Vegetation at the interface of ecological and engineering sciences

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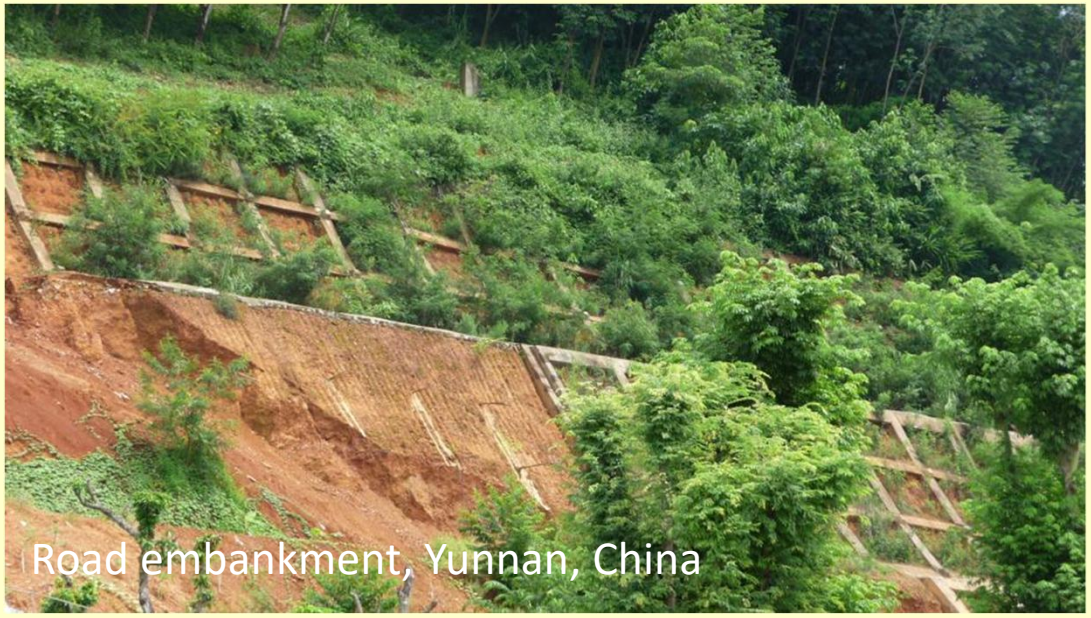
Why should there be an interface?

