Investigation of soil structure and modelling the water and heat cycle of soil

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Budapest

Presentation outline

- Soil structure and methods of its characterisation
- From natural curiosity to data-model fusion – methods for studying complex systems and their responses to changes in drivers
- Aims of mathematical modelling in the Terra Preta project
- Input and reference data requirement
- Case studies
- Conclusions

Soil structure

„arrangement and organization of primary and secondary particles in a soil mass”
„the spatial heterogeneity of different components or properties of soil”

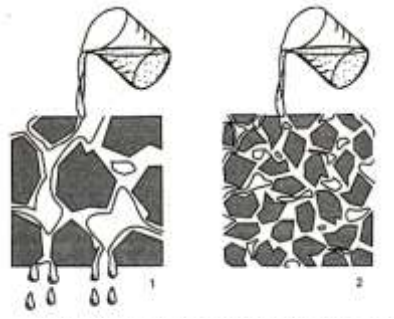
- the bonding of the soil particles into structural unit is the genesis of soil structure.
- controls the amount of water and air in the soil
- influences soil fertility, plant development and soil-related ecosystem services

Factors influencing structural development of arable soils

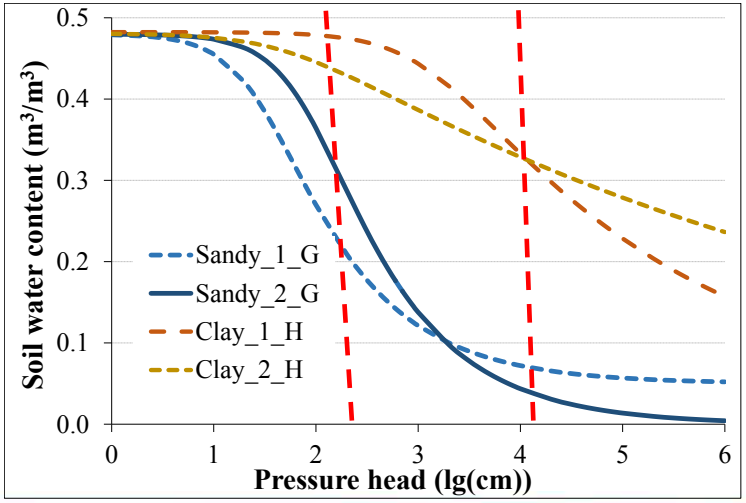
- Climate
- ***Organic matter***
- Tillage
- Plants, roots, residues
- Animals
- Microbes
- Fertilisers
- Wetting and drying
- Exchangeable cations
- Inorganic cements
- Clay
- Water

Characterisation of soil structure: indirect methods

- Size and stability of particles and aggregates
- Water-stable aggregates
- Microaggregates
- Characterisation of the pore space
  - Measuring total porosity

