Modeling the reduction in soil loss due to soil armouring caused by rainfall erosion

T.A. Cochrane[1], D.C. Yoder[2], and D.C. Flanagan[3], S.M. Dabney[4], P. Weber[5]

[1] University of Canterbury
[2] University of Tennessee
[3] National Soil Erosion Research Lab., USDA-ARS
[4] National Sedimentation Lab., USDA-ARS
[5] Solid Energy Ltd., New Zealand

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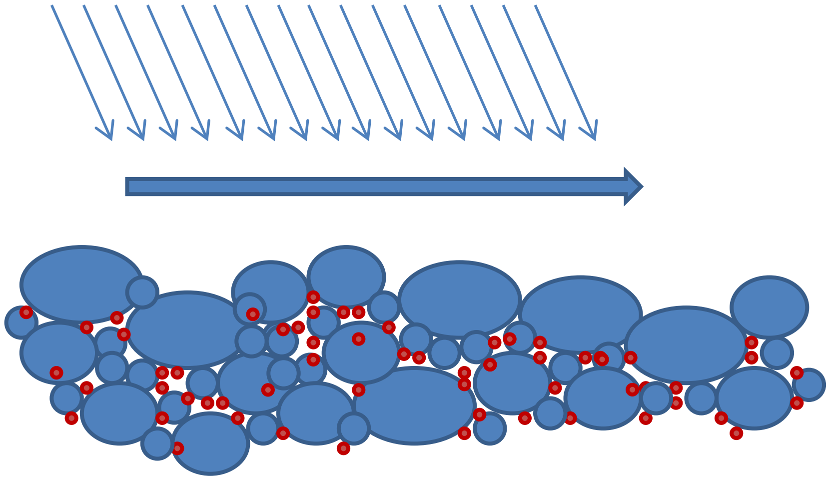
Introduction: What is armouring?



1. Rainfall triggers:
   - Sheet erosion
   - Concentrated flow erosion

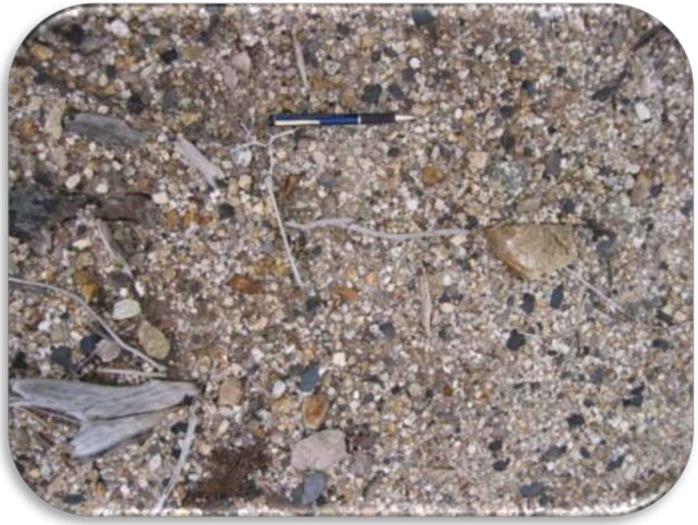
2. Fine soil material is eroded away leaving coarser material behind.

3. Coarse material provides protection for the underlying soil, reducing further erosion.

OUR current erosion models do NOT account for this – thus over-predicting erosion / sediment yields on soils susceptible to armouring.

Where does it occur?

- Field observations of "natural" armouring of topsoil in various types of soils (rangeland, etc).
- After land use change (disruption of soil)
  - Construction sites
  - Mining
  - Road construction



A need to understand soil armouring

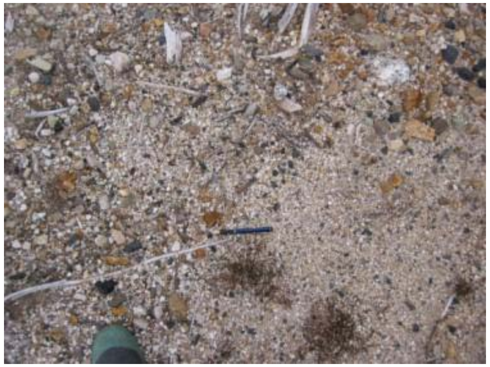
- At what rate does armouring occur?
- How much does armouring change soil erosion?
- What other factors impact armouring?
- How can we model it?

