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Soil Science Challenge Grants Program

The University of Western Australia

Soil biological mechanisms underpinning the effects of soil amendments: project summary

Project period: June 2022 to December 2025

Aim

This project characterised soil biological mechanisms and identified effective and economical principles for biological and chemical fertilisers combinations.

Findings

Deoxyribonucleic acid-stable isotope probing (DNA-SIP) experiments revealed the decomposition of complex carbon compounds (e.g. cellulose, chitin) are largely restricted to Actinobacteriota. In contrast, the addition of more labile forms of carbon (C) (e.g. glucose) were degraded by fast-growing Firmicutes that have a range of strategies to outcompete other microbial taxa.

Application of urea, solid digestate and digestate-incorporated biochar on ryegrass growth, nitrogen (N) cycling and nitrous oxide (N_2O) emissions under limed and unlimed soil conditions affected microbial processes and regulation of nitrification and denitrification. Waste-derived products were evaluated by measuring greenhouse gas (GHG) fluxes. Soils amended with digestate loaded biochar and compost were overall low GHG emitters, with only a small amount N_2O being produced.

Investigations of compost-amended soil under drought and rewetting identified that rapid rewetting resulted in the greatest microbial N uptake, whereas moderate and/or slow rewetting led to higher shoot N and available N concentrations compared to rapid rewetting. Clay amendments improved compost quality by stabilising carbon, conserving N and optimising physicochemical properties. The dual role of bentonite and kaolinite in enhancing long-term C sequestration and producing nutrient-rich, slow-release fertilisers demonstrates their value as low-cost, sustainable additives.

Simulations demonstrated the effectiveness of organic amendments in agricultural systems depends not only on their substrate quality, but also on threshold constrained C and N coupling, mediated by microbial biomass and soil physical protection. Compost-fertiliser combinations improved organic carbon, microbial biomass and N availability, confirming biogeochemical benefits. However, responses were non-linear and site dependent.

Overall, no single amendment worked in all situations. Engineered biochar mineral materials can improve both carbon dioxide (CO_2) capture and soil carbon retention, but their performance depends on how they are designed and the soils they are applied to. Iron-modified biochars emerged as the most effective materials for promoting long-term carbon storage, particularly where they enhance organo-mineral interactions and redox processes. However, their success depended on soil conditions, especially soil pH. In alkaline soils, simpler iron-based minerals sometimes outperformed more complex composites.

The project also developed a soil health index integrating multiple physical, chemical and biological properties. On average, farms with biological inputs showed higher soil health than conventional farms, and similar or slightly higher values compared with adjacent natural sites (bushland or grassland). Conventional farms tended to have reduced soil health relative to natural sites. Overall, farms with added organic inputs had consistently higher soil health indices in all regions, including Western Australia.

Publications

This project has published the following papers with additional papers currently in preparation or in review. This section will be updated once additional papers are published.

Ang, RA, Mickan, BS & Jenkins, SN 2025, Revisiting potential benefits of microbial inoculants in agriculture: opportunities and challenges, *Advances in Agronomy*, vol. 194, pp. 55–107, DOI: 10.1016/bs.agron.2025.06.001

Gurung, SK, Mickan, BS, Jenkins, SN, Rengel, Z, Siddique, KHM & Solaiman, ZM 2025, Turning waste into resilience: the effect of black soldier fly larvae frass and wheat straw biochar on bell pepper growth, soil fertility and rhizosphere bacteria under water stress, *Plant and Soil*, DOI: 10.1007/s11104-025-07672-4

Rajapakshe, OL, Gurung, SK, O'Connor, J, Mickan, BS, Singh, PK, Waite, IS, De Mascio, C, Abbott, LK & Jenkins, SN 2025, Lauric acid controls nitrogen release and inhibits nitrification in wastewater-enriched compost, *Journal of Environmental Management*, vol. 392, 126778, DOI: 10.1016/j.jenvman.2025.126778

Truong, THH, Marschner, P & Weng, ZH 2025, Moderate rate of historic compost application effectively improved wheat drought resilience but not microbial responses', *Journal of Sustainable Agriculture and Environment*, vol. 4, no. 4, e70115, DOI: 10.1002/sae2.70115

Zhang, Z, Gurung, SK, Sharma, M, O'Connor, J, Singh, PK, Waite, I, Mickan, BS, Bolan, N, Abbott, LK & Jenkins, SN 2026, Co-application of struvite with phosphorus-solubilising bacteria enhances soil microbial activity and bioavailable phosphorus in alkaline soil, *Journal of Environmental Management*, vol. 398, 128408, DOI: 10.1016/j.jenvman.2025.128408

Zheng, Y, Abbott, LK, Bolan, N, Hu, H, Jenkins, SN & Mickan, BS 2025, Biochar interacted with organic compounds from digestate in controlling N2O emissions, *Journal of Environmental Management*, vol. 385, 125591, DOI: 10.1016/j.jenvman.2025.125591

Zheng, Y, Abbott, LK, Bolan, N, Singh, PK, Jenkins, SN & Mickan, BS 2025, Evaluating the potential of digestate-loaded biochar in improving soil biological health and plant nutrition with less greenhouse gas emissions, *Environmental Pollution*, vol. 377, 126431, DOI: 10.1016/j.envpol.2025.126431

Zheng, Y, Bolan, N, Jenkins, SN & Mickan, BS 2024, Organic particles and high pH in food waste anaerobic digestate enhanced NH4+ adsorption on wood-derived biochar, *Science of the Total Environment*, vol. 946, 174458, DOI: 10.1016/j.scitotenv.2024.174458

More information

Learn more about the Soil Science Challenge Grants Program.

Contact the project lead, Emerita Professor Lynette Abbott, AM.

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We acknowledge the continuous connection of First Nations Traditional Owners and Custodians to the lands, seas and waters of Australia. We recognise their care for and cultivation of Country. We pay respect to Elders past and present, and recognise their knowledge and contribution to the productivity, innovation and sustainability of Australia's agriculture, fisheries and forestry industries.