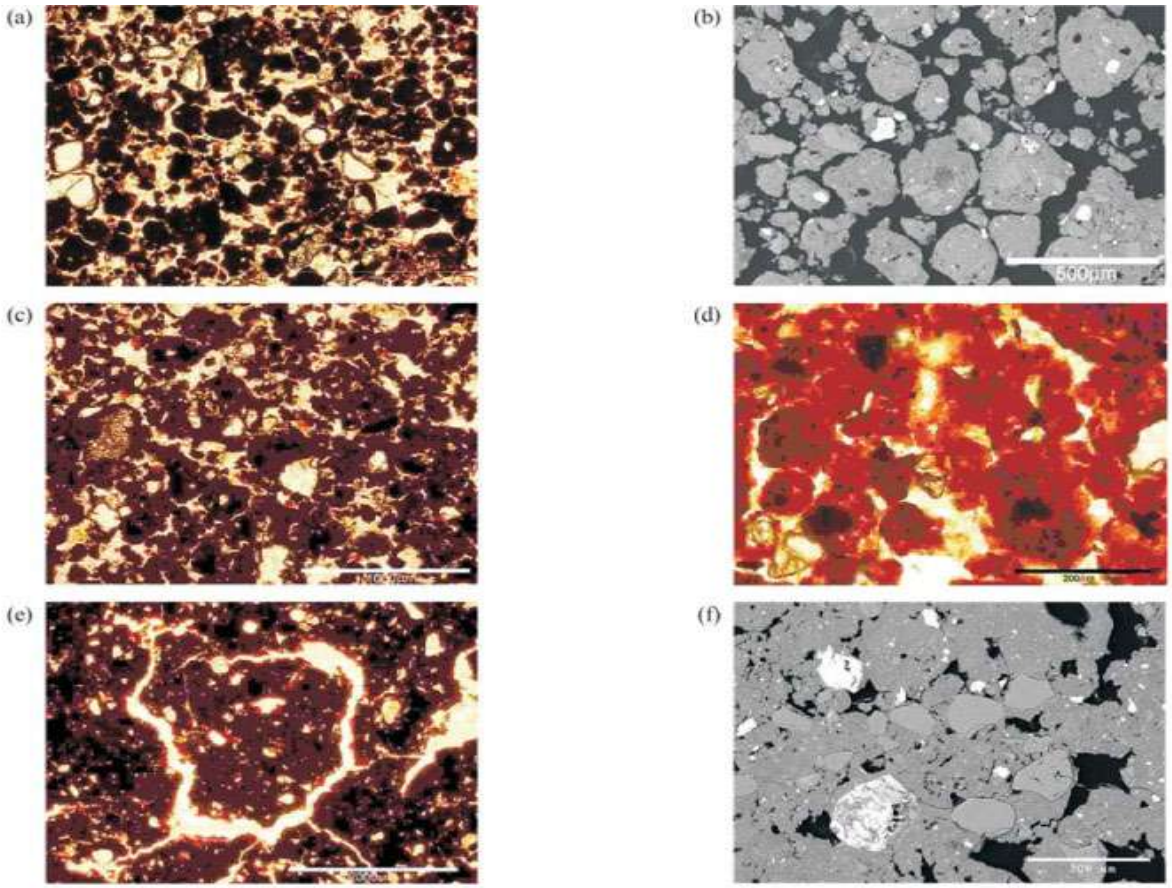


  - Determining the water retention curve (pore-size distribution)