https://www.usatoday.com

Concrete riverbanks, Houston, USA



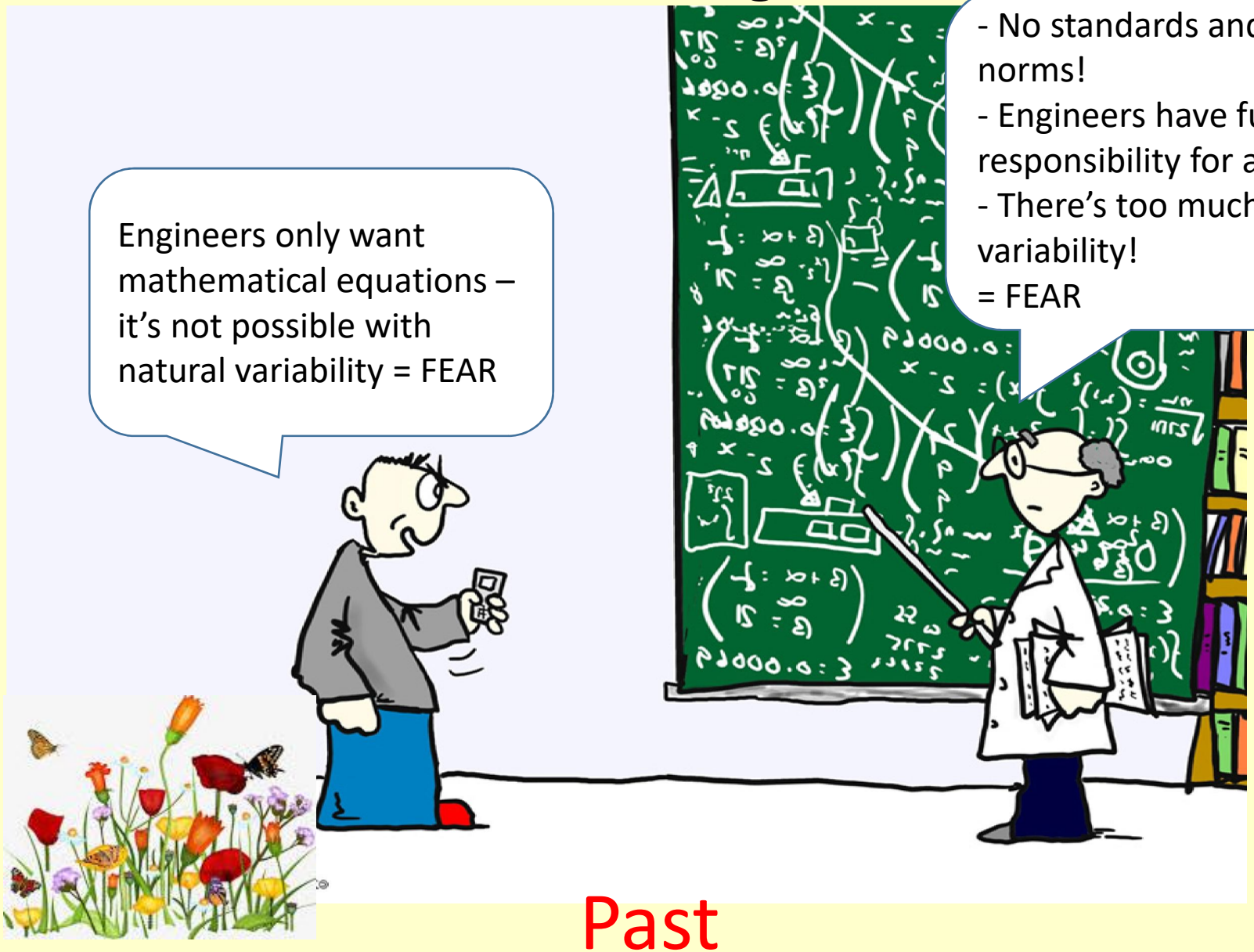
Road embankment, Yunnan, China

1000 Buddha temple, Hong Kong

- People don’t like concrete
- Because people want multifunctional landscapes
- And quite often, vegetation wins anyway…

