The impact of woody vegetation on fluvial erosion

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BIOLOGICAL SYSTEMS ENGINEERING, VIRGINIA TECH

For the next 30 minutes…

- Where I'm coming from
- Vocabulary
- Prior research
- Recent research
- Summary

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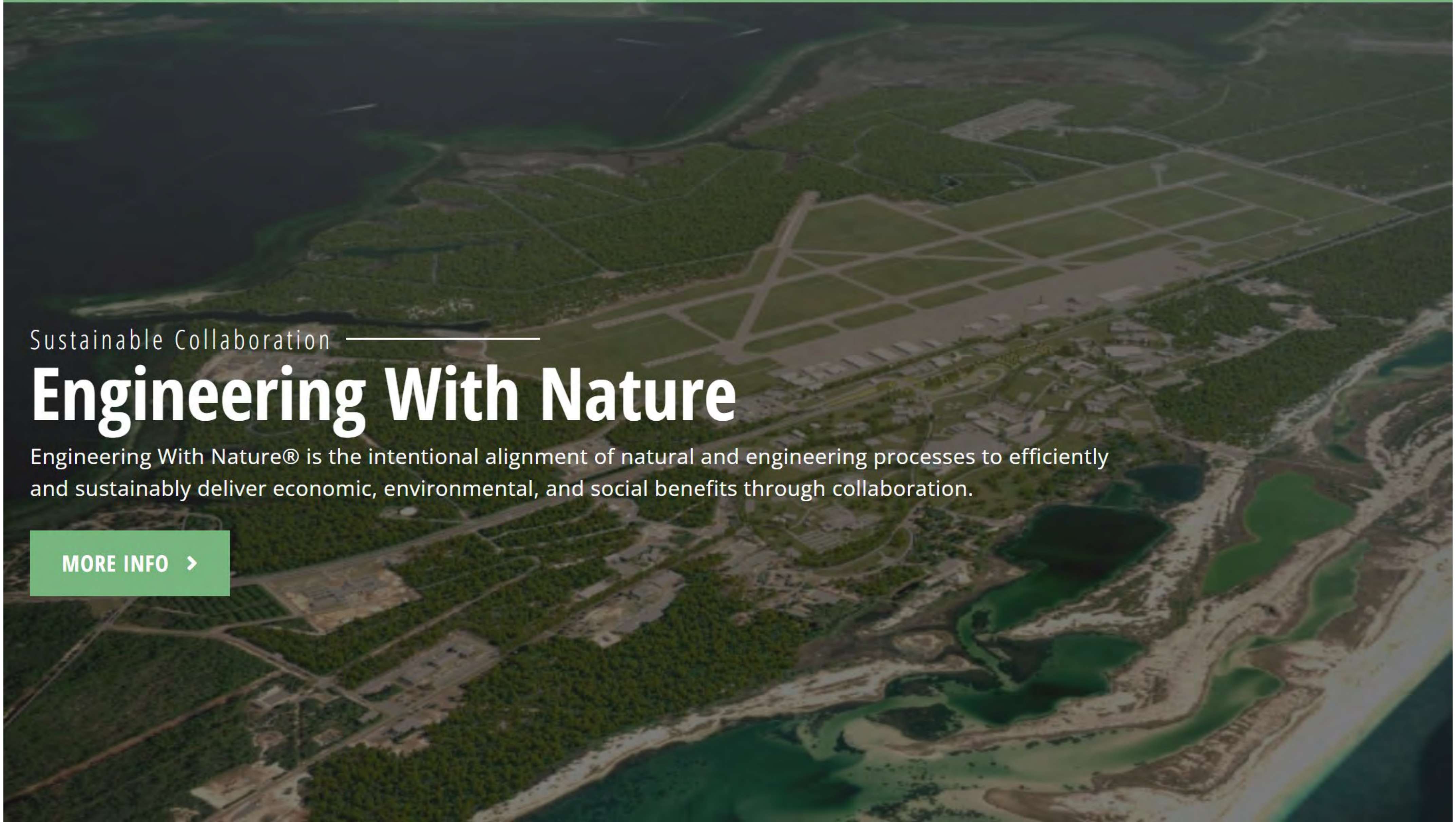

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The difficulty lies not so much with developing new ideas as in escaping from old ones.

John Maynard Keynes

Soil
Water
Vegetation

Stream Restoration

1. Fluvial erosion of cohesive streambanks
2. Roots and fluvial erosion
3. Vegetation and boundary shear stress

Wetland Restoration

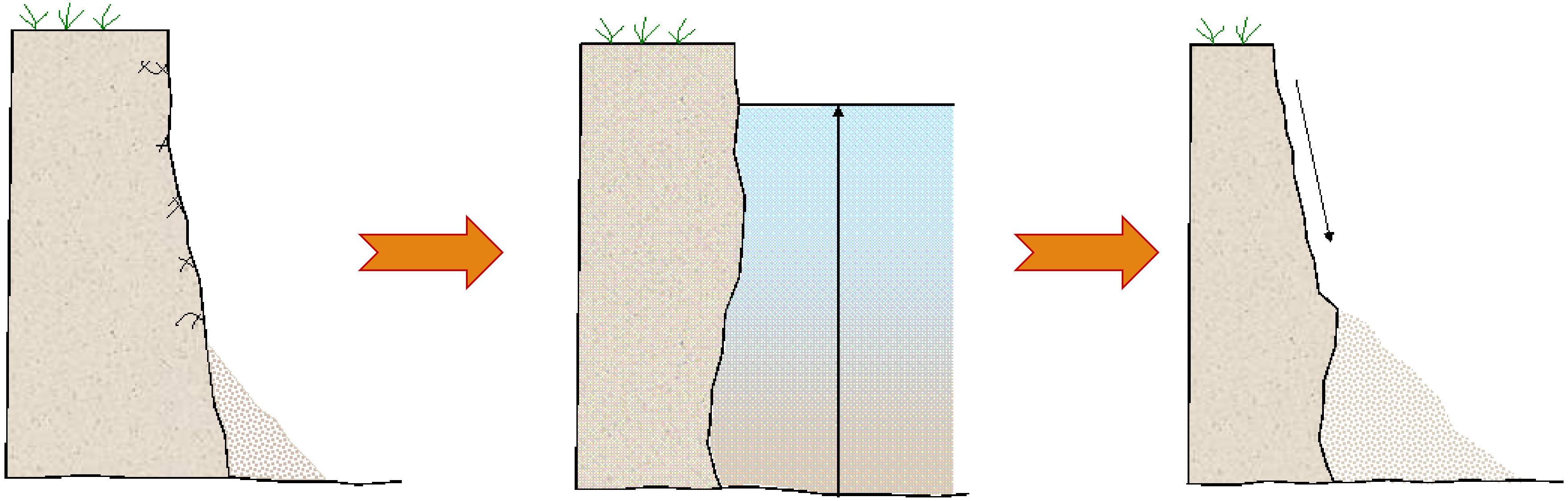
1. Flow resistance due to wetland vegetation
2. Wetland water balances
3. Wetland ET

How does bank erosion occur?

