SUSTAINABLE LAND USE

SOIL AMENDMENTS

SLU15

NATURE-DEMO

ADDRESSED HAZARDS

PROTECTED CRITICAL INFRASTRUCTURE

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Primary functions and key services

(Larney and Angers, 2012; Leogrande et al., 2024; Wu et al., 2017; Garbowski et al., 2023)

- **Water retention improvement in the soil:** enhances soil's ability to hold moisture, making it available to plants for longer periods. Hence reducing irrigation needs and improving drought resilience.
- **Soil fertility:** increases nutrient availability, supporting healthy plant growth and resilience in times of water scarcity.
- **Soil structure improvement:** improves soil porosity and reduces compaction, improving water infiltration and root penetration.
- **Erosion control:** stabilises topsoil, reducing loss of soil particles through runoff and wind erosion.

Infrastructure protection – Prevents soil degradation that can affect **irrigation systems, drainage networks**, and **transportation infrastructure in agricultural areas.**

Climatological hazards:

- Moderate mitigation of drought by improving water retention and nutrient availability.

Meteorological hazards:

- Moderate mitigation of wind and water erosion through improved soil structure and organic matter content.

Hydrological hazards:

- Limited mitigation of surface runoff by increasing soil infiltration and reducing peak water flow.
- Moderate mitigation of soil erosion by improving soil stability and reducing vulnerability to heavy rainfall

Site suitability, scale and coverage

Soil amendments are applicable in:

- Agricultural landscapes with declining soil fertility
- Peri-urban and rural areas experiencing soil degradation
- Regions affected by drought, extreme temperatures, and poor soil structure

Environmental impacts

(EU taxonomy)

- ☑ **Climate change mitigation**
- ☑ **Climate change adaptation**
- ☑ **Sustainable use and protection of water and marine resources**
- ☑ **Transition to a circular economy**
- ☐ **Pollution prevention and control**
- ☑ **Protection and restoration of biodiversity and ecosystems.**

What is it?

Soil amendments is a NbS measure that entails adding materials to soil to improve its physical, chemical, and biological properties. These amendments can be organic (e.g., compost, manure, biochar) or inorganic (e.g., lime, gypsum, mineral fertilisers) and are used to enhance soil fertility, improve structure, increase water retention, and support plant growth. Soil amendments play a critical role in restoring degraded soils, increasing agricultural productivity, and enhancing ecosystem resilience against climate-related hazards such as drought, erosion, and soil degradation.
(Larney and Angers, 2012; Leogrande et al., 2024).

Soil amendments. Image Credit: Left: [Freepik], [n.d.], Free to Use.
Right: [Freepik], [n.d.], Free to use.

Challenges this NbS addresses

- **Drought -** prevention and reduction (improves soil water retention, reducing evaporation and increasing plant resilience).
- **Erosion –** control (improves soil structure and stability, reducing vulnerability to wind and water erosion).
- **Soil degradation –** recovery (replenishes depleted soils by restoring nutrient levels and organic matter content).

Ecosystem services

- **Increased microbial activity:** organic matter supports a diverse microbial ecosystem, which plays a key role in nutrient cycling, soil health and carbon retention.
- **Carbon sequestration:** introduced organic amendments such as compost and biochar, contribute to long-term carbon storage in soils, reducing atmospheric CO_2 levels (Xu et al., 2022).
- **Reduced erosion:** enriches soil, making it more resilient to erosion from wind and water.
- **Water conservation:** reduces irrigation needs by increasing soil moisture retention.
- **Enhanced biodiversity:** supports beneficial soil organisms, pollinators, and microbial communities emissions by reducing wildfire spread.

