

# Understanding the Life-cycle of Soils: Past and Future Civilization Collapses

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# This Presentation Outlines

- Life-cycle of Soils: weathering (soil formation) rates vs soil erosion rates
- US initiative on Weathering Systems Science
- New UK Consortium on Biogenic Weathering
- My effort to link US and EU initiatives
- Conference this summer on trace metals and health

# Science

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**SOILS**  
The Final Frontier

AAAS

Soils: The final frontier?

# Global mass movements

- Anthropogenic erosion has been estimated to be an order of magnitude higher (100 gigatonnes/year) than natural erosion
- Roughly 50% of this erosion is due to inappropriate agricultural practices
- Man has thus become a geological force!
- Globally, more than twice as much carbon is held in soils as in vegetation and the atmosphere combined and soil protection is thus a major issue for the buffering of climate change

# Study of life-cycle of soils for sustainability

- Soil the most important resource after water
- With soils eroding faster than they are being formed - we are living unsustainably
- Earth habitants 6 billion and rising
- If we loose our soils, we will not be able to feed the Earth population
- Therefore soil protection strategies and EU Soil Directive imperative for viability on Earth

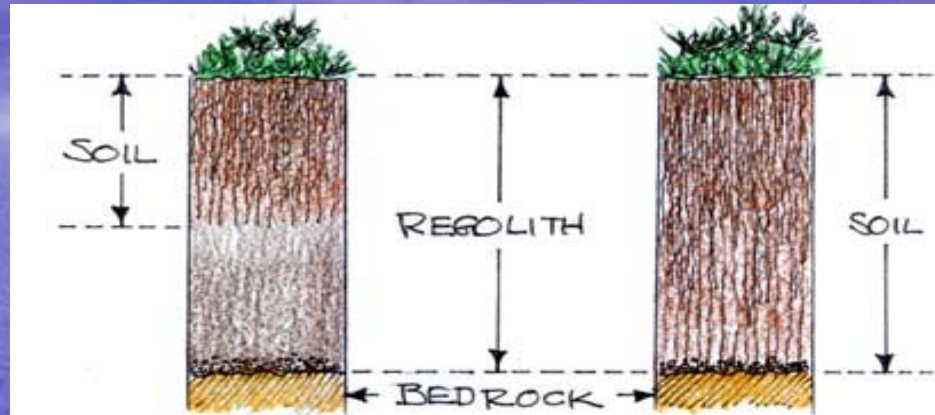
# Ronald Wright (A Short History of Progress): empires that collapse show similar behaviour

Sticking to entrenched belief and practices,  
robbing the future to pay the present,  
spending the last reserves of natural capital on  
reckless binge of excessive wealth and glory  
-does this sound familiar????

# Past civilization collapses

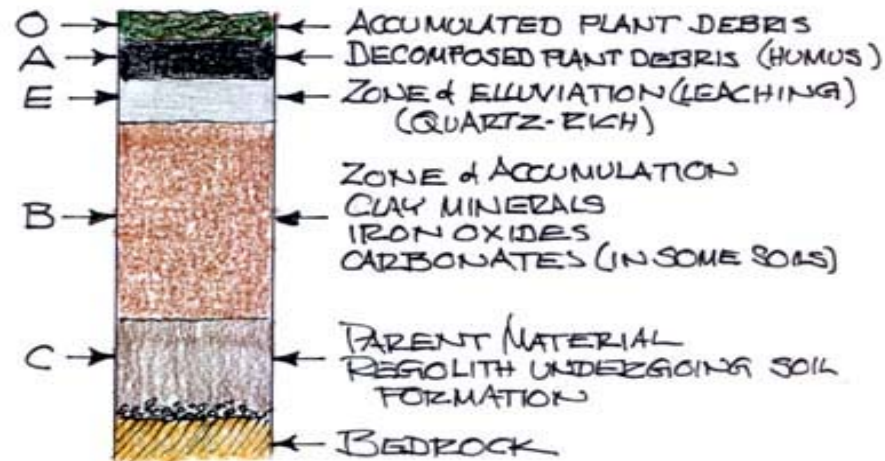
- **Localized**, e.g. the world's first civilisation – the Sumer from Southern Mesopotamia, which is now Iraq – collapsed around 2000 BC as a result of soil degradation
- With 6 billion people and rising the collapse is more likely to be **global**...

# Soil horizons



## SOIL HORIZONS

### HORIZON





QuickTime™ and a  
TIFF (LZW) decompressor  
are needed to see this picture.