Subaerial Processes/Erosion

Fluvial Entrainment/ Erosion

Bank Failure



Freeze-thaw and wet-dry cycling weaken soil

Soil entrained during high flows

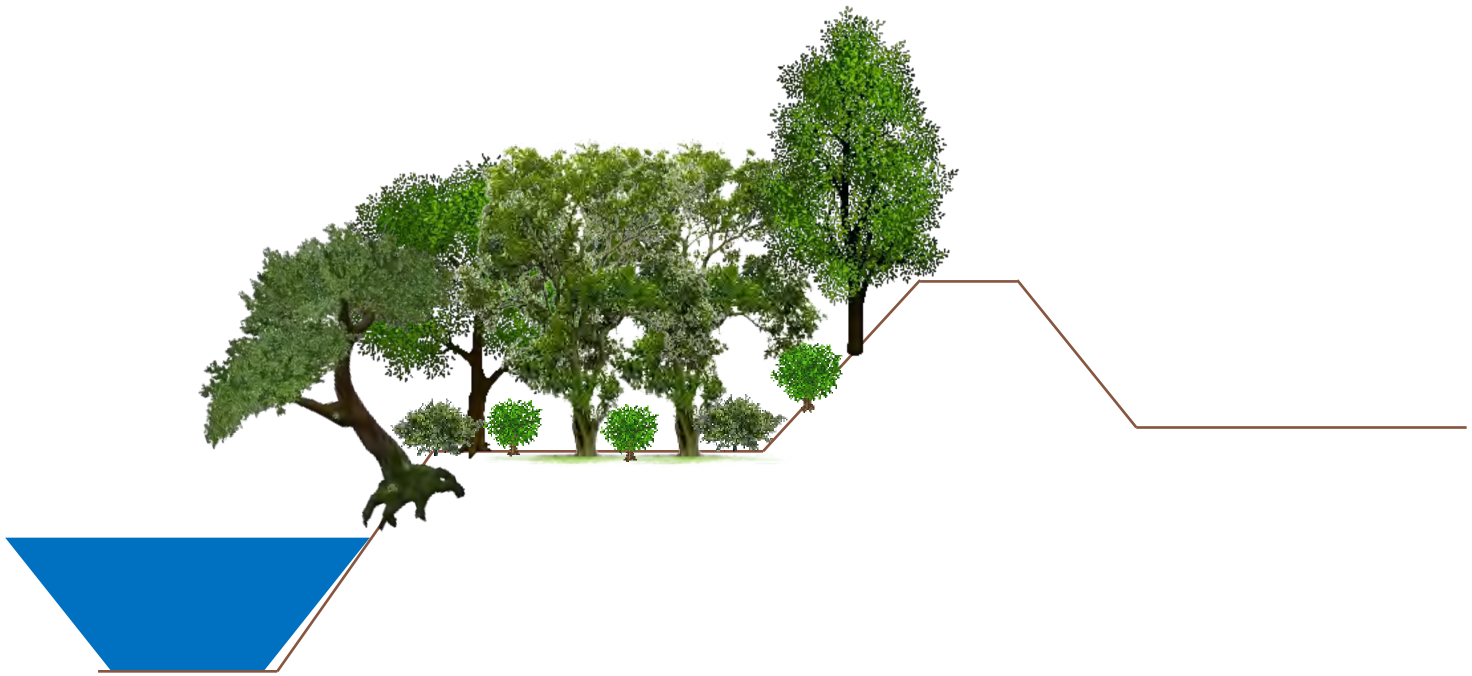
Mass failure from slope instability

The excess shear stress equation models fluvial erosion rate

$$E_r = K_d(\tau - \tau_c)^a$$

E_r = Erosion rate (L/T)
K_d = Erodibility coefficient ($L^2 \cdot T/M$)
τ = Actual shear stress ($M/L \cdot T^2$)
τ_c = Critical shear stress ($M/L \cdot T^2$)
a = Exponent, assumed equal to 1