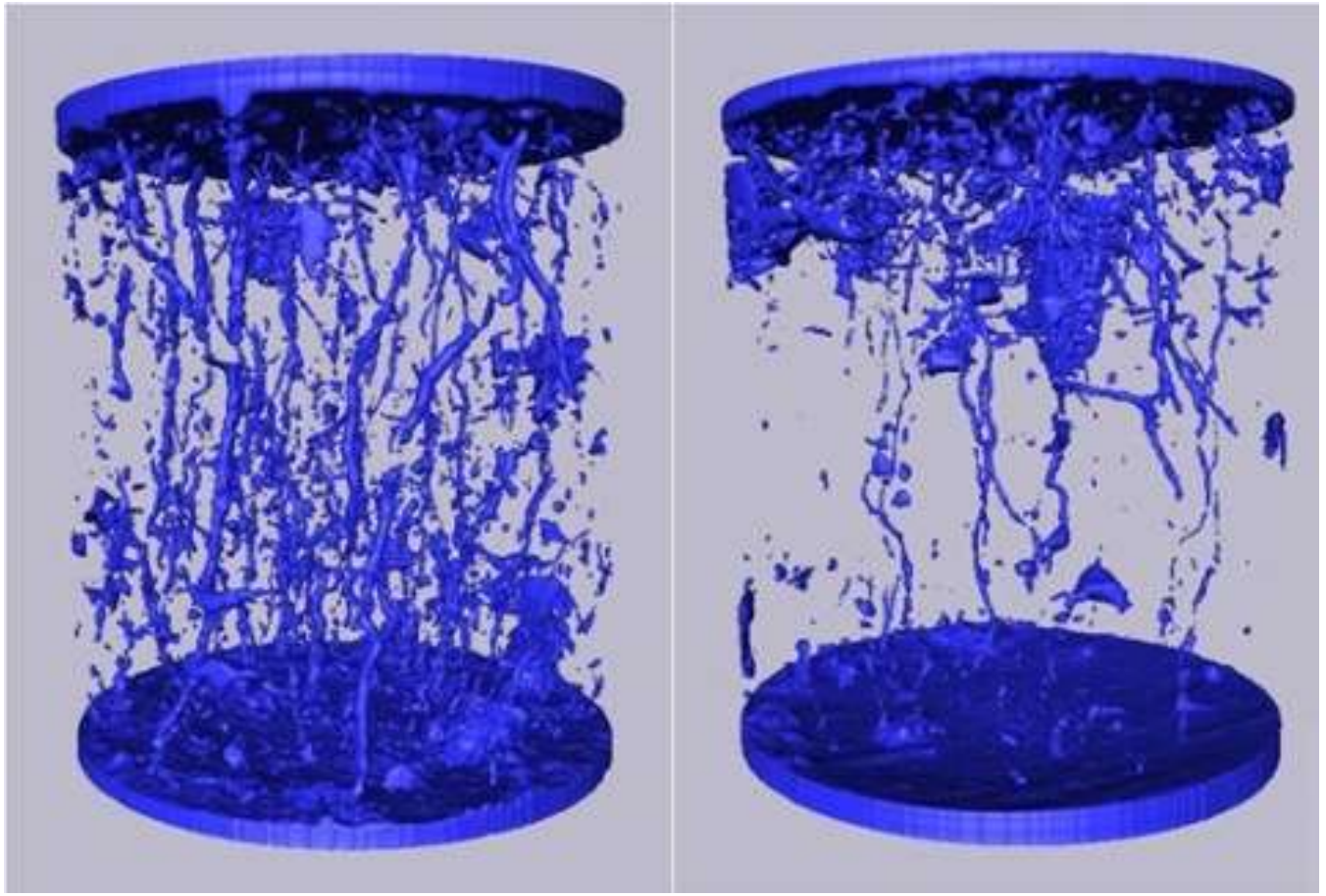
Characterisation of soil structure: direct methods

Micromorphological method (microscopic study of soil sections)



Characterisation of soil structure: direct methods

Computer-Assisted Tomography (CT-scans)



Mathematical modelling

Driving variables in daily time-step

- **soil properties**
- **crop parameters**
- **site-specific parameters**
- **general parameters**

