Soil Water Retention as Indicator for Soil Physical Quality – Examples from Two SoilTrEC European Critical Zone Observatories

Svetla Rousseva[1], Milena Kercheva[1], Toma Shishkov[1], Emil Dimitrov[1], Martin Nenov[1], Georg J. Lair[2], Daniel Moraetis[3]

[1] ISSAPPNP, Sofia, Bulgaria; [2] BOKU, Austria; [3] Technical University of Crete, Greece

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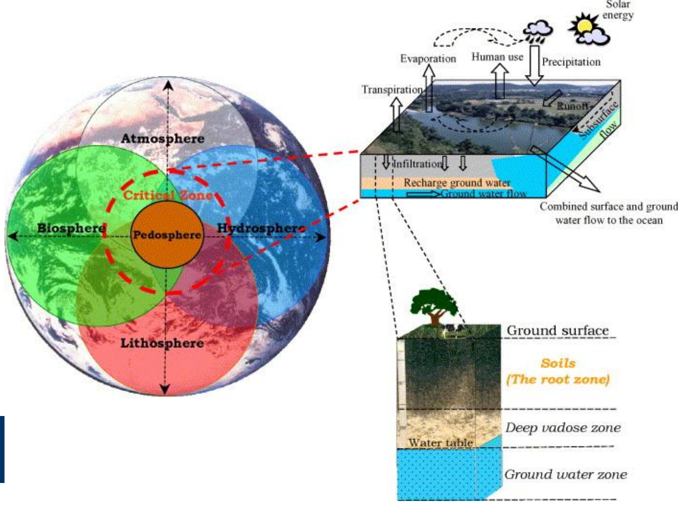
Aim

- To present and discuss parameters and relationships based on the SWRC data from soil profiles characterizing two European SoilTrEC Critical Zone Observatories

Concepts – soil water retention

- Soil water retention:
  - Characterized by the Soil Water Retention Curve (SWRC)
  - Soil characteristic of primary importance for majority of soil functions.
- The characteristics derived from the SWRC are directly related to soil structure and soil water regime, and can be used as indicators for soil physical quality – example is the S-parameter proposed by A. Dexter in 2004.

Critical Zone definitions



- "Heterogeneous, near-surface environment in which complex interactions involving rock, soil, water, air and living organisms regulate the natural habitat and determine the availability of life-sustaining resources" (National Research Council, 2001)
- The environment that extends from the top of the tree canopy to the bottom of our drinking water aquifers; where terrestrial life flourishes and feeds most of humanity.
- The intersection area of pedosphere, atmosphere, hydrosphere, lithosphere and biosphere.
- The heart of the CZ is where soils are formed, degrade and provide their essential eco-services.