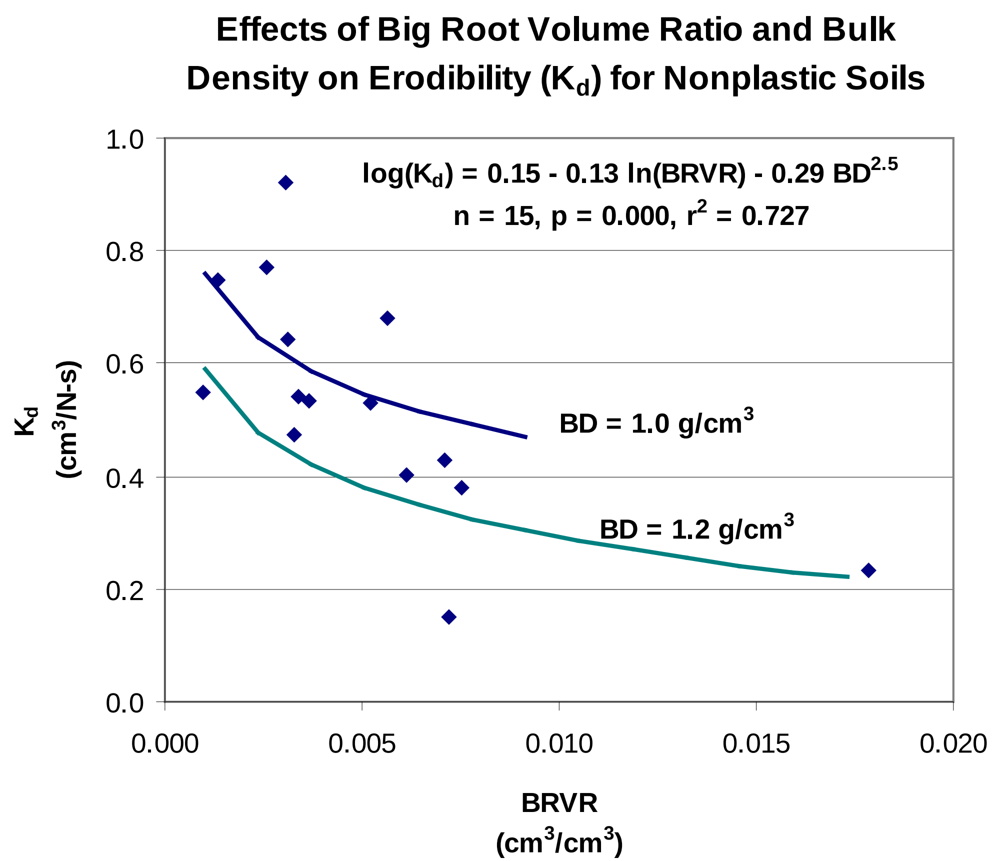
My vision of woody vegetation on levees

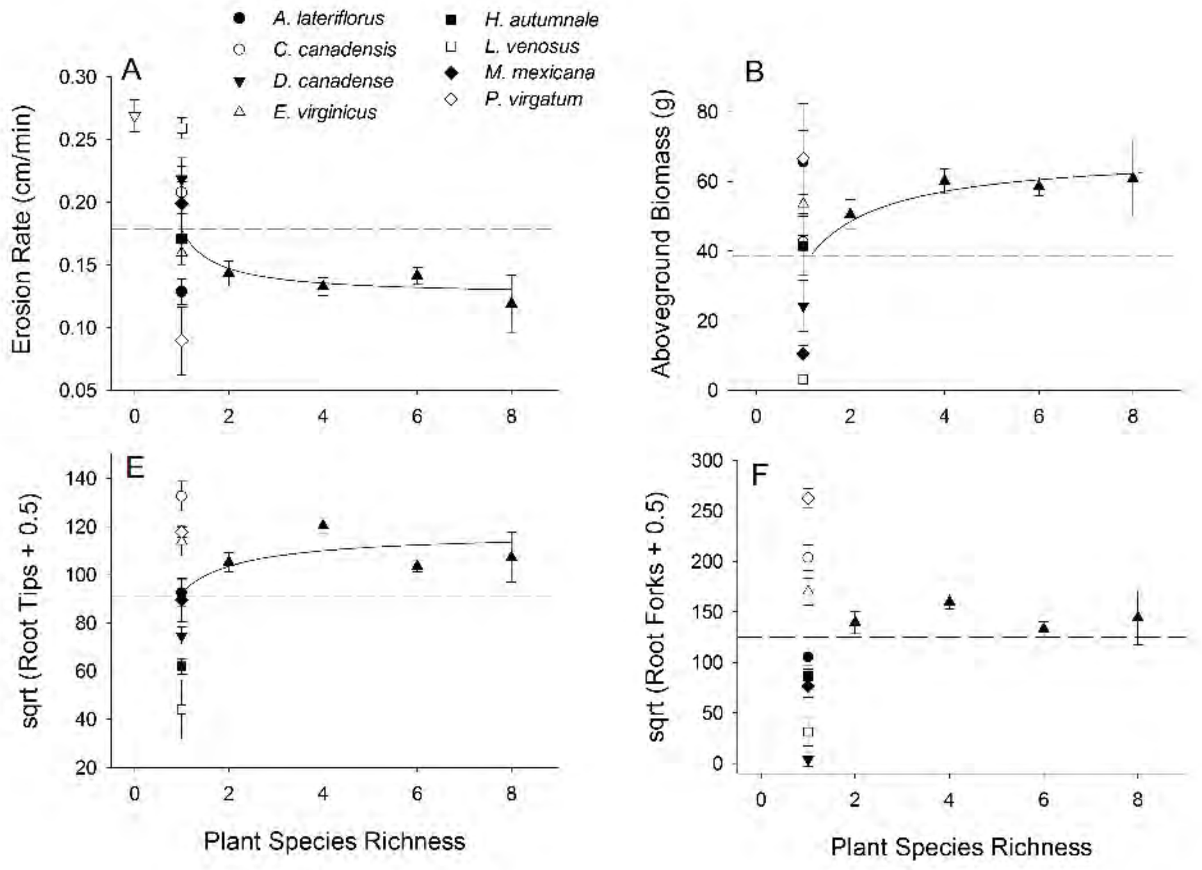


http://clipart-library.com/free/tree-with-transparent-background.html

Results from prior research

Roots in soils reduce fluvial erosion





Wynn, T. M. and S. Mostaghimi. 2006. The effects of vegetation and soil type on streambank erosion, southwestern Virginia, USA. *JAWRA* 42(1):69-82.

Allen, D.C., B.J. Cardinale, and T.M. Wynn-Thompson. 2016. Plant biodiversity effects in reducing fluvial erosion are limited to low species diversity. *Ecology* 97(1): 17-24. doi: 10.1890/15-0800.1

Results from recent research

Do Roots Bind Soil?

Comparing the Physical and Biological Role of Plant Roots in Streambank Fluvial Erosion

Daniel J. Smith, PhD

How do plant roots influence streambank soil erosion rates?

1. Physical binding of soil
2. Impact of root fibers on near-bank velocity and turbulent stress

3. Stimulating soil microbes through organic carbon inputs

A recirculating flume was modified to allow for erosion and hydrodynamics testing in a streambank setting

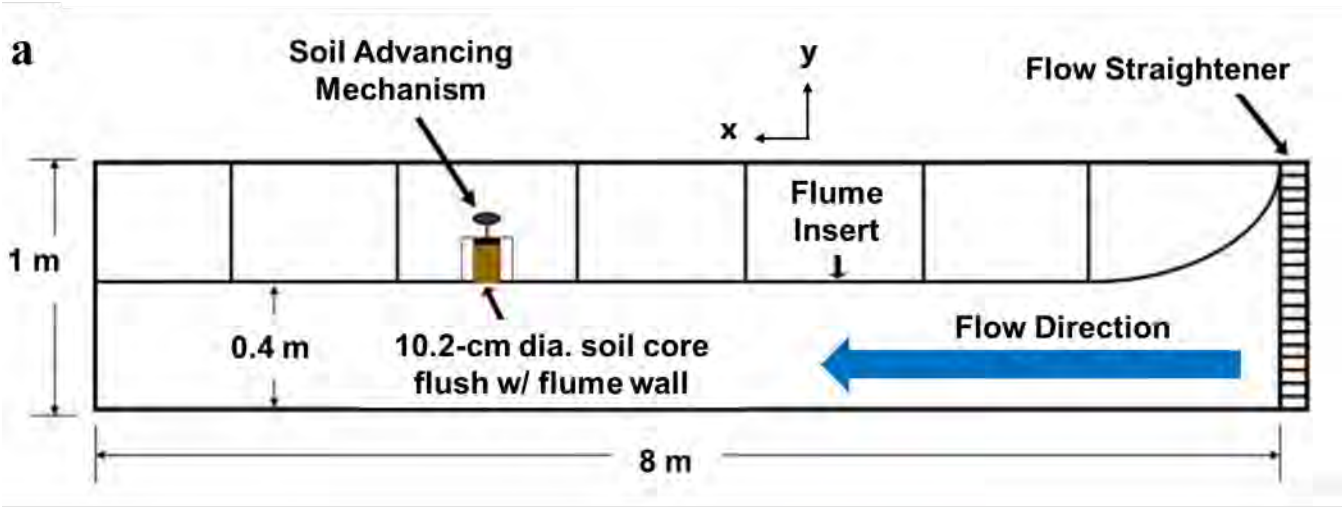
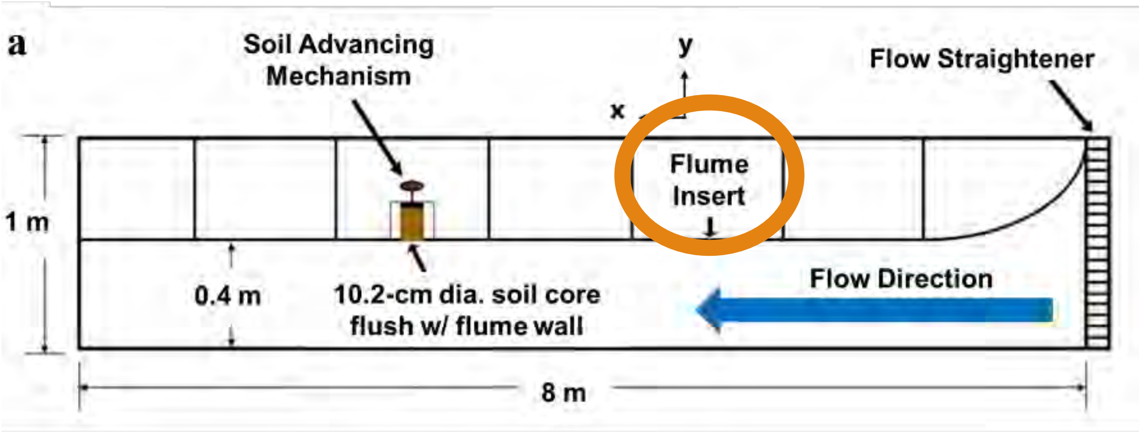


