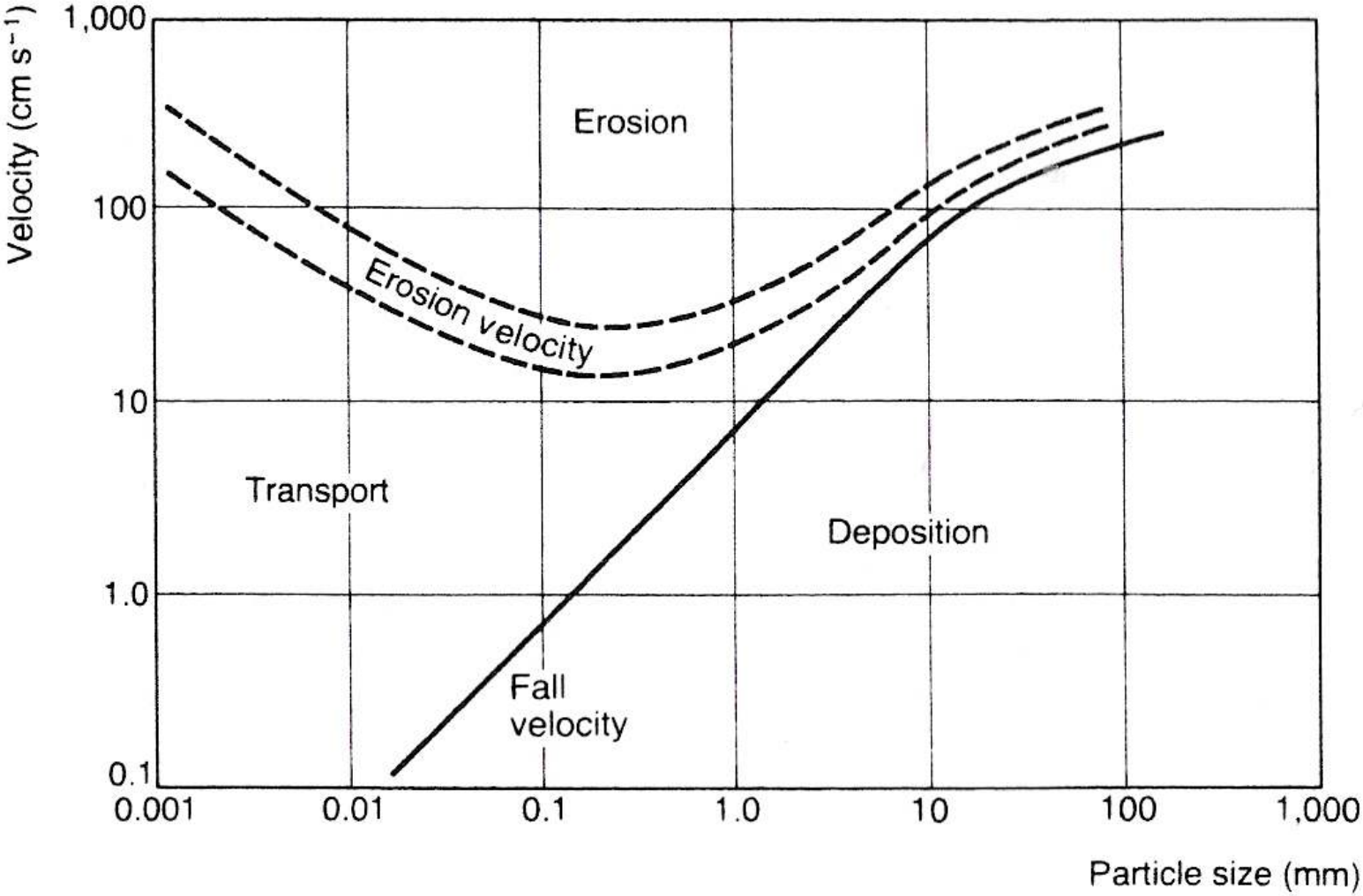


Fig. 2.2 Critical water velocities for erosion, transport and deposition as a function of particle size (after Hjulström, 1935).