Ecologists

Civil & Geotechnical Engineers



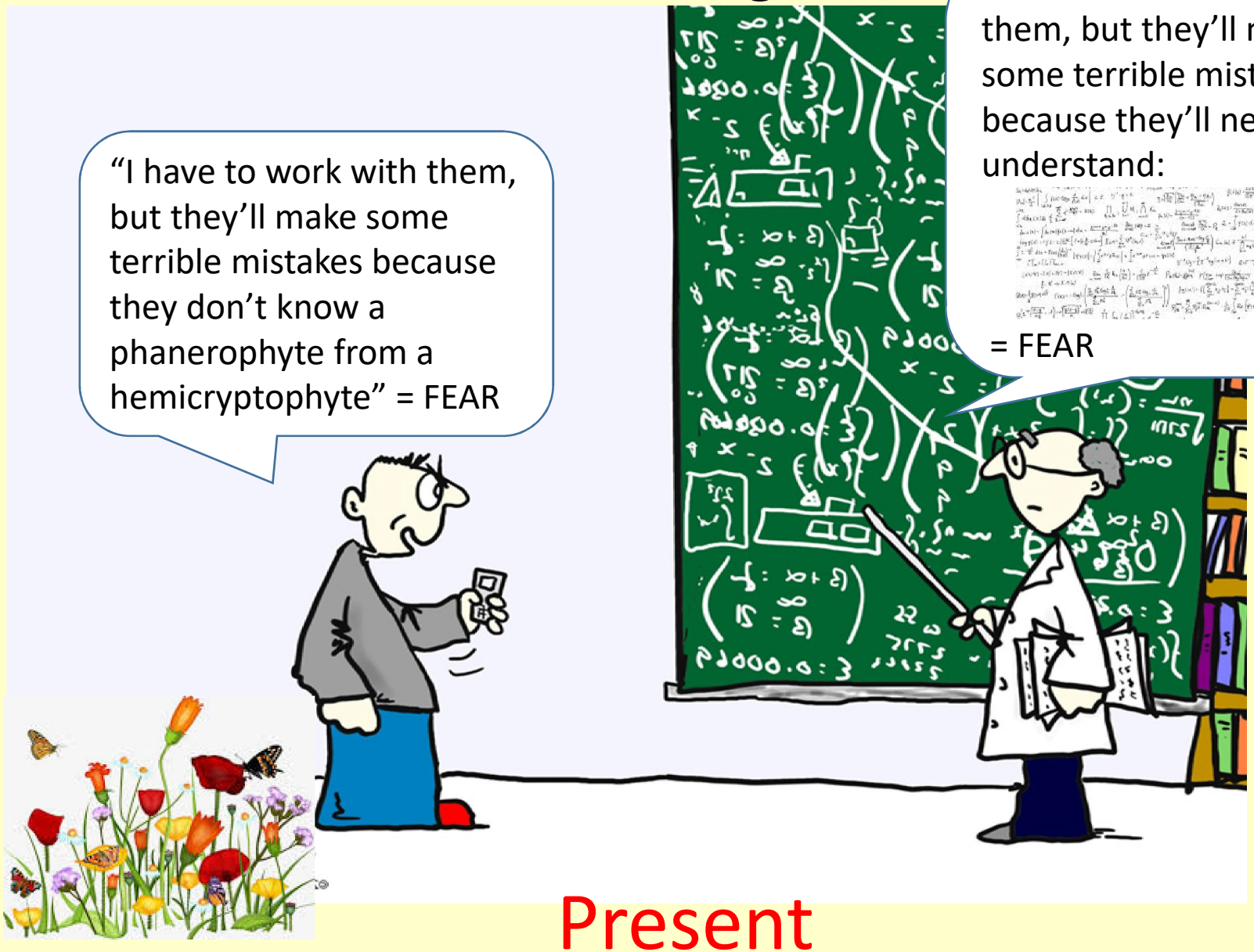
Past

>2010 Green Explosion

EC Green Infrastructure Strategy 2013

Ecologists

Civil & Geotechnical Engineers



Present

Solutions to bridge the gap between ecologists and engineers

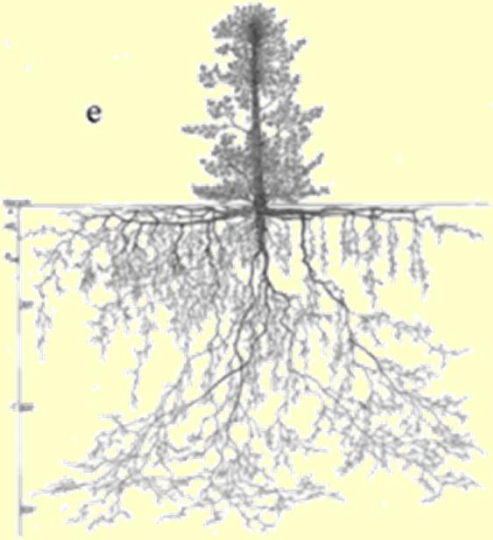
- Companies that employ ecologists and engineers to work onsite together – but full integration of ideas may be compromised due to budget/lack of knowledge/specialist training
- Training – Currently 1 full Master degree in EU, several master modules, some professional training courses
- Research projects together