Photo Credit: Riley DeHority

Inserts simulating three different streambank conditions were constructed

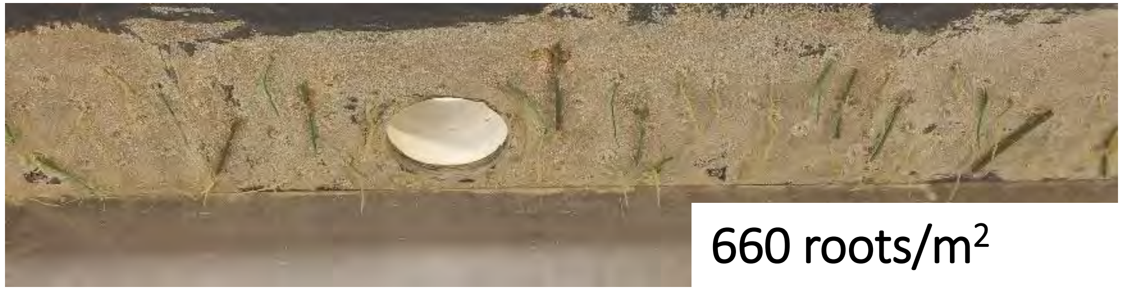


Sand Wall (Unvegetated)

Flexible Root Wall (Herbaceous Vegetation)

5500 roots/m^2

Rigid Root Wall (Woody Vegetation)



660 roots/m^2

Why would roots increase near-bank turbulent stress?

A function of vegetation volume per unit volume

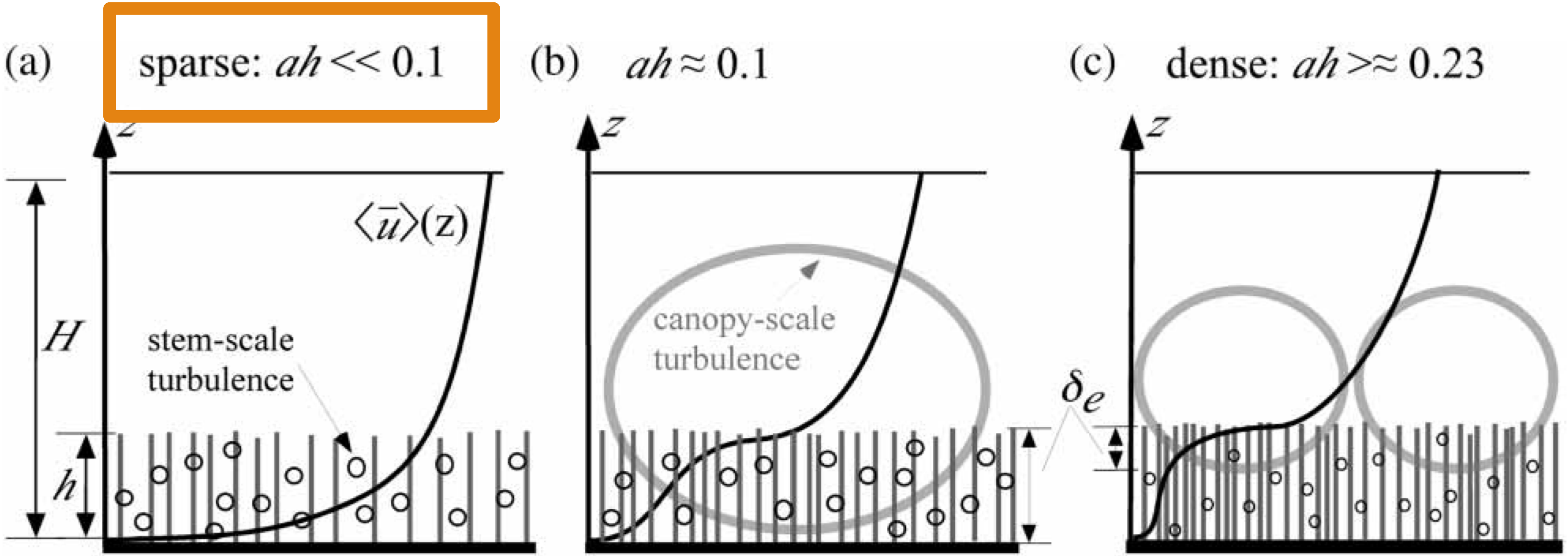


Figure modified from Nepf 2012

3D velocity data and distance to bank surface were measured via a Vectrino II Acoustic Doppler Profiler (ADP)

