Building healthy sandy soils in agricultural landscapes

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Lynette Abbott and Hira Shaukat from The University of Western Australia, provide insights into research on enhancing health in sandy soils

Sandy agricultural soils generally have lower productivity than soils with higher concentrations of finer clay and silt particles, but they are widespread and important worldwide for food and fibre production. For example, in the Mediterranean climatic region of Southwestern Australia, deep sandy soils are common and result from extremely long periods of weathering with little or no opportunity for re-mineralisation.

Over decades, farmer practices and extensive research have been successful in developing strategies to overcome constraints on sandy soils in Southwestern Australia (Davies, 2023). Widespread adoption of reduced tillage has significantly reduced the exposure of sandy soils to wind and water erosion. Other practices such as liming, replacing previously cleared deep-rooted vegetation, and claying have further addressed the constraints of soil acidity, soil salinity and water repellence.

However, climate change, highlighted by significantly reduced rainfall since the 1970s, is projected to have ongoing impacts on agriculture in this region (Hughes et al., 2022). Therefore, maintaining the health of sandy soils continues to be a priority.

Building healthy sandy soils is challenging due to their limited capacity to retain soil carbon, even though no-tillage and reduced cultivation practices have been widely adopted by land managers (Western Australian No Tillage Farmers Association (WANTFA)). Reduced tillage has been very important or capturing the benefits of reduced soil disturbance, retention of stubble, and strategic grazing practices, to overcome water and wind erosion of sandy soils. However, some of the retained organic matter under long Mediterranean (hot and dry) summer leads to the development of water-repellence (Roper et al., 2021), a significant problem in dryland agriculture.

To address water repellence, some farmers have adopted the practice of adding clay to their sandy soil.

For practical and financial reasons, on-farm sub-soil clay is sourced through strategic ripping, spading and delving (Betting, 2021). Strategic deep tillage has usually been employed to disrupt hardpans that restrict root growth and impede water movement through the soil profile (Parker, 2024).

Additionally, liming has been widely promoted (Gazey, 2018) to ameliorate naturally acidic soil profiles and any increased acidity associated with agricultural practices such as long-term use of some fertilisers and incorporation of legumes as a contributor to biologically fixed nitrogen.

Brown to red brown non-wetting sands with subsoil acidity (pH-CaCl2 4.2 in top 30 cm), cattle and lupin-wheat rotations. Badgingarra, Western Australia. Photo: Hira Shaukat

Yellow/brown deep sandy duplex soil (pH-CaCl2 4.7 in top 30 cm), sheep pasture. UWA Farm, Pingelly, Western Australia. Photo: Lynette Abbott

How does reduced tillage improve physical, chemical and biological components of soil health?

Reduced tillage can improve soil structure and penetrability for roots and water, leading to improved growing conditions for crops and pastures. While retention of crop residues increases the input of organic matter into the soil, in sandy soils, this results in rapid cycling of nutrients and potential loss via leaching, especially for nitrogen. In sandy soils, there is little opportunity for crop residues to contribute to soil carbon stocks because of their limited capacity to protect organic matter from microbial degradation. Overgrazing of stubble in reduced tillage systems can cause wind erosion and water erosion, as might occur in heavy summer rainfall events.

Although reduced tillage provides the benefit of minimum soil disturbance (and hence reduced erosion) it does not fully enable capture the benefits of microbial processes involved in nutrient cycling from organic matter. Inclusion of the practice of claying sandy soils exposed to negative impacts of reduced tillage can improve the constraints of soil structure and water repellence, and increase soil carbon retention by protecting organic matter from rapid microbial degradation. Claying sandy soil contributes to building long-term soil biological and chemical health by improving nutrient cycling efficiency from retained soil organic matter and enabling more effective use of applied fertiliser, including biological amendments.

Mixed annual and perennial pasture species.
Yellow/brown deep sandy duplex soil.
UWA Farm, Pingelly, Western Australia. Photo: Lynette Abbott

How does using lime improve the physical, chemical and biological components of soil health?

The ineffective function of soil communities can occur due to a range of soil constraints, in contrast to how communities contribute to healthy soil (eBook available here). For example, microbial activities involved in nutrient cycling from soil organic matter can be impeded in acid soils (Horn et al. 2021) and also in saline soils (Yan & Marschner, 2013).

Using lime to overcome soil acidity (in surface soil and at depth) has the potential to directly improve growing conditions for crops and grassland plants as well as improve environmental conditions for some soil organisms.

For example, overcoming acidity can improve nodulation of some legumes, especially subterranean clover (Howieson & Ewing, 1984) leading to more effective biological nitrogen fixation in farming systems that include legumes in rotations.

Furthermore, constraining the development of soil acidity can enhance nutrient cycling processes, and support biological processes that contribute to soil aggregation, soil aeration and the diversity of communities of soil organisms.

How does strategic deep ripping improve physical, chemical and biological components of soil health?

Strategic deep ripping of sandy soil has the potential to overcome severe soil constraints to plant growth. This practice can regenerate soil profiles by increasing aeration, providing access to subsoil clay and disrupting hardpans whether inherent to soil or formed through long-term cropping with limited inclusion of pasture and grassland rotations. All of these outcomes can result in improved conditions for soil organisms that have the potential to restore efficient nutrient cycling processes, reduce water repellence, and facilitate unimpeded root growth. Improved root function can support rhizosphere communities that contribute to nutrient uptake and the efficiency of fertiliser use.

Can sandy soils be managed to deliver biological amendments to improve plant establishment with reduced tillage?

Because of the limited capacity of sandy soils to sequester carbon for the long-term resilience of farming systems, there is potential to strategically deliver soil biological amendments that have properties comparable to those of stored soil carbon into the root zone. For example, the AUSPLOW Deep Blade System already provides separate delivery tubes for seeds and liquid fertiliser directly into a pre-prepared seedbed that enhances root growth.

While there are considerable opportunities for using soil biological amendments in cropping systems (Macdonald et al., 2021), the limited supply of waste resources, and cost of transport, makes widespread application impractical in broadacre sandy soil farms. A combination of reduced tillage and precision placement of refined soil biological amendments could improve sandy soil characteristics for enhanced seedling establishment.

In this scope, the University of Western Australia, School of Agriculture and Environment, is leading a four-year, multifaceted research project funded by the Australian Department of Agriculture, Fisheries and Forestry (DAFF). The project focuses on understanding the soil biological mechanisms underpinning the effects of soil amendments on soil health, productivity, and resilience. A major goal is to establish combinations of soil management practices, including soil amendments, that provide beneficial soil health outcomes and efficient use of fertilisers.

Our research is funded by the Soil Science Challenge Program of the Australian Government Department of Agriculture, Fisheries and Forestry.

SOIL HEALTH APP

The SOILHEALTH app provides information about complex aspects of soil health in a digital format. It contains seven animated videos, an eBook, and podcasts, and it is available for both iOS and Android devices. This free app was designed by Cheryl Rimmer and funded by the Australian National Landcare Program Smart Farms Small Grants Round 2.

CLICK HERE for references

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