Research Projects – Fundamental to Applied

A Question of Scale

Root/soil level

Plant level



L. Kutschera

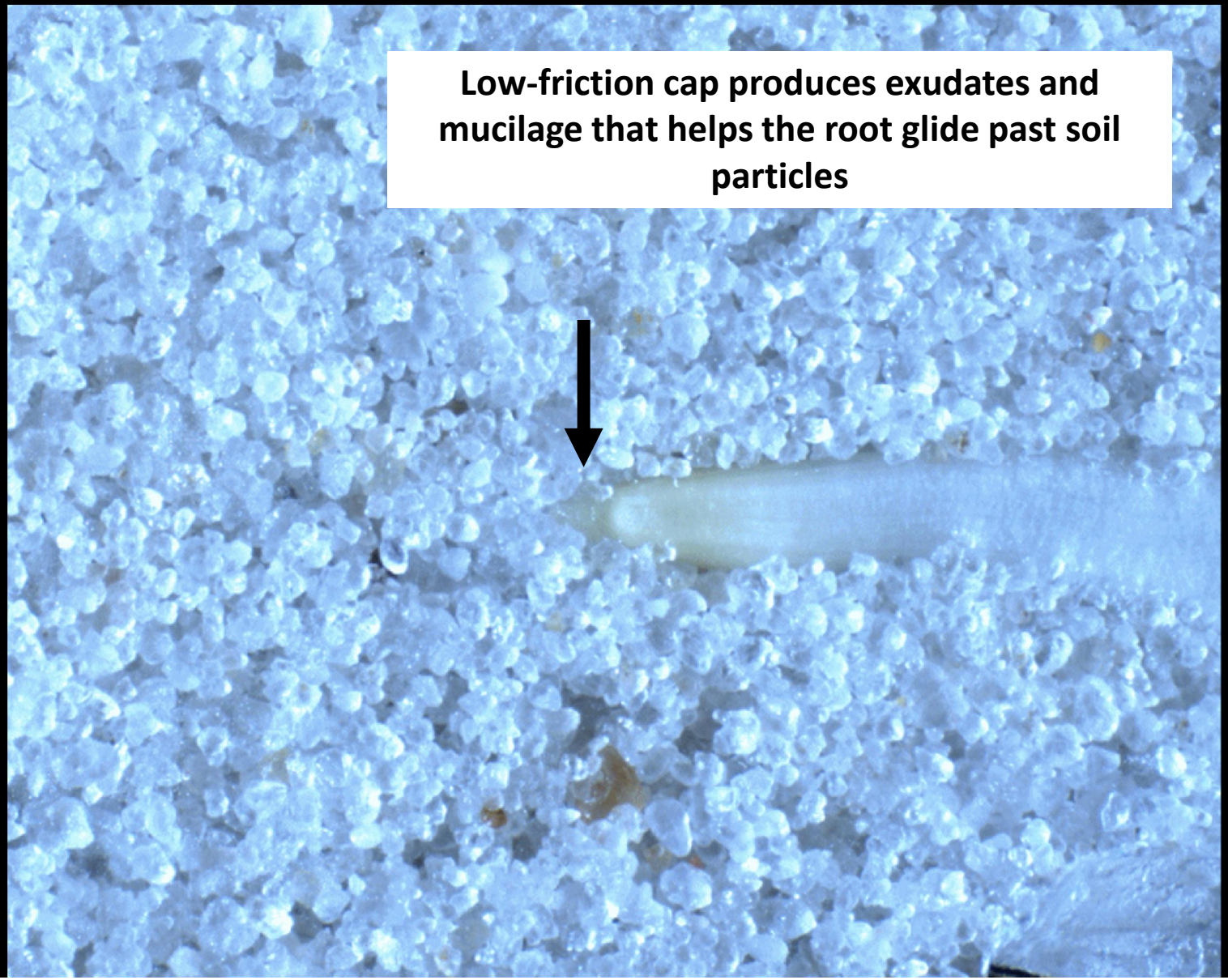
Landscape level

Root/soil level

Or, ‘how to make soil’

Erosion, desertification, soil physical stabilization, liquefaction after earthquakes

Wild type maize root in sand

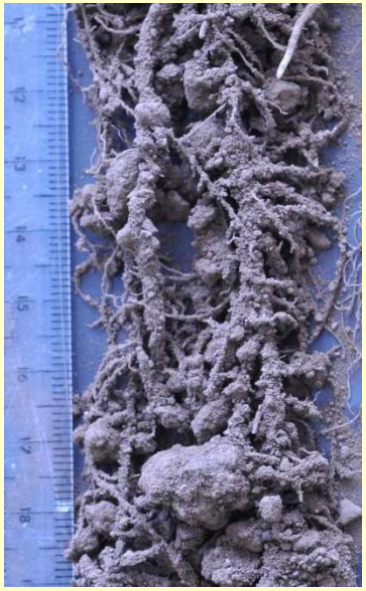


Vollsnes et al, (Eur. J. Soil Sci., 2010)

Root exudates

James Hutton Institute

Maize



Chemical compounds released from the tips of growing roots.

10-30% of photosynthetically incorporated carbon exuded by roots.

Stimulates interactions with microbial communities.

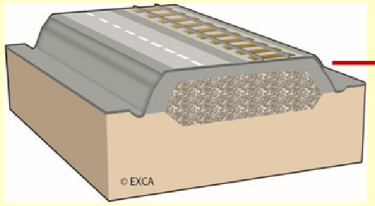
Walker TS, et al 2003. Bengough et al 2011

Lots of fundamental questions at this level…

In the making of a road embankment, how much C is transferred to the different soil fractions in topsoil and subsoil brought to the surface?

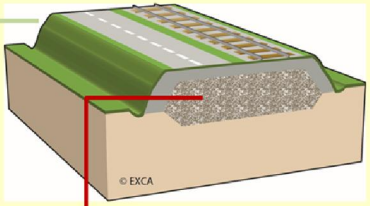
Vegetated stripped topsoil

Vegetated excavated subsoil

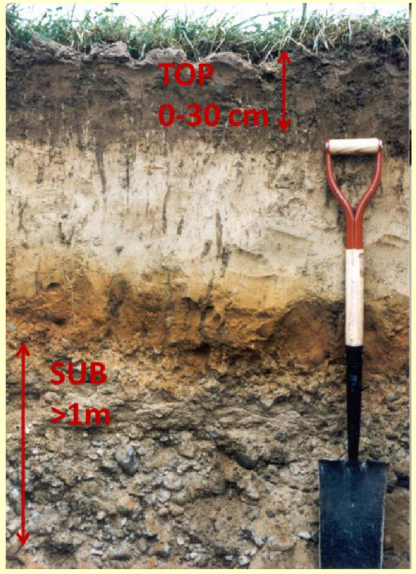


Top-soil
- Surface soil (O horizon)
- Rich in C
- High aggregates
- High microbiological activity

Mineral soil
- Deep soil (Mineral horizon)
- Poor in C
- Low aggregates and microbiological activity



PhD L. Rossi (2016 – 2019)