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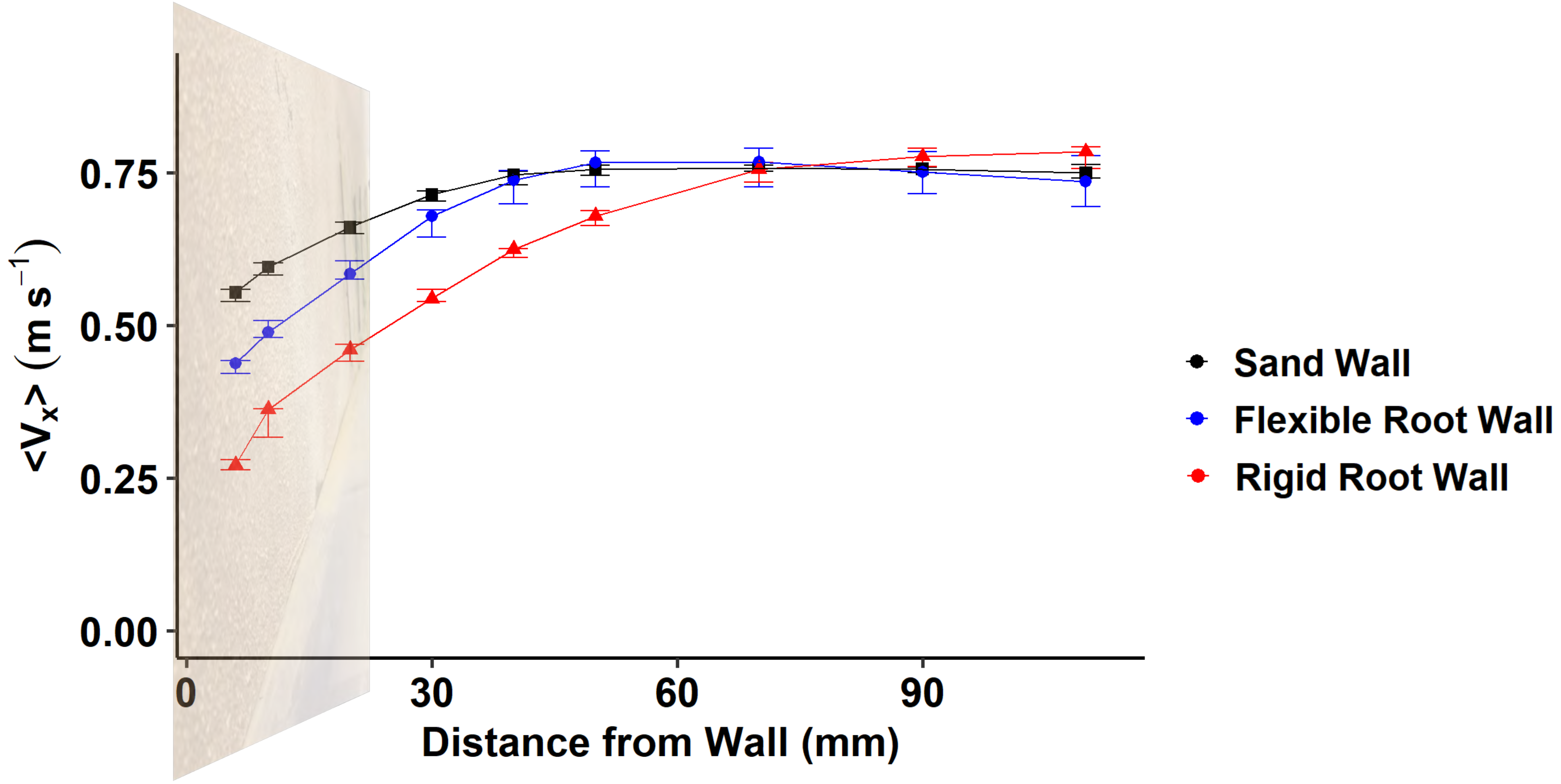
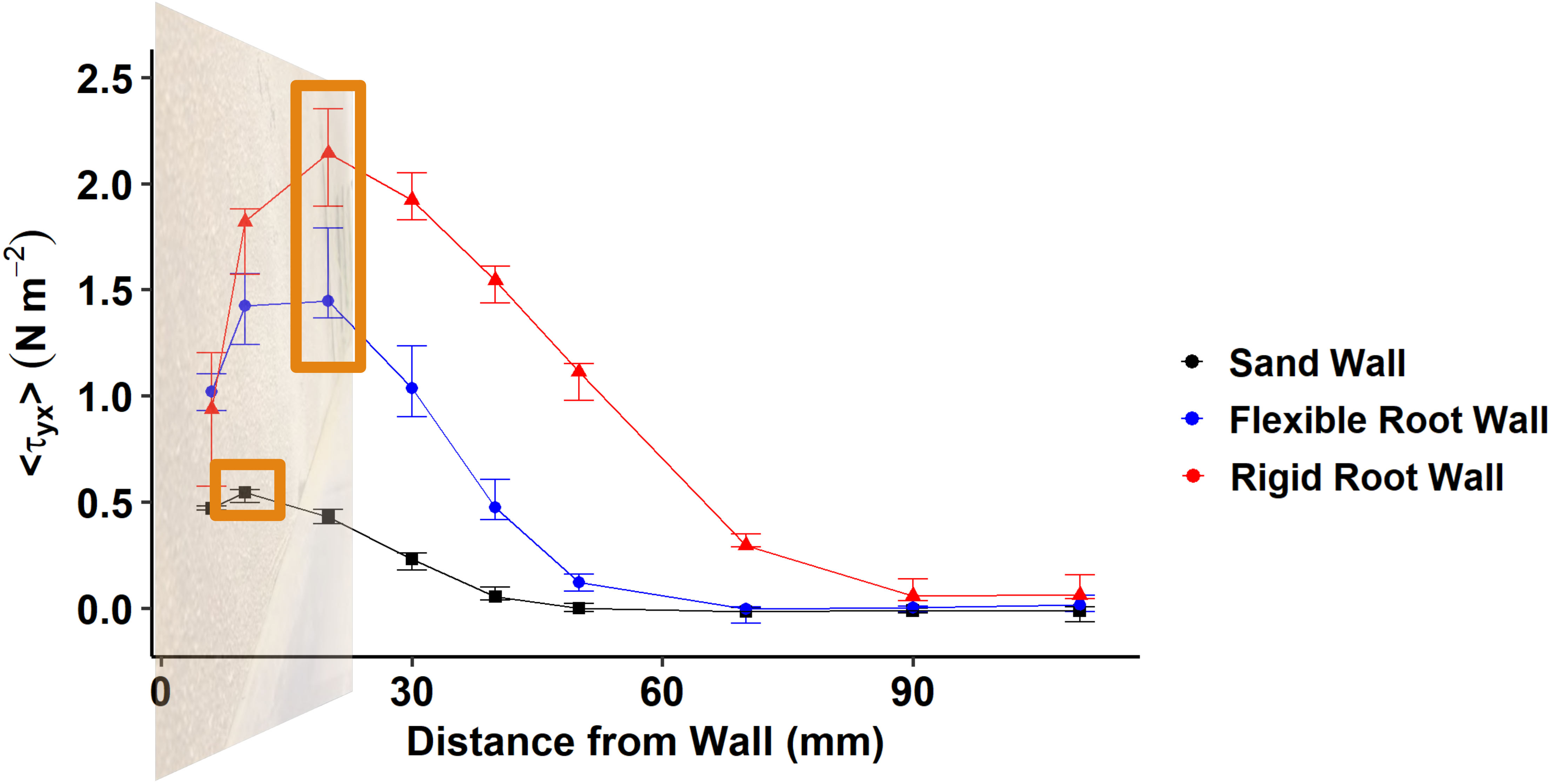
Biological Systems Engineering

The near-bank velocity along the rigid wall was 11% to 51% lower compared to the sand wall



Max near-bank turbulent stress was ~4x higher for the rigid wall compared to the sand wall