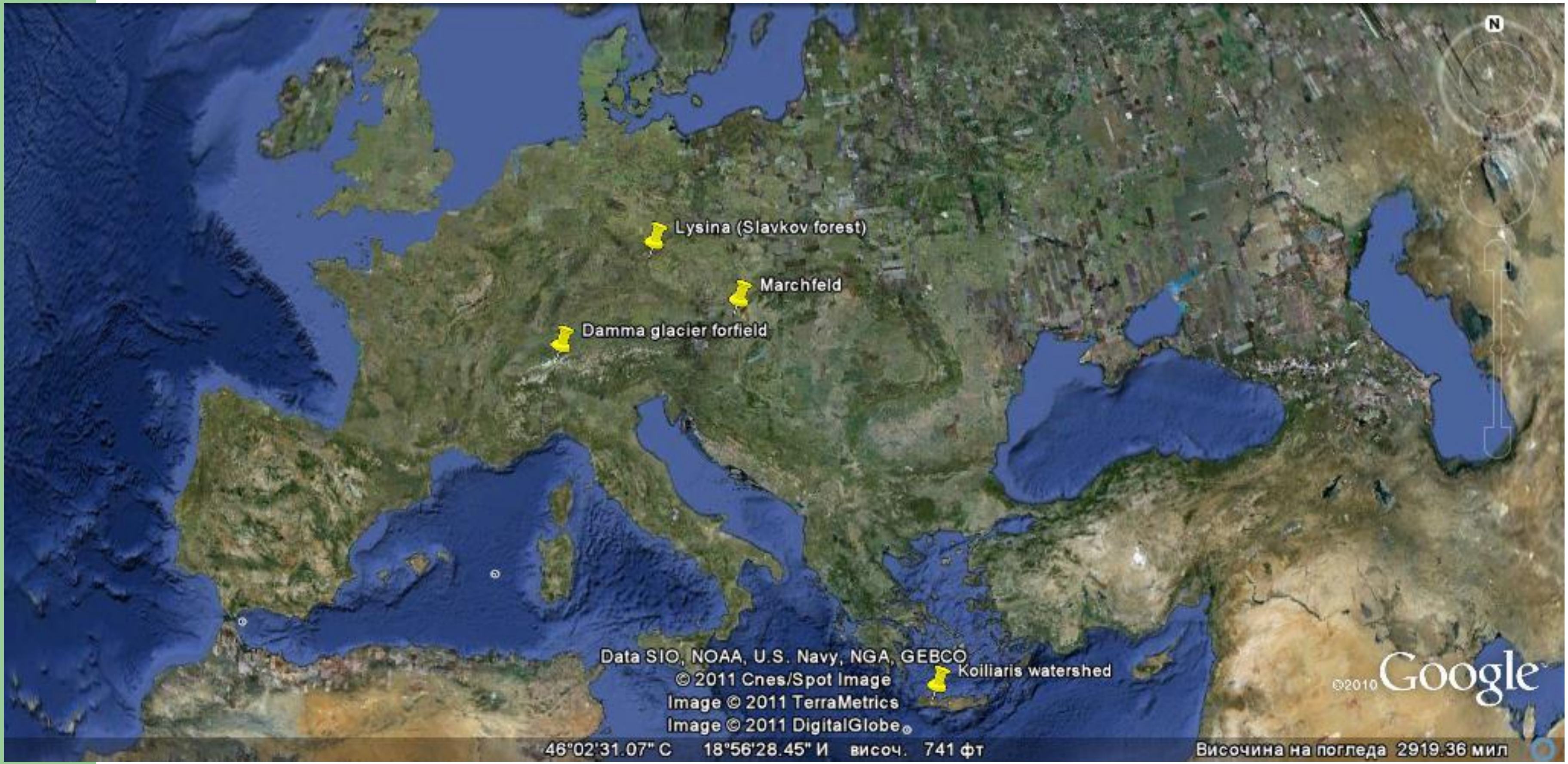
SoilTrEC

- The SoilTrEC is an international consortium (**Soil Tr**ansformations in **E**uropean **C**atchments) consisting of researchers from Europe, USA and Asia. The consortium is combining experiments and modelling to describe soil formation and functions using a global network of Critical Zone Observatories (CZOs)
- Objectives of the SoilTrEC (www.soiltrec.eu):
    1. Describe from 1st principles how soil structure impacts processes and function at soil profile scale
    2. Establish 4 EU Critical Zone Observatories to study soil processes at field scale
    3. Develop a Critical Zone Integrated Model of soil processes and function
    4. Create a GIS-based modelling framework to delineate soil threats and assess mitigation at EU scale
    5. Quantify impacts of changing land use, climate and biodiversity on soil function and economic value
    6. Form with international partners a global network of Critical Zone Observatories for soil research
    7. Deliver a programme of public outreach and research transfer on soil sustainability.

European SoilTrEC Critical Zone Observatories

- 4 European CZOs were established in the framework of SoilTrEC project to represent key stages of soil development and degradation
  - The BigLink field station, located in the chronosequence of the Damma Glacier forefield in alpine Switzerland and established to study the initial stages of soil development on cristalline bedrock;
  - The Lysina Catchment, and satellite catchments Pluhuv Bor and Na Zelenem, in the Czech Republic with productive soils on varying parent rock type managed for intensive forestry;
  - The Fuchsenbigl Field Station in Austria as an agricultural research site with highly productive soils managed as arable land and adjacent Marchfeld area with a chronosequence of Danube sediment soils;
  - The Koiliaris Catchment in Crete, a degraded Mediterranean region with heavily impacted soils during centuries through intensive grazing and farming, under severe risk of desertification