# Why is soil erosion a problem? Consider rate of soil formation

- 10 cm of A and B horizons
  - 50 years to 1000 years
  - In extreme conditions - 10,000 years
    - depending on
      - Temperature
      - Rainfall, and
      - Plant cover

# Annual soil loss

- Due to intensive agricultural practices
  - 27 billion tons of topsoil lost
  - With a population of 6 billion
  - 4.5 tons per person!
- We eat roughly 750 kg of food a year
  - For every kg of food we eat
  - We lose 6 kg of soil!

# Rate of soil loss

- Loss of the most productive soils
  - 7 % each decade
- In the past 20 years we have lost
  - 20 - 30% of our topsoil!
- This is definitely unsustainable!

# Soil formation rates - limited data

mm/100 yr

- 0.4 Granite in Virginia
- 6 Quartz diorite in Puerto Rico
- 10 California - bare metamorphic rock
- 1.5 California - under 1 m of soil
  
- 7 World quoted average

# Soil erosion rates: EEA Report 10

	mm/100 yrs
• Spain	200
• Albania	180
• France	120
• Bulgaria	115
• Belarus	85
• Switzerland	70
• Austria	65
• Cyprus	35
• Slovak Republic	30
• FYR Makedonia	30
• Armenia	30

- Europe's Environment  
The Third Assessment  
2003
- Compare with what is  
generally referred to as  
soil formation average  
rate - 7 mm/100 yrs!

# 100 years from now: 2105

Europe



QuickTime™ and a  
TIFF (LZW) decompressor  
are needed to see this picture.

# Soil formation rates vs soil erosion rates

- In agricultural areas
  - Soil erosion rates up to
    - ~3 orders of magnitude faster than formation rates!!!
- Soil second most important resource
  - We need to have a re-think and conserve soils
  - We need to better understand soil formation mechanisms
  - We need to focus on understanding the whole life-cycle of soils



# The future - will humanity survive the 21<sup>st</sup> century?

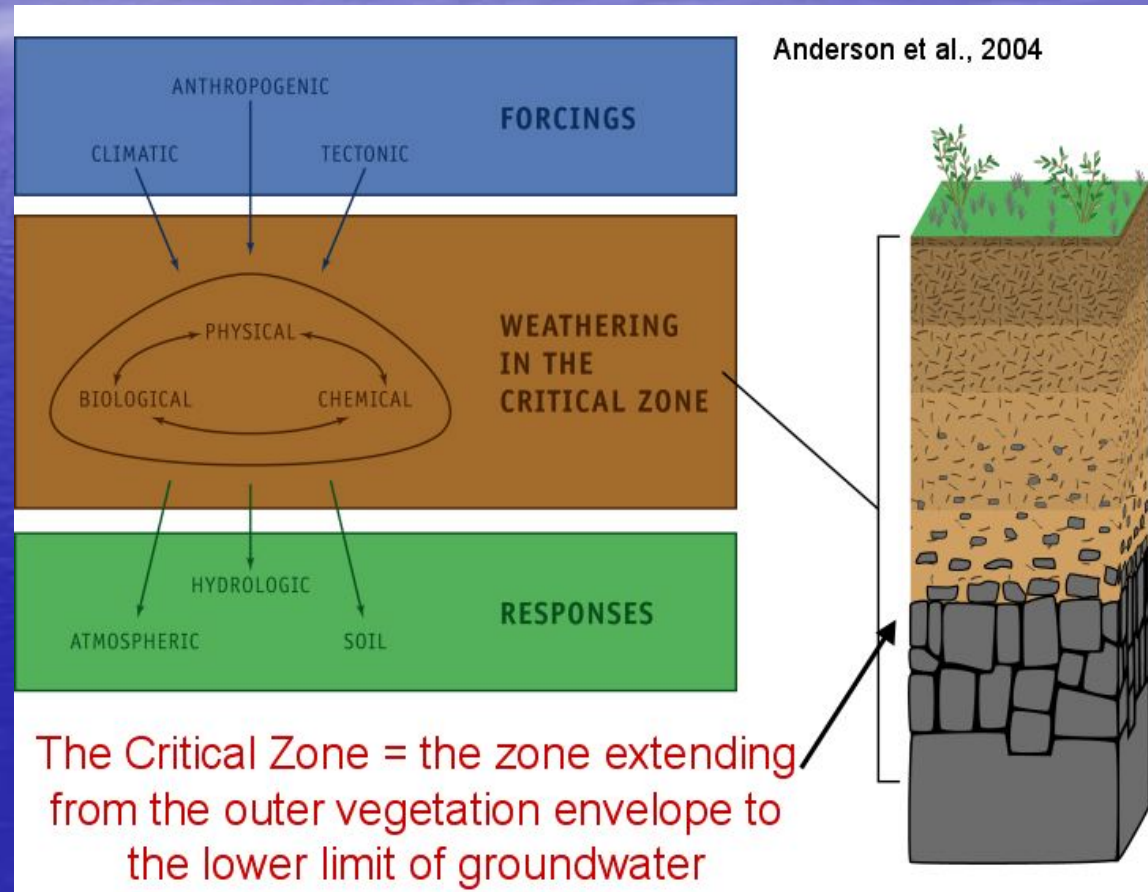
- We are heading for a civilization collapse due to lack of soil protection strategies
- We need to sell this to the European Commission!!!