Erosion testing was also done on bare soil samples using each of the wall types

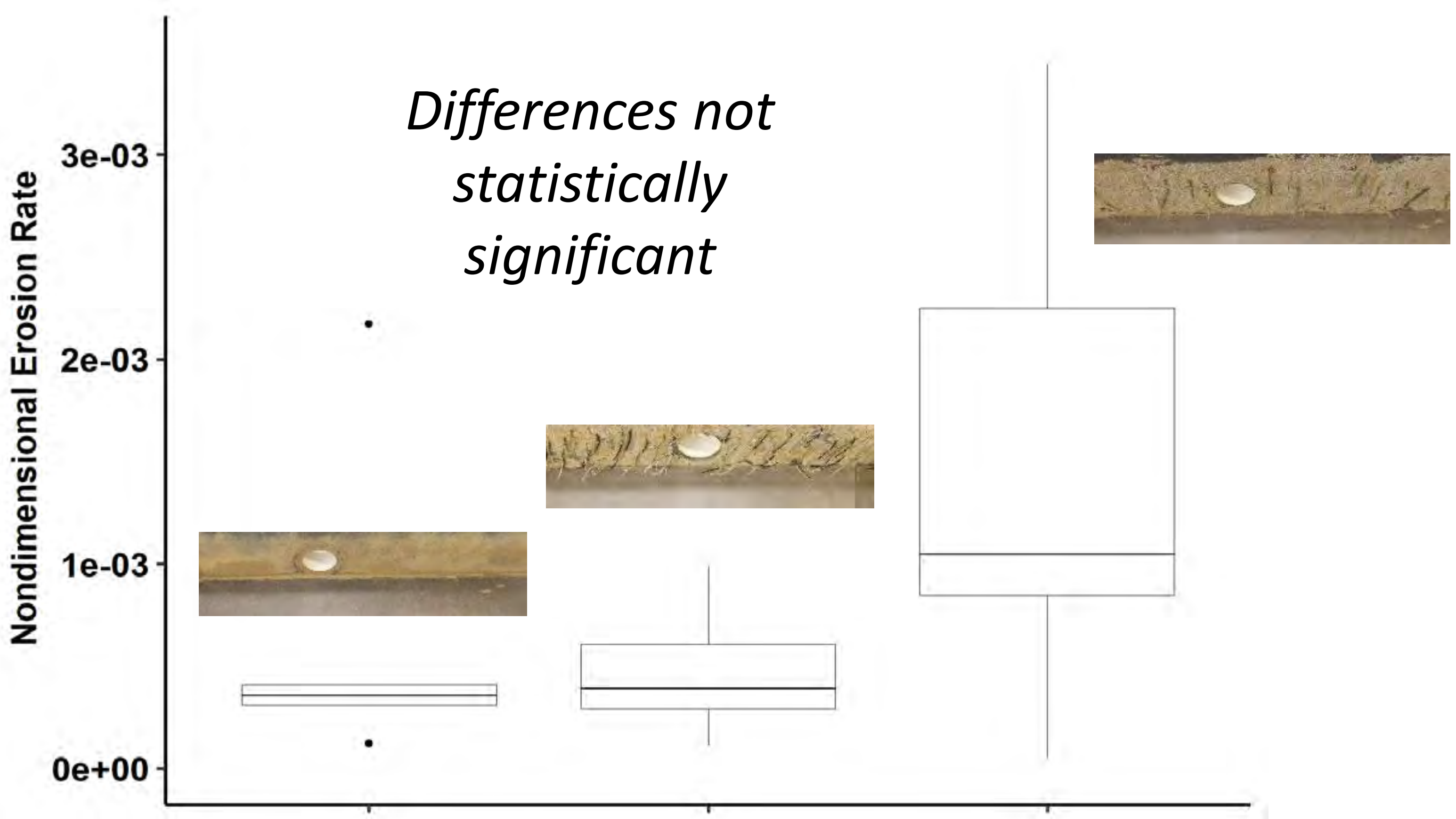
Sand Wall

Flexible Root Wall

Rigid Root Wall

6 samples per treatment

The rigid wall had ~3x higher soil erosion rate compared to the sand wall



Sand Wall: NR

Flexible Wall: NR

Rigid Wall: NR

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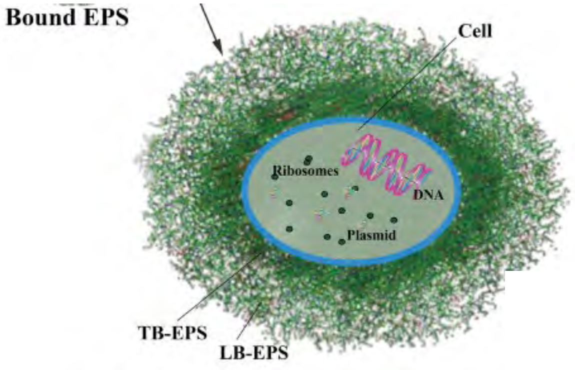
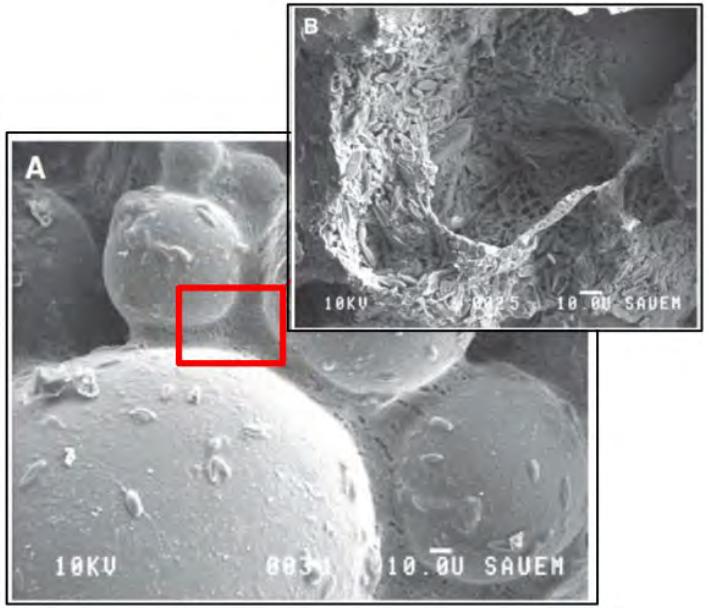
How do plant roots influence streambank soil erosion rates?

1. Physical binding of soil
2. Impact of root fibers on near-bank velocity and turbulent stress
3. Stimulating soil microbes through organic carbon inputs

Organic material is used as carbon source by soil microbes, stimulating the production of "sticky" compounds called EPS



Shi et al. (2017)



Teasdale et al (2018) and Gerbersdorf et al (2015)

EPS = "sticky" organic compounds

Biofilm = microbes + EPS

EPS is primarily composed of:

- Carbohydrates
- Proteins
- Etc.

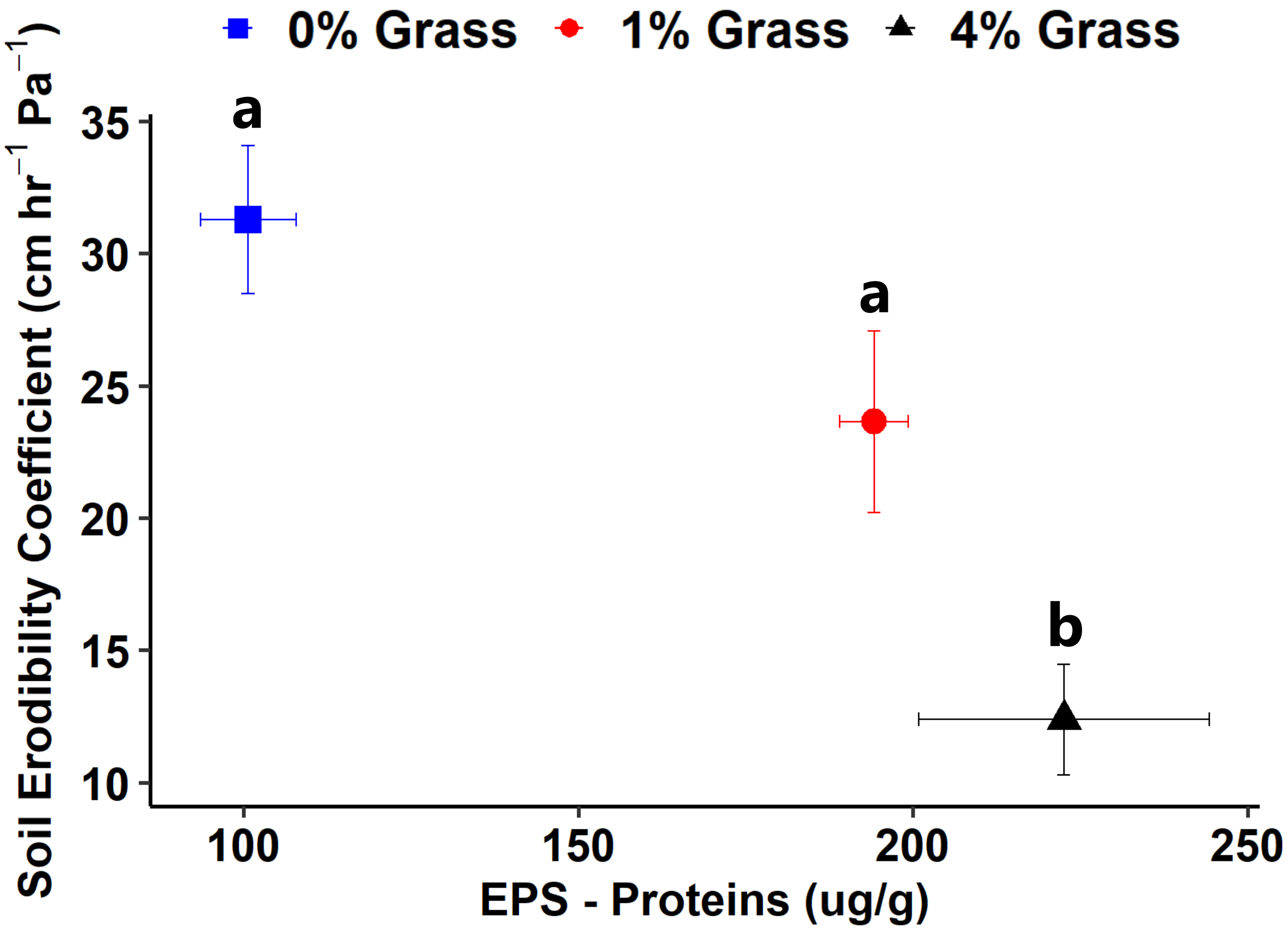
Dry and crushed grass clippings used to stimulate microbial production of EPS