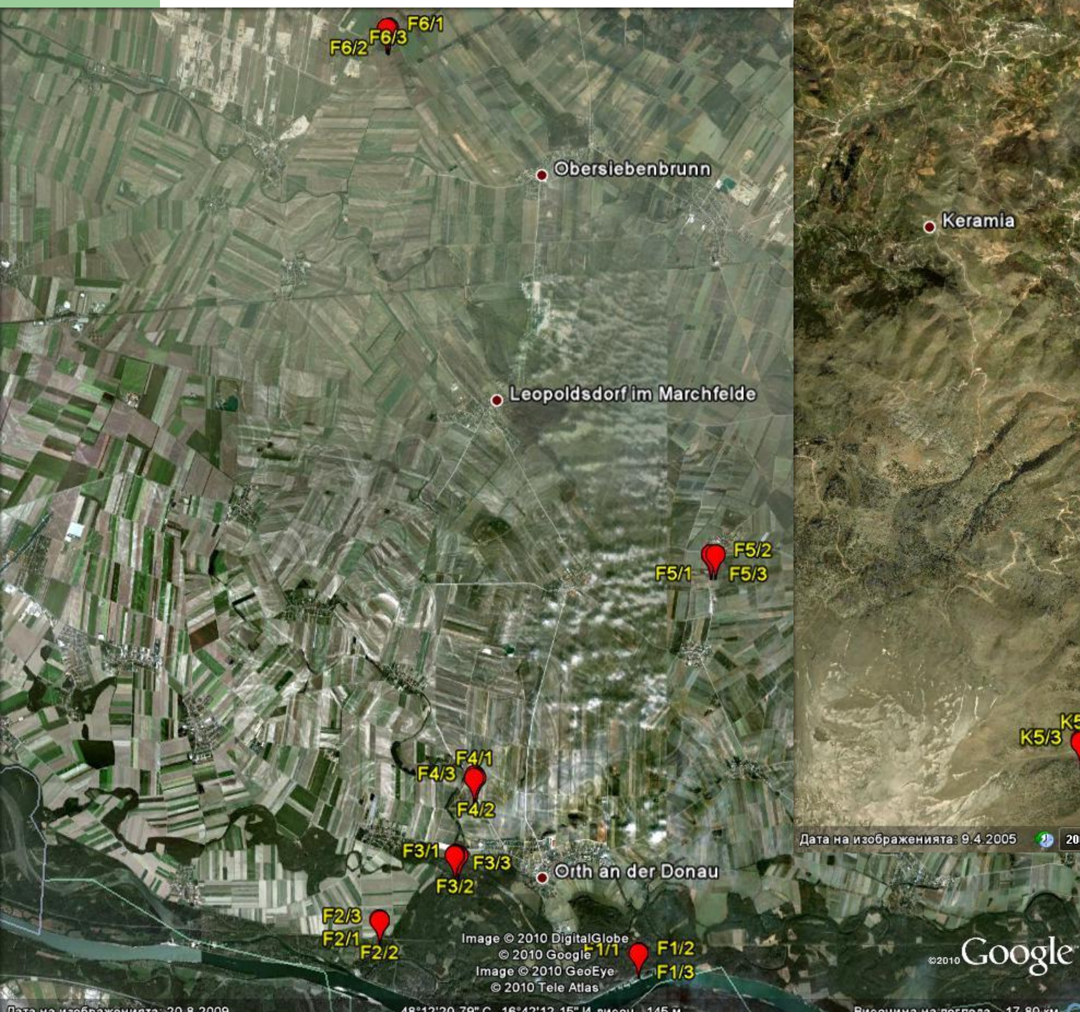
European SoilTrEC Critical Zone Observatories