A erosão do solo: Processo

Desprendimento -> Transporte -> Deposição

Desagregação:

Forças de adesão e coesão em função do tamanho dos agregados

Impacto da gota de chuva

Enxurrada

Quantidade de energia disponível

Enxurrada

Diminuição da quantidade de energia

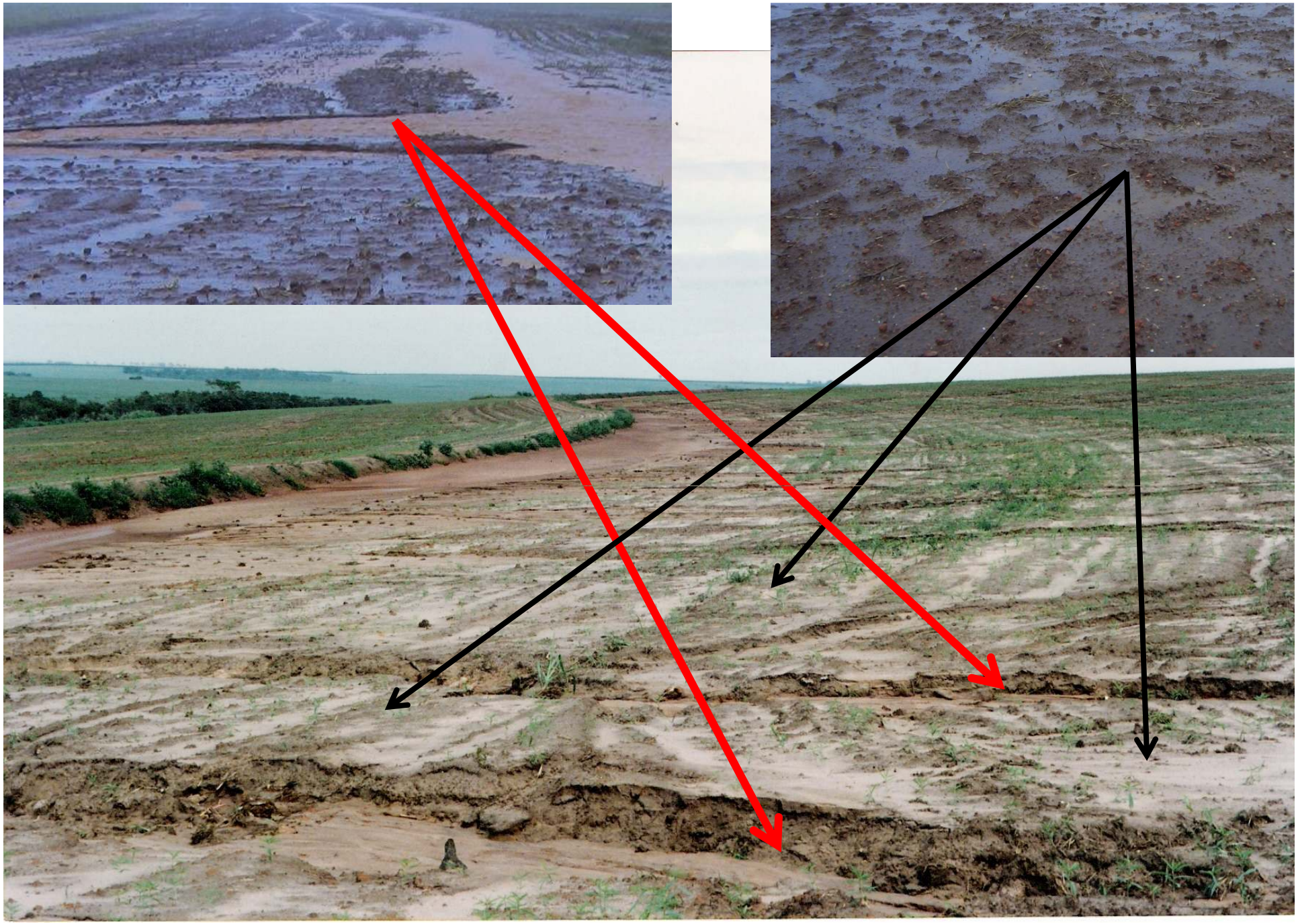
A erosão do solo: **Formas**

Impacto da gota → Laminar → Muito seletivo

Enxurrada → Dispersa (não recorrente) → Sulcos

Enxurrada → Concentrada (recorrente) → Voçorocas efêmeras

Concentrada (recorrente) → Voçorocas permanentes



Large Storm effects:

Edwards and Owness (1991):