# US Initiative on Weathering

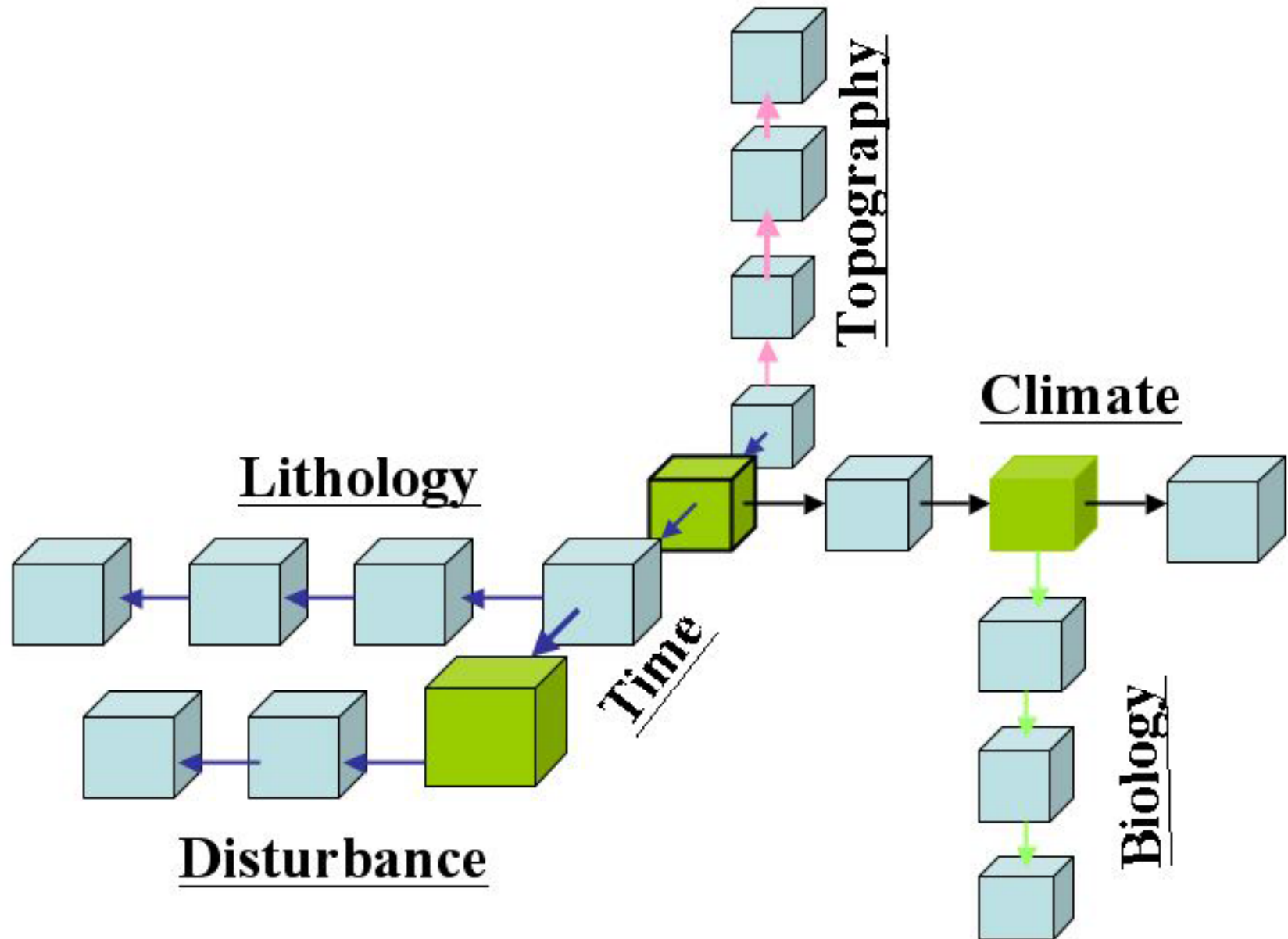
- Lead by Susan Brantley, Penn State
  - Article in EOS, 2004: Anderson et al.
- Have had a number of workshops and meetings
  - Last one was in Newark, Delaware, Oct 05
  - Next one will be at the International Soil Science Conference in the US - July 2006
- Now have seed funding for five field sites
- Are keen to link with Europe