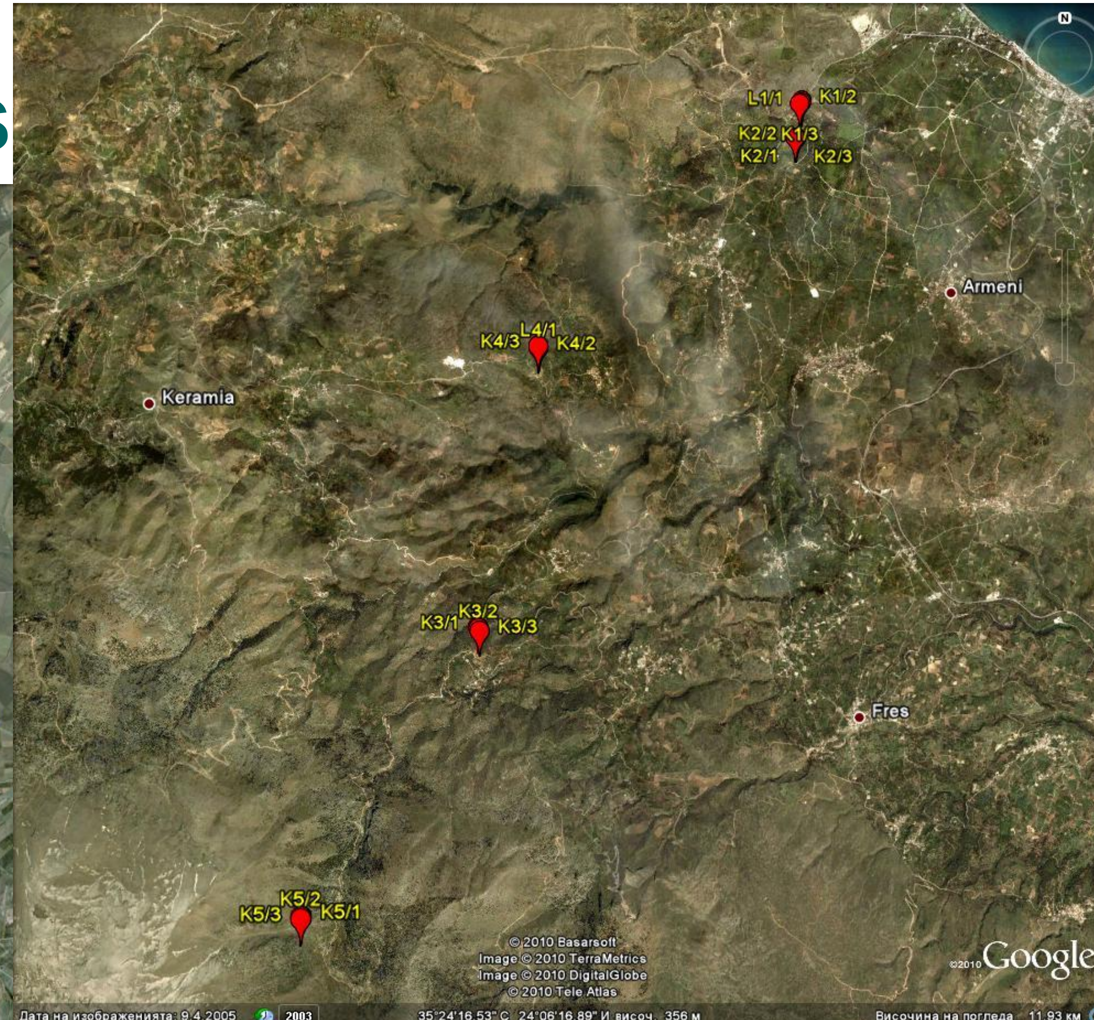


Studied soils

- Representative for:
  - highly productive soils managed as arable land in the frame of soil formation chronosequence at “Marchfeld” (Fuchsenbigl CZO), Austria and
  - heavily impacted soils during centuries through intensive grazing and farming, under severe risk of desertification in context of climatic and lithological gradient at Koiliaris, Crete, Greece.

Studied sites







Measurements

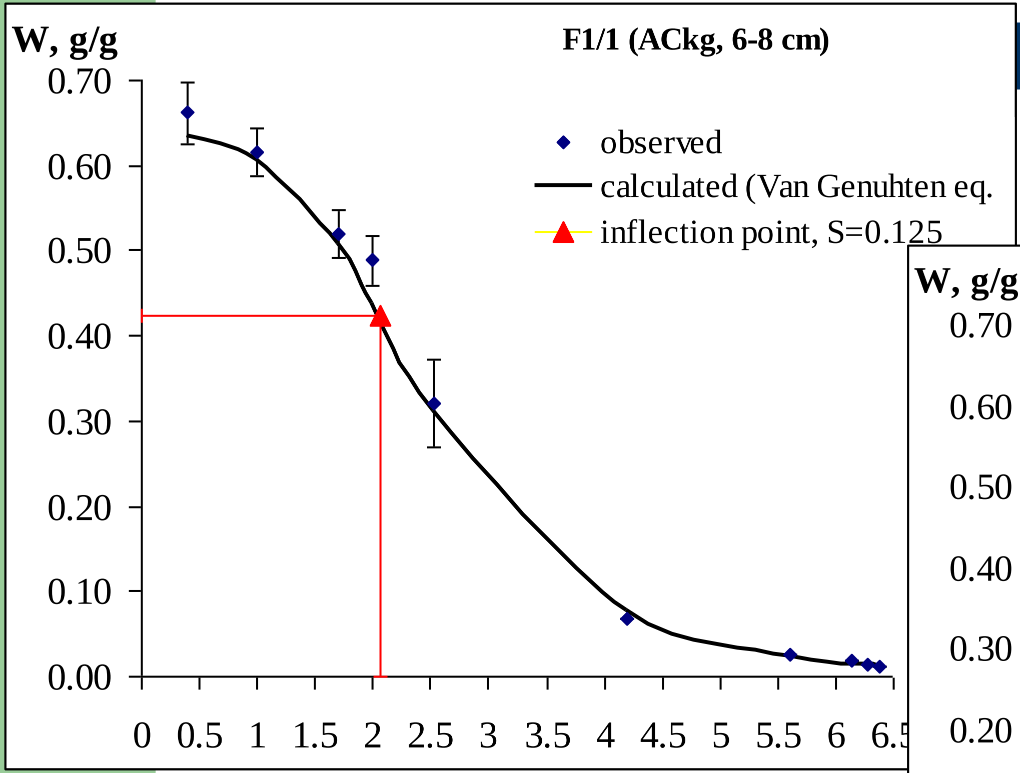
- The soil samples were wetted on a sand bath at 0.25 kPa instead of full water saturation in order to avoid the destruction of the soil structure by slaking (can occur in sandy soils). Duration – more than 20 days.
- The drainage of the wetted samples (SWR) was done as follows:
  - at suctions 1, 5, 10 and 30 kPa using the undisturbed soil cores (100 cm^3 and 50 cm^3) by a suction plate method (Shot filters G4);
  - at suctions between 30 and 1500 kPa using pressure-membrane equipment;
  - at suctions above 1500 kPa using vapour pressure method with controlled relative humidity in desiccators with saturated solution of different salts.
- Equilibrium at each potential was established for 5-7 days.

