Circular Economy Lab & Observatory

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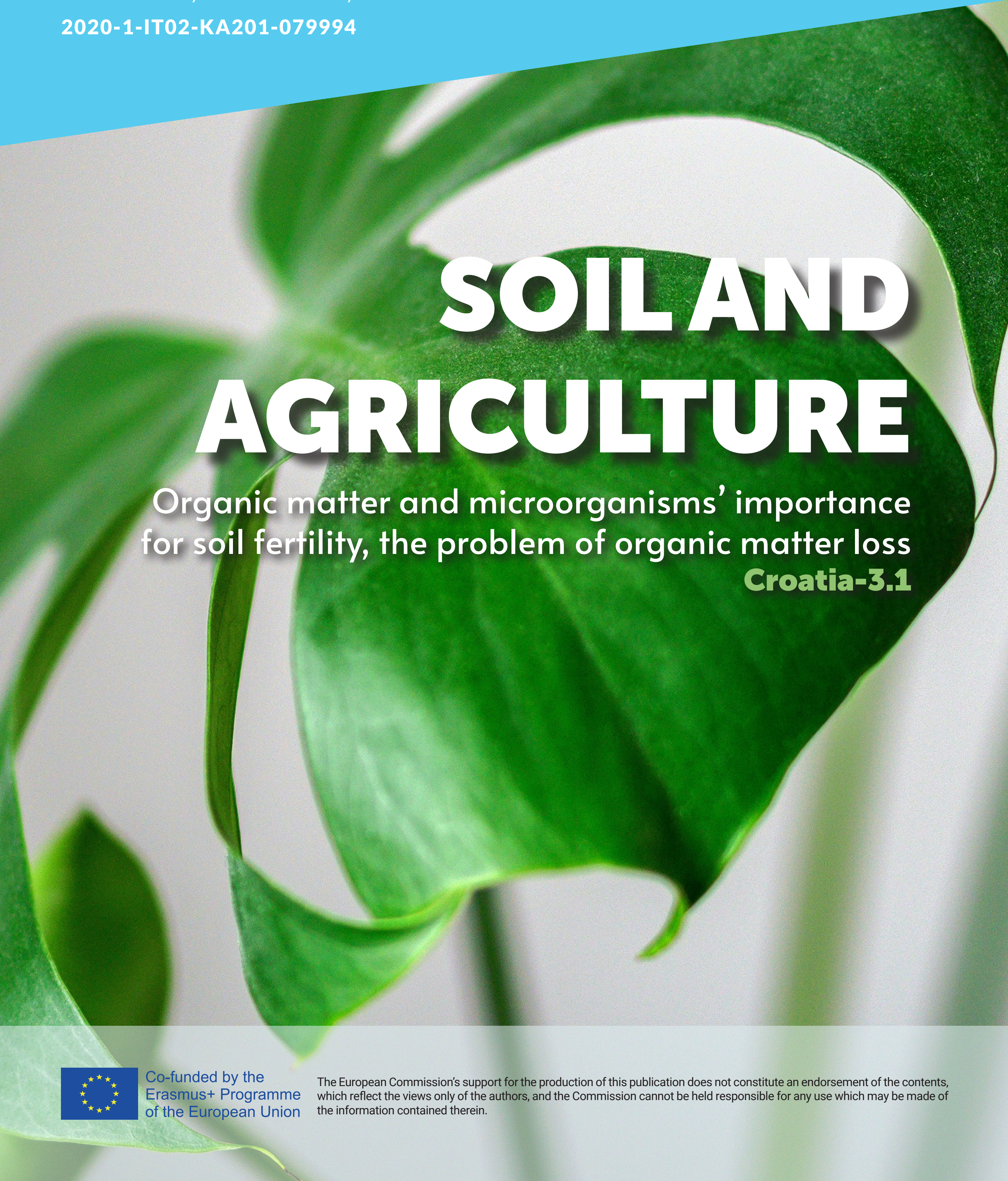
SOIL AND AGRICULTURE

Organic matter and microorganisms' importance for soil fertility, the problem of organic matter loss

Croatia-3.1



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Organic matter and microorganisms' importance for soil fertility, the problem of organic matter loss

