Role of soil in water and nutrient retention

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Multifunctionality, healthy soil

In the previous understanding, the role of soils was limited to production function, which is closely related to agriculture. Climate change, the deterioration of water quality and the loss of biodiversity point to the importance of other functions of soil, such as nutrient cycling, habitats for organisms, water purification by reducing pollution, prevention of floods and droughts through soil retention, and CO2 sequestration.

Food Security

Healthy soils increase fertility, yields and the nutrient value of foods, boosting human health and food access globally.

Farmer Livelihoods

Farmers improve yields and reduce the need for costly synthetic inputs when they build healthy soils.

Soil Stability

Restoring soils educes soil erosion and desertification.

Habitat Preservation

Regenerative agriculture supports wildlife and pollinators.

Water Conservation

For each 1% increase in organic matter, U.S. cropland could store the equivalent of 150 days of water flowing over the Niagara Falls.

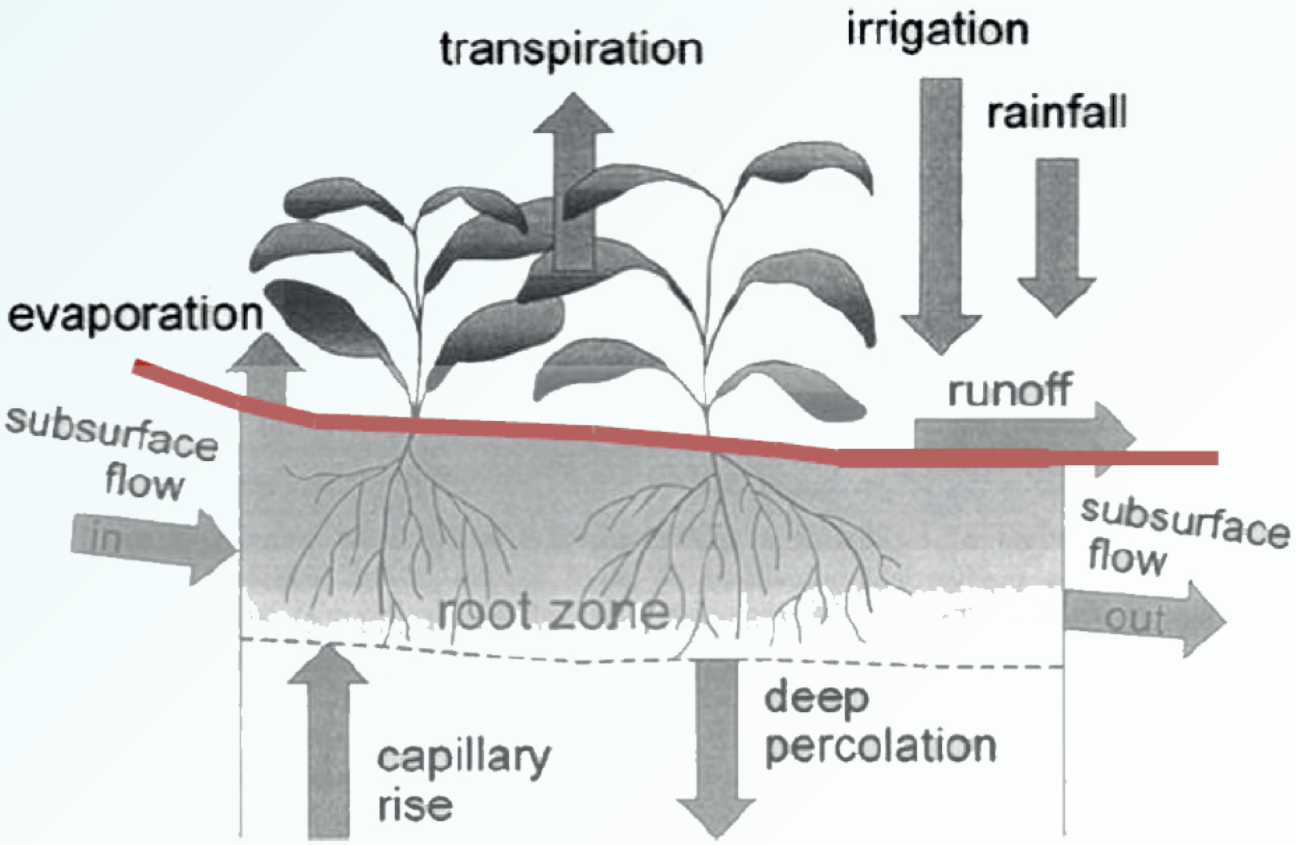
Source | https://www.breakthroughstrategiesandsolutions.com/about

Water in soil

The main sources of water in soils
are precipitation, water underflow
from deeper soil layers,
and to a lesser extent,
condensation and artificial irrigation.