0 g grass clippings

1 g grass clippings per 100 g soil (1%)

4 g grass clippings per 100 g soil (4%)

25% to 61% average reduction in soil erodibility was significantly correlated with EPS proteins



Spearman rho

rho = -0.61

$p < 0.001$

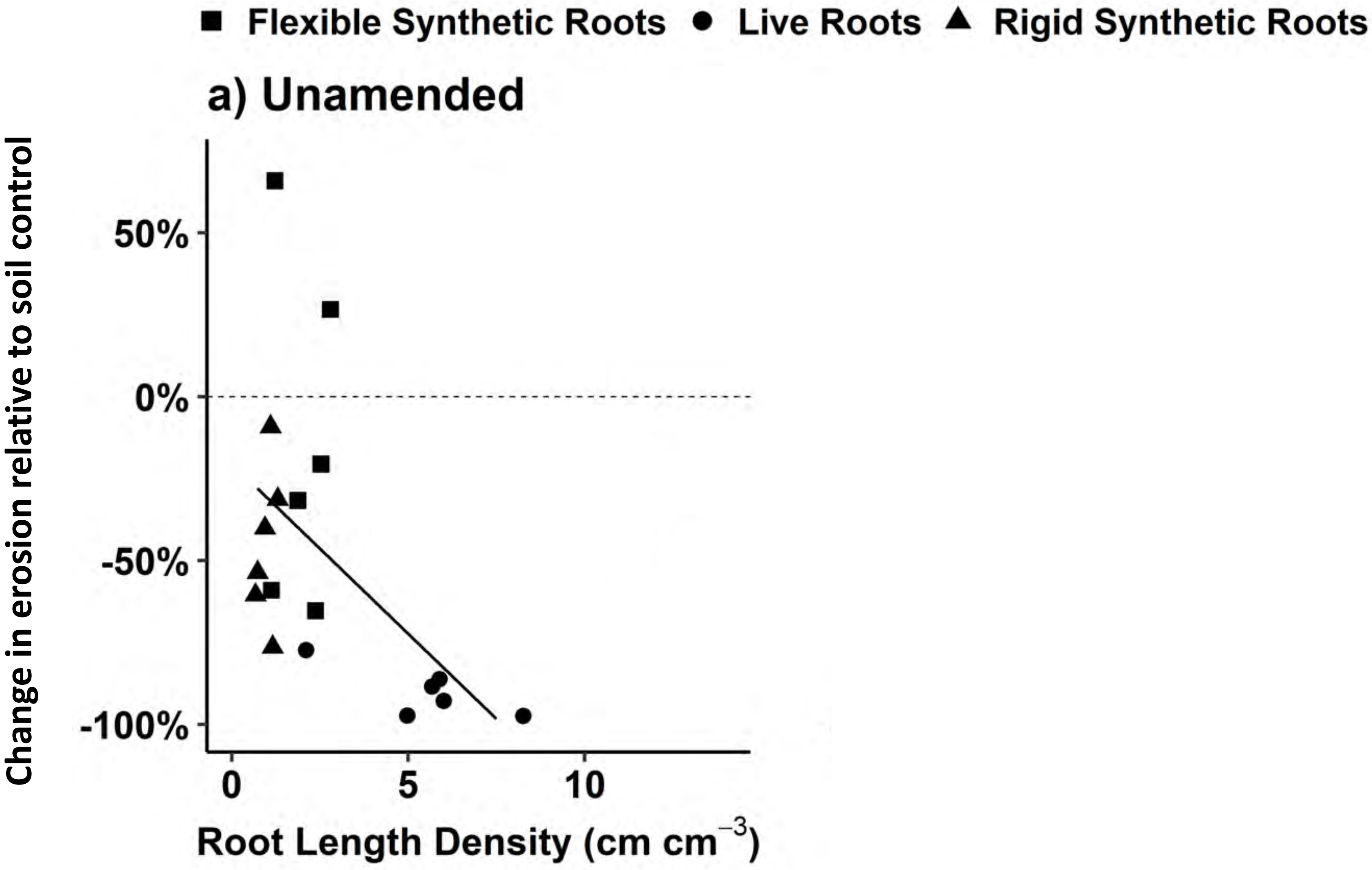
What happens when you add roots and organic matter?

	Bare soil	Flexible Synthetic Roots	Rigid Synthetic Roots	Live Roots
Unamended Soil				
Amended Soil				