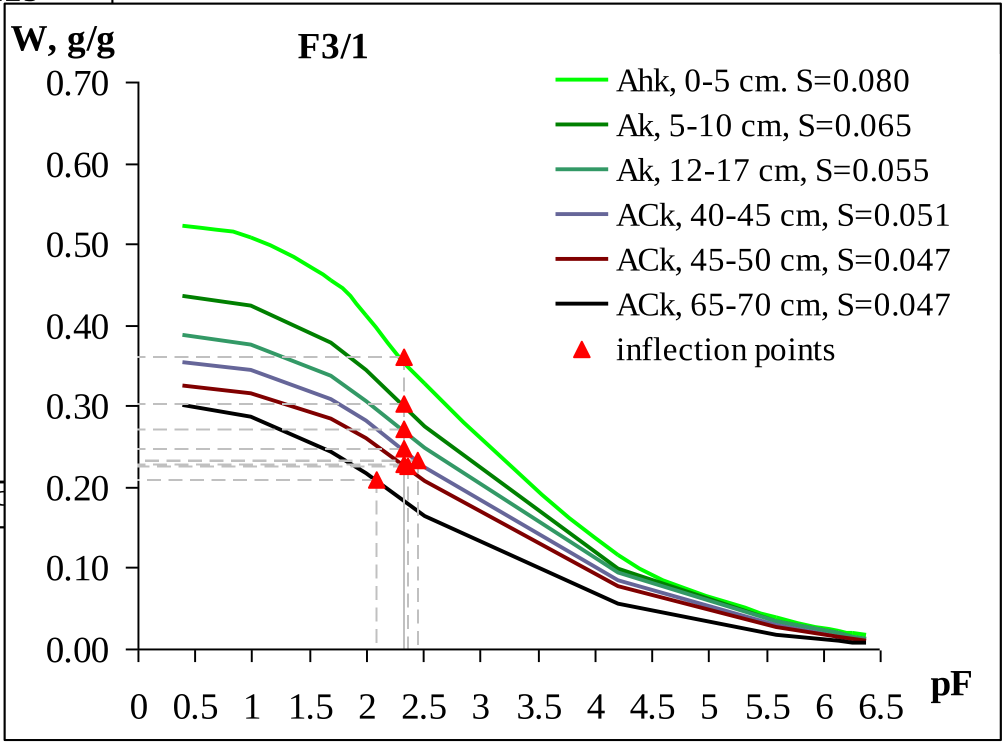
Soil physical quality parameter (S-parameter)

- Defined as the slope of the water retention curve at its inflection point (Dexter, 2006), determined with the parameters of van Genuhten (1980) water retention equation obtained from the measured values:

$$\Theta_{INFL.} = (\Theta_{SAT.} - \Theta_{REZ.})(1-1/m)^{-m} + \Theta_{REZ.}$$

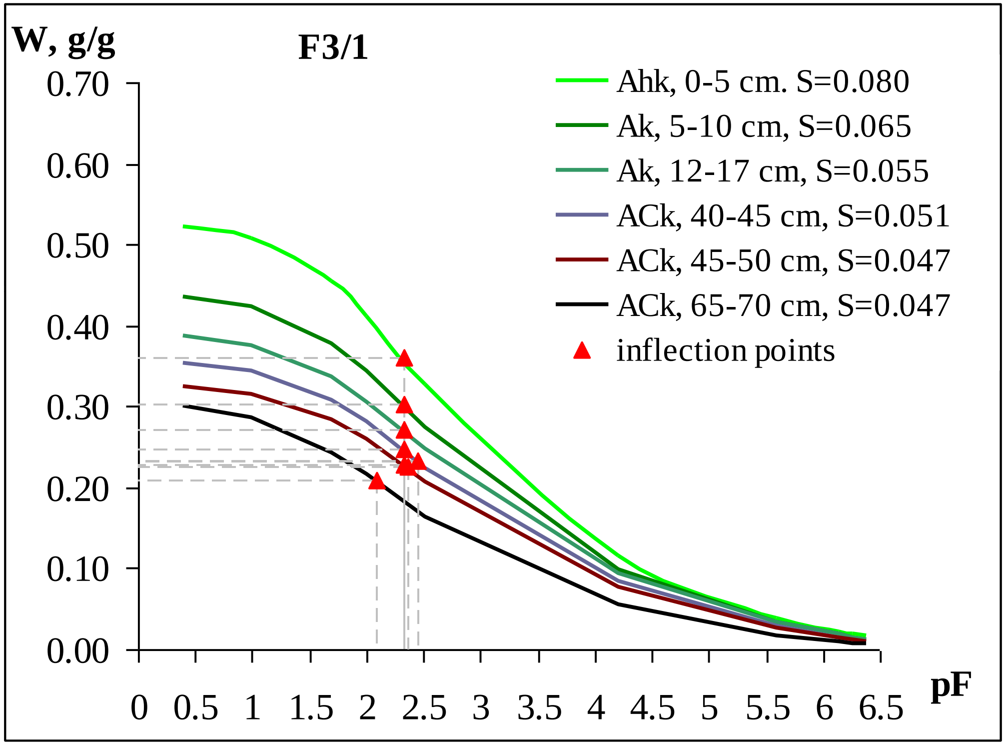
Soil physical quality parameter (S-parameter)