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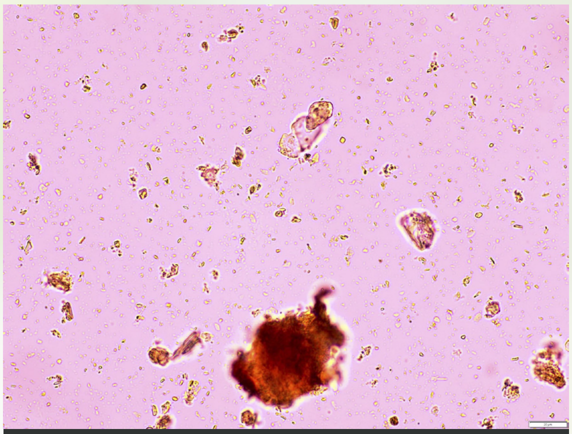
Plants are the most important autotrophic organisms, which create chemical energy and oxygen necessary for most life on Earth. The growth and development of most plants requires soil. It provides them with a foothold for growth and development, but also represents a medium through which plants receive water and nutrients, which bind to the absorption complex of the soil. The suitability of the soil for plant growth and development depends on the physical and chemical properties of the soil.



Soil under a microscope (photo by group CRO3.1)

The soil mainly consists of mineral components, while organic matter makes up approximately 10%. Organic matter is any material that originates from living organisms (fungi, bacteria, plants, and animals) and is found in the soil and undergoes a decomposition process. Soil organic matter consists of varied materials, from living organisms, through dead organisms whose parts can still be recognized, to completely decomposed organic materials known as humus. Humus is overly complex, stable, and decomposes very slowly.

It is not food for soil organisms but is an especially important component of the soil. Although compared to other soil fractions, it has a relatively small percentage (less than 5%), its large active surface and physical and chemical properties have a significant effect on all soil properties. Humus is also a reserve of nutrients in the soil that it gradually releases and makes available to plants.

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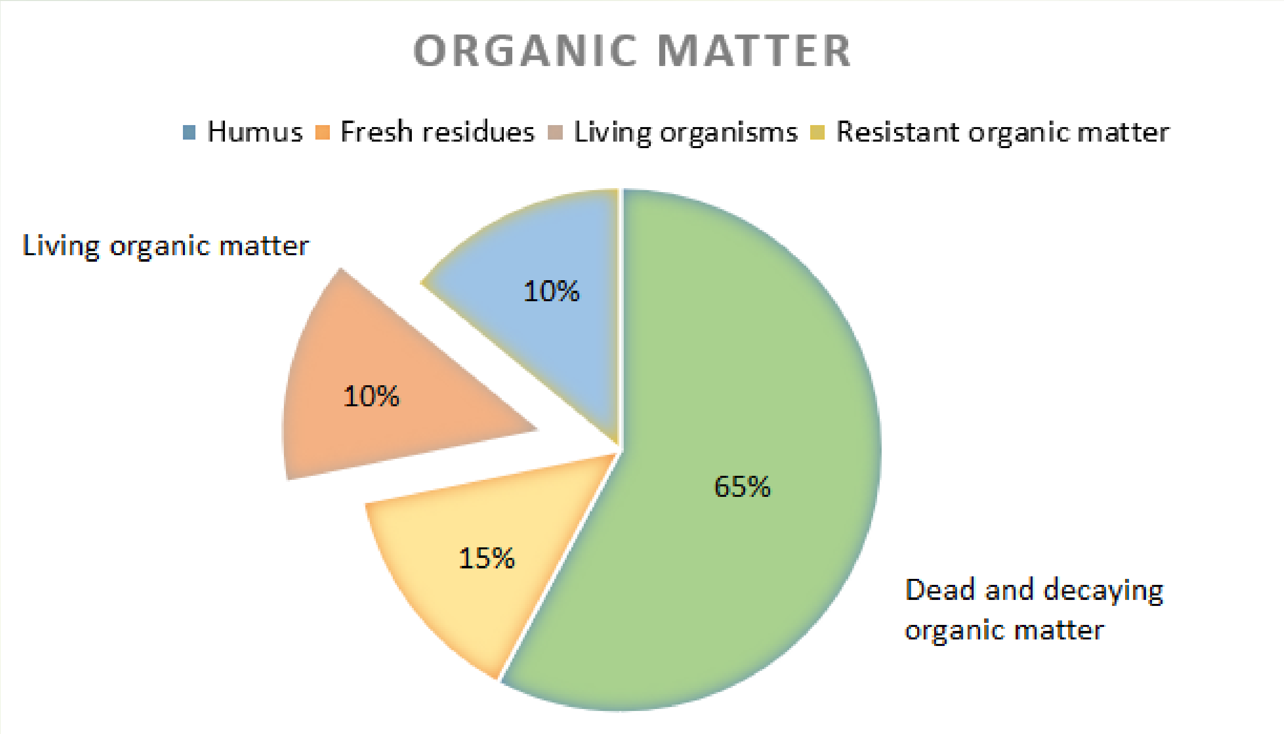