Observations and Experiments

Lab based rainfall simulation experiments

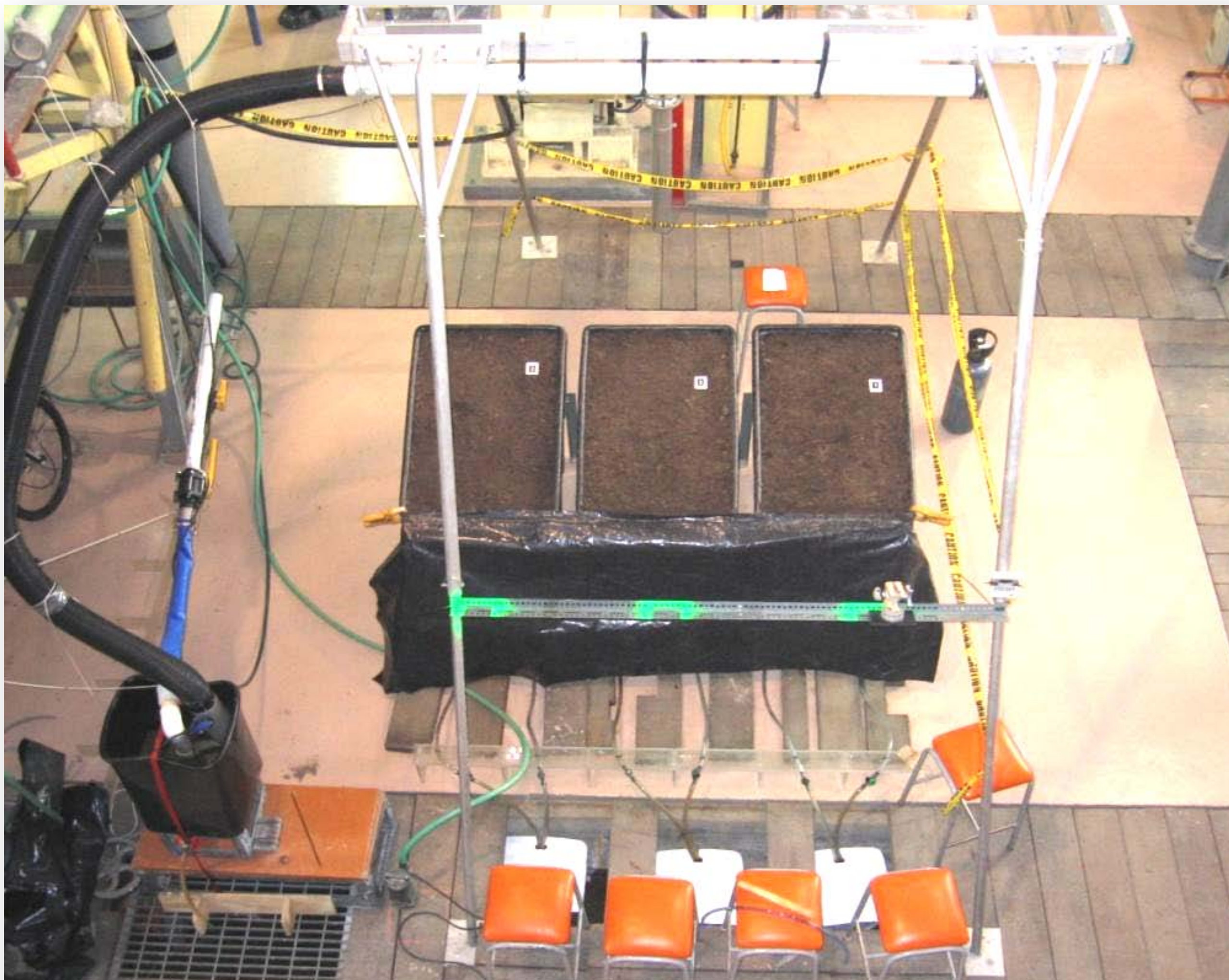
Exp	Soil type	Slope (deg)	Reps	no. of rain events	rain event length	Intensities (mm/hr)
1	Topsoil A	18	3	6	1 hr	**66, 44, 33, 52, 21, 80**
2	Topsoil A	18	3	5	1 hr	**22, 22, 22, 22, 80**
3	Topsoil A	18	3	5	1 hr	**45, 45, 45, 45, 80**
4	Topsoil A	18	3	5	1 hr	**66, 66, 66, 66, 80**
5	Topsoil B	24	3	5	1 hr	**22, 22, 22, 22, 80**
6	Topsoil B	24	3	5	1 hr	**45, 45, 45, 45, 80**
7	Topsoil B	24	3	5	1 hr	**66, 66, 66, 66, 80**
8	Topsoil B	24	3	3	1 hr	**80, 22, 22**
9	Granite sub-soil	5	2	4	0.5 hr	**80, 80, 22, 22**
10	Mine waste rock	5	1	4	0.5 hr	**80, 80, 22, 22**