CO_2 enriched with 2% ^{13}C

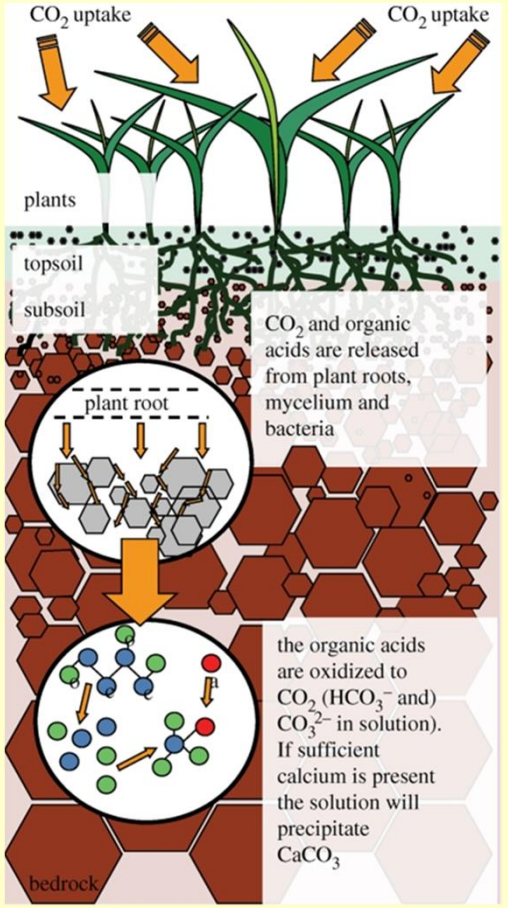
Applied questions

Civil Engineering Magazine Archive / Volume 77 Issue 4 - April 2007

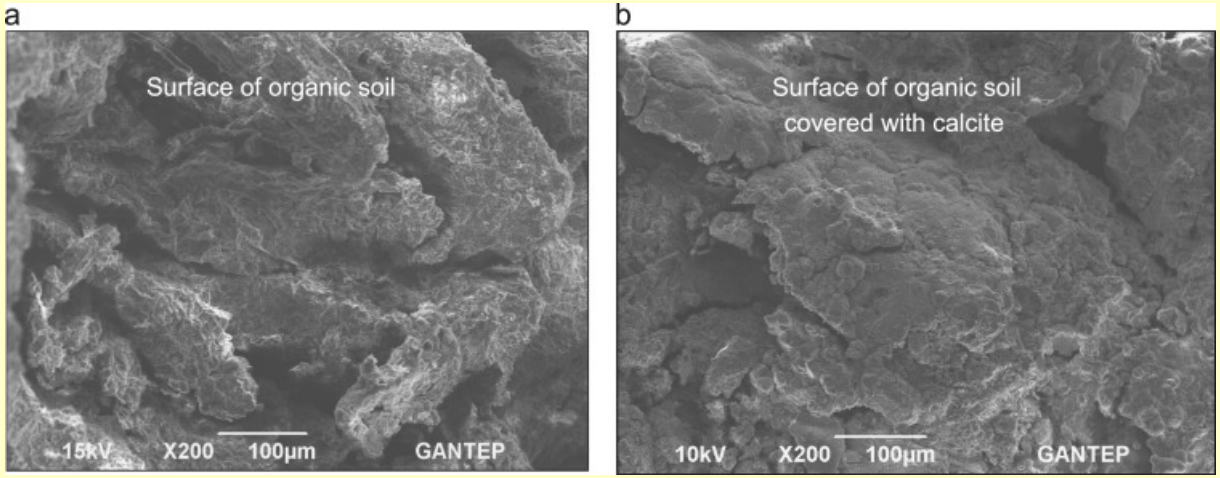
Technology

Bacteria Turn Soil into Stone

Brett Hansen



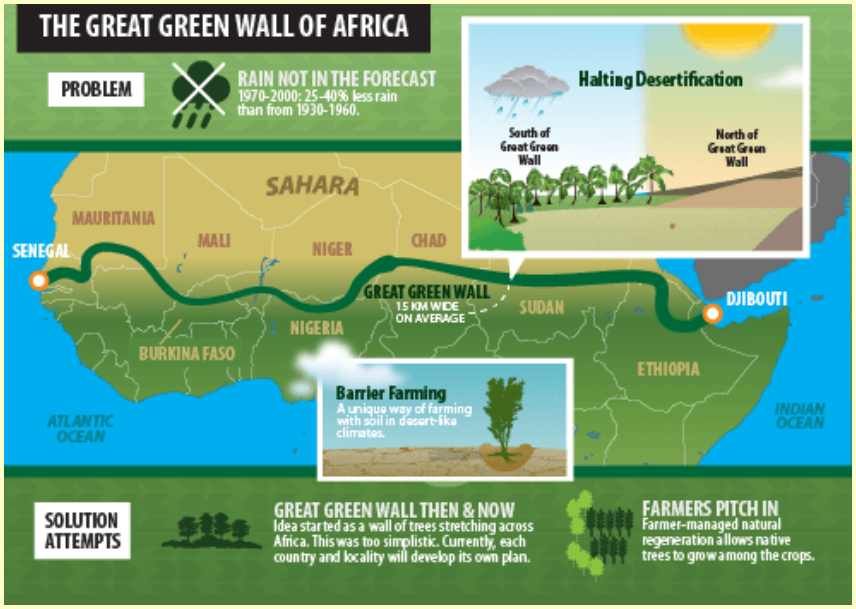
Microbial calcium carbonate induced precipitation (MICP)



SEM images of organic soil. (a) before MICP treatment and (b) after MICP treatment.
Canakci et al 2015

Microbes hydrolyze urea to produce ammonium and carbonate ions, and in the presence of calcium ions which can precipitate calcium carbonate; produce calcite which binds particles together. Natural process that takes 100s years, but 24 hours in the lab.

MICP can save the world…!?