# US Weathering Systems Science

- Study of the Critical Zone
- Field rates differ from laboratory rates
- Need to establish soil observatories with instrumentation
- Five sites now funded
- [www.wssc.psu.edu/](http://www.wssc.psu.edu/)



# Critical Zone Exploration Network



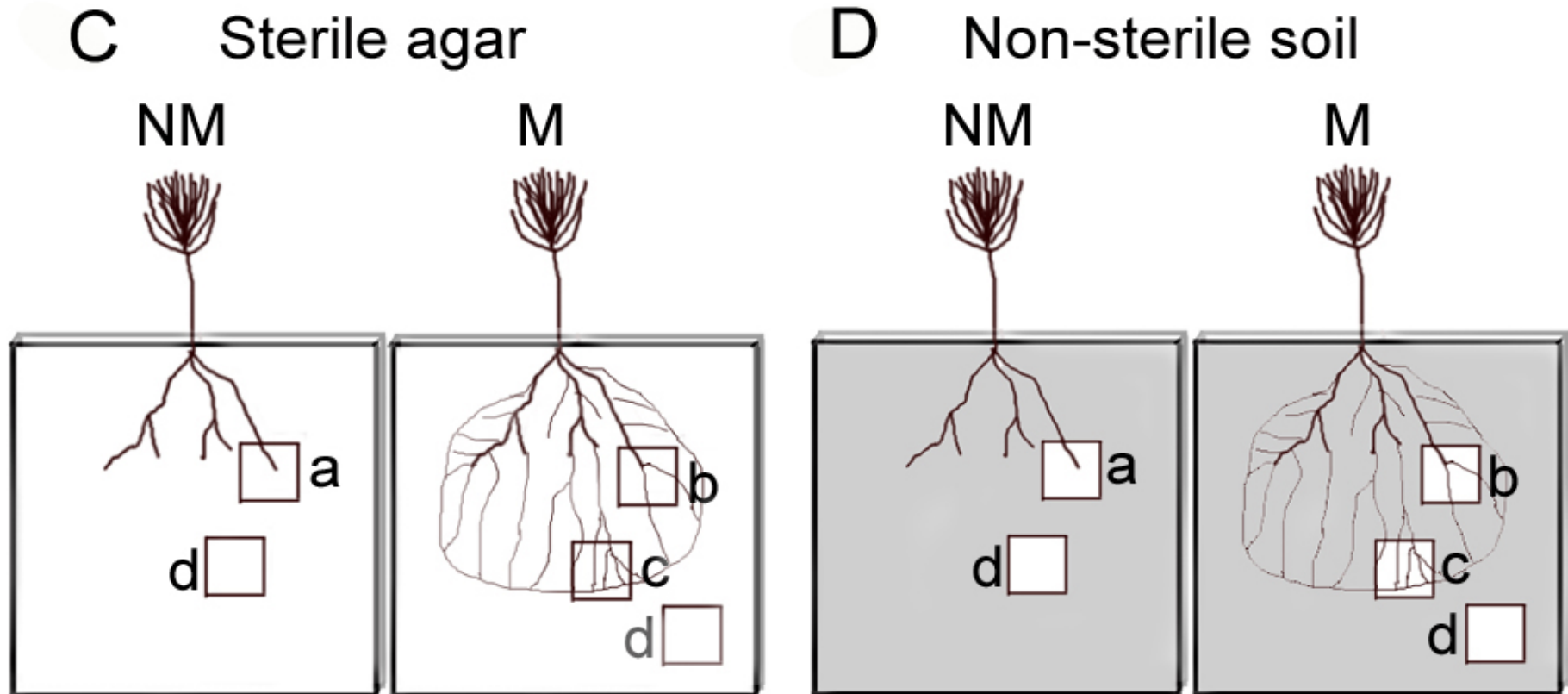
# Biogenic Weathering Consortium

## 2.6 million Euros, funded by NERC

- Collaboration between
- Bristol (Vala Ragnarsdottir)
  - Earth Sciences, Physics, Interface Analysis Ctre
- Leeds (Liane Benning)
  - Earth Sciences, Material Science
- Sheffield (Steve Banwart and Jonathan Leake)
  - Engineering, Biology

More info to be found at [www.wun.ac.uk/wsc/](http://www.wun.ac.uk/wsc/)

# Goal: Quantify exchange of photosynthesis produced sugars in exchange for nutrients from fungi



# Fungi

- Form slender filaments or hyphae
  - Separate or nonseparate
  - Commonly multinucleate
  - Constitute mycelium, soma or thallus
  - Several decimeters in diameter
  - Easily visible

## Mycorrhizal fungi



# Biogenic weathering key question

- What is the mass transfer between symbiotic mycorrhizal fungi pine trees?
- Trees produce sugars through photosynthesis and these are exchanged with nutrients from fungi
- Fungi produce organic acids, that dissolve minerals for fungal uptake (P, K, Fe, Zn, Cu other trace metals...)