+ Field observations at mine restoration site



+ Observed armouring of sandy soils on steep slopes

Experimental setup under a rainfall simulator



Observed changes

Fresh

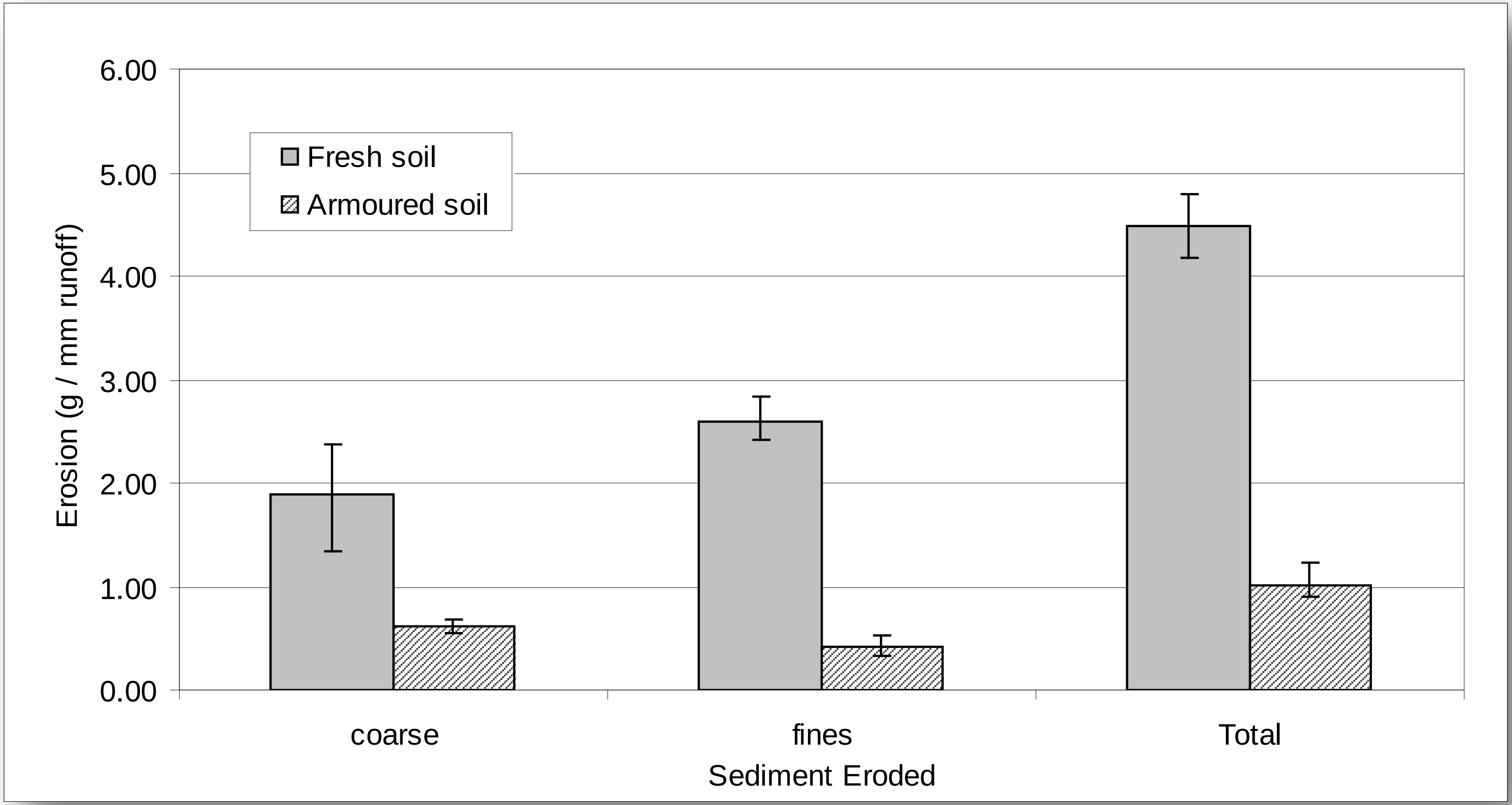
Armoured

Armouring experiments before and after

4 hours @ 22mm hr^{-1}

Experiment results