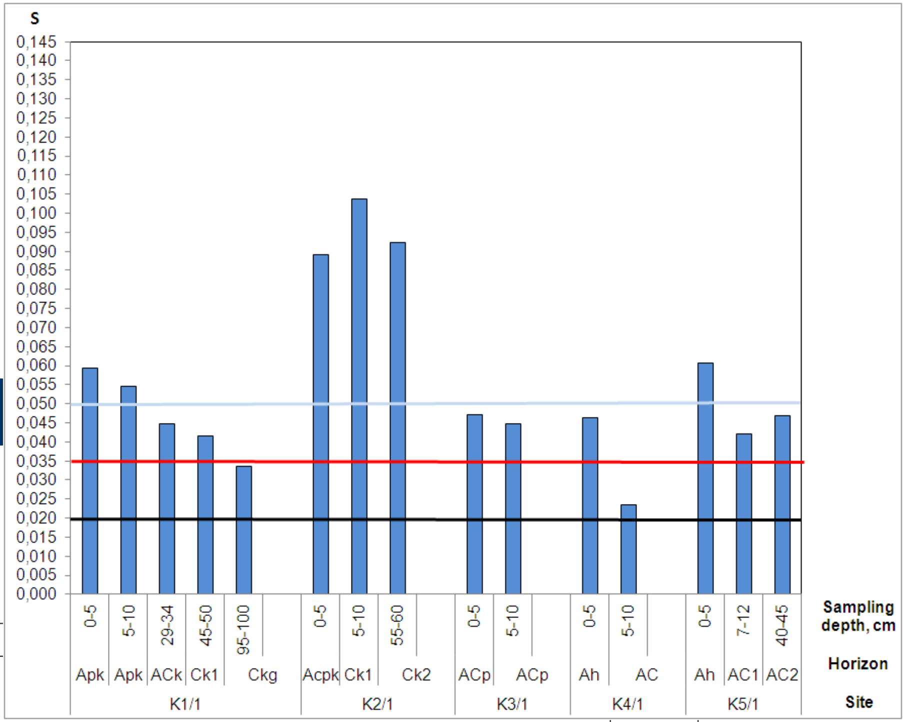


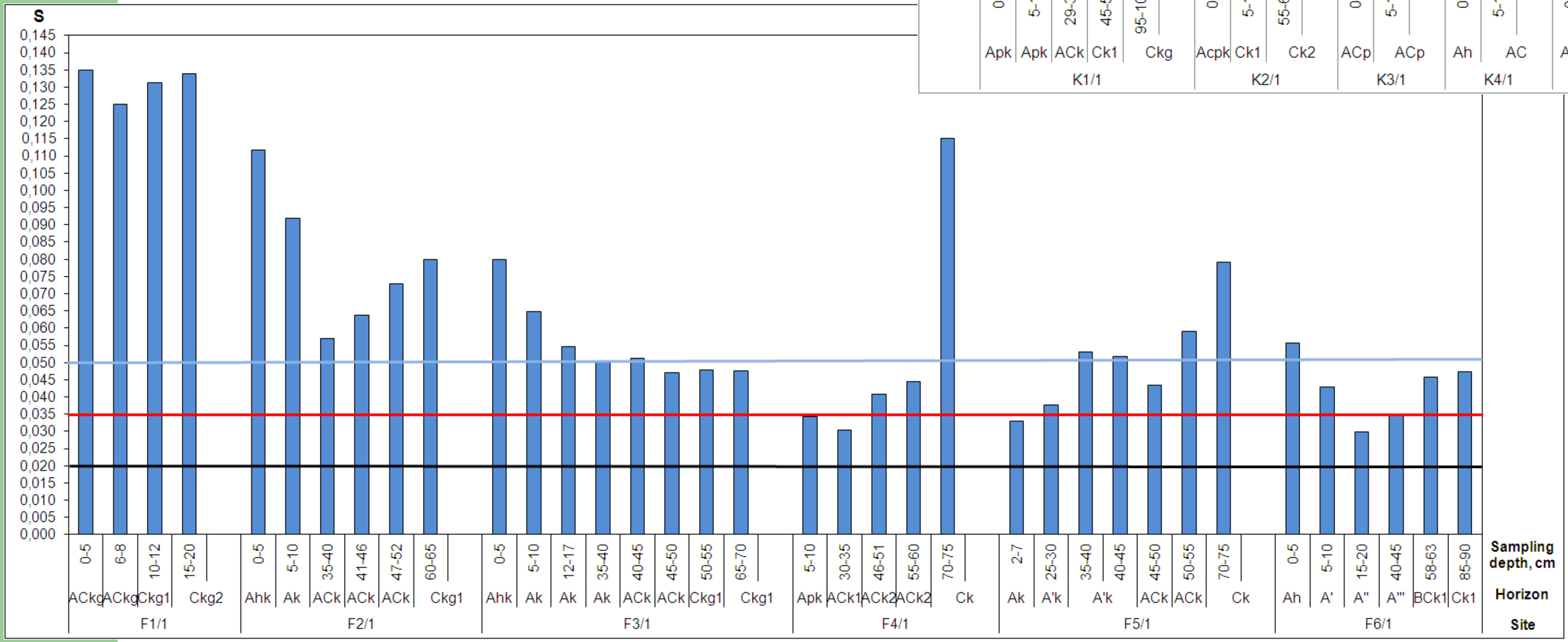
S-parameter

- Categorized (Dexter, 2004) to assess soil physical quality as follows:
  - S < 0.020 very poor,
  - 0.020 ≤ S < 0.035 poor,
  - 0.035 ≤ S < 0.050 good
  - S ≥ 0.050 very good