Soil organic matter composition (graph by group CRO3.1)

Furthermore, humus can prevent the toxicity of some potentially harmful substances by binding them to its surface and preventing them from being absorbed by the plant.

Humus improves soil structure, glues structural aggregates[1], and makes them stable.

In texturally heavier soils with a high content of clay, humus increases the permeability[2] of the soil and the permeability of the soil to water and reduces the compaction[3] of such soils. On the other hand, in texturally light soils with a high sand content, humus increases water retention.

The physical and chemical properties of the soil and its fertility largely depend on the share and composition of the organic component.

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The organic component consists of the products of incomplete decomposition of plant and animal remains, which are almost completely mineralized, while some are transformed by soil microorganisms into more or less stable chemical compounds resistant to further decomposition. Different organisms play a vital role in the cycle of nutrients in the soil: macrofauna (centipedes, snails), mesofauna (mites) and microorganisms.

Soil microorganisms are actinomycetes[4], fungi and algae. Living soil organisms contribute to the cycle of organic matter in different ways: fauna contributes to the shredding of organic matter and the increase of its surface area, thereby facilitating the mineralization of organic matter by microorganisms, the formation of humus, the mixing of organic and inorganic soil components, and the creation and maintenance of pores in the soil (for water and oxygen).

In this way, it is possible to break down the remains of dead animals and plants and transform them into components that will provide food for the growth and development of new plants.

In this way, they enable the circulation of organic matter in the environment, enabling an unbroken "circle of life".

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Soil organic matter is the largest pool of carbon (as the basis of life) in the terrestrial biosphere. Soils rich in organic matter will allow the growth of various plants that are part of food chains that include numerous heterotrophic organisms(dogs, fish and humans), thus contributing to biodiversity. [1]

Scarce field in Slavonija due to excessive tillage (photo by group CRO3.I)

Numerous factors affect the loss of organic matter from the soil, such as natural disasters (floods, fires, desertification, winds, etc.) but also human influence through agriculture (excessive exploitation and use of harmful chemicals, e.g., pesticides), forestry (excessive cutting without reforestation), expansion of urban and industrial areas, and various pollution from industry, traffic, etc. One of the biggest factors in loss of organic matter is soil erosion. It can be caused by wind, water, and soil cultivation.

Erosion degrades the soil by carrying away organic matter, microorganisms, and nutrients, especially affecting the surface layer of the soil, which is also the richest in organic matter. That organic matter is food for microorganisms, making them accumulate in the few centimeters of surface area of the soil. Because of that, even loss of a thin layer of soil during wind or water erosion results in an unequal substantial reduction in organic matter and microorganisms.

Tillage techniques [5] affect the rate of decomposition of organic matter in the soil as well as the erosion of the surface layer. Tillage breaks the structure of the soil and disrupts the pores through which water drains, leaving the soil in a state that is sensitive to erosion. Soil cultivation accelerates the decomposition of organic matter.

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After converting forest and grassland areas into agricultural surfaces, there is a sudden drop in the amount of organic matter in the soil. This results in the need for fertilizing the soil with mineral fertilizers and adding soil improvers. Fertilization with mineral fertilizers increases the yield and biomass, thereby a larger amount of organic matter remains in the soil. However, when fertilizing, more nutrients are usually added than the crop needs. Even when the amount that the crop needs is added, the plants simply cannot manage to use all of the added nutrient.