Water losses in soils are mainly due to
surface and subsurface runoff,
water infiltration into deeper layer,
evaporation of water from the soil
surface and, during the growing season,
transpiration by plant.

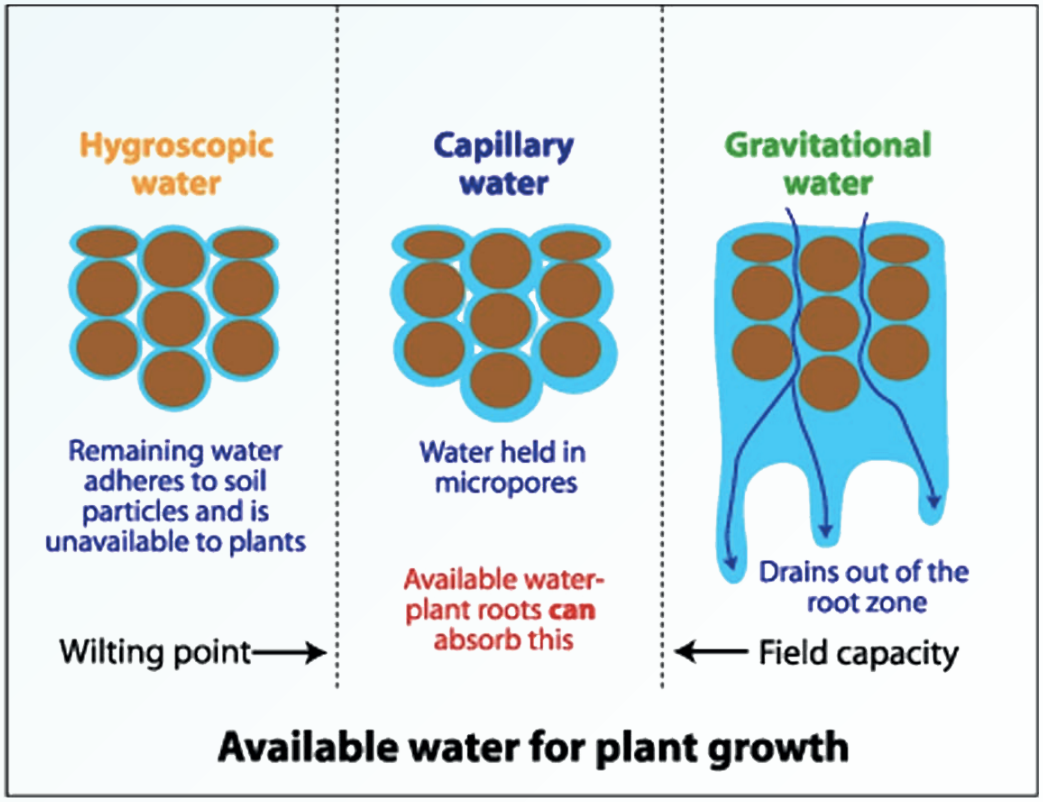
The amount of water retained in the soil,
and that is available to plants,
depends most heavily on:
• the right soil structure
• the granulometric composition
• organic matter content.



Available water for plant growth

Capillary water is held in pores that are small enough to hold water against gravity, but not so tightly that roots cannot absorb it. This water occurs as a film round soil particles and in the pores between them and is the main source of plant moisture.
This capillary water can move in all directions in response to suction and can move upwards through soil for up to two metres, the particles and pores of the soil acting like a wick.

Gravitational water is held in large soil pores and rapidly drains out under the action of gravity within a day or so after rain.
Plants can only make use of gravitational water for a few days after rain.

