Compost & Soil Health Improvement

Fact Sheet 1:

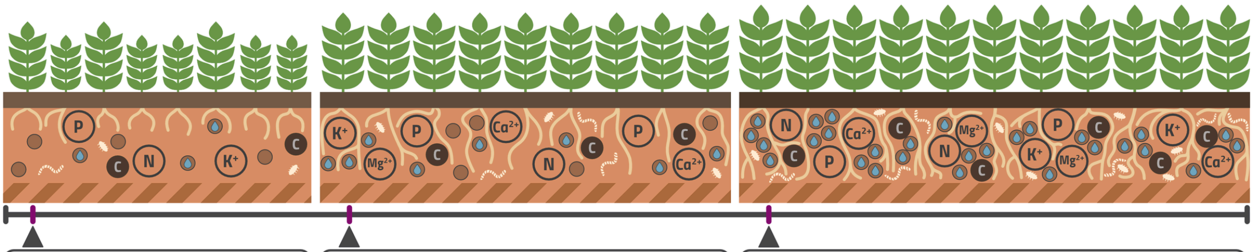
Evidence from Long-Term Trials

ECN
Compost and Digestate for a Circular Bioeconomy

Why Compost Matters in the Long-Term for Soil Health

This ECN Fact Sheet compiles evidence from long-term field trials to show how repeated quality-assured compost applications from abundant green- and bio-waste materials support sustained soil health and farm productivity. Bringing the evidence together shows that the long-term use of compost builds soil structure and carbon content, improves water retention, increases biodiversity, enhances nutrient supply, preserves soil quality, and stabilises yields, which together strengthen farm resilience and soil health over time.

Compost Application Builds Soil Health and Crop Resilience



Year 1

- **SOC and SOM** – First measurable increase
- **MICROBES** – Early activity boost
- **NUTRIENTS** – Initial nutrient boost[a]
- **SOIL STRUCTURE and WATER** – Slightly improved porosity
- **YIELDS** – No major change yet

Year 5

- **SOC and SOM** – Humus build-up
- **MICROBES** – Sustained biomass gains
- **NUTRIENTS** – Residual N; Higher available P and K
- **SOIL STRUCTURE and WATER** – Noticeable porosity; Water holding capacity and infiltration improvements
- **YIELDS** – Stability improves; Higher quality

Year 20

- **SOC and SOM** – Stocks stabilise at high level
- **MICROBES** – Mature soil food web; Significant increase in soil, fauna, and fungi
- **NUTRIENTS** – Long-term bank of total and available nutrients formed
- **SOIL STRUCTURE and WATER** – Bulk density down and medium sized pores up: boosts plant-available water and increases drought resilience
- **YIELDS** – Stable yields and enhanced crop quality

Key Findings of Long-Term Compost Application

- SOM Consistently maintains and increases soil organic matter, improving structure and the soil web.
- C Stores and stabilises organic carbon in soils.
- Improves structure, porosity, and water retention, enhancing drought resilience.
- Enhances soil biodiversity, supporting structure and nutrient supply.
- Provides a reliable, steady supply of available nutrients.
- Shows no significant accumulation of impurities and heavy metals after long-term use.
- Supports stable crop yields and quality after repeated applications.

[a] *Mainly from nutrients that are initially not readily available.*

Effects on Soil Health Indicators and Evidence from Compost Trials

Soil Organic Matter[1, 13, 23]

- It serves as a reservoir for nutrients and water.
- It drives microbial activity and nutrient cycling.
- It provides soil structure and habitat.
- Compost increased SOM in all trials.

Evidence from the Trials

5-year trial	At <20 t/ha[b] → +35% SOM
9-year trial	At 47–49 t/ha → +24% SOM → +8–10 t/ha SOM
9- and 12-year trial	At 7–10 t/ha → average SOM increase of +0,1–1,9% points in amended plots

Soil Organic Carbon[8, 9, 12, 13, 19, 22]

- It acts as a reservoir for nutrients and water.
- It feeds and provides niches for organisms.
- It builds soil structure and stability.
- It helps sequester CO_2 from the atmosphere.
- Repeat application stabilises SOC.
- Organic carbon converts into humus in soil, which serves as a reliable carbon sink.
- Compost increased SOC in all trials

Evidence from the Trials

1 tonne fresh mass	Net CO_2-eq. savings of 143 kg ha^{-1} yr^{-1}
4- to 10- year trial	11–45% applied C remained as SOC
7-year trial, ongoing	+77% SOC on average
27-year trial	+42% in 0–20 cm; +63% in 20–40 cm
2-y. solid digestate[b]: +19–23% SOC grasslands; +11–12% croplands	

Soil Biology[9, 13, 17, 23]

- Soil organisms drive nutrient cycling and soil aggregation.
- Soil biology creates resilient, self-sustaining soil ecosystems.
- Repeated compost applications boost microbial biomass, enzyme activity, and earthworm populations.