S-parameter


S
0,145
0,140
0,135
0,130
0,125
0,120
0,115
0,110
0,105
0,100
0,095
0,090
0,085
0,080
0,075
0,070
0,065
0,060
0,055
0,050
0,045
0,040
0,035
0,030
0,025
0,020
0,015
0,010
0,005
0,000
0-5
5-10
29-34
45-50
95-100
0-5
5-10
55-60
0-5
5-10
0-5
5-10
0-5
7-12
40-45
Sampling depth, cm
Apk
Apk
ACk
Ck1
Ckg
Acpk
Ck1
Ck2
ACp
ACp
Ah
AC
Ah
AC1
AC2
Horizon
K1/1
K2/1
K3/1
K4/1
K5/1
Site


S
0,145
0,140
0,135
0,130
0,125
0,120
0,115
0,110
0,105
0,100
0,095
0,090
0,085
0,080
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0,070
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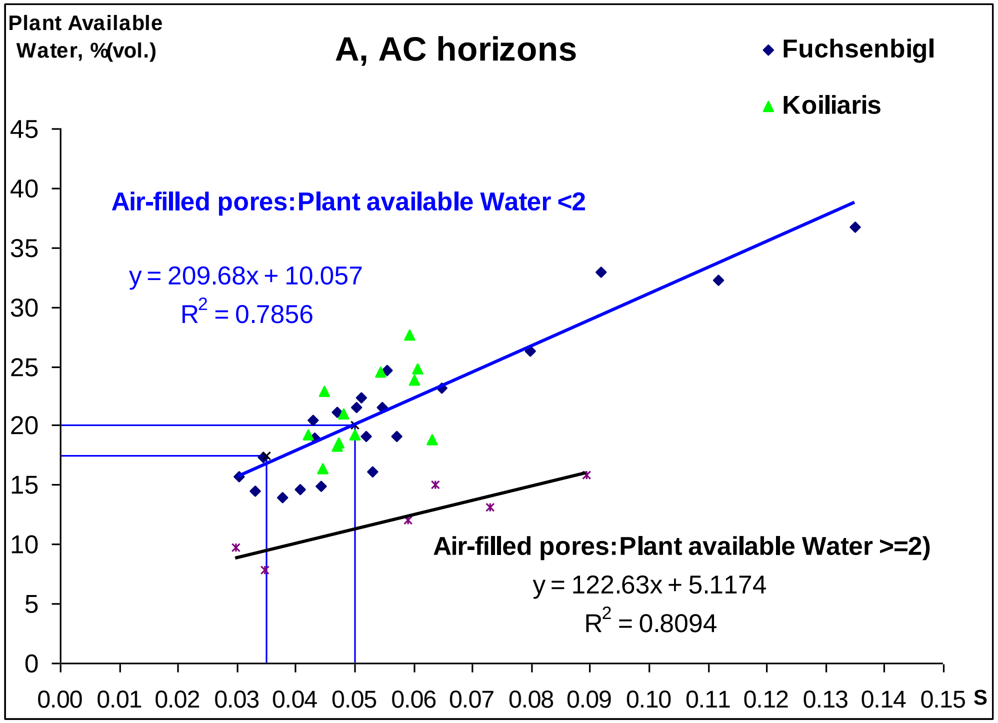
0,060
0,055
0,050
0,045
0,040
0,035
0,030
0,025
0,020
0,015
0,010
0,005
0,000
0-5
6-8
10-12
15-20
0-5
5-10
35-40
41-46
47-52
60-65
0-5
5-10
12-17
35-40
40-45
45-50
50-55
65-70
5-10
30-35
46-51
55-60
70-75
2-7
25-30
35-40
40-45
45-50
50-55
70-75
0-5
5-10
15-20
40-45
58-63
85-90
Sampling depth, cm
ACkg
ACkg
Ckg1
Ckg2
Ahk
Ak
ACk
ACk
ACk
Ckg1
Ahk
Ak
Ak
Ak
ACk
ACk
Ckg1
Ckg1
Apk
ACk1
ACk2
ACk2
Ck
Ak
A'k
A'k
ACk
ACk
Ck
Ah
A'
A''
A'''
BCk1
Ck1
Horizon
F1/1
F2/1
F3/1
F4/1
F5/1
F6/1
Site