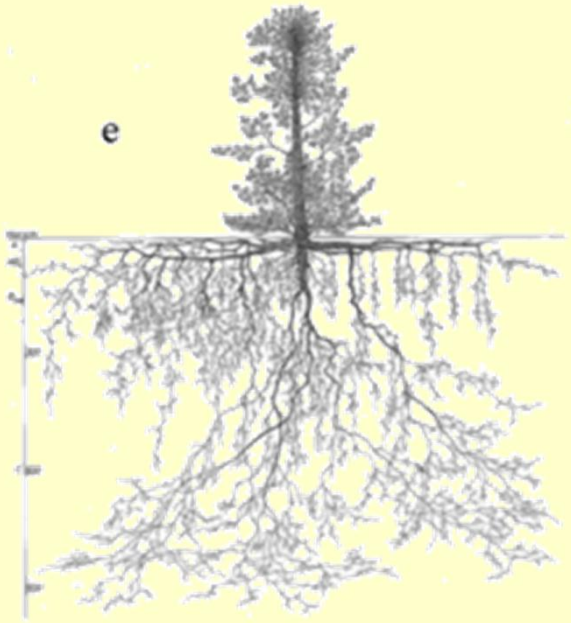
https://www.dogonews.com

http://thehigherlearning.com

MICP is ok in the lab, but large amounts of ammonia by product can form in remediation projects.
Lots of work by chemists & ecologists to test the method in the field

Zhu et al 2016

Individual plant level

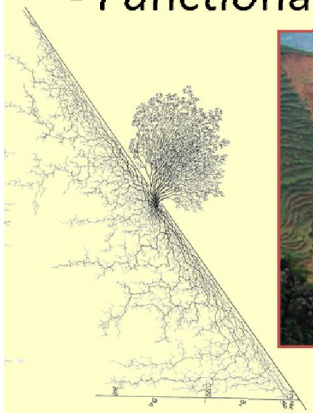


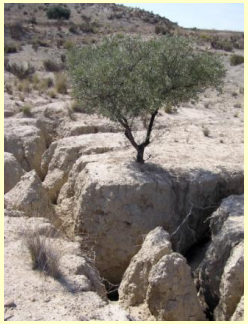
L. Kutschera

Mechanical and hydrological interactions

Slope/embankment stability, flood retention, erosion control

- Most published work performed at this level (collaborations INRA-CNRS-CIRAD-IRD-IRSTEA- University Montpellier)
- Functional trait data can be used in engineering, hydrological and erosion models





Degradation process

Traits to investigate for mitigation

Shallow landslides

Fine root density	Rooting depth	Root mechanical properties	Lateral root spread	Stem density

Superficial soil erosion

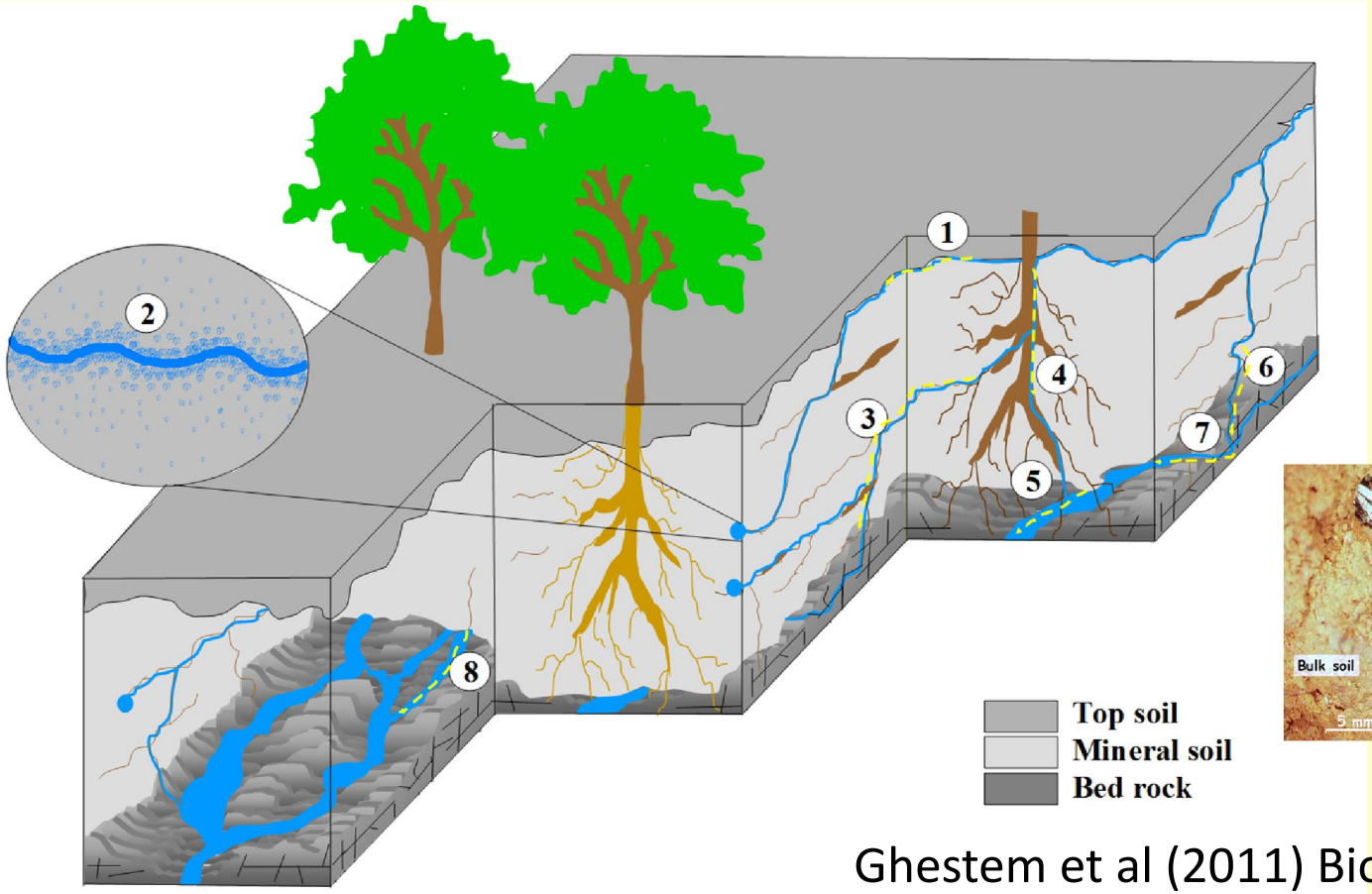
Fine root density	Stem bending stiffness	Stem density	Architecture	Debris obstruction potential

