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EDITORIAL

From innovation to integration: Plant and soil sciences for people and planet

1 | A PIVOTAL MOMENT FOR PLANTS, SOILS AND SOCIETY

This Special Issue, inspired by the *Plants, People, Planet* symposium "Innovation in plant and soil sciences to tackle critical global challenges" held at the University of Sheffield, UK in August 2024, arrives at a pivotal moment for Earth's terrestrial systems. Human activities, including land clearing for agriculture, rapid urban sprawl, and the heavy use of chemical inputs, have pushed biogeochemical cycles of carbon, nitrogen and phosphorus well beyond their safe operating limits (Mitchell-Innes et al., 2025; Nielsen et al., 2025; Yu et al., 2025). Simultaneously, climate change is escalating the frequency of extreme weather events, such as heatwaves and prolonged droughts, which threaten global food security and the stability of native ecosystems (Hill et al., 2025; Johnson et al., 2025; Keyser-Gibson et al., 2025; Myrans et al., 2024). The contributions brought together here reflect the breadth of responses now being explored to meet these intersecting challenges. Across the research, opinion and review articles, this special issue spans approaches ranging from molecular breeding and microbial biotechnology to geoengineering and transdisciplinary social-ecological research. Rather than advancing any single solution, these works collectively underscore the need to rethink how plant, soil, microbes and human systems are managed as interdependent components. Together, they argue that safeguarding our future requires a fundamental shift away from compartmentalised and simplistic management, towards strategies that explicitly recognise and work with the intricate linkages between plants, soils, microbes, people and the planet (Aguilar-Trigueros & Frew, 2025; Nielsen et al., 2025; Ramírez-Carbajal et al., 2025). Recordings of the talks that relate to several of these papers are available to view at https://www.newphytologist.org/symposia/innovation-in-plant-and-soil.

2 | ENHANCING CLIMATE RESILIENCE AND ADAPTIVE STRATEGIES

A central theme of this issue is the challenge of sustaining crops and landscapes in a warmer, drier world. Rising temperatures are expected to sharply reduce agricultural productivity: for example, each 1°C increase is projected to lower global wheat yields by around 6% (Hill et al., 2025). In response, research on breeding for climate resilience emphasises restoring genetic diversity lost through modern high-yield selection. By exploiting landraces, synthetic hexaploid lines and wild relatives, breeders can target key traits, such as stomatal conductance, photosynthetic efficiency and reproductive tolerance to heat stress, to produce truly climate-ready wheat varieties (Hill et al., 2025). Adaptation strategies extend well beyond annual crops. Horticultural research in this issue highlights the importance of phenotypic and hydraulic plasticity in shaping resilient landscapes (Keyser-Gibson et al., 2025). Plants' capacity to adjust traits like vessel diameter and specific leaf area under water stress has direct implications for urban design, where water resources are increasingly limited. Evidence suggests that irrigation in managed landscapes can often be substantially reduced without sacrificing plant performance, offering a viable route to conserving urban water supplies (Keyser-Gibson et al., 2025). In regions facing severe freshwater scarcity, including many Pacific Island nations, novel water sources may also play a role. Emerging desalination technologies can provide slightly saline water for short-term drought relief, and research in this special issue shows that several staple crops, including taro, pumpkin and yam, survive better with moderately saline water than under complete drought (Myrans et al., 2024). Together, these findings point to integrated genetic, physiological, and technological strategies for adapting agriculture and landscapes to a changing climate.

3 | SOIL HEALTH AND THE HIDDEN POWER OF MICROBES

Many of the adaptive strategies highlighted in this issue rest on a renewed recognition of soil biology as a cornerstone of environmental resilience. Soils represent Earth's most biodiverse ecosystem, home to more than half of all species, yet their biological complexity remains underrepresented and undervalued in many restoration and management frameworks that prioritise physical or chemical indicators alone (Nielsen et al., 2025). Several contributions within this special issue highlight the role of soil microbes and arbuscular mycorrhizal fungi as keystone drivers of ecosystem function and sustainable management. Emerging mechanistic frameworks move beyond simple measures of

presence to consider how mycorrhizal fungal network architecture and connectivity can be used to group fungi by functional attributes, such as rapid nutrient transport, resilience or structural complexity (Aguilar-Trigueros & Frew, 2025). These approaches improve predictions of fungal contributions to nutrient cycling and soil stability across environmental gradients and offer a basis for integrating microbial traits into management and modelling frameworks.