Evidence from the Trials

Experimental trials report up to +100% microbial biomass.	
Green compost applications → +20% microbial biomass	
↑ earthworm densities; Stimulated C, N, and P cycling enzymes	
9-year trial	Sandy soils, 20-80 t/ha → +10-46% biomass
Solid digestate stimulates biomass most vs. whole or liquid dig.[c]	

Soil Nutrient Supply[1, 10, 11, 13, 15, 19, 23]

- Compost builds a "nutrient bank", reduces nutrient leaching, and decreases reliance on synthetic inputs.
- Long-term compost use steadily increases essential macro- (N, P, K, Mg, Ca, S) and micronutrients in the soil, acting as a slow-release, multi-nutrient fertiliser.
- Effects of slow N release and long-term nutrient banking visible after 4–5 years, with higher N availability and yields.
- N and SOC are closely linked.
- Reduced N losses from compost in soil result in greater SOC build-up.

Evidence from the Trials

High rates of 45-55 t/ha in 3-year rotation, supplied annually: 60–70 kg/ha P_2O_5, 100–110 kg/ha K_2O, 65–75 kg/ha MgO	
Repeated compost use → up to +90% soil organic N	
Compost and digestate supplied P, K, S above baseline fertilisation.	
9-year trial	Potential mineralisable nitrogen increased to 60% after nine years of green compost application.
11-year trial	Without compost, soil P_2O_5 and K_2O dropped ~⅓
20-year trial	P and K just as readily available as with mineral fertilisation. Total P and K contents can be taken into account for fertilisation.
27-year trial	Total N increased 13% in 0–20 cm layer, and 25% in 20-40 cm layer relative to soil under fallow.

Soil Structure & Water[3, 8, 9, 11, 13, 16, 20, 23]

- Humic substances in compost provide stable soil structure for microbes, air, and water.
- Soil bulk density and porosity control water storage, availability, and infiltration.
- Repeat application improves all aspects.

Evidence from the Trials

Long-term use reduced bulk density of arable soil by 5-15%.	
12-year trial	+5–7% water capacity in medium to heavy soils
24-year trial	At 15 and 45 t ha^{-1} yr^{-1} → ~ +350% infiltration rate versus mineral fertilised plots

[b]Across the Fact Sheets, compost application rates and related data refer to compost expressed in fresh mass (FM).
[c]There is still limited long-term research on the use of anaerobic digestate to provide robust evidence of its sustained benefits for soil health.

Crop Yield & Quality[1,8,20,23]

- Long-term compost use supports stable, resilient yields, especially under stress such as drought.
- Compost can improve crop quality traits and sometimes reduce plant disease versus mineral-only fertilisation.
- Compost stabilises annual and seasonal yield fluctuations, depending on location, conditions, and rotation.
- Drought resilience: compost-amended plots maintain yields under water stress compared with mineral-fertilised soils.

Evidence from the Trials

Yield effects typically appear after 3–6 years of regular compost use; shorter trials may not capture the benefit.

Cereal Trial: +0,5–0,6 t ha^{-1}, with higher grain protein than mineral-only controls, without compromising quality.

Crop quality improvements: long-term compost application increased oil content in pumpkin seeds and protein in wheat.

7-year trial	Compost plots matched mineral fertilisation yields.
11-year trial	All compost treatments increased cumulative corn yields.

Soil Quality[2,7,11,13,16,23]

- Soil quality reflects the level of impurities, contaminants, and heavy metals in soil.
- Long-term trials show that quality-assured compost does not cause harmful accumulation of heavy metals or organic contaminants in soils or crops.
- Compost binds heavy metals to organic matter, reducing their bioavailability and maintaining soil quality.
- Compost microbes act physiologically, behaviourally, and morphologically to adsorb persistent organic pollutants (POPs).
- Repeated compost and digestate applications showed no negative effects on crop or soil quality.

Evidence from the Trials

Potatoes under mineral fertilisation had higher cadmium (Cd) content; Cd in compost was bound to SOM and less available.

