Transforming **U**nsustainable management of soils in key agricultural systems in EU and China

Developing an **i**ntegrated platform of alternatives to reverse soil degradation

Improving soil structure to retain more soil moisture

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Short description

Water storage and flow in soils depend highly on soil structure, which strongly determines soil porosity. Structural stability and water transmission characteristics of the soil and the system of the connecting pores determine the soil infiltration capacity and control runoff. There is a strong interaction between soil structure and hydro physical properties, as well as between the pore network and degradation processes, their interrelationships are complex and multifactorial and not yet fully understood. Soil structure may be characterized as individual and differently stable aggregated soil particles' shape, size, and spatial arrangement.

Target area

Soil structure degradation is a universal issue that impacts ecosystems and human livelihoods across climates. Sustainable land management practices can help mitigate these effects. It can occur in all climates, though the causes, severity, and forms of degradation may vary depending on regional factors such as climatic conditions, soil type, land use, and agricultural practices. In cultivated areas, it is common that the traffic of heavy machinery causes fragmentation and ultimately disaggregation of the soil structure in the topsoil and compaction in the subsoil. In dry conditions, the soil surface with degraded structure can easily be exposed to wind erosion.

Problem identification

The problem of soil structural degradation can be identified by soil structural stability assessment. Soil structure assessment is supported by the TUdi app, under "structure" measures **dev-tudi.web.app**

Detailed description of protection

Improving soil structure is crucial for promoting healthy plant growth, enhancing root development, and increasing water retention. Soil structure refers to the arrangement of soil particles (sand, silt, clay) and organic matter into a larger aggregate. A well-structured soil allows air, water, and roots to move freely, while poorly structured soil (like compacted or overly sandy soil) can inhibit plant growth.

The soil structure is determined primarily, but not exclusively, by the soil texture, which is an expression of the particle size distribution.

In the case of sandy, loamy sand soils the proportion of fine particles, like clay, is so small that it does not support the formation of a good soil structure and is often structureless with a single-grain appearance. Their porosity is mainly characterized by large diameter pores, resulting in rapid infiltration of precipitation but low water availability for plants.

In heavy clay soils, the favorable soil condition for soil tillage is only maintained for a short period of a year. Tillage in both too-dry and too-wet soil conditions damages soil structure. In dry clay soils, cracks up to a finger's width can form on the surface, which can partly facilitate deep penetration of precipitation, but also cause deeper drying out in times of drought. Because of the very high clay content, the proportion of strongly bound

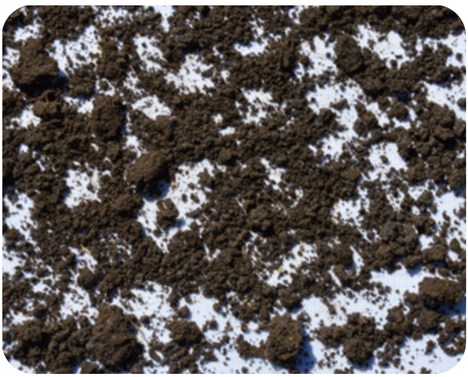


Fig. 1: Granular structure of loamy soil, in topsoil (Chernozem).

Fig. 2: Well-developed subangular blocky structure of a loamy soil (Chernozem).

water to clay particle surfaces is high, so the available water for plants is very low in dry periods.

The particle size distribution of loam soils is balanced. The presence of clay particles with a large surface area supports the formation of soil aggregates (granular or blocky structure and their transitions are common), while sand-sized particles help to maintain soil looseness. In the absence of significant limitations (lack of organic matter or soil compaction, e.g. due to machinery traffic), a good soil structure can develop and provide (compared to the other textured soils) the largest amount of plant available moisture.

Extreme chemistry can harm soil structure. Both strongly acidic and strongly alkaline conditions result in weak soil structure. The chemistry of the soil layer affects the structural stability and determines the condition of plants. Under strongly acidic conditions the lack of Ca-ions can cause weak soil structure, while under strongly alkaline conditions (e.g. in the

Fig. 3: Columnar structure of a clay soil (Solonetz).

case of Solonetz soils) the presence of Na-ion on the colloids (clay) surfaces causes columnar structure development in the subsurface, and coupled with the disaggregation of the structural units (soapy surface appearance if wet).

Elongated waterlogging can happen because both of natural (topography) or artificial reasons (e.g. subsoil compaction under arable land). Proper drainage, as the removal of the excess water from arable lands can help to maintain soil structure by preventing its degradation by water.

Improving soil structure requires a long-term soil management practice targeting better soil conditions. The most common practices to improve soil structure coupled with increasing the organic matter content of the soil, applying soil cover, reducing processes resulting in soil compaction, and encouraging soil biological activity. In some cases, e.g. in poorly drained soils (such as clay) mechanical additions like incorporating sand, perlite, or other drainage-improving materials can loosen the soil and allow better root growth which can help loosen compacted layers and improve air and water movement, achieving better soil structure in long term.

Fig. 4: Results of soil aggregate stability test (see the TUdi DST app), applying tea strainer, glass and water. The stability of the soil structure decreases from left to right.

Pros/Cons of technique, obstacles to implementation

On the positive side, water and soil loss can be reduced effectively from the start of vegetation. On the negative side, additional costs for equipment and through a reduction in travelling speed occur. The required tools can be built by crafty farmers with well-equipped workshops, however this needs a lot of skill, time, and experience. In some countries (e.g., Austria, Germany) some companies already offer planting technology for creating cross dams.