Soil lacking organic matter (photo by group CRO3.1)

In conditions where soil microorganisms have larger amounts of nutrients at their disposal, especially nitrogen, the decomposition of soil organic matter accelerates. Furthermore the production of mineral fertilizers is unsustainable because of the excessive usage of fossil fuels which change the earth's climate by increasing greenhouse gas emissions.

Soil salinization refers to an increase in salt concentration in the workable soil layer. Salts such as some sulfates, nitrates, chlorides, and carbonates are naturally found in soils, but they usually don't cause problems in the soil because their concentrations are low enough. The reason for salinization can also be poor water quality (water that contains a lot of dissolved salts) for irrigation [6].

Salinization often occurs under the influence of sodium (Na^+) and chlorine (Cl^-) ions, but other ions can also be the cause. The negative impact of saline soils results in difficulties in receiving water. The excess salt causes a drop in the water infiltration potential of the soil, making it difficult to receive water. Soil acidity is a major problem in agricultural production, especially in humid regions where, due to heavy rainfall, it comes from separation of alkalis (NaOH, KOH, etc.) from the surface layers of the soil.

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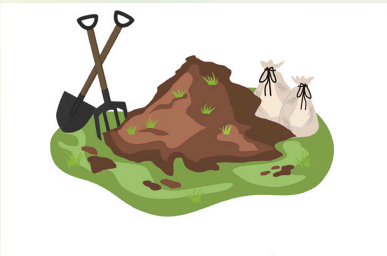
Soil acidification develops due to imbalances in the cycle of nitrogen, sulfur and carbon, the use of ammonium fertilizers, symbiotic nitrogen fixation [7], and acid rain.

Several factors contribute to the toxicity of acidic soil, such as absence of certain nutrients, but the most limiting factor for agricultural production on acidic soils is the increased toxicity of aluminum. The importance of organic matter is undeniable, and its loss has great consequences such as unbalanced intensity of its creation and decomposition which results in a more unstable content of humus, therefore the soil loses its fertility. This loss causes a decline in the number of plants, making the average concentration of oxygen in the atmosphere much lower, having grave impact on all aerobic beings. [11]



Organic residues from agriculture can be used as fertilizers (sketch by group CRO3.1)

The importance of organic matter in soil fertility is unquestionable.

That is why it is necessary to do everything in order to preserve it and, if possible, increase it, especially in soils poor in organic matter. There is a large number of measures that are available for erosion control, and they are divided into: structural interventions and agronomic (agricultural) practices.

Structural interventions mainly refer to spatial interventions that include the construction of terraces, retentions [8], receiving and drainage channels, planting trees in the form of windbreaks, etc. Agronomic practices are based on changes in soil and crop management, such as reduced tillage, cover cropping [9] and planting of plants in critical locations.

The choice of the most appropriate practice depends on the specifics of the agricultural area.

Soil rich in organic matter and microorganisms (photo by group CRO3.1)

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New technologies reduce the need for tillage, e.g. the use of herbicides reduces the need for weed control by tilling the soil, new seed drills enable precise seed placement without prior preparation of the seed layer, liquid organic fertilizers can be injected into the soil, and solid ones can be applied in strips.

Some soil improvers can also be applied on the surface of the soil. In addition to herbicides, weed control is carried out by applying crop rotation and growing cover crops, as well as their timely mulching and mowing. Except in the case of organic agriculture where herbicides are not used, production without tillage or with reduced tillage often yields higher economic profits than that which uses conventional tillage systems.

Although reduced tillage is very widespread and provides numerous benefits to the soil, such a method of tillage is very demanding and needs to be adapted to the properties of the soil and the needs of the culture. Rather than using mineral fertilizers, organic residues from factories, agriculture and cities can be used as a substitute. [III]

Instead of throwing them away, they can be composted and used as fertilizers. Organically bound nutrients are better because they are more stable than mineral fertilizers and have a lower possibility of leaking and evaporation. Furthermore, this method of fertilization is richer in microelements, more precisely trace elements that are necessary for carrying out vital processes.