Impurities (e.g. glass, metal, plastic) in biowaste compost were well below standard thresholds, including for organic standards; and levels even declined over 15 years.

Multi-year UK and EU trials detected no build-up of organic contaminants (PAHs, dioxins, furans, phthalates) in soils.

17-year trial	Nitrate leaching at 195 cm depth is greater under mineral N fertiliser vs. compost-derived N.
20-year trial	No significant differences in soil or wheat heavy metal content were found between compost, mineral, or combined fertilisation.

Case Studies to Highlight

1978 – 2023 — DOK Trials[12]: 40+ years of compost and manure increased SOC and biodiversity, stabilised humus levels, and enhanced microbial biomass versus mineral-only systems.

1992 – 2012 — Bioforschung Austria[11]: After 20 years, compost matched mineral fertilisers for P_2O_5 and K_2O uptake, increased plant-available P and K, reduced nitrate leaching at all rates, and showed no significant heavy metal differences in soil or crops.

2011 – 2013 — WRAP DC-Agri[23]: Multi-year trials showed yield gains, SOM improvements, higher microbial activity, and greater soil resilience, with no negative effects on crop quality or pollutants.

2016 – 2022 — INRAE's Digestate–Organic Amendments Trial[18]: Six-year trials with raw digestate plus biennial compost or farm manure application maintained SOC levels and increased soil P and K compared to mineral-only fertilisation.

2018 – ongoing — Navarra Project[8]: Long-term compost increased SOC and maintained yields similar to mineral fertilisation. Stable compost achieved the highest carbon conservation.

Organic Matter Facts[14]

Promoting Nitrogen and Phosphorus Availability	Capturing Potassium, Calcium, and Magnesium
• Native soil P mainly comes from parent rock. • P is often abundant but bound to minerals, so plants cannot access it. Its limitation is about availability, not absence. • Soil microbes unlock bound P, and compost boosts microbial biomass and P input, increasing plant-availability and reducing leaching. • Nitrogen (N) in soil comes from exogenous organic matter, including from compost, natural atmospheric inputs, and deposition. • Microbes release N and P from decomposing organic matter for plant uptake.	• K^+, Ca^{2+}, and Mg^{2+} are soluble cations (positively charged) that leach easily from organic matter and residues. • After N and P, K and Ca are the most limiting nutrients, especially in soils low in SOM. • Their positive charges let them adsorb onto negatively charged SOM and mineral surfaces. • Plants take them up by exchanging H^+ ions for these adsorbed cations. • Compost increases organic matter and cation exchange capacity, helping soils retain K^+, Ca^{2+}, and Mg^{2+} for plants.

Broader Implications

Climate Mitigation	Long term compost application supports carbon sequestration and aligns with global initiatives like the international "4 per 1000" Initiative: Soils for Food Security and Climate.
Water Resilience	Enhanced infiltration, water-holding capacity, and drought tolerance make farming systems more robust under climate extremes.
Nutrient Circularity	Compost is a reliable long-term fertiliser, recycles food waste, and, along with digestate, reduces reliance on finite mineral reserves and energy-intensive mineral nitrogen production.
Policy Relevance	Findings support EU soil health goals and circular economy strategies, strengthening the case for wider compost and digestate adoption.

Compost is more than a fertiliser substitute, it is a multifunctional soil amendment that builds organic matter, improves structure and water retention, enhances biodiversity, and supports stable crop yields.

By sequestering carbon and reducing reliance on energy-intensive mineral fertilisers, compost contributes directly to climate mitigation while strengthening the resilience of farming systems.

Scaling up the use of green- and bio-waste compost unlocks both agronomic and environmental co-benefits, making compost a cornerstone of sustainable soil management.