Cost-benefit profile

Bushel, 2018 studied the economic and environmental potential of manure-based biochar (MBC) in agriculture. The study identified a minimum viable price of $383 per ton for MBC to achieve a debt service coverage ratio of 1.00x, and $485 per ton to maintain a debt service coverage ratio of 1.25x. A value-based pricing model suggests that dairy feedstock MBC could be priced between $388 and $688 per ton, while a blended feedstock could range from $422 to $722 per ton, depending on market conditions and competition from plant-based biochars. The author highlighted also environmental benefits, such as improved manure management and soil health, making the MBC a sustainable alternative to traditional soil amendments.

Amended soils multiple ecosystem services and benefits for pollution mitigation and beyond have been analysed in several studies. Further research on quantitative assessment of this NbS typology remediation benefit remains limited though (Alshehri et al., 2023). A systematic literature search conducted by Alshehri et al (2023) highlighted the phytoextraction as the NbS mechanism most assessed by scientific research on the topic, with a main focus on heavy metals and hydrocarbons removal potential. Alshehri et al (2023) refers to the unit-price of remediation assessed per m² (soil) or m³ (soil/groundwater), ranging from $0.31 to $87.7 and averaging 19 USD2022m2, and active bioremediation strategies unit prices ranging from $50.7 to $310.4 averaging 157.6 USD2022m².

Relatively recent studies performed in deforested lands of Brazil (Latawiec et al., 2019), demonstrated low-productivity cattle ranching and the cost-effectiveness of introducing biochar to improve soil properties and agricultural productivity of degraded soils, although effects were very context-dependent. This particular study showed a 27% average increase in Brachiaria production over two years (Latawiec et al., 2019). Biochar addition evidenced the increase of macronutrients and soil pH. Particularly, each hectare amended with biochar reported a save of 91 tonnes of CO2eq through land sparing effect, 13 tonnes of CO2eq sequestration in the soil, equating to U$455 in carbon payments (Latawiec et al., 2019). Even though biochar was estimated as 617% more expensive than common fertilisers, the studies reported that it could improve productivity of degraded pasture lands in Brazil if investments in efficient biochar production techniques were used and biochar was subsidised by low emission incentive schemes. The highest additional meat production and profit was observed for the treatment with biochar (between US$191 and US$324/ha), followed by the combination of fertiliser with inoculant (between US$172 and US$295/ha) and biochar with fertiliser (between US$139 and US$237.

If the biochar was produced for charcoal or other industrial purposes instead of being amended to the soil, farmers could additionally profit between US$30 and US$85 per month, considering the maximum number of kilns that can be operated simultaneously without the necessity of additional labour (Latawiec et al., 2019).

Main components

- **Organic amendments:** compost, manure, biochar, and green manure that enrich soil with organic matter.
  - **Compost:** decomposed organic matter that provides nutrients, improves soil aeration, and enhances moisture retention.
  - **Manure:** animal manure adds organic matter and nutrients, boosting soil fertility and supporting microbial life.
  - **Biochar:** charred biomass that acts as a soil conditioner, improving soil structure, water retention, and carbon sequestration.
- **Inorganic amendments:** lime, gypsum, and mineral fertilisers used to correct soil deficiencies and improve structure.
- **Application methods:** direct soil incorporation, topdressing, and liquid amendments to enhance nutrient absorption.
- **Soil health improvement techniques:** enhances microbial diversity, nutrient cycling, and water-holding capacity.

Organic amendment sketch, made by composting food residues.

Image Credit: [Freepik], [n.d.], Free to use.

Example of installation

- **Residual Effect of Compost and Biochar Amendment on Soil Chemical, Biological, and Physical Properties and Durum Wheat Response** (Leogrande et al., 2024)
- **Location:** Bari, Italy
- **Implemented by:** Council for Agricultural Research and Economics (CREA-AA) and the University of Bari
- **Description and results:** This study evaluated the residual effects of compost and biochar amendments on soil properties and durum wheat response under field conditions. The findings highlighted significant improvements in soil organic carbon content, total nitrogen, and water extractable organic carbon, with compost showing the highest soil water extractable organic carbon.

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