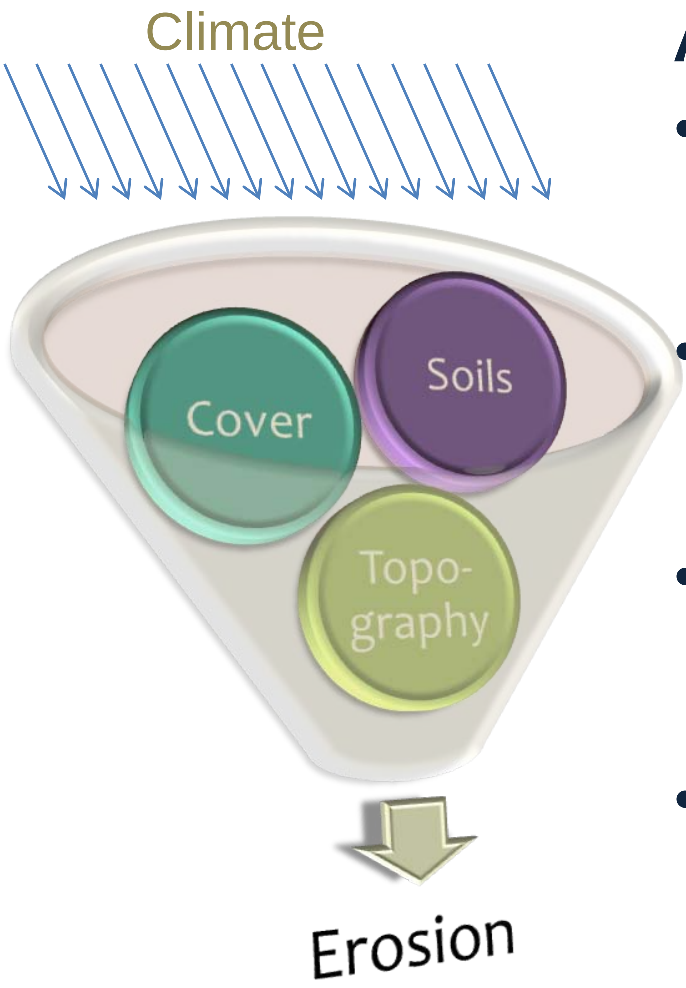
Erosion from fresh soil vs. armoured soil under 22 mm/hr rainfall



Modeling armouring

Manual

- Change cover or soil erodibility after each event.
- Can be readily done using either:
  - RUSLE 2
  - WEPP
- BUT, need to know armouring rate (change in rock cover)



