IUSS - Soil science research approaches and future needs

Prof. Dr. Rainer Horn/Germany
Some general statements about soils

Soils serve a variety of functions:

- **Biomass production** – agriculture, fibre, (only 11% arable soils are without limitations), and wood based resources

- **Environmental interactions** – regulating the flow and filtering of substances from water, emitting and removing atmospheric gases

- A key component in the **Carbon Cycle and global change** but they are endangered by an intense degradation

- **Source and sink** for bioenergy and biowaste – soil and environment degradation due to deformation and following erosion

- Support of habitat and **biodiversity**

- Protection of **cultural heritage** and archaeology

- Providing **raw materials**
Soils are reactors

Soils are essential for food production

- 9 Billion people 2050
- >1 Billion people are starving already today
- +70 % food /2050
- 2,6 Bill. people live directly from agriculture, but 52% on degraded land
- + 300 km²/ day are irreversibly lost worldwide
- Vienna city is gone within 1,5 days!

- Sustainable development goals (SDG´s) for soils must be reached in time in order to perhaps maintain soil functions and adjust the management based on soil resilience demands.
- Soil regeneration requires decades to centuries

Hillel 2004
Soils are heterogeneous (examples from Europe)

- nutrient storage
- nutrient availability
- nutrient translocation

Soils have defined but only limited properties and functions. They are sensitive and can be irreversibly degraded if land use is not adjusted to soil properties.
### Examples for soil types

- **Mollisols, Alfisols, Ultisols**
  - I: 3.06 million km², 2.38%, 424 millions, 5.9%
  - II: 6.40 million km², 4.98%, 993 millions, 13.8%
  - III: 5.85 million km², 4.55%, 331 millions, 4.6%
  - IV: 5.28 million km², 3.95%, 820 millions, 11.4%
  - V: 21.23 million km², 16.51%, 2073 millions, 28.8%
  - VI: 17.13 million km², 13.32%, 850 millions, 11.8%
  - VII: 11.58 million km², 9.01%, 797 millions, 11.1%
  - VIII: 21.46 million km², 16.69%, 1281 millions, 17.8%
  - IX: 36.78 million km², 28.61%, 784 millions, 10.9%

- **Entisols, Inceptisols, Vertisols**
  - 11.9%  
  - 24.3%

- **Oxisols, Spodosol, Glacier, rocky land**
  - 33.8%  
  - 52%

  - 54.3%  
  - 23.8%

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Source: Blum and Eswaran, 2004, modified
Although we know negative and often irreversible impacts of continuous human activities on soil properties and functions....

We must define the relevance and consequences under various climatic, hydraulic conditions and for various landuse systems to avoid further degradation but maintain soil performance and resilience.
A few examples of soil sciences research approaches.
We have to quantify soil functions on **local and global scale** based on existing soil map information.

The potential of sustainable intensification of food production in Europe based on the natural resilience and performance of soils.

**CONTINENTAL SCALE - EU 25**

Limiting indicators on analyzed land:

- Analysed arable land: 671,672 km²
Soil Processes are always coupled at all scales—the link between physical, chemical and biological processes.

Microbiological processes

Hydraulic components
- rigidity of pore systems
- pore pressure
- swelling, shrinkage

Physico-chemical processes

Water fluxes
- water, suspension, heat
- non-linear, hysteretic
- pore water pressure (pwp), hydraulic potential

Soil mechanical processes
- undrained
- elasto-plastic, hysteretic
- non-linear
- water suction dependent

viscoelastic

Mechanical components
- crit. state soil mechanics
- effective stress
- total stress

Hydrology

Richards et al 2000
We know and need to react: Development of the mechanical stress input in agriculture and forestry - anthropogenic effects

Increased area requires more powerful machinery

Enhanced stress intake and depth distribution

Around 1900

About 1960

Today

Future?
Soil degradation due to increasing soil deformation

Effects on the environment

After rain storm
Rapid water table increase in rivers and lakes
Erosion
Surface water runoff increase
N\textsubscript{2}O (CH\textsubscript{4}) gas emission
N - loss due to stagnant water
Heavy machinery compacts arable, forest, and pasture soils
Dust emission increased