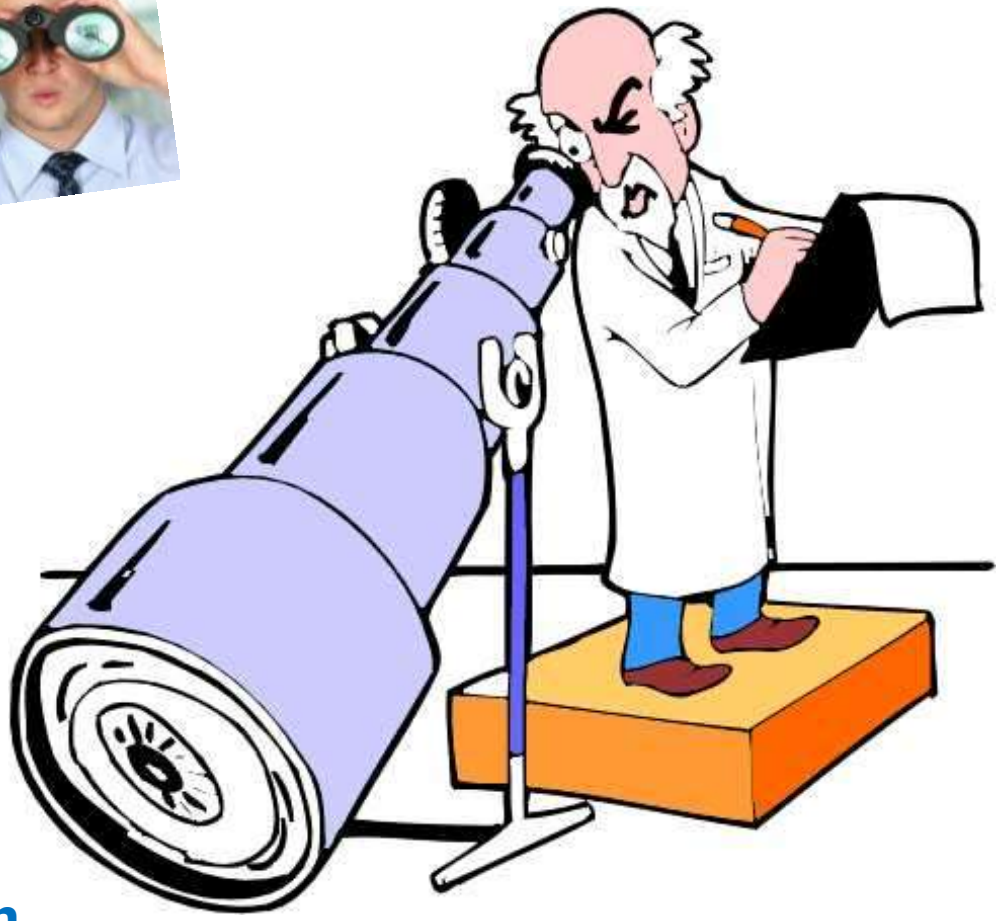
Initial and boundary conditions

Daily estimates of soil temepature and water content profiles and soil CO2 emission