The influence of soil microbes also extends to human nutrition and health. AM fungal inoculation has been shown to increase zinc and iron bioavailability in bread wheat, providing a natural pathway to biofortification without elevating anti-nutritional compounds like phytate (Nguyen et al., 2025). Soil-derived microbial communities underpin traditional food systems and cultural practices (Kalumbilo et al., 2026). Research in this Special Issue shows that wild plants used as natural inoculum for cereal-based fermentation in Zambia host root endosphere microbiomes shaped by plant species and site-specific soil properties. This selective filtering creates a microbial 'terroir', where local soil conditions directly influence the starter cultures essential for food stability and preservation of cultural heritage (Kalumbilo et al., 2026).

In parallel, restoration ecology is shifting towards soil-based indicators of success. By incorporating measures such as microbial biomass, invertebrate functional traits and enzyme activity, rather than relying only on vegetation cover or species richness, practitioners can gain a more nuanced understanding of ecosystem recovery trajectories and enhance habitat suitability for threatened species (Nielsen et al., 2025).

4 | TRANSITIONING TO A CIRCULAR ECONOMY: OPPORTUNITIES AND CHALLENGES

Insights into soil function also underpin growing interest in circular approaches to land management that aim to close nutrient loops and reduce dependence on synthetic fertilisers that carry high greenhouse gas footprints (Buss et al., 2025; Durant et al., 2025; Elder et al., 2025). One area of opportunity lies in nutrient recovery from human urine, which offers a 'golden opportunity' of a largely untapped source of nitrogen, phosphorus, and potassium (Yu et al., 2025). Source separation through urine-diverting toilets, followed by conversion into concentrated fertilisers, could supply a substantial share of agricultural nutrient demand while lowering the energy intensity associated with the Haber–Bosch process and mineral fertiliser production (Yu et al., 2025). However, the reuse of organic wastes also introduces important regulatory and ecological challenges. Biosolids and other recycled inputs can contain contaminants of emerging concern, including pharmaceuticals and pesticides, that threaten soil function (Carter et al., 2026; Durant et al., 2025; Elder et al., 2025). It has been shown that widely detected azole antifungal compounds can disrupt mycorrhizal associations, sharply reducing phosphorus uptake in salad crops such as spring onion and lettuce (Durant et al., 2025). The Thomas Review by Carter et al. (2026) synthesises current knowledge on a broad range of emerging contaminants, including pharmaceuticals, micropalastics/nanoplastics and 'forever chemicals' (or PFAS), which can be taken up by plants and enter the human food chain. Taken together, these findings highlight the need for stronger regulatory frameworks to ensure that circular nutrient strategies enhance, rather than compromise, long-term soil health and ecosystem function.

5 | GEOENGINEERING AND LANDSCAPE-SCALE INTERVENTIONS

Beyond nutrient cycling, emerging geoengineering and landscape-scale interventions leverage plant–soil interactions to mitigate rising atmospheric CO_2 concentrations (Steeley et al., 2025). These approaches seek to accelerate or amplify natural biogeochemical processes but raise questions about scalability and ecological trade-offs. Enhanced rock weathering has emerged as a key focus, involving application of silicate minerals such as basalt to soils to accelerate natural weathering reactions that draw down CO_2 and ultimately store it as bicarbonate in ocean systems. When combined with agroforestry practices, including cacao-based systems, enhanced weathering could offer multiple co-benefits by sequestering carbon while improving soil pH and supplying slow-release nutrients such as potassium and magnesium (Steeley et al., 2025). Complementary to this approach is growing interest in large-scale silicon supplementation of croplands. Silicon, a non-synthetic soil amendment, has been shown to enhance plant resistance to drought and pests with clear, underexplored potential to increase soil carbon storage (Johnson et al., 2025; Li et al., 2025). Emerging mechanistic frameworks link plant silicification to soil carbon cycling, suggesting that silicon-induced shifts in plant stoichiometry influence litter decomposition and microbial activity in ways that promote the long-term stabilisation of soil organic carbon (Li et al., 2025). Alongside mineral-based interventions, nature-based climate solutions are being re-examined to understand how managed disturbances, such as fire and grazing, influence the persistence of soil organic carbon. The Thomas Review by Pellegrini et al. (2026) in this issue highlights the need to adjust management practices locally to ensure that these disturbances do not undermine the potential of soil carbon storage across global ecoregions.