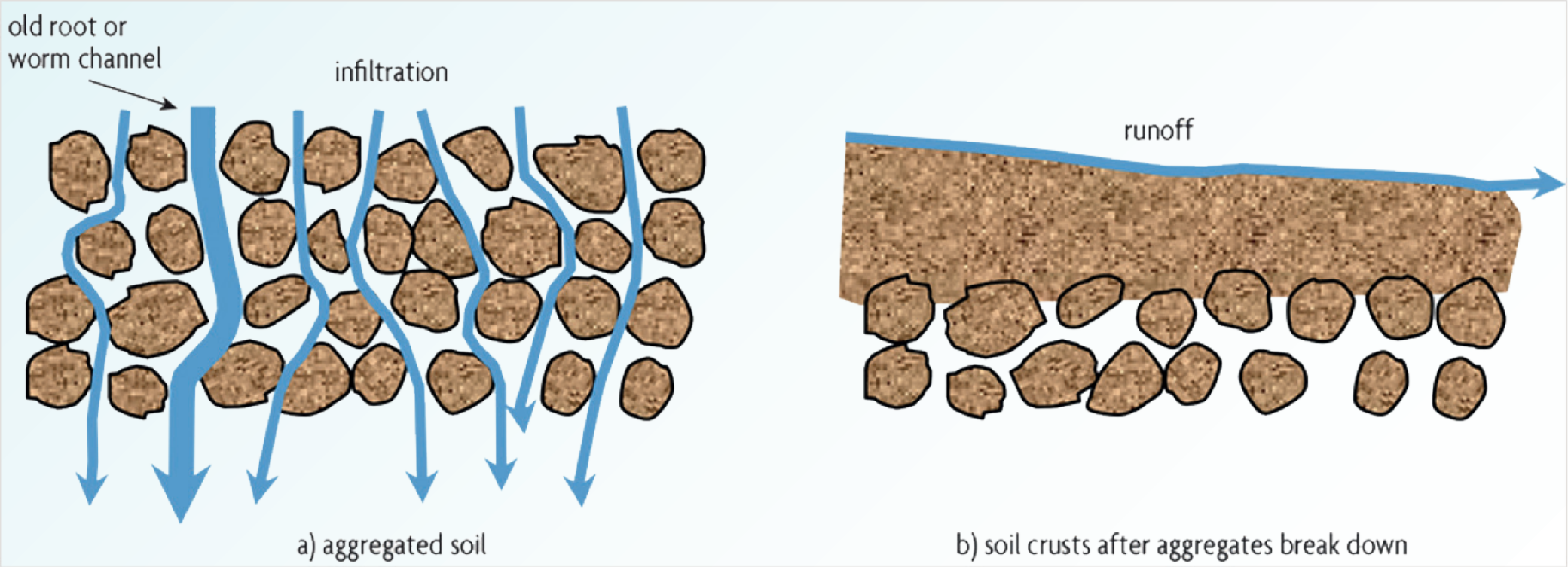


Source : www.tes.com

Source | http://bettersoils.soilwater.com.au/module2/2_1.htm

Water holding capacity

The amount of water retained in the soil is linked to porosity. That is why the critical factors are particle sizes (texture), and arrangement of particles (structure). Factors which also affect moisture storage are: organic matter content, carbonate levels, and stone content.