S-parameter and PAW

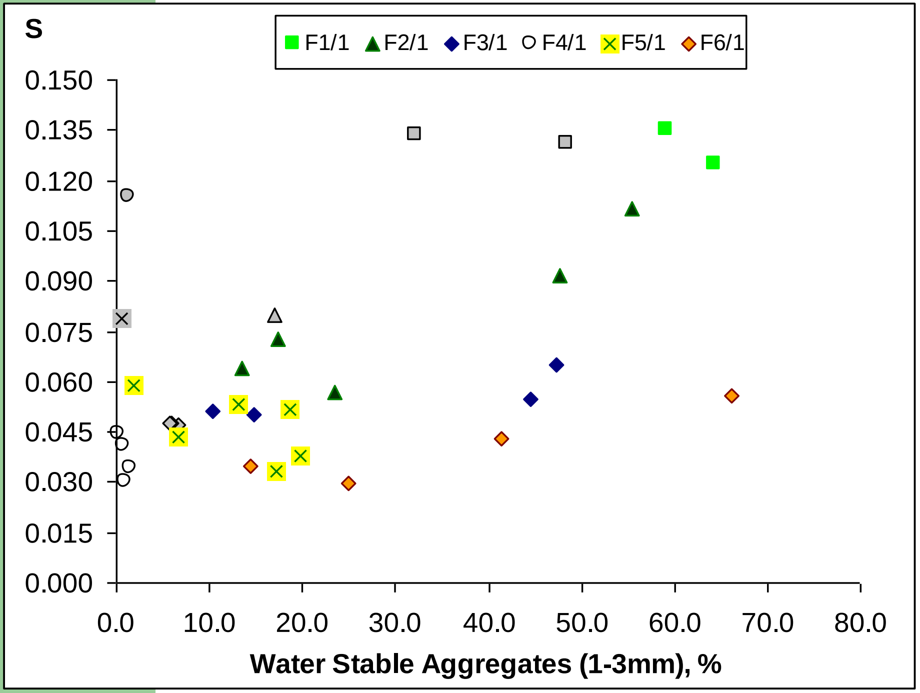
- S>=0.05 corresponds to PAW>20%vol. in the top-soil horizons
- Most of the studied top soil horizons have good physical quality according to S and plant available water (PAW)
- Exceptions are the croplands (F4, F5) which are with poor structure

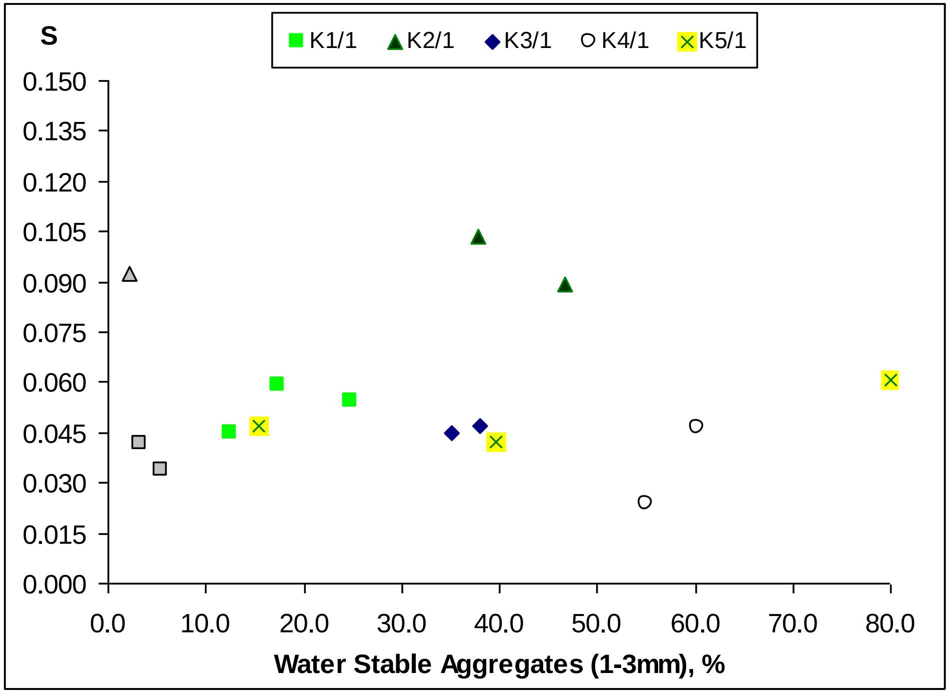


S-parameter and soil structure stability

- Indicator of soil structure stability – water stable soil aggregates with size 1-3 mm.
- The grey colored points correspond to C horizons of the profiles.
- The scattering is due to the high values of S in subsoil, which not always coincides with favorable physical properties, as it was seen from the relationship of S to plant available water content.
- The high values of S in subsoil horizons are due to the low PAW (illustrated on the figure above) and restrict the application of the S categories in these cases.

S-parameter and soil structure stability





Conclusion

- The potential of the soil physical quality parameter (S) calculated from the measured soil water retention curves was explored for soils from two European SoilTrEC CZOs.
- Good agreement was found between the S-parameter and the plant available water depending on the ratio air-filled pores/plant available water
- The application of the S-theory for assessments of the soil physical quality is restricted in cases where the high values of S in subsoil horizons are combined with low PAW.