From natural curiosity to data-model fusion

natural curiosity

observation



qualitative information

From natural curiosity to data-model fusion

- Natural curiosity ➔ observations ➔ information

Measurements

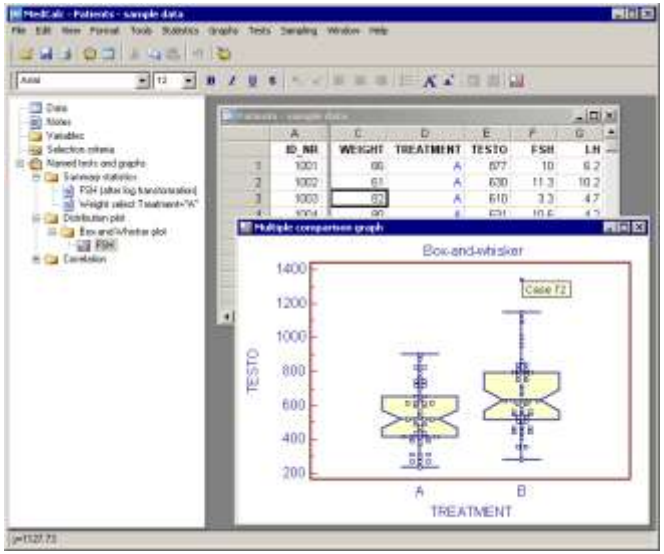
data

monitoring

spatio-temporal data base

From natural curiosity to data-model fusion

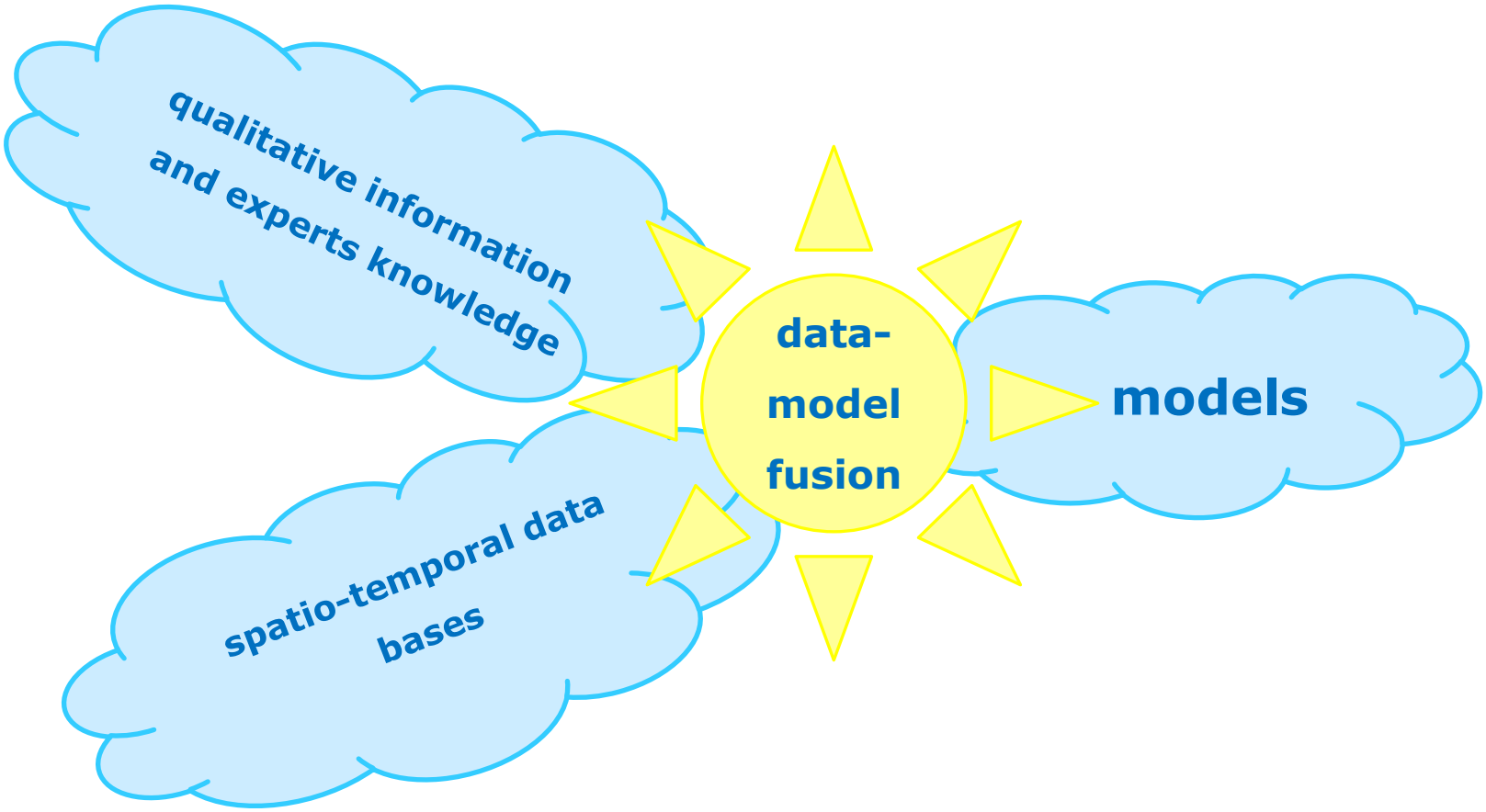
- Natural curiosity ➔ observations ➔ information
- Measurements ➔ monitoring ➔ data bases
- **Statistical analyses ➔ empirical models**



- **Physical laws/relationships ➔ process-based models**
- **Finer spatio-temporal resolution of the models**