Effects/results/case studies

Organic matter additions, such as mature compost or animal manures (e.g., cow, horse) improve soil aeration, water retention, and promote beneficial microorganisms, add nutrients and enhance soil aggregation. Green manure are the plants that can be grown and tilled into the soil to increase organic content and prevent erosion. Applying mulches to the soil surface improves moisture retention and reduces erosion while gradually decomposing and enhancing soil structure.

Under intensive cultivation and heavy machinery traffic, soil tillage can break up soil aggregates and compact the deeper layers (e.g. plough pan with platy structure), leading to poor water infiltration conditions, limited drainage and water ponding on the surface. Reduced tillage and avoidance of heavy machinery traffic, especially on wet soil are preventing soil compaction and maintaining natural soil structure.

Applying organic mulches (e.g., wood chips, straw) on the soil surface helps retain moisture, reduce temperature extremes, and gradually enrich the soil in organic matter. Cover crops help protect the soil from erosion and prevent nutrient loss, and their roots permeate the soil, preserving the soil structure. Living roots release organic compounds, such as polysaccharides and proteins, which act as binders, helping soil particles to stick together and form aggregates. Both applications promote the growth of micro- and mesofauna in the soil, as well.

More literature

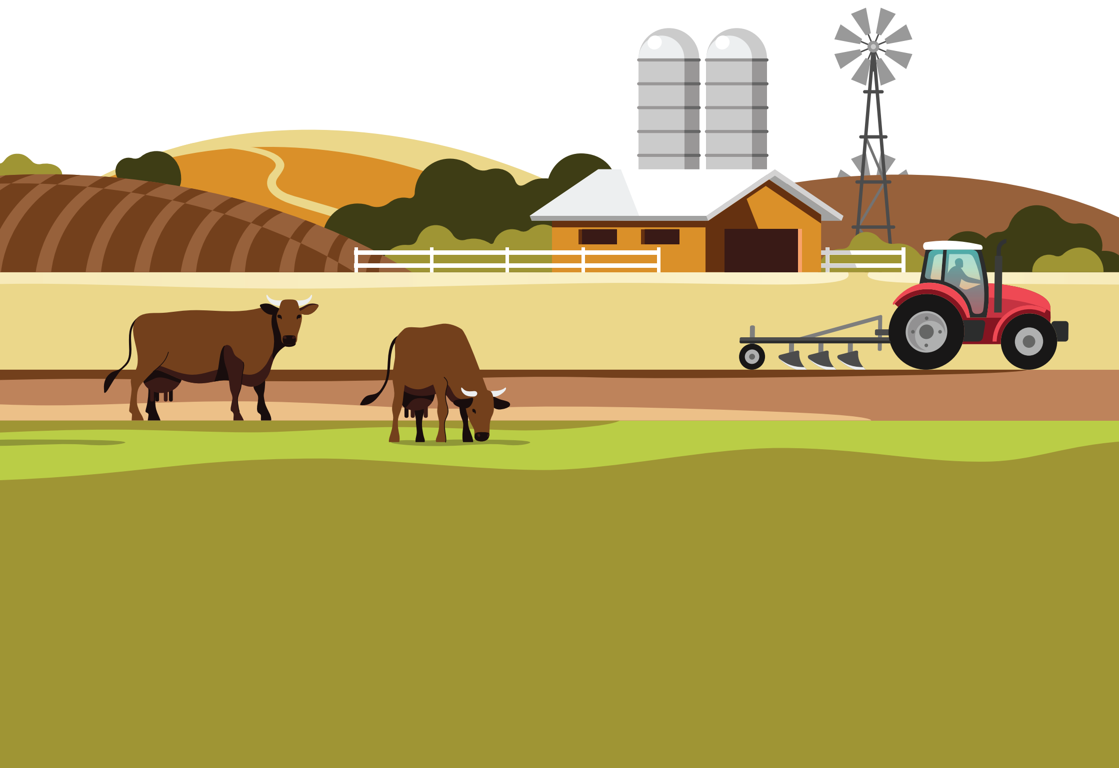
Peoplau et al 2024. **DOI: 10.1111/ejss.13549**

Tobiasová et al. 2023. **DOI:10.3390/su151411047**

Summary

Soil structure is affected by how solid small soil particles are assembled into larger clumps, called soil aggregates. The soil organic matter content and the tillage practices also have a major influence on the structure. The soil structure controls the soil pore size distribution, air permeability and water-holding capacity of the soil. The size and stability of soil aggregates determine the resistance of soils to different moisture conditions. The consequence of poor soil structure is a reduction in soil water-holding capacity, which means that soils are less able to supply moisture to plants.

Soil restoration practices that add organic matter to the soil or prevent it from degradation (e.g. crop residue incorporation, mulching, cover crop), promote soil life (applying sustainable crop rotation, organic fertilization) and reduce mechanical stresses (e.g. non-inversion tillage, no-tillage or planning traffic frequency or heavy traffic control) help to maintain or improve soil structure. Enhancing soil structure provides more favorable growing conditions for plants, improved water retention and reduced surface erosion.



Summary table

	Rating	Comments
Soil health overall	***	
Water budget	**	
Soil structure	***	
Erosivity	**	
Nutrient balance	***	
Soil life	*	
Practicability	-	
Economy	-	

Consortium

Agrisat; Beijing Forestry University; Beijing Normal University; Centre for Agricultural Research; China Agricultural University; Czech Technical University in Prague; Lincoln University; New Bulgarian University; Northwest A&F University; Northwest UNIVERSITY; Pensoft Publishers; Spanish National Research Council; University of Lancaster; BOKU University, Vienna; University of Turin; Federal Agency for Water Management, Austria

Project coordinator

José A. Gómez
Institute of Sustainable Agriculture of the Spanish Council for Scientific Research
joseagomez@ias.csic.es

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