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Editorial

Soil: the key to the past, the present and the future

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Soil science as practiced today is the integration of many disciplines consisting of the traditional 'hard' sciences (e.g. chemistry, physics, biology) and 'soft' sciences (e.g. sociology, anthropology and economics). Brevik *et al*. (2015) and Dobrovol'skii (2006) note, however, that an interdisciplinary approach among the more traditional sub-disciplines, such as soil physics, soil chemistry, pedology and soil biology, has been the characteristic of soil research for many years. In recent years anthropologists, economists, engineers, medical professionals, military professionals, sociologists and artists have made significant contributions to the advancement of soil knowledge. This has resulted in a more holistic study of the soil.

This special issue of *Soil Research* is an outcome of the National Soils Conference of Soil Science Australia, a multidisciplinary conference that was held in Canberra from 18 to 23 November 2018. It was attended by over 470 national and international delegates with the presentations covering soil physics, soil chemistry, soil microbiology, ecology, agronomy and horticulture, hydrology, geophysics, extension and economics, and modelling of soil, water and plant systems. More than 260 oral and poster papers were submitted to the conference and published in the Conference Proceedings (Hulugalle *et al*. 2018). A special focus of the conference was the interaction between soil practitioners from the private industry and soil scientists from governmental and academic institutions. Private industry members typically work in isolation and are not employed as soil scientists but address problems that require a knowledge of soil science.

The papers presented at the conference reflected many issues that humanity is facing today, such as global warming, disposal of urban and industrial wastes, declining soil health, challenges associated with maintaining crop yields in a sustainable manner, and effective research communication pathways. Papers were presented under several themes that included novel analytical methodologies, soil microbial ecology and food webs, soil physical and chemical properties, soil carbon dynamics and greenhouse gas emissions, soil nutrition, extreme soils, waste management and soil degradation associated with pesticides, and industrial and other pollutants. This special issue of *Soil Research* includes several papers presented at the conference that addressed various themes, with many addressing multiple topics in soil science, providing a multidisciplinary overview of soil science in Australia and overseas.

One of the fundamental parameters used in soil science is the (dry or wet) bulk density of soil and this topic was addressed by Murad *et al*. (2021) who reported on novel analytical methodologies. They described a new low-cost measurement technique that assessed soil density and stiffness moduli more rapidly, efficiently and precisely, using shear wave velocity measurements with a piezoelectric extender and bender elements. An empirical relationship was developed between shear wave velocity and bulk density of soil in laboratory conditions that was then tested on sands and clayey soils for validation. A high degree of accuracy occurred with respect to several statistical parameters. The authors proposed that their methodology was more rapid and facile than traditional destructive methods of determining bulk density.

Many papers presented at the conference investigated the impact of strategic tillage in no-till systems on soil processes while addressing multiple conference themes; two of these papers are included in this special issue. Mehra *et al*. (2021) addressed novel methodologies, soil physical properties and soil carbon dynamics. They investigated the soil-pore and root geometry of a wheat crop with micro X-ray computed tomography (μXCT) after 'strategic' conventional tillage (CT) in a continuous no-tillage (NT) cropping system. Total soil porosity was higher under CT compared with NT. Vertical distribution of root biomass and root length density were higher under NT and CT respectively. The authors suggested that low soil disturbance under continuous NT may have encouraged accumulation of more root biomass in the top 100 mm depth. Overall, μXCT image analyses indicated that this tillage shift improved total soil carbon due to improving soil-porosity and root architecture. Azam and Gazey (2021) addressed the themes of soil physical and chemical properties in several laboratory and field experiments on surface and subsurface liming to ameliorate soil acidity in Western Australia. They reported that multiple applications of lime to the surface increased subsurface soil pH but only to a depth of 0.2 m with a large proportion becoming stratified in the top few centimetres of the soil. Deep incorporation through excavation and spading with a rotary hoe increased soil pH and decreased aluminium concentration. They concluded that incorporation of lime using cost-effective strategic deep tillage was necessary to address subsoil acidity. Condon *et al*. (2021) reviewed the distribution of surface and subsoil acidity, and past research on its amelioration in southern New South Wales and arrived at similar conclusions. Their review also considered different forms of lime and organic materials as ameliorants.

