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Soil Science Challenge Grants Program

The University of Sydney

High-resolution evaluation and monitoring of soil change for Australia: project summary

Project period: June 2022 to December 2025

Introduction

Assessing soil condition, and understanding how human activities alter it, is essential for informed land management and long-term environmental stewardship. Conventional monitoring approaches assess soil against generic national thresholds that do not account for natural soil diversity, systematically misclassifying soils that differ from an external benchmark, not because they are degrading but because they formed under different conditions.

This project developed and tested a pedogenon framework as a new way to assess soil condition by comparing each soil with its own natural potential. Pedogenons are geographical units defined by similar soil-forming conditions (climate, organisms, relief, parent material, and time) that remain stable over long periods. Because soils forming under similar conditions share broadly comparable characteristics, each pedogenon provides a scientifically grounded baseline against which to measure change. Each pedogenon is divided into the genosoil and the phenosoil. The genosoil is the portion occurring under conditions of minimal human disturbance and serves as the reference against which change is measured. The phenosoil is the portion of the same pedogenon that has been subject to human pressure, through tillage, grazing, drainage, vegetation clearing, or other land use practices.

Findings

A continental pedogenon map was produced through a two-step procedure designed to handle the computational demands of mapping at continental scale. The first step involved compiling a set of 27 environmental variables representing the main soil-forming factors. The second step produced the pedogenon map at 90 m spatial resolution using the Google Earth Engine platform. The project grouped Australia into 1,370 pedogenons. The pedogenons were validated using over 41,000 pH and 15,000 soil organic carbon (SOC) observations, as these soil properties are strongly influenced by soil-forming factors and are expected to vary systematically between pedogenons. The next step was to partition each pedogenon into its genosoil and phenosoil components. This was achieved by applying the Global Human Modification Index and the Habitat Condition Assessment System as proxies for human disturbance. To enable the translation of scientific information into practical land management and policy decisions, the project grouped the pedogenons into 236 larger soil districts with a median size of 22,000 km².

Following its development, the framework was used to develop a continental SOC capacity map that provides a national pre-disturbance SOC baseline. Comparisons of SOC changes were then made over an area representing 27% of the continent and incorporating 351 pedogenons. Data used to make

comparisons against the baseline were drawn from almost 15,000 existing soil profiles from the Australian Soil Data Federator. The analysis showed that soils with naturally high carbon levels were more likely to have lost carbon under human influence, while soils with lower natural carbon levels showed smaller or more mixed changes.

Additional research from 40 pedogenon classes across New South Wales, Queensland and Victoria indicate the framework can detect gradual changes in soil condition as human pressure increases. Analysis relative to a pH optimum of 6.5 shows that many soils have been improved by corrective management, while a significant proportion have declined due to acidification or alkalinisation. Total organic carbon shows a predominantly decreasing trend.

Continental-wide soil surface conditions from paired samples further show that cropping soils generally decrease soil organic carbon but increase total nitrogen, phosphorus, potassium, and calcium relative to soils under pasture and native vegetation.

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.

Francos, N, Sharififar, A, Flynn, T, Styc, Q, Evangelista, SJ, Padarian, J, Ng, W, Field, DJ, Minasny, B & McBratney, AB, 2025 The global pedogenon map: Combining and spatialising the factors of soil formation, *Geoderma*, vol. 460, 117462, DOI: 10.1016/j.geoderma.2025.117462

Minasny, B, McBratney, A, Sharififar, A, Borrelli, P, Evangelista, SJ, Feeth, J, Field, D, Francos, N, Heuser, I, Hunakunti, A, Irving, D, Jayasekara, T, Moreira, FMDS, Morgan, CLS, Ng W, Pachon Maldonado, JC, Roman Dobarco, M, Styc Q, Thiene, M, Watt, D, Wensley, P, Wiese, L & Yang, JE 2025 Soil security: the missing piece in climate, food, and water agenda at COP30, *The Innovation Geoscience*, vol. 3, 100169, DOI: 10.59717/j.xinn-geo.2025.100169

Minasny, B, McBratney, AB & Rumpel, C 2025 AI as a catalyst for cross-disciplinary breakthroughs in soil carbon sequestration research, *European Journal of Soil Science*, vol. 76, no. 4, e70165, DOI: 10.1111/ejss.70165

Minasny, B & Dupla, X, 2026 Accelerating weathering, lessons from a century of soil rejuvenation, *Frontiers in Climate*, vol. 8, 1824420, DOI: 10.3389/fclim.2026.1824420

Ng, W, Styc, Q & McBratney, AB 2026 Australian pedogenons in the global context, *CATENA*, vol. 269, 110148, DOI:10.1016/j.catena.2026.110148

Styc, Q, Minasny, B, Jang, HJ & McBratney, AB 2025, 'Modelling soil organic carbon dynamics at the continental extent using pedogenon mapping', *European Journal of Soil Science*, vol. 76, no.2, e70070, DOI: 10.1111/ejss.70070

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More information

Learn more about the Soil Science Challenge Grants Program.

Contact the project lead, Professor Budiman Minasny.

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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.