# Integrating US and EU initiatives

- My goal was to link together the communities
  - Geochemists
  - Soil scientists
  - Hydrologists/hydrogeologists

# Soil degradation in Europe

- 52 million hectares of land in the EU are affected by degradation process - 16% of the total land area in the EU
- 75% of the total area analysed in south Europe has a low (3.4%) or very low (1.7%) soil organic matter
- The percentage of soils in Europe with less than 2.6% organic matter rose from 35% to 42% in the period 1980-1995.
- Soil organic carbon loss in England and Wales over the past quarter of a century is as high as 16%!

# EC stated in 2001

- Soil loss and declining soil fertility are a main threat to sustainable development, because they diminish the viability of agricultural land...
- Therefore it is important to instigate a European Soils Directive

# EC application in 2005

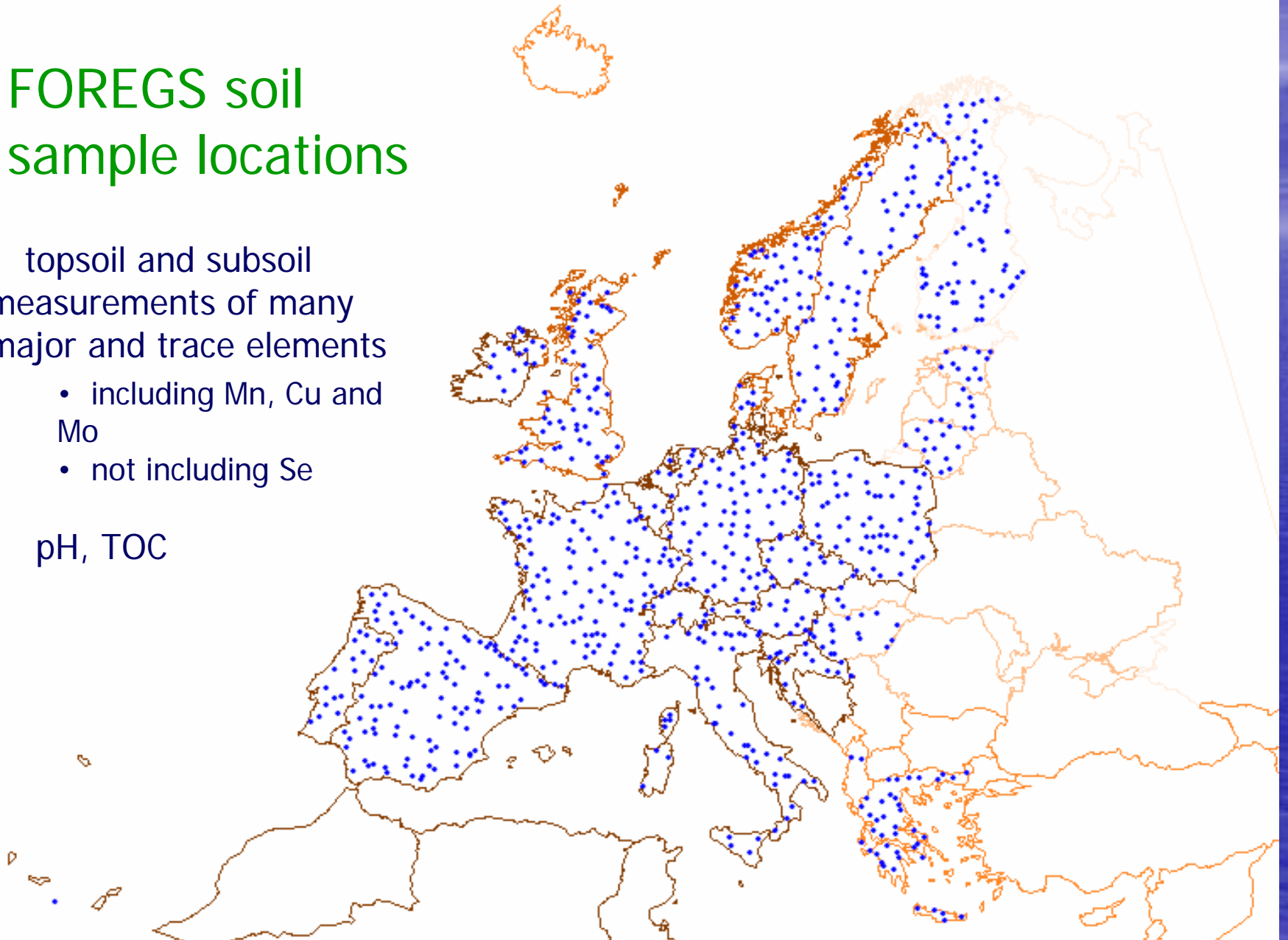
- I applied for a SSA to unify the fragmented EU soils community - did not get funded
- But hope to piggy back on a funded CA on river basins (RISKBASE) - coordinated by Jos Brils, TNU, Netherlands
- Anyone interested to join - please come talk to me