Carbon storage and dynamics in soil–water–plant–air systems were reported by many authors at the conference. This special issue includes three such papers that had vastly different foci. Carbon dynamics in soils of saline environments were studied by Wong *et al*. (2021), who assessed soil carbon stocks and fractions in temperate mangroves and salt marshes in southern Australia. Salt marsh sites generally had the highest soil organic carbon concentration. Particulate organic carbon was highest at the surface of saltmarsh sites and decreased with depth, except in the mangrove sites where it did not decrease with depth. They suggested that much of the particulate organic carbon originated as root materials, and that their retention was likely to be related to waterlogging, which decreases decomposition rates. Badgery *et al*. (2021) addressed the multiple themes of soil carbon dynamics/storage, economics and extension when reporting a pilot scheme in central west New South Wales that evaluated a market-based instrument to encourage farmers to change their management to increase soil carbon. They assessed soil organic carbon stock changes in four land uses using the Australian Government's Emissions Reduction Fund methodology on farms. The land uses were: (1) reduced tillage cropping; (2) reduced tillage cropping with organic amendments (e.g. biosolids or compost); (3) conversion from cropping land to permanent pasture; and (4) conversion from cropping land to permanent pasture with organic amendments. Pasture was found to have higher rates of carbon sequestration than reduced tillage cropping; and application of organic amendments increased sequestration rates. Osanai *et al*. (2021) reported carbon dynamics, fractions and storage, and their interactions with crop rotation, nutrient availability and tillage method in the surface and subsoil of an irrigated Vertisol in north-western New South Wales. They found that maize rotation and changes in the particulate organic fraction influenced carbon stocks in the topsoil, although the overall change in soluble organic carbon stock was small. The large increase of 31% in subsoil soluble organic stock was dominated by changes in the mineral-associated organic fraction, which were influenced by historical cropping systems and recent maize rotation directly and indirectly via changes in soil nitrogen availability.

The theme of soil fertility and crop nutrition was addressed by many authors. This special issue includes two papers whose focus differed markedly. Quin *et al*. (2021) addressed the interaction between nitrogen nutrition and greenhouse gas emissions, and studied nitrous oxide production at a commercial sweet-cherry orchard in southern Tasmania when nitrogen fertiliser was applied either pre- or post-harvest, or equally split between the two. They reported that nitrous oxide emissions were related to rainfall but also that emissions were greater when nitrogen fertiliser was applied pre-harvest. McLeod *et al*. (2021) integrated various themes, such as soil chemistry, crop nutrition, economics and extension, in their study of soil-based constraints to dryland crop production and management in Aceh, Indonesia. Their survey showed that the dominant soils in this region were Entisols, Inceptisols and Ultisols, with some Andisols and Mollisols. Low fertility due to low carbon, nitrogen, and basic cation concentrations were widespread in all soil groups. The Ultisols and some Entisols and Inceptisols were acidic, with high aluminium saturation and low available phosphorus. The authors concluded that to sustainably increase crop yields, these soils needed lime where soils were acidic, fertilisers for nutrients, and stable carbon-rich amendments for system stability.

The themes of soil physics, chemistry and degradation due to pollutants were addressed by Crawford *et al*. (2021) in a study, which assessed the risk of secondary salinity occurring in the Condamine-Balonne catchment in southern inland Queensland due to irrigation with saline coal-seam gas water from mining operations. Field data were used to conceptualise the regolith architecture, undertake hydrogeological modelling, estimate the available moisture storage capacity of the unsaturated zone and model paddock deep drainage characteristics. They concluded that irrigation-induced deep drainage had commenced mobilisation of salt stored in the unsaturated zone, and that land management and salt discharge into the Condamine River were linked. They further noted that the risk of the unsaturated zone moisture storage capacity being exceeded was high and may result in salinisation of both land and surface water.

Conclusions

Interdisciplinary is the integration of knowledge and methods from different disciplines, using a real synthesis of approaches (Jensinius 2012). An example of an interdisciplinary study that was able to reverse historical soil degradation is reported by Emadodin *et al*. (2009). The papers presented at the conference were either multidisciplinary or intradisciplinary. True interdisciplinary research, however, was absent. Hejazi (2019) notes that to maximise the impact of research on global issues as such climate change, food security and land degradation, interdisciplinary studies are essential. He further concludes that the solutions to these problems do not rest within any single discipline but at the boundaries of many disciplines. Future and many ongoing soil science projects would profit from such an interdisciplinary approach.

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