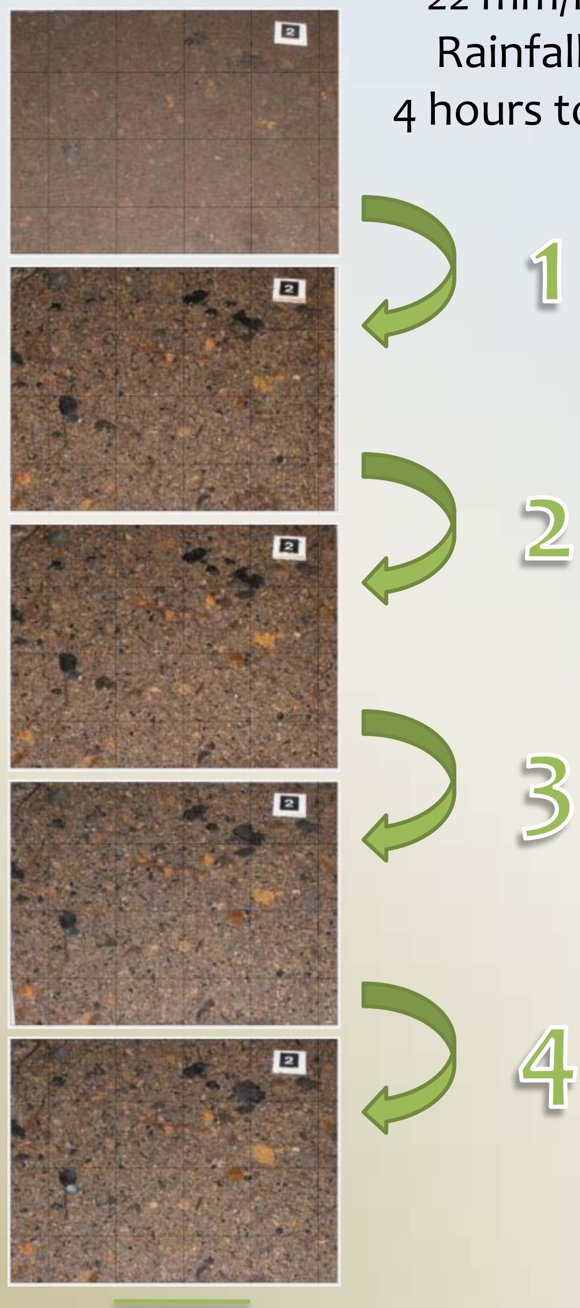
Automatic

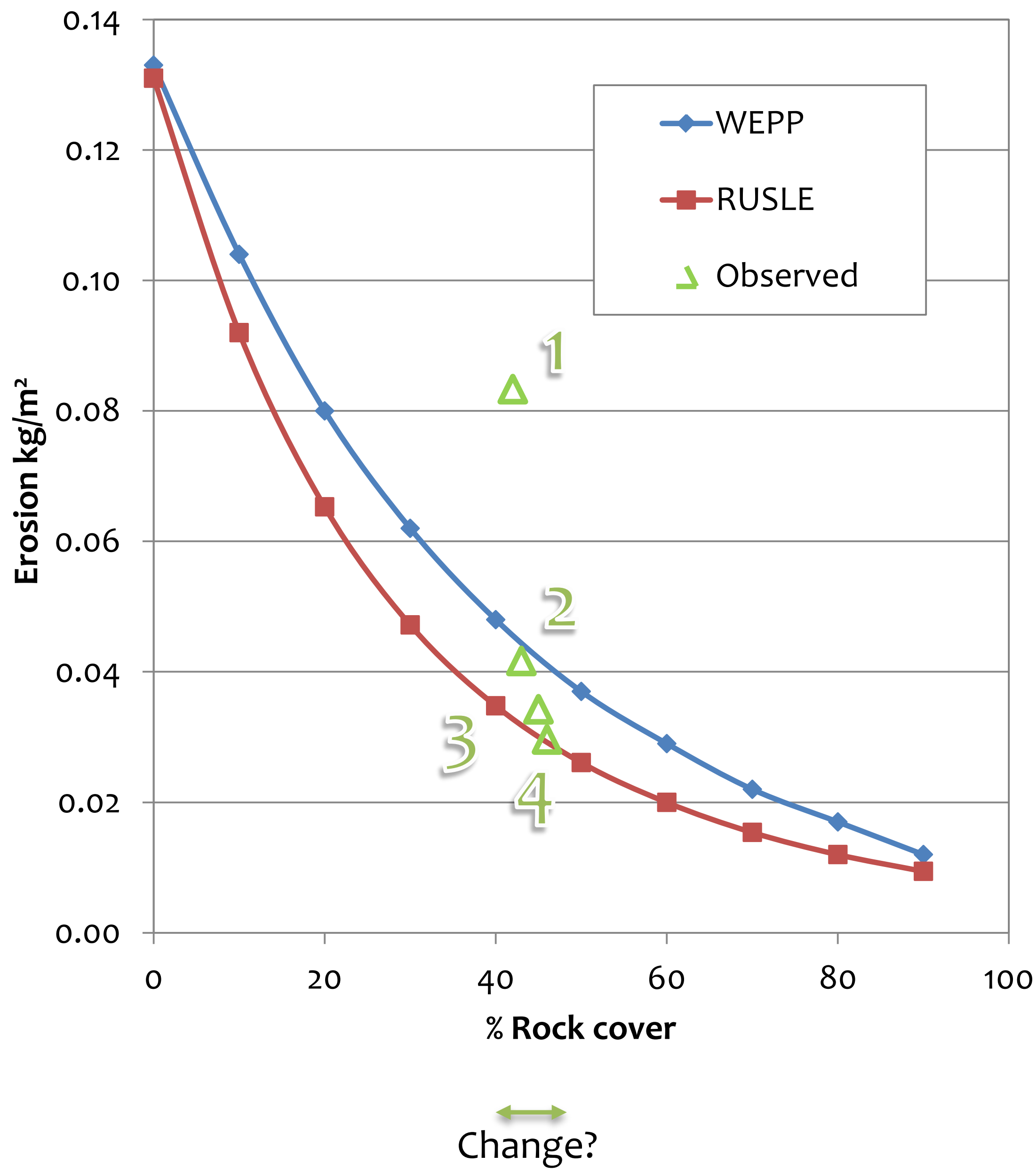
- Model internally accounts for armouring
- Needs:
  - % Rock cover
  - Mass cover
- Takes care of disturbances to armouring layer
- Requires code changes