# New geochemical maps

- **FOREGS** - published by Geological Survey of Norway (Salminen et al. 2005)
- **Baltic Soil Survey** - published by Geological Survey of Germany (Reimann et al. 2003)

# FOREGS soil sample locations

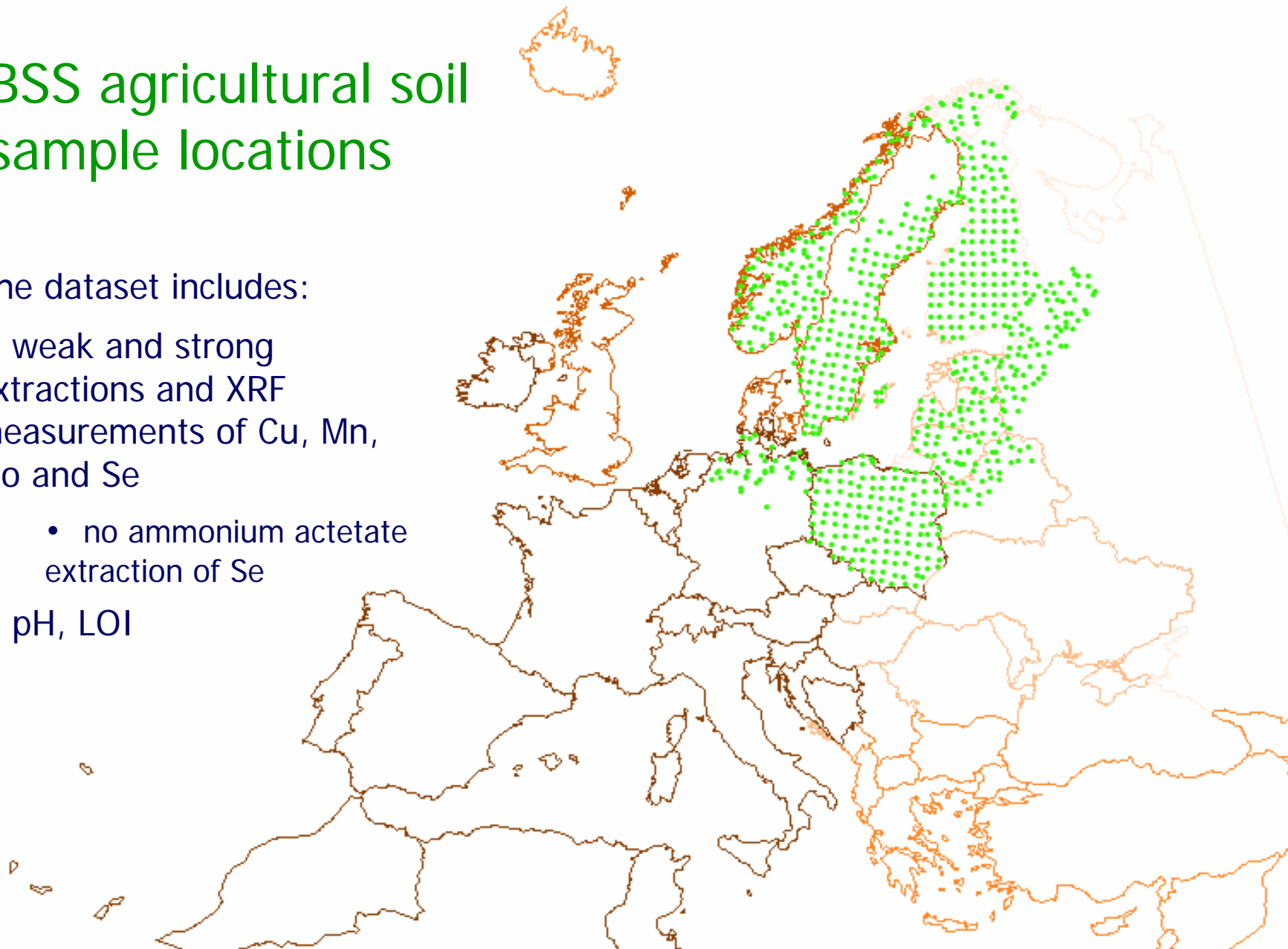
- topsoil and subsoil measurements of many major and trace elements
  - including Mn, Cu and Mo
  - not including Se
- pH, TOC