6 | URBAN ECOSYSTEMS AND HUMAN-CENTRED SCIENCE

Urban environments represent an increasingly important frontier for plant and soil science, shaped by distinctive combinations of biophysical stressors and social constraints. Soil sealing, proximity to roads, and fragmented patterns of land custodianship all influence how urban ecosystems function and how they are managed (Edmondson et al., 2025; Mitchell-Innes et al., 2025; Verbeek et al., 2025). Research on urban green infrastructure demonstrates that biodiversity in cities is not determined by habitat size alone. Studies of vegetated

roundabouts show that larger green spaces with higher soil moisture can function as local biodiversity hotspots for both plant and bacterial communities (Mitchell-Innes et al., 2025). Complementary work on the Amsterdam elm further reveals that urban trees can maintain surprisingly diverse and adaptable arbuscular mycorrhizal communities, indicating a shift in fungal partners rather than a simple loss of symbioses under urban conditions (Verbeek et al., 2025). There are also important ecological implications of infrastructure such as solar parks, which are rapidly expanding as part of the transition to renewable energy. While solar installations contribute to climate mitigation, their shading effects can alter local microclimates, with evidence of reduced plant and microbial biomass beneath panels (Scholten et al., 2025). These findings highlight the need for innovative solar park designs, such as tracking systems or semi-transparent panels, that balance energy production with the protection of soil health and urban ecosystem function (Scholten et al., 2025).

7 | TRANSDISCIPLINARY INNOVATION AND HERITAGE

Transdisciplinary research is one of the most significant advances showcased in this Special Issue, emphasising the integration of natural sciences with social anthropology and local stakeholder knowledge (Elder et al., 2025). Case studies in urban forest management show that co-designing research with policymakers, charities, and community groups produces evidence that is more likely to inform effective and equitable decision-making. By directly engaging with issues such as tree equity and community participation, these approaches help ensure that the social and environmental benefits of urban forests are more evenly distributed (Edmondson et al., 2025). The papers within this Special Issue also highlight the importance of revitalising and safeguarding cultural heritage as part of environmental innovation. Research on the Tlahuica–Pjiekakjoo culture in Mexico documents the world's most extensive mycocultural heritage, including knowledge of more than 200 edible mushroom species (Ramírez-Carbajal et al., 2025). Collaborative partnerships between scientists and indigenous communities are essential for preventing the loss of this knowledge, which plays a critical role in sustainable rural livelihoods, biodiversity conservation and long-term forest stewardship (Edmondson et al., 2025; Ramírez-Carbajal et al., 2025).

8 | CONCLUSIONS

The innovations presented in this Special Issue make clear that solutions to many of our most pressing global challenges lie beneath our feet. From recovering nutrients in human waste (Yu et al., 2025) and breeding heat-tolerant wheat (Hill et al., 2025) to enhancing carbon sequestration through basalt amendments in cacao agroforests (Steeley et al., 2025), the papers in this Special Issue offer practical, testable pathways towards more sustainable land management by leveraging natural processes and reducing externalities. Together, they demonstrate that embracing the complexity of plant–soil-microbe interactions, alongside the biocultural knowledge of human communities, is essential for building ecosystems that are resilient, productive and self-sustaining (Nielsen et al., 2025; Ramírez-Carbajal et al., 2025). The remaining challenge lies in moving from proof of concept to large-scale application, a transition that will require sustained interdisciplinary collaboration and rigorous monitoring to ensure these innovations deliver lasting benefits (Field et al., 2024; Nielsen et al., 2025; Steeley et al., 2025).

KEYWORDS

climate change, farmers, food security, plants, policymakers, society, soil, urban planners

AUTHOR CONTRIBUTIONS

All authors contributed to the conceptualisation of this manuscript. Katie J. Field led the writing and produced the first draft of the manuscript, and Yolima Carrillo, Stuart A. Campbell, Jurriaan Ton and Adam Frew contributed to drafting, editing and finalising the paper. All authors approved the final draft.

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The authors declare no conflict.

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