Typical engineering equation for slope stability + vegetation:

$$\frac{\sum\left[(c'+c'_v)\lambda+\left((W+W_v)\cos\propto-(u+\Delta u_v)\lambda-\left((U_2+\Delta U_{2v})-(U_1+\Delta U_{1v})\right)\sin\propto-D_w\sin(\alpha-\beta)+T\sin\theta\right)\tan\phi'\right]}{\sum\left[(W+W_v)\sin\propto+D_w\cos(\alpha-\beta)-T\cos\theta\right]}$$

Stokes et al (2014), Plant & Soil

- How do plant roots alter infiltration & percolation processes in natural and anthropogenic soils?
- What are the consequences for soil microbial functioning, carbon leakage and the water cycle?



Ghestem et al (2011) BioScience

Landscape level

What people can see (socioeconomics)

Flood control, erosion, desertification, slope/embankment stability,

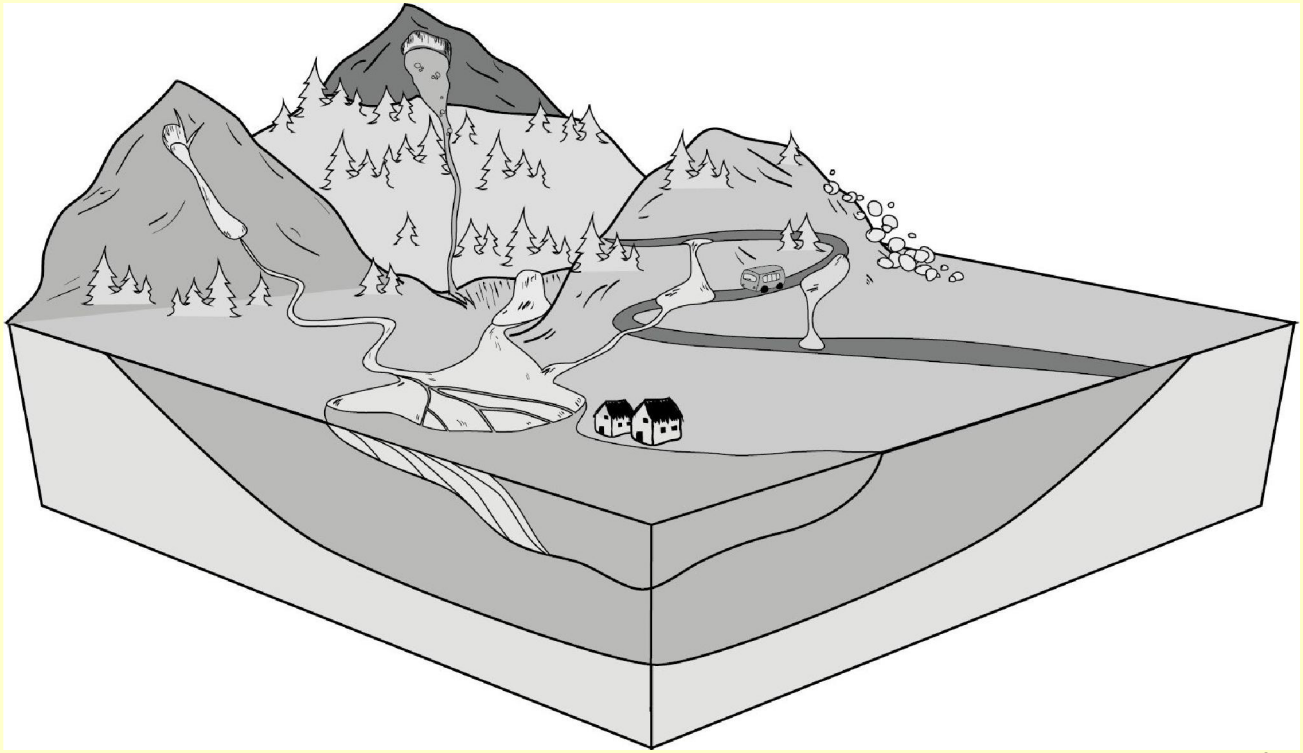
Engineers like simulations of landscapes over time (using ‘real’ plant models) – helps stakeholders & people to ‘see’