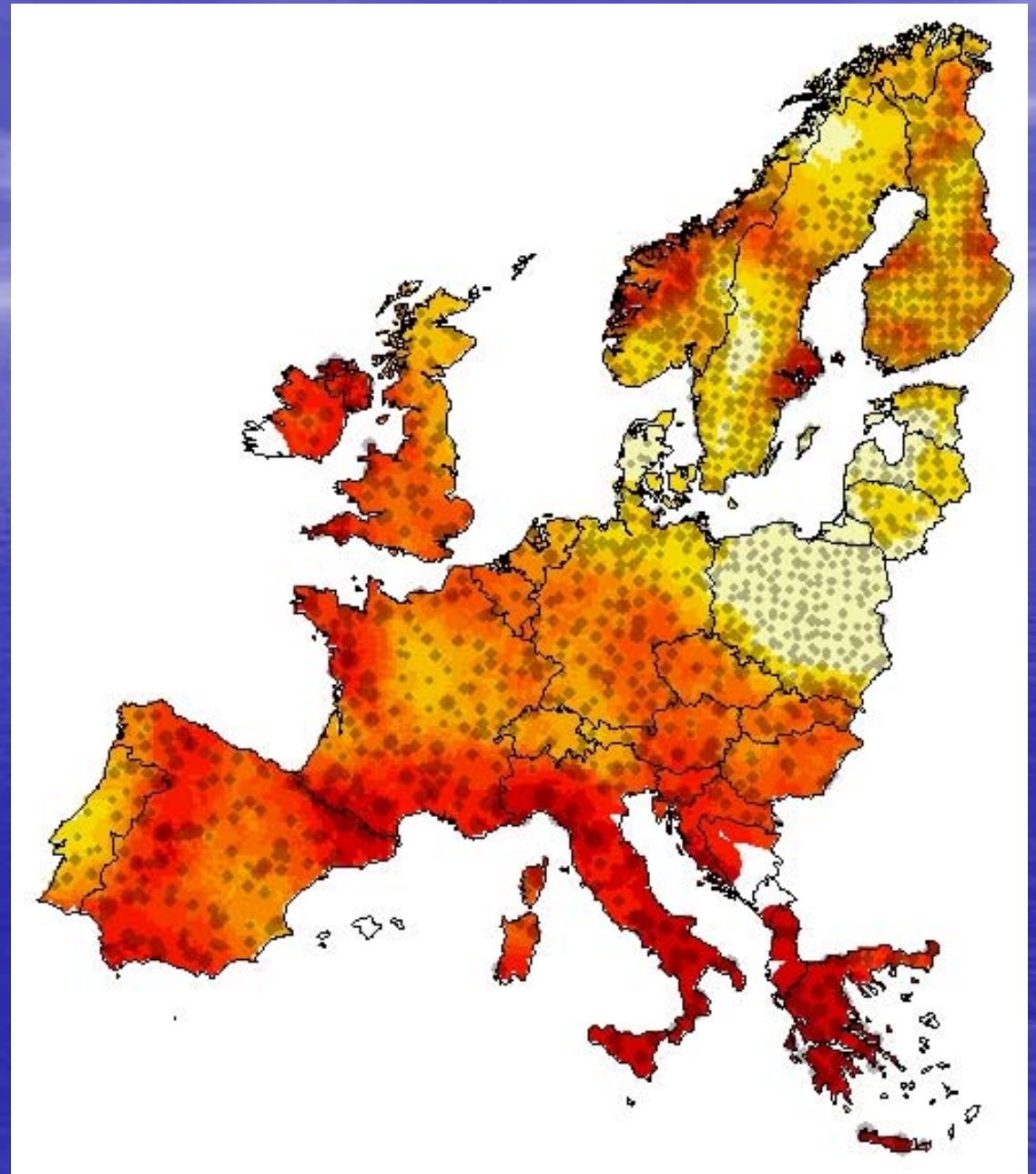
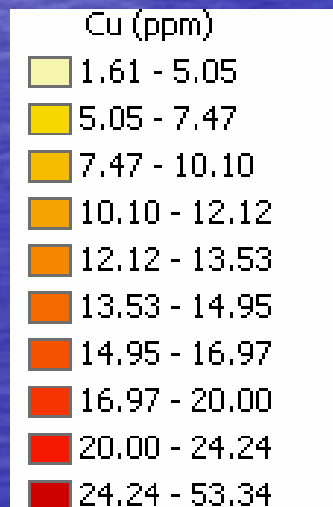
# BSS agricultural soil sample locations

