Characterization of soil microtopography effects on runoff and soil erosion rates under simulated rainfall

J. Vermang, L.D. Norton, C. Huang, D. Gabriels
• Introduction and hypothesis
• Materials & methods
• Results
  – Rainfall simulations
  – Rougness indices
  – Erosion modeling
• Conclusion
• Soil surface roughness: important factor influencing soil erosion

• WEPP: interrill sediment delivery $D_i$

$$D_i = K_{iadj} \cdot I_e \cdot \sigma_{ir} \cdot SDR_{RR} \cdot F_{nozzle} \cdot (R_s/w)$$

$SDR_{RR}$: function of random roughness
• How does soil surface roughness influence runoff and soil erosion?
• Which indices describe soil surface roughness well?
• Possibility to improve erosion modeling
• Introduction and hypothesis
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Materials & methods

- Soil: silt loam
- Sieving to four roughness classes
  - Very smooth (0.3 – 1.2 cm)
  - Smooth (1.2 – 2.0 cm)
  - Rough (2.0 – 4.5 cm)
  - Very rough (4.5 – 10.0 cm)
- Soil trays: 0.6 x 1.2 m
- Slope set at 5%
Materials & methods

• Rainfall simulator
  – Oscillating nozzle simulator
  – Rainfall intensity: 50.2 ± 2.1 mm/h
  – Duration: 1.5 h
Materials & methods

• Soil surface roughness measurements
  – Instantaneous profile laser scanner
  – Before and after rainfall simulations
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Results: Runoff

A graph showing the relationship between cumulative rainfall (mm) and runoff rate (mm h⁻¹) for different surface roughness conditions: Very smooth, Smooth, Rough, and Very rough.
Results: Runoff

- Highest final runoff rate for very smooth surface (0.3 – 1.2 cm), lowest for rough surface (2.0 – 4.5 cm)
- Very rough surface NOT lowest final runoff rate due to
  - Formation of depositional crust
  - Topography forcing water to flow to the depressions rather than to infiltrate
Results: Soil loss

Wash rate (g m$^{-2}$ min$^{-1}$) vs. Cumulative rainfall (mm)

- **Very smooth**
- **Smooth**
- **Rough**
- **Very rough**
Results: Soil loss

- Total soil loss highest for very smooth soil surface, lowest for rough soil surface.
- Final wash rates comparable for all soil surface roughnesses.
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Results: Roughness indices

- Random Roughness (RR)
- Characterisation by the variogram:
  - Range, sill, (sill-nugget)/range
- Fractional Brownian motion (fBm)
  - Fractal dimension, crossover length
- Revised Triangular Prism surface area Method (RTPM)
  - Fractal dimension
Results: Roughness indices

- DEM: correction for slope and scanning artifacts
Results: Roughness indices

- Random Roughness (RR)
Results: Roughness indices

- Variogram:
  - Geometric anisotropy
  - Exponential model

- Rough surface:
  small scale periodic patterns

Sill = 6.6 mm² 
Range = 38 mm  
Smooth (1.2 – 2.0 cm)

Sill = 26.5 mm² 
Range = 22 mm 
Rough (2.0 – 4.5 cm)
Results: Roughness indices

- Variogram parameters
  - Sill: good predictor
  - Range: Smooth surface not in line
Results: Roughness indices

- Fractional Brownian motion

- Fractal dimension (D): decreasing trend
- Crossover length (l): no constant trend
Results: Roughness indices

- Revised Triangular Prism method
  - Better predictor than fBm
  - Little significant differences
• Expectations for use in erosion models:
  – RR differentiates good between roughness classes
  – Improvements can be expected with real measured values of RR
  – Use of Sill or RTPM:
    • spatial correlation
    • lower significant differences
  – Best option: use of DEM by depression filling models
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Conclusion

- **Effect on runoff & soil loss**
  - delay in runoff rather than the decrease of soil erosion amount.

- **Roughness indices**
  - Random roughness performs well
  - Spatial correlation taken into account:
    - Variogram sill and RTPM fractal dimension perform best
Thank you for your attention!

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