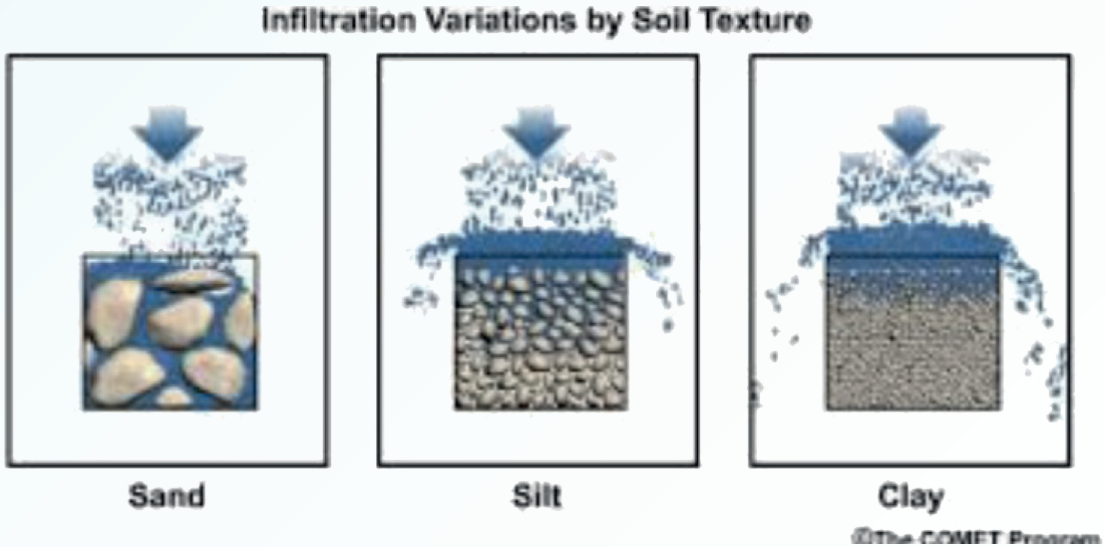


Source | https://www.sare.org/publications/building-soils-for-better-crops/what-is-organic-matter-and-why-is-it-so-important/

Soil texture

The ideal soil is called loam, it is a mixture of sand, clay, and silt. It holds water very well,

but is still porous enough to drain excess water.



Source | http://lizschroeder.weebly.com/blog/soil-permeability-and-water-holding-capacity

The farmer has no control over soil grain size, but …
should adjust his practices and production method accordingly.

On sandy soils, where water moves quickly into the soil profile, it is important to use practices that promote water storage.

The introduction of deep-rooting plants and organic fertilization, which slows the movement of water deep into the soil profile, have a very good effect here.

In contrast, **clay soils** have insufficient permeability, which causes water to remain on the soil surface, creating stagnant water or, in the case of slopes, runoff from fields.

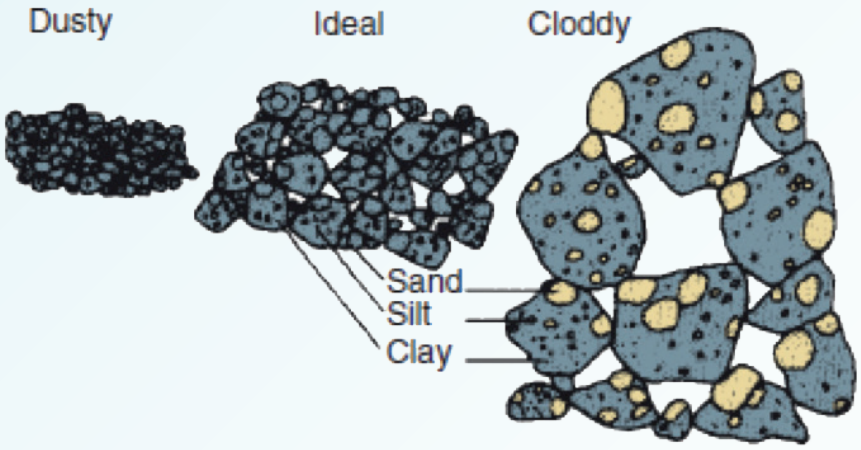
With clay soils it is extremely important that fieldwork is not carried out when the soil is too wet, as this results in compaction and consequent additional loss of permeability.

Source | Siebielec G. 2019. Dobre praktyki rolnicze w zarządzani struktura gleby i rodzajem uprawy w celu ograniczenia strat substancji nawozowych [w] Zrównoważone rolnictwo w służbie bioróżnorodności

Soil structure

Soil structure is the arrangement of soil particles (sand, silt, clay and organic matter) into granules, crumbs or blocks. Well-structured soils are usually crumbly and friable and have plenty of pore space to allow water and air movement and healthy root development.

Source | https://www.rolawn.co.uk/soil-structure



A cloddy structure reduces:

- the risk of rainwater losses,
- improves fertilizer use by plants,
- reduces the risk of erosion, and
- ensures the best water-air relations in the soil.