The dataset includes:

- weak and strong extractions and XRF measurements of Cu, Mn, Mo and Se
  - no ammonium acetate extraction of Se
- pH, LOI



# Geostatistical map of total Cu (aqua regia) in European topsoils





# The role of trace metals in disease

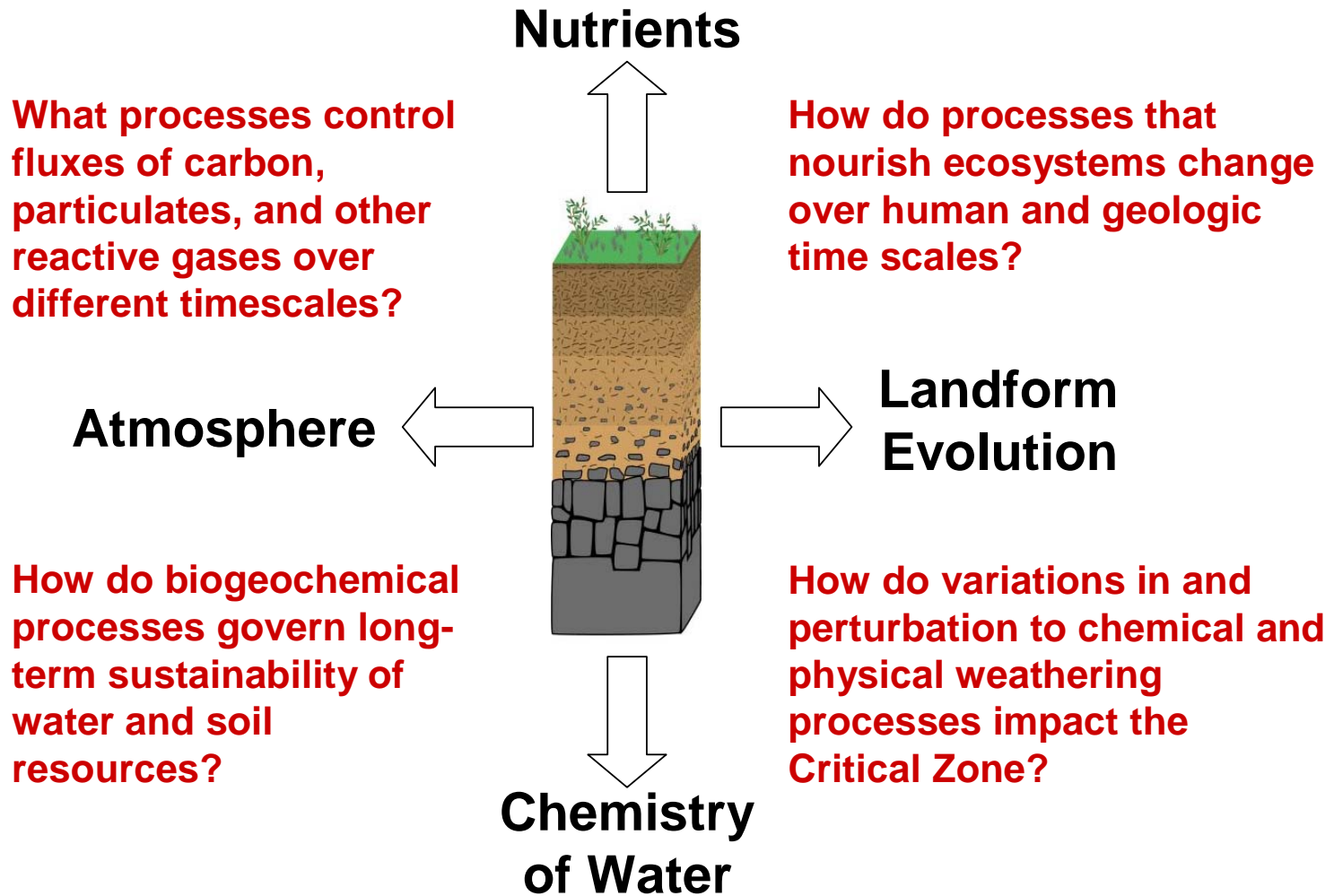
## Iceland, June 26-29, 2006

- Open scientific meeting to conclude FatePride - a Quality of Life (5th Framework) research programme
- Main aim of FatePride - investigate whether trace metals have a role to play in the development of prion diseases
- Meeting open to all trace metals and diseases
- More info to be found at
  - <http://www.arp-manchester.org.uk/FetePride.htm>

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# How Do Critical Zone Interfaces Affect Humanity?





**Are there any questions?**