Marc Jaeger, UMR AMAP

PhDs: D. Bouchet,
M. Millan (2012 – 2015)

The BIG Question…

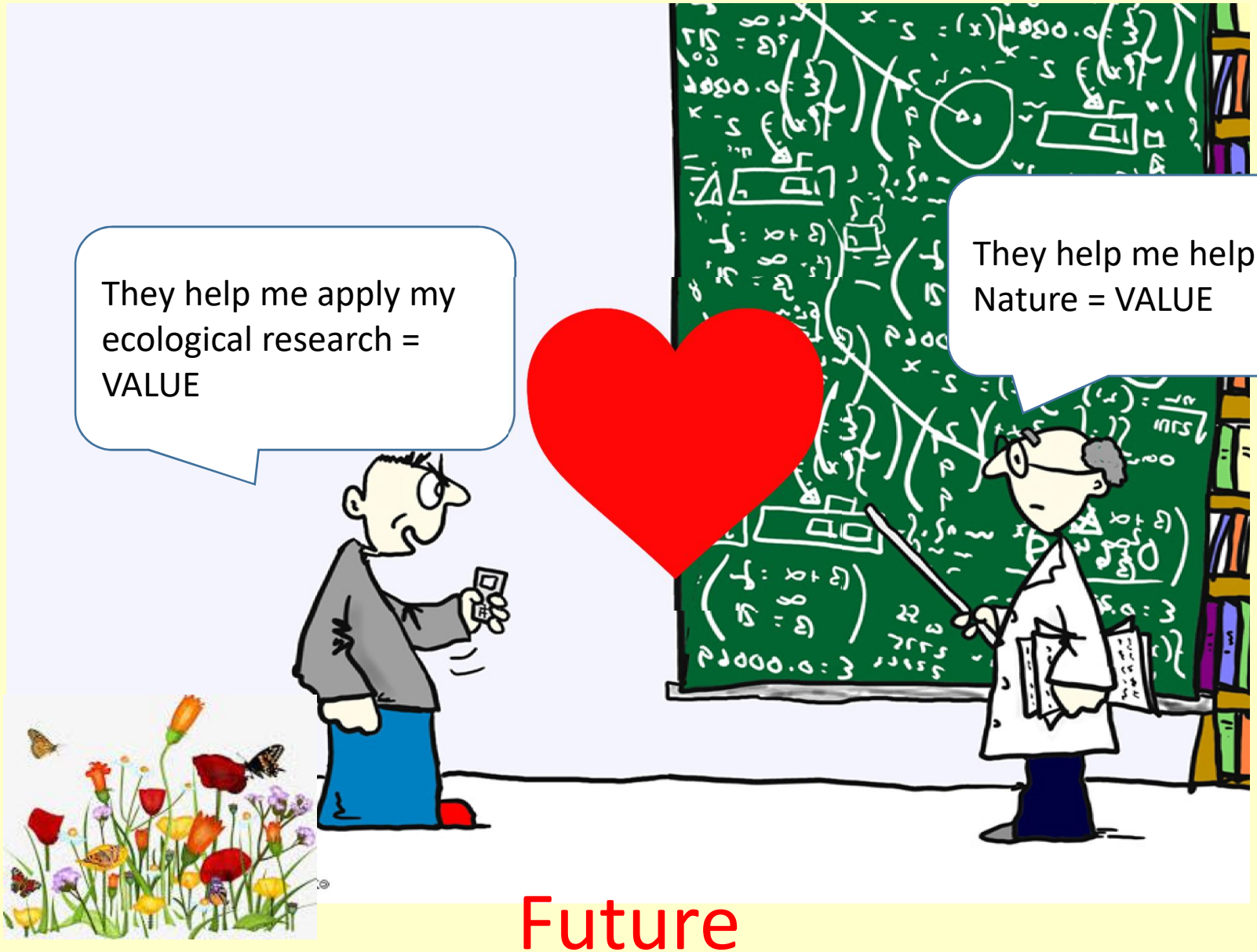
Can we scale up knowledge from other scales to the landscape level?



K. Sudmeier UNEP

Ecologists

Civil & Geotechnical Engineers



Future