Source | https://biocyclopedia.com/index/principles_of_horticulture/soil_structure.php

Care for soil structure

- **Agrotechnical treatments**: During each tillage operation a certain number of aggregates are destroyed, so the less intensive the tillage, the better the state of the soil structure.
- **pH regulation**: Calcium compounds in combination with humus cement the tubercles of the soil. This makes the tubercles more resistant to the damaging effects of water and reduces the risk of soil clumping when wet and crusting when dry.
- **Rotation with structure-building plants**: These include faba bean plants (e.g. peas, lupins, clovers, alfalfa, serradella). The richer the root system, the more favourable the structure.
- **Perform mechanical tillage when soil moisture is adequate**: To reduce the risk of structure deterioration on light soils, spring tillage should be limited on these soils. This will also maintain an adequate level of soil moisture.
- **Organic matter** glues soil particles together, which means that it participates in the formation of aggregates.
- Using a ground cover of **intercrops or mulch** for as much of the year as possible, which protects the soil clods from being washed away and the soil from drying out

Source | Siebielec G. 2019. Dobre praktyki rolnicze w zarządzani struktura gleby i rodzajem uprawy w celu ograniczenia strat substancji nawozowych [w] Zrównoważone rolnictwo w służbie bioróżnorodności

Organic Matter

Organic matter is concentrated in the top 5cm of soil and contributes to the darker colour of surface soil. It consists of not fully decomposed organic and natural fertilizers, dead plant and animal and products resulting from the activities of soil microflora and fauna soil.

Soil organic matter is a source of nutrients, improves soil structure, reduces erosion, and largely determines the level of rainwater retention in the soil, which in turn determines its availability to crops.

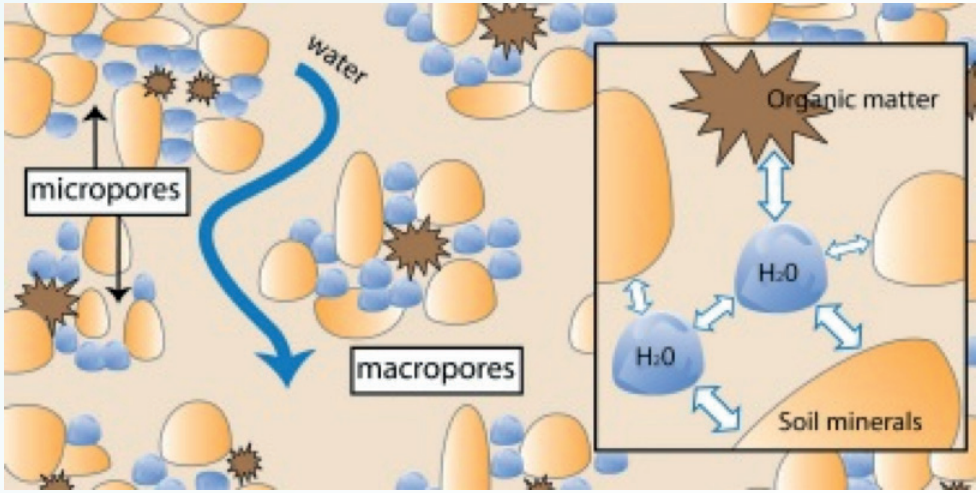
Therefore, it is important to maintain a balance between the rate of decomposition (mineralization) of organic matter and its supply in the form of plant residues or organic and natural fertilizers.

Source | https://esdac.jrc.ec.europa.eu/themes/soil-organic-carbon-content

Source | Siebielec G. 2019. Dobre praktyki rolnicze w zarządzani struktura gleby i rodzajem uprawy w celu ograniczenia strat substancji nawozowych [w] Zrównoważone rolnictwo w służbie bioróżnorodności

Organic Matter

- Organic matter has a very large surface area and, therefore, many ion exchange sites.
- Like clay particles, organic matter is usually negatively charged and so can attract and loosely hold positively charged ions.
- Organic matter holds more than 95% of a soil's nitrogen. It can also hold 15 to 85% (normally 30 to 50%) of a soil's phosphorus.
- Organic matter/metal complexes provide a very effective way of holding the micronutrient elements iron, copper, manganese and zinc in soil in forms that are readily available to plants
- It improves a soil's structure by binding soil particles together to form stable aggregates. The formation of stable soil aggregates creates gaps and pores for air and water movement into and through the soil and provides pathways for root growth.