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There are several strategies that are applied in the management of saline soils. If shallow saline groundwater is not the problem, the soil can be kept constantly moist. For example, if drip irrigation and surface mulch (which reduces evaporation) are used, the salt concentration in the soil will be lower compared to that which occurs when the soil dries out. But the only way to get rid of salt is to wash it with water and the surface horizon of the soil (root zone). In case the soil is not sufficiently permeable, drainage pipes will be needed to remove excess water with dissolved salts.

The problem of soil acidity is weakened by calcification (using calcium materials such as limestone and dolomite). Organic matter reduces the negative effects of acidity because it slows down the acidification process and stabilizes the pH. Organic matter binds acidic cations (H+ and Al3+ ions) very tightly. However, since organic matter slows down acidification, it also makes it difficult to raise the pH with the use of calcareous (chalky) materials. Namely, there are very few acidic cations in the soil solution, and if we had to raise the pH of the soil solution, a few kilograms of limestone would be enough. [IV]

Organic matter is any material that comes from living organisms. Soil organic matter is made up of a variety of materials, ranging from living organisms to dead organisms with identifiable parts to completely decomposed organic materials known as humus. Humus is excessively complex, stable, and it decomposes slowly. It is not food for soil organisms, although it is one of the most important components of soil. Humus is also a nutrient reserve in the soil that it slowly releases and makes available to plants.

More people should compost to reduce the usage of mineral fertilizers (sketch by group CRO3.1)

Together we can restore the world's forests (photo by group CRO3.1)

Living soil organisms contribute to the organic matter cycle in a variety of ways, including shredding organic matter and increasing its surface area, facilitating mineralization of organic matter by microorganisms, the formation of humus, the mixing of organic and inorganic soil components, and the formation and maintenance of pores in the soil. In this way, the remains of dead animals and plants can be broken down and transformed into numerous components that will provide food for the growth and development of new plant life.

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They enable the circulation of organic matter in the environment, allowing for an unbroken "circle of life." Natural disasters, but mostly human influence through agriculture, forestry, urban and industrial expansion, and various pollution from industry, traffic, and so on, all have an impact on the loss of organic matter from the soil.

Organic matter is undeniably important, and its loss has serious consequences, such as an unbalanced intensity of its creation and decomposition, which results in a more unstable content of humus, and therefore the soil loses its fertility. This loss reduces the number of plants, lowering the average concentration of oxygen in the atmosphere, thus having a negative impact on all aerobic organisms.

That is why it is critical to do everything possible to preserve and, if possible, increase it, particularly in soils lacking organic matter. The value of preserving soil fertility and organic soil components has long been recognized, however in recent years, a number of initiatives have been launched with the goal of preserving existing fertile soils and restoring conditions where they are in jeopardy.

The Bonn Challenge, for example, aims to restore 350 million hectares of degraded and cleared forests by 2030. Aside from such global initiatives, there are smaller local initiatives that, when combined, can have a significant conservation impact on "living" soil and thus biodiversity in our environment.

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BIBLIOGRAPHY

[1] Soil aggregates are groups of soil particles that bind to each other.
[2] A measure of the ability of a material to transmit fluids.
[3] Compaction is a procedure that, typically via mechanical means, removes air from the soil while increasing its density.
[4] Actinomycetes is a group of bacteria known for decomposing more resistant organic materials.
[5] The preparation of land for growing crops.
[6] Irrigation is the artificial application of water to the soil through various systems of tubes, pumps, and sprays.
[7] Symbiotic nitrogen fixation is part of a mutualistic relationship in which plants provide a niche and fixed carbon to bacteria in exchange for fixed nitrogen.
[8] The action of absorbing and continuing to hold a substance.
[9] Cover crops are plants that are planted to cover the soil rather than for the purpose of being harvested.

[I] https://franklin.cce.cornell.edu/resources/soil-organic-matter-fact-sheet
[II] https://www.recare-hub.eu/soil-threats/loss-of-organic-matter-in-mineral-soils
[III] https://www.frontiersin.org/articles/10.3389/fpls.2017.01617/full
[IV] https://ec.europa.eu/eip/agriculture/sites/default/files/eip-agri_brochure_soil_organic_matter_matters_2016_en_web.pdf

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GROUP

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