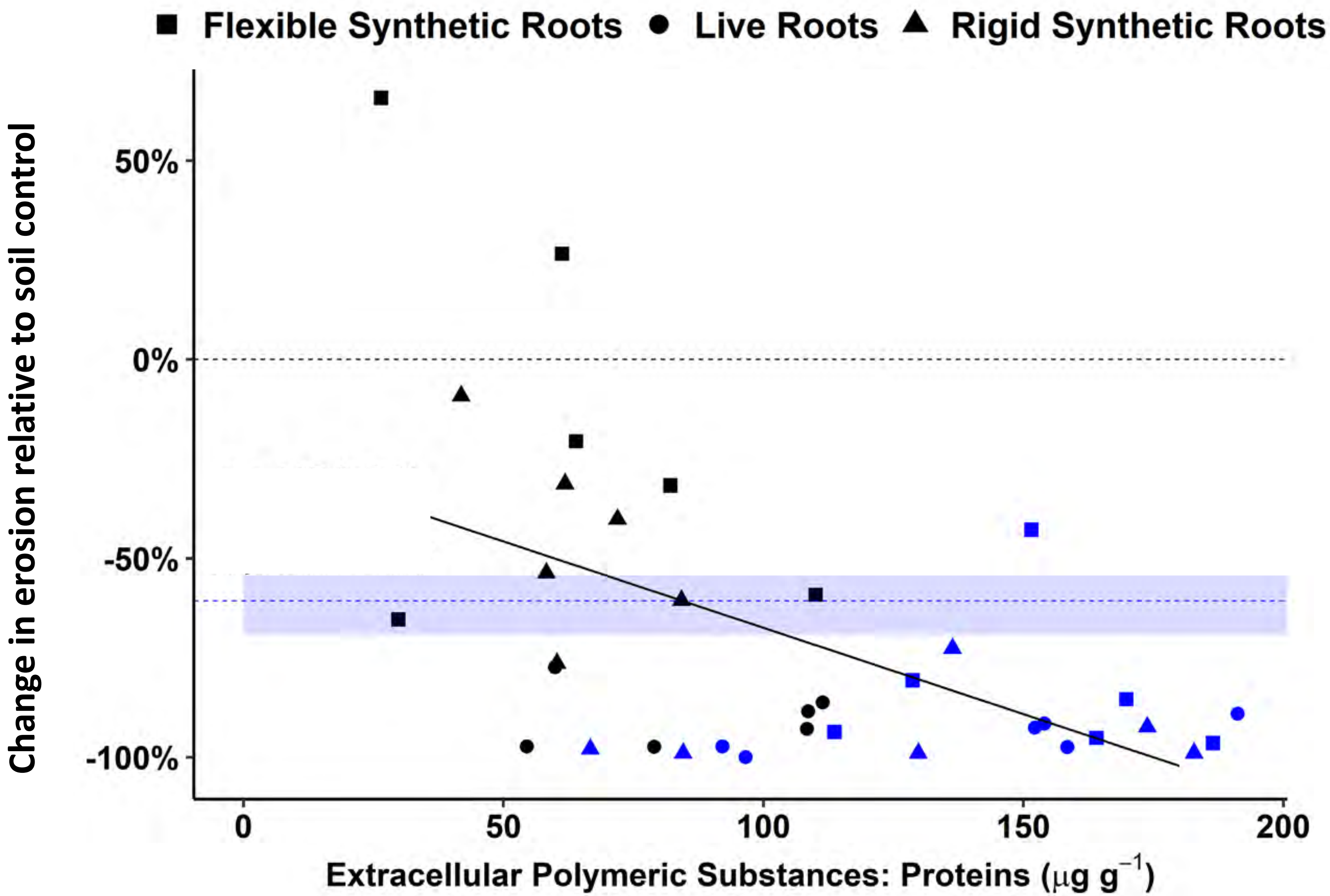




Erosion reduction by fibers + microbes comparable to live roots (90 – 98% on average)



2x increase in average EPS proteins; primary driver of higher soil resistance



Compared to bare soil:	1% Grass	4% Grass	Synthetic Roots	1% Grass + Synthetic Roots
Soil erosion rate…	25% lower	61% lower	24% to 45% lower	90% to 98% lower

Conclusion:

EPS production + synthetic root fibers = comparable reduction in erosion to vegetated soil with many roots

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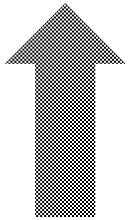
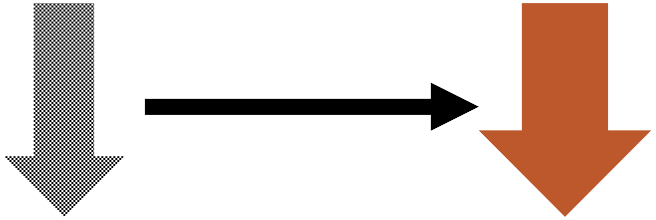
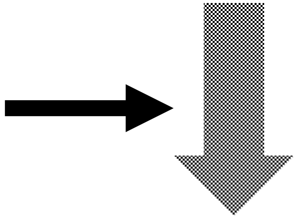
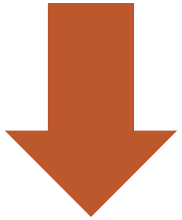
Overall conclusions	**Soil erosion rates**
Sparsely spaced rigid/larger diameter roots	
Soil microbes	
Synthetic roots	No effect to 
Synthetic roots + soil microbes	

Overall, with all mechanisms considered together, roots reduce erosion rates

Do Roots Bind Soil?

Yes!

But EPS appear to work like "webs" that stick fibers and soil together, increasing the benefit of root binding

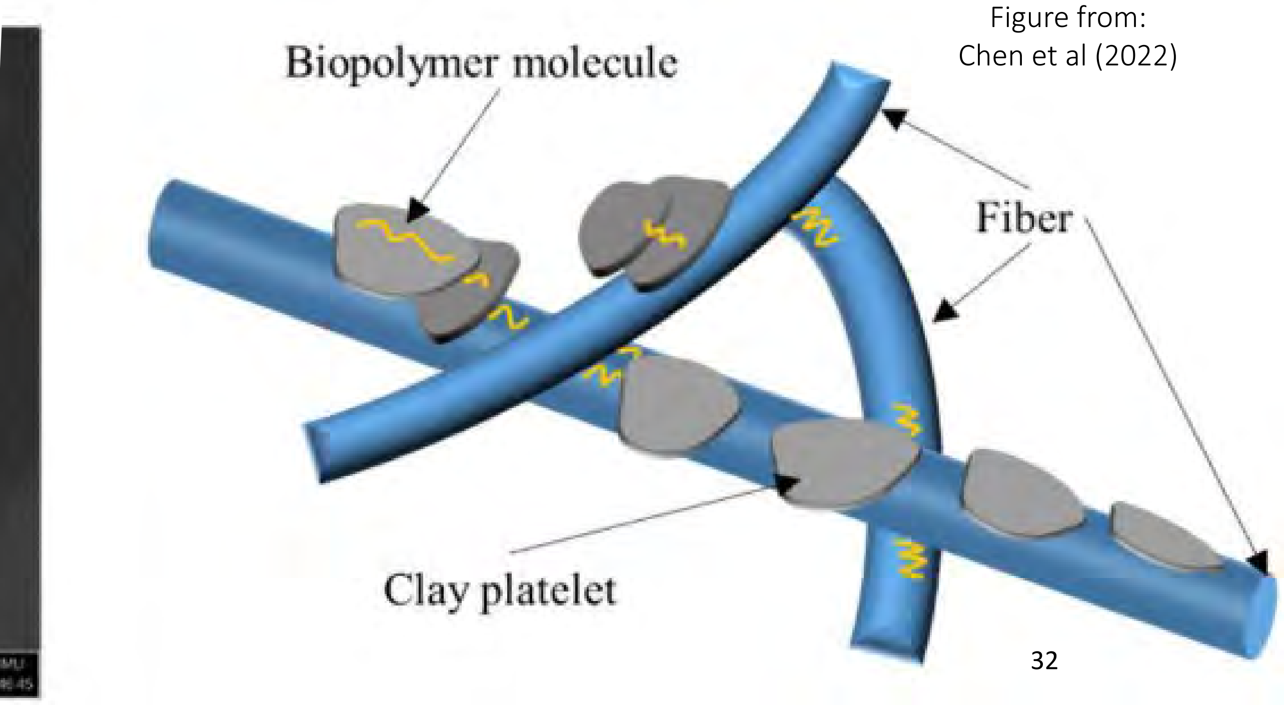


Figure from:
Chen et al (2022)


Questions?