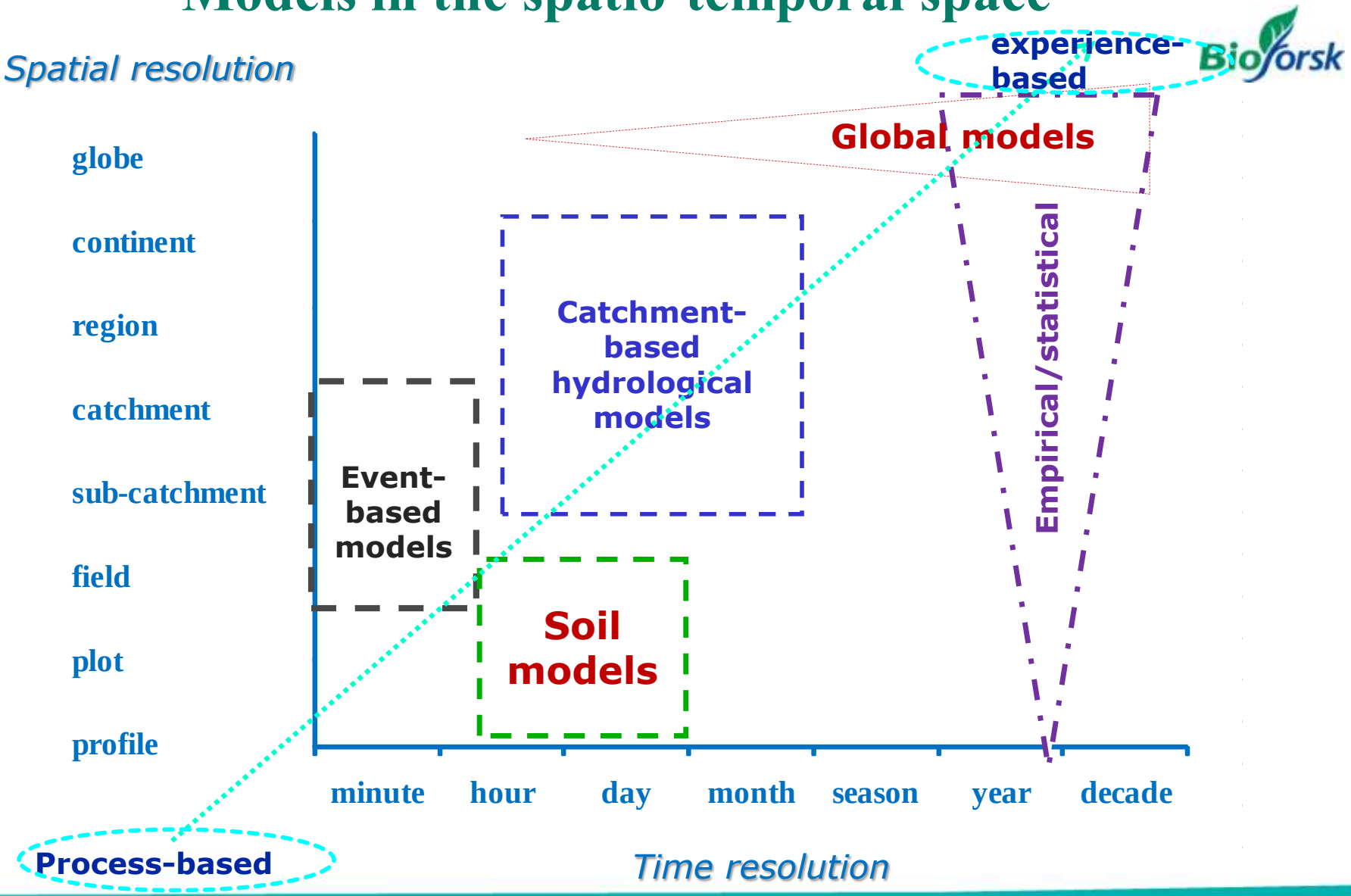
(improving requirements and computing capacity)

From natural curiosity to data-model fusion



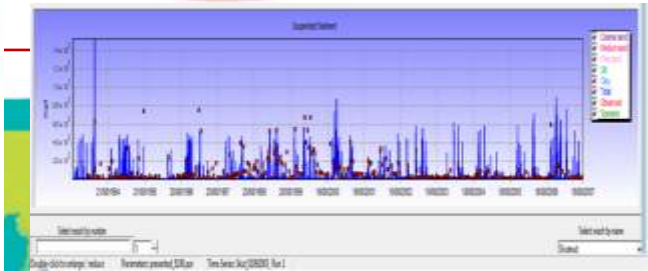
Data-model fusion is an advanced approach for studying complex systems

Models in the spatio-temporal space



Model application

1. Problem definition, preliminary information
2. Model selection ("good modelling practice" principles; Benchmark criteria)
3. Model parameterisation using data-model fusion
   - Available data from the study site
   - Literature review
   - Expert assumptions (qualitative information)
   - Measurements and monitoring
3. Calibration procedure
   - Minimising the difference between the reference observed and modelled values
   - Stepwise calibration approach (soil temp – soil water content – CO2)
4. Validation procedure
5. Scenario analyses
   - Management scenarios
   - Climate change scenarios
   - Biochar application