Manual modeling

40% rock

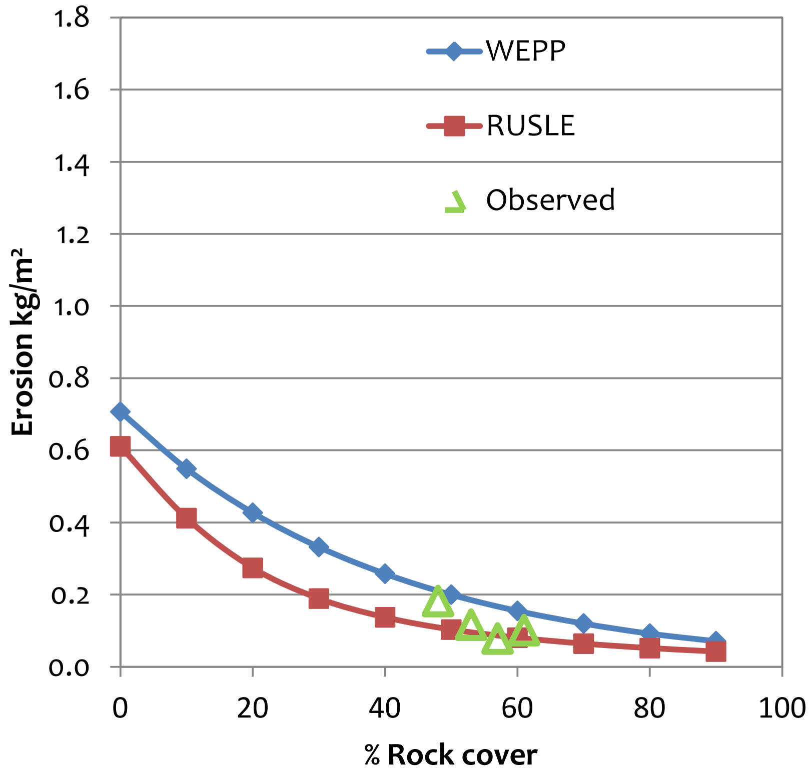
22 mm/hr
Rainfall
4 hours total



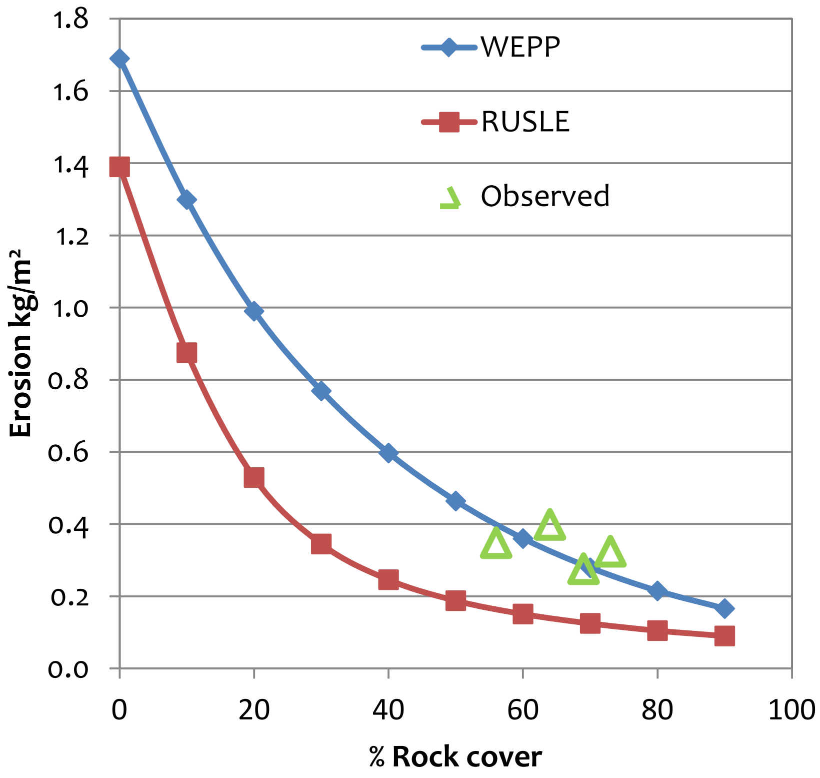


Additional experiments

45 mm/hr



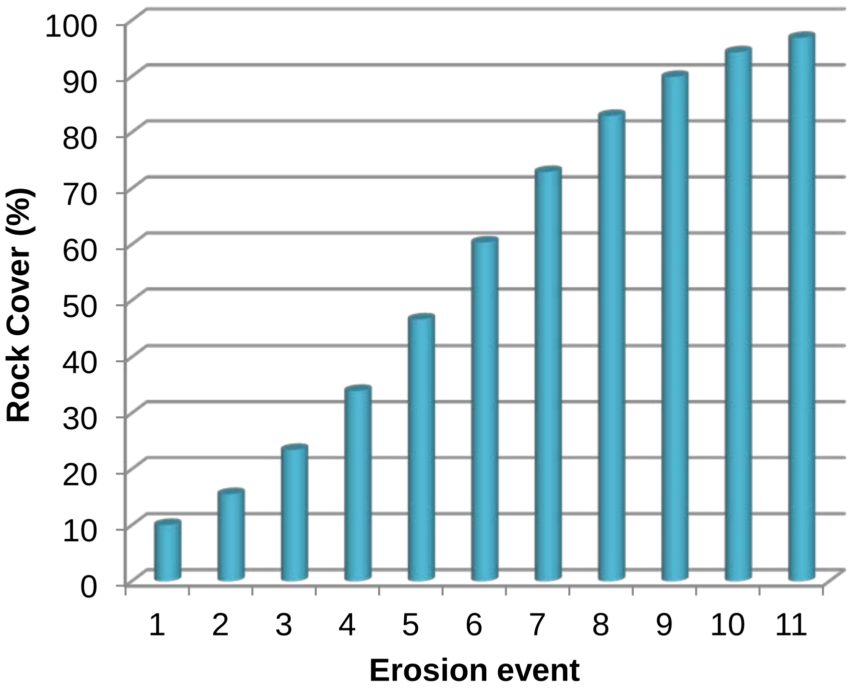
66 mm/hr

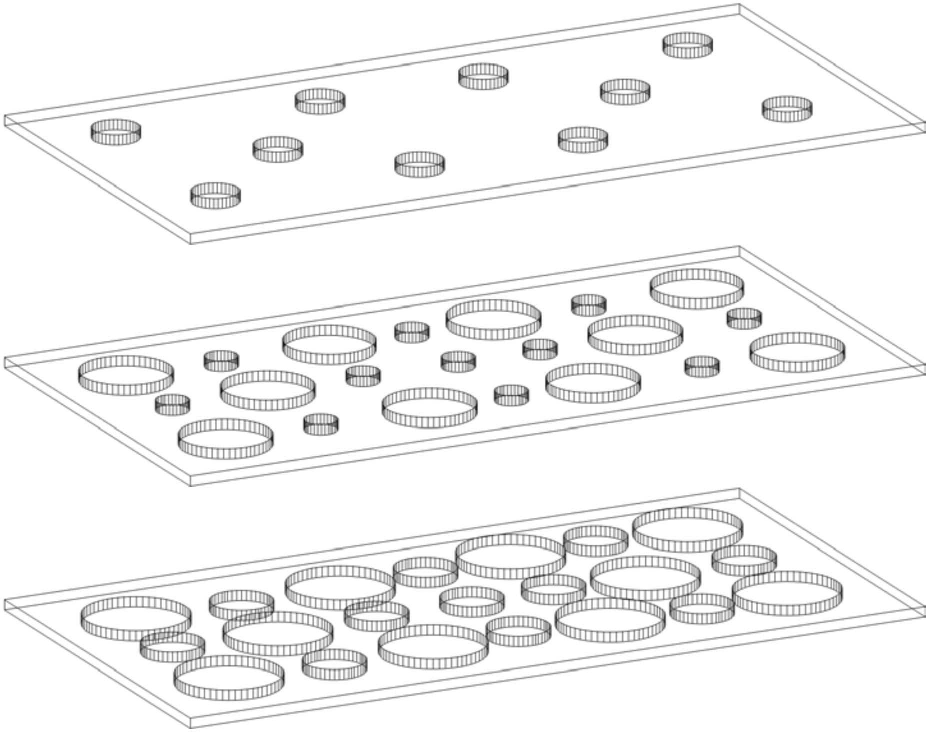


Proposed automatic modeling with RUSLE

Main Inputs	• Current rock cover (RC_o) - what is found just after the first rainfall following a coverage disturbance event • Rock cover mass (MC_0) - what you would have if you pick up all rock from the surface
Assumption 1	• MC can be calculated from rock size distribution – rock particles represented as sphere/cubes to simplify calculations
Assumption 2	• The mass fraction of rock in any soil "slice" is the same as the percent cover times the density ratio [$\rho_{rock}/\rho_{soil} \approx$ 2.65g/cc / 1.35g/cc $\approx$ 2]