1. Amlinger, F. et al. (2007) Beneficial Effects of Compost Application on Fertility and Productivity of Soils. Vienna: Federal Ministry of Agriculture and Forestry, Environment and Water Management.
2. Ayilara, M. S. et al. (2020) Waste Management through Composting: Challenges and Potentials. Sustainability 2020, 12, 4456; doi:10.3390/su12114456.
3. BGK (2008) Bodenverbesserung durch langjährige Kompostanwendung. H&K Aktuell, 10/08, S. 3-4. Cologne: Bundesgütegemeinschaft Kompost e.V.
4. BGK (2018) Organische Düngung: Kompost für die Landwirtschaft. Grundlagen der guten fachlichen Praxis. Cologne: Bundesgütegemeinschaft Kompost e.V.
5. BGK (2025) Jahreszeugnis 2025. Anlage VZEK. Cologne: Bundesgütegemeinschaft Kompost e.V.
6. Bruns, C., Gottschall, R. And Richter, F. (2020) Nährstofflücken Schliessen: Biogutkomposte im Ökolandbau. Bioland, March Edition.
7. Chmelíková, L. (2024) The Effect of Compost in Organic Farming: Results from Field and Practical Trials: Projekt ProBio. Lehrstuhl für Ökologischen Landbau und Pflanzenbausysteme, Technische Universität München. Presentation; Wieselburg: 2. Österreichischer Kompostkongress.
8. CIC (2025) An Italian Long-Term Trial: The Navarra Project. University of Bologna. Presented by Confalonieri, A.; Italy: Fondazione per l'Agricoltura F.lli Navarra (FE).
9. Elsen, A., Martens, S., Tits, M., Declercq, T., Bries, J. and Vandendriessche, H. (n.d.) Long-term effects of compost amendments on crop yield, soil quality, soil organic carbon and nitrogen mineralization. Presentation; Soil Care Project.
10. Don, A., Brügge, K., Aiteew, K., Emde, D. and Poeplau, C. (2026) Stickstoff und Humusdynamik: Grundlagen und Wechselwirkungen. Presentation; Online-Fachveranstaltung HumusKlimaNetz, 23 January 2026. Thünen Institut für Agrarklimaschutz.
11. Erhart, E. (2024) Long-Term Trials and Results from Compost Use in Agriculture. Bioforschung Austria. Presentation; Wieselburg: 2. Österreichischer Kompostkongress.
12. Fliessbach, A. et al. (2024) The DOK Trial: A 45-Year Comparative Study of Organic and Conventional Cropping Systems. Dossier No. 1741. Frick, Switzerland: Research Institute of Organic Agriculture (FiBL). At: shop.fibl.org > 1741.
13. ISWA (2020) The Benefits of Compost and Anaerobic Digestate When Applied to Soil. Rotterdam: International Solid Waste Association.
14. Jacke, D. and Toensmeier, E. (2005) Edible Forest Gardens: Ecological Vision and Theory for Temperate Climate Permaculture. Vermont: Chelsea Green Publishing Co.
15. LZ Rheinland (2022) Kompost spart Phosphor: Langzeitversuche bestätigen hohen P- und K-Wert von Kompost. Landwirtschaftliches Wochenblatt Rheinland, Bonn/Münster.
16. LZ Rheinland (2023) Mit Humus und Kompost den Boden verbessern. Landwirtschaftliches Wochenblatt Rheinland, Bonn/Münster.
17. Midden, C. v. et al. (2023) The Impact of Anaerobic Digestate on Soil Life: A Review. Applied Soil Ecology, Volume 191. Science Direct. https://doi.org/10.1016/j.apsoil.2023.105066.
18. Mora-Salguero, D. et al. (2025) Long-term Effects of Combining Anaerobic Digestate with Other Organic Waste Products on Soil Microbial Communities. Front Microbiol. 2025 Jan 7;15:1490034. doi: 10.3389/fmicb.2024.1490034.
19. Munna, M. N. H. and Lal, R. (2026) Long-Term Organic Inputs Effects on Soil Carbon and Nitrogen Sequestration in a Temperate Agroecosystem. Soil Use and Management, 42:e70161. https://doi.org/10.1111/sum.70161.
20. Reynold, W. D. et al. (2015) Temporal effects of food waste compost on soil physical quality and productivity. Canadian Journal of Soil Science, 95: 251 – 268. doi:10.4141/CJSS-2014-114.
21. Rizzo, S. et al. (2025) Separately Collected Organic Fraction of Municipal Solid Waste Compost as a Sustainable Improver of Soil Characteristics in the Open Field and a Promising Selective Booster for Nursery Production. Agronomy 2025, 15, 958. https://doi.org/10.3390/agronomy15040958.
22. Slepetiene, A. et al. (2022) The Effect of Anaerobic Digestate on the Soil Organic Carbon and Humified Carbon Fractions in Different Land-Use Systems in Lithuania. Land, 11(1), 133. https://doi.org/10.3390/land11010133.
23. WRAP (2015) DC-Agri; field Experiments for Quality Digestate and Compost in Agriculture — WP1 report, Prepared by Bhogal et al.