Consequences for plant production
Reduced growth, higher uncertainty, less yield
Increased fungi diseases, more weeds

Soil quality declines due to
- reduced pore volume,
- reduced aeration
- Water infiltration reduced,
- soils remain longer wet and cold,
- more slaking problems,
- reduced water storage

Effects on soil management
- higher draft energy required,
- higher fuel consumption,
- wet and cold soils result in smaller number of working days,
- more fertilizers needed

Consequences of climate change: topsoil drought, reduced accessibility of deeper soil, yield and carbon storage!
In short: we work also on anthropogenic influences like:

- physically: Sealing, land slides, erosion, compaction, desertification, improvement of water storage SWRT, waste deposit sealing systems, earth cable installation problems etc.

- chemically: (de-)salinization, pollution by organic and inorganic compounds, decline in organic matter, fertilizer application, liming etc.

- biologically: decline in biodiversity and biological activity.
Discussion of Soil Protection & Sustainable Land Management

..... always depends on our advanced knowledge, but also the link to the public, organisations and politicians
Soils, their coupled functions, limited resilience and related vulnerability are topics which request our complete energy and scientific activity worldwide urgently.

A few examples of urgently needed research topics: We must interest farmers, the public and politicians-

Environment and health topics like Arsenic

Climate Changes aspects

Soil erosion

Land sliding

Coastal Population, %

Australia

USA

Japan

Globally

80

44
We know the relevant values for a sustainable landuse management - we can apply our knowledge to maintain chemical, physical and biological soil properties. An approach to formulate an European soil protection law.

<table>
<thead>
<tr>
<th>Actual value</th>
<th>Precaution value</th>
<th>Action value</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>intensity change of soil properties and functions</td>
<td>irreversibly degraded</td>
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**Cadmium (mg/kg dry matter)**

- **soil** (according to soil texture)

  **Precaution value**:
  - clay: 1.5
  - loam/silt: 1
  - sand: 0.4

  *(at pH<6, precaution value like sand)*

- **exposure pathway**
  - soil - human

  **Action value**:
  - garden: 2
  - Playground for children: 10
  - housing area: 20
  - park: 50
  - industrial area: 60
Values for a sustainable land use planning! We can prepare recommendations to formulate laws e.g. avoidance of soil deformation

In order to sustain soil properties and functions, a more site related land use and soil management strategy is needed! We must intensify these approaches!!!

<table>
<thead>
<tr>
<th>Actual value (Reference)</th>
<th>precaution value (PV)</th>
<th>Action value (AV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil properties</td>
<td>AC &lt; 8 Vol.%</td>
<td>AC &lt; 5 Vol.%</td>
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<tr>
<td></td>
<td>ks &lt; 20 cm/d</td>
<td>O2 availability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ks &lt; 10 cm/d</td>
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No problems
- e.g. Cambisol, Inceptisol, Spodosol
- (sandy material)

Labile soils: Loamy Alfisols E, (Bt), Cv

Sensitive soils: e.g. Kolluvisol, stagnic Luvisols, Gleysol, derived from glacial till or loam, Vertisols,

Actual values depend on: parent material texture, structure, bulk density, Corg. etc.

Modified according to the German Soil Protection Law (1998)
We need to educate and to fascinate people for soils worldwide starting from the Kindergarten up to the professionals and public as partners to counteract or avoid further soil degradation.
Conclusions

IUSS is able to promote:

   - Development of site specific management strategies including the structure rigidity as boundary condition.

2. We know, that land use and soil protection are not conflicting each other, if the boundary conditions are considered – soil degradation must and can be prevented because it can not be reameliorated worldwide quickly!

3. IUSS has the potential to deliver the essential information for a more sustainable future land management
Many thanks for your attention
Soil is the Central Dogma, Soil Governance requires an intense and continuous support in the 21st Century

Picture taken from Jae Yang