Assumption 3	• The mass-cover relationship for rock cover has the same shape as the residue mass-cover relationship: $RC = 100\,[\,1 - \exp(-a * MC)]$
Assumption 4	• The same value of "*a*" used for all of the soil "slices"

Exposure of rock cover





RC_o = 10%
MC_o = 1 kg/m²
Erosion/event = 3 kg/m² (exaggerated)

What RUSLE already does and doesn't do with rock cover

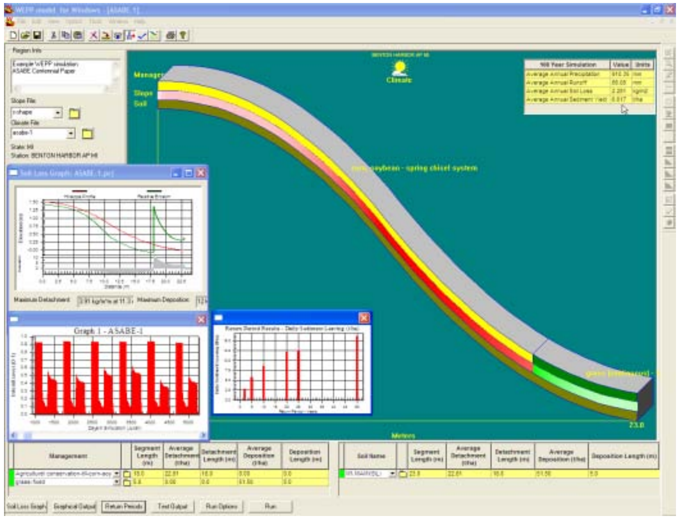
- already correctly calculates how the rock and other surface covers overlap
- already accounts for the conformance of rock to the surface
- **does not** account for the impact of soil-disturbing operations on the soil-based rock cover, but
  - does for [gravel-rock] mulch applied to the surface
  - a burial fraction and a resurfacing fraction for gravel-rock calculated for each operation
  - running the soil-based rock through the same routines as added rock would automatically take care of partial tillage and other operations.

Issues to address – re: Disturbance

- Burial and resurfacing values for current operations for rock are about the same as for the more fragile residues
  - 20% for a ridge-till planter
  - 90% for a straight chisel
- After each disturbance operation, RC should approach the initial RC_o value, rather than zero.

Automatic modeling with WEPP

- Similar approach as RUSLE: rock cover
- Already accounts for %rock content in soil
- Change in soil roughness with armouring
- Code changes required



Future work

- Verification studies
  - Field plots
  - Disturbance of armouring layer
    - Concentrated flows - rills
    - Rainfall patterns, hail, snow
    - Mechanical disturbance
- Movement of particles larger than 2 mm in steep slopes
- Coding 

  - Include automatic armouring
  - Erosion of larger particles in steep slopes?

Questions?