Source | http://bettersoils.soilwater.com.au/module2/2_2.htm

https://www.qld.gov.au/environment/land/management/soil/soil-properties/water

Maintain and build organic matter

- Plowing straw and green manure
- Cultivation of catch crops
- Cultivation of legumes and papilionaceous plants
- Using natural (manure) and organic fertilizers (e.g. compost)
- Replacing conventional tillage with no-tillage or reduced tillage

can also increase organic matter reserves. Simplifying tillage reduces soil aeration, which also decreases the breakdown of organic matter. However, reduced tillage or no-till only result in organic matter accumulation when used for many years.

Source | Siebielec G. 2019. Dobre praktyki rolnicze w zarządzani struktura gleby i rodzajem uprawy w celu ograniczenia strat substancji nawozowych [w] Zrównoważone rolnictwo w służbie bioróżnorodności

Environmental hazards associated with soil erosion

Environmental hazards associated with soil water erosion are not limited to the erosion site and the soil itself.

Soil material torn up by runoff water is transported out of the field and enters surface waters, contaminating them primarily with phosphorus and nitrogen and with crop protection products.

Another important element is the siltation of roads, ditches and rivers.

Prevent water erosion of soils to reduce water and fertilizer losses

- Adjust crop production so that the **soil is covered with vegetation all year round**. The root system of the plants stabilises the soil aggregates, which increases the infiltration of water into the soil profile and therefore reduces surface run-off and water erosion
- **Appropriate direction of tillage and inter-row cultivation** on slopes. Perpendicular to the direction of the slope, so as to limit water movement
- **Mulching** the soil to cover the surface with plant residues; this not only effectively protects the soil from erosion but also helps to retain water in the soil
- **Tillage simplification** - among the tillage systems in anti-erosion agrotechnics, the no-tillage system with mulching of the soil surface and direct seeding are recommended in particular. These tillage methods improve both the absorption of rainwater and reduce its runoff

Source | Siebielec G. 2019. Dobre praktyki rolnicze w zarządzani struktura gleby i rodzajem uprawy w celu ograniczenia strat substancji nawozowych [w] Zrównoważone rolnictwo w służbie bioróżnorodności

Living soil

Soil is a living thing: 1 gram of soil contains billions of organisms, including microorganisms such as bacteria and fungi.

- The abundance and diversity of living organisms in the soil are the key drivers of soil ecosystems that control soil fertility, nutrient cycling and greenhouse gas balance
- The soil biosphere controls the cycling of major plant nutrients such as carbon, nitrogen, phosphorus and sulfur. Without the active role of microorganisms, soil cannot provide nutrients that are essential for plant growth and development.
- Microorganisms help clean up the environment by decomposing wastes, converting them into soil, detoxifying contaminated soil, and making it suitable for the existence of other organisms

https://www.fao.org/3/ca8251en/ca8251en.pdf

Source | https://ifdc.org/2020/12/02/soil-biodiversity-for-healthy-soils-and-healthy-lives/

Improving the activity and biodiversity of the soil environment

- The maintenance of a **high content of organic matter** in the soil. The use of natural and organic fertilizers, crop residues, and catch crops provides a food for animals and microorganisms.
- Use **mineral fertilizers and pesticides in a balanced way**. Do not exceed recommended doses and standards and choose chemicals with low toxicity.
- **Maintaining the natural pH** of the soil by liming, which creates better habitat conditions for most microorganisms.
- Using **microbially enriched bio-fertilizers** and fertilizers that support the native bacterial flora of the soil.
- The use of multi-year, **diversified crop rotations**. Plant species diversity promotes biological activity and soil biodiversity.
- Establishing **mid-field shelters** - they play a very important role in promoting biodiversity,
- Simplifying agrotechnical practices. Numerous studies also point to the beneficial effect of **reduced (no-tillage) tillage** on the enzymatic activity of soil, where the soil structure is only slightly disturbed, so that there are not too many losses in the functioning of the ecosystem, while a significant amount of oxygen is available to the soil. Oxygen availability has a positive effect on enzymatic activity as well as on the biomass of soil microorganisms.

Source | Gałązka A. 2020. Bioróżnorodność mikroorganizmów glebowych [w] Poradnik dla doradców rolnych. Najlepsze sposoby zarządzania glebami użytkowanymi rolniczo w kontekście zmian klimatycznych.

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