“With more than 4,000 rainfall events during the study period (28 years), the five biggest erosion-producing events on each watershed (of 229) accounted for 66% of the total erosion”

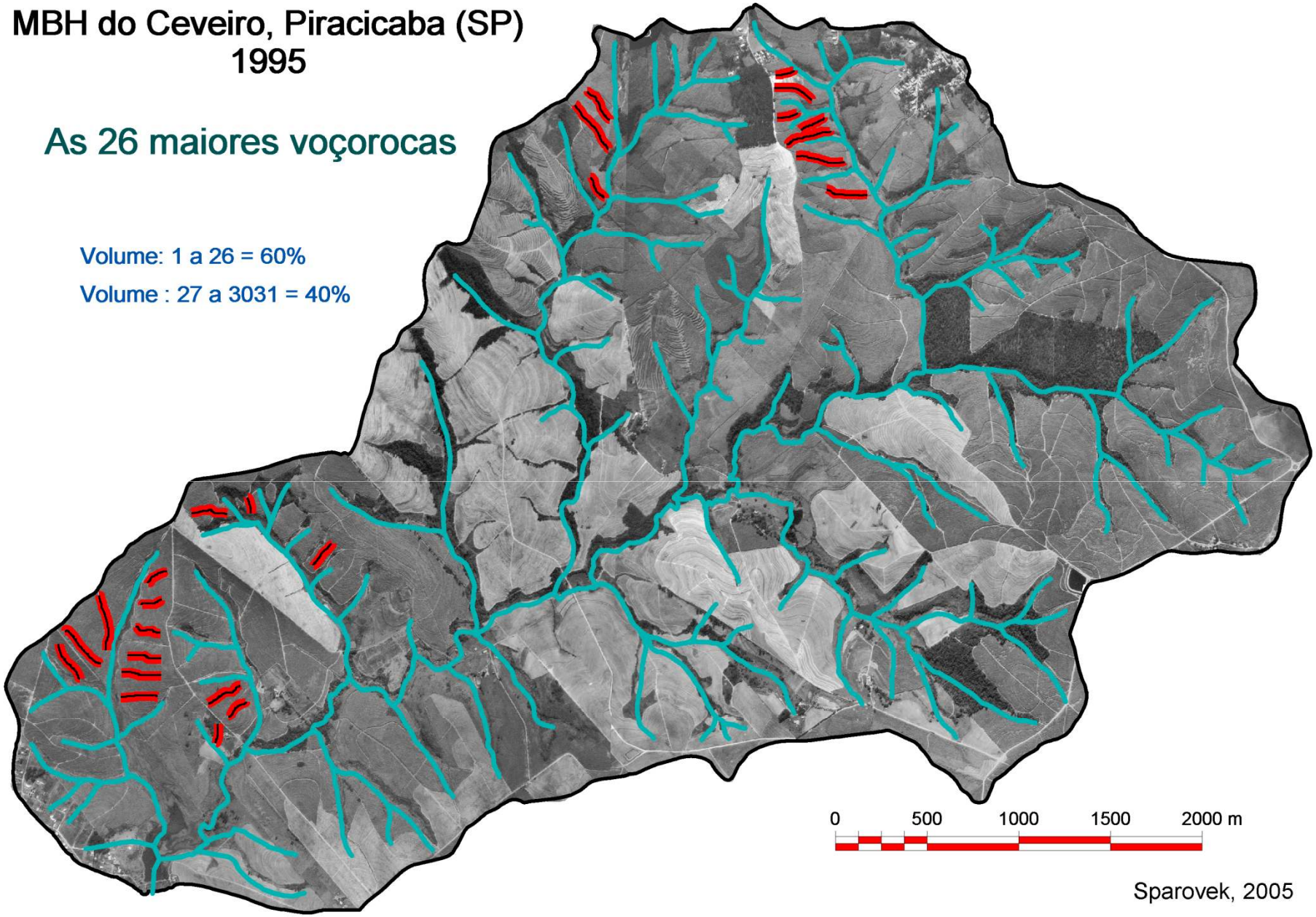
Strom Rank	Cummulative % of 25 year
1	25
2	41
3	52
4	60
5	66

MBH do Ceveiro, Piracicaba (SP)
1995

As 26 maiores voçorocas

Volume: 1 a 26 = 60%

Volume : 27 a 3031 = 40%



Sparovek, 2005