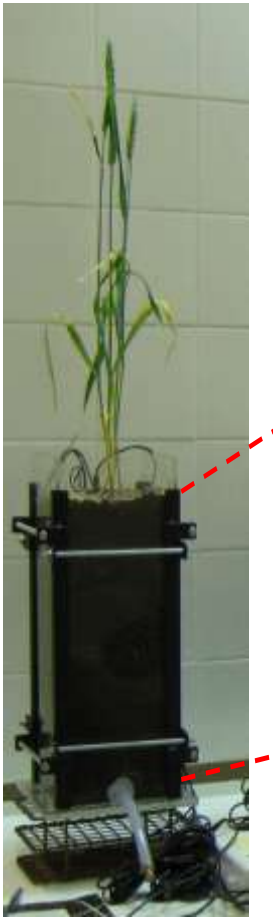


Model data requirement

1. Driving variables (meteorological data)
2. Initital and bounary conditions
3. Crop properties (LAI, rooting depth, crop height, crop cover factor etc.)
4. Soil properties (soil water retention curve and hydraulic conductivity function)
5. Site-specific properties
6. Reference data (measured soil temperature, water content and CO2 emission)

Soil structural changes – through measured water retention curves before and after biochar application.

Effect of soil consolidation on soil water retention and soil water regime



- TR = f(PET): transpiration

TR = I – E – ΔW

Upper boundary:

+ I : irrigation

- E = f(PET): evaporation

ΔW

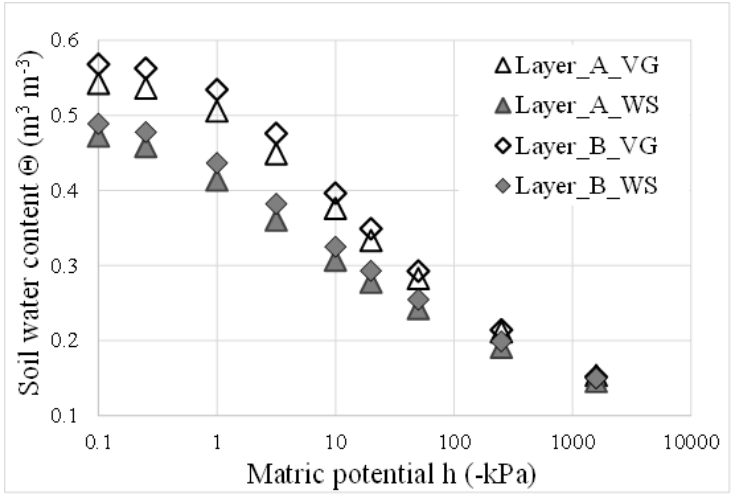
Changes in the amount of water in the soil column

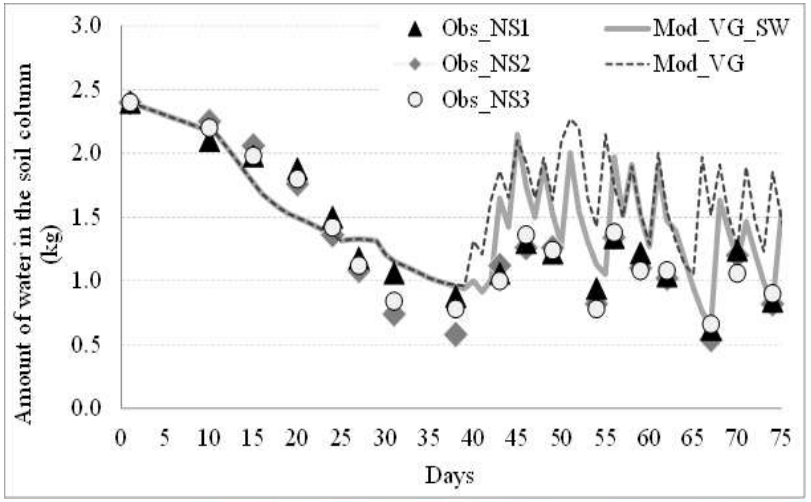
0

0

Bottom boundary:

zero flux



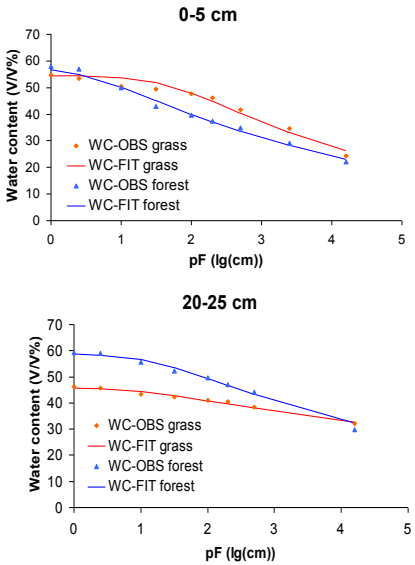


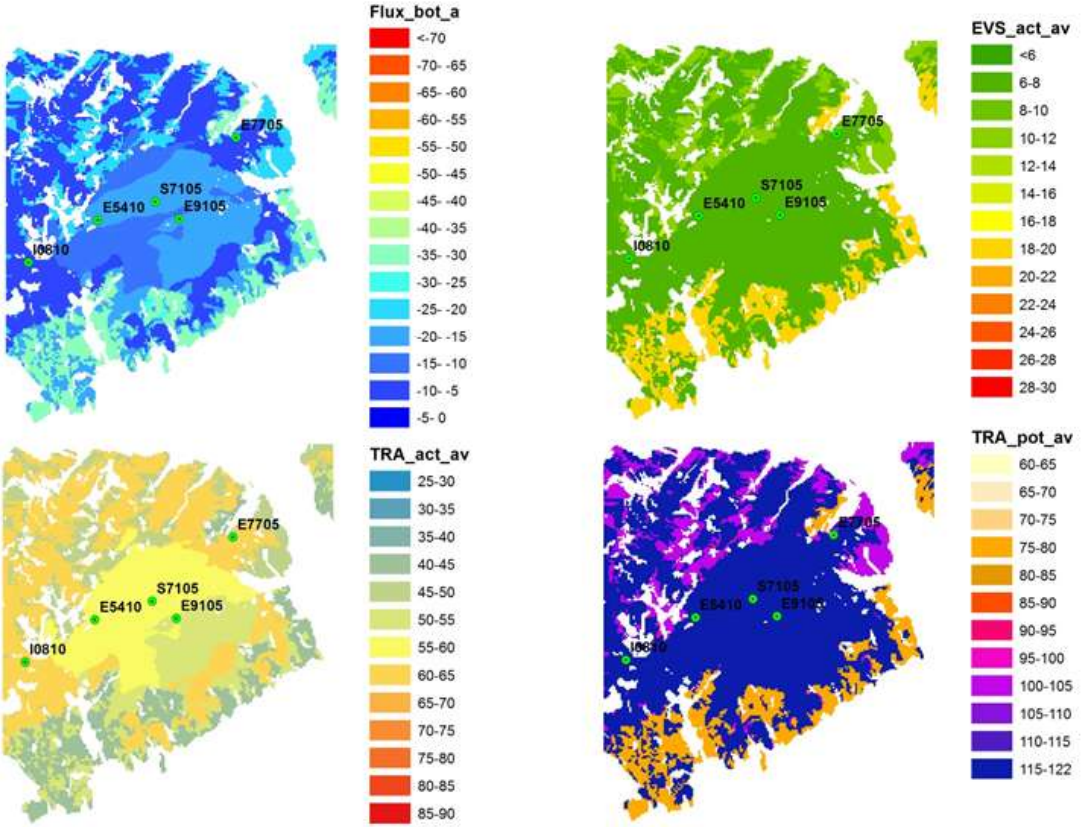
Impact of climate and land use changes on soil water balance elements

Climate: RCA scenario (temperature: +2.4 ºC, precip. + 280 mm

Land use 1.: arable to grass, grass to forest, forest remains forest

Soiinput:





Thank you for the attention!