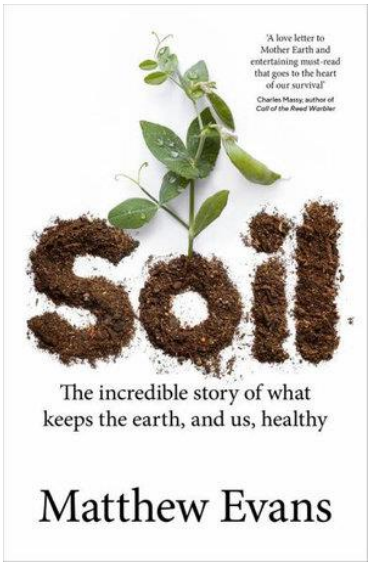
PLANT AND SOIL NEMATODES

FURTHER READING: SOIL HEALTH, SOIL BIOLOGY AND SUSTAINABLE AGRICULTURE

Australia has some of the oldest and poorest soils in the world but unfortunately, their condition has worsened since European settlement. Large areas are now unproductive due to salinisation and desertification, while some of the management practices used in modern agriculture have increased water and wind erosion and further degraded the soil though compaction and loss of organic matter. Land managers are often aware of these problems but most have no idea how to overcome them. One way to start is to read the following books. In addition to learning about the soil biota and the ecosystem services they provide, you will see the pathway that some farmers in Australia, New Zealand and other countries are taking to improve the health of their soils, revitalise their food production system and make their farming system more sustainable.

Evans M (2021) *Soil. The incredible story of what keeps the earth, and us, healthy*. Murdoch Books, Crows Nest, NSW. 272 pp

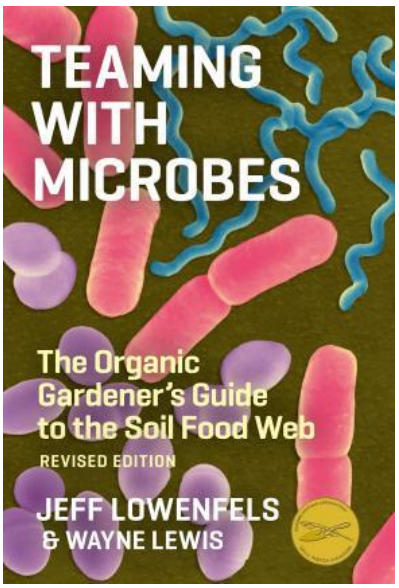


The thin layer of soil covering the earth's surface is the most important component of our food production system, but humans have been degrading it for centuries. Matthew Evans, a farmer from Tasmania, provides many examples in his book.

- About 40% of the world's agricultural land has been abandoned because it is no longer fertile
- 40-50% of the current agricultural land is seriously degraded
- We lose a soccer pitch of soil every five seconds due to erosion or desertification
- If current soil management practices continue, we only have about 60 years of topsoil left
- Australia loses 2.2 tonnes of soil from water erosion/ha/year.
- About half our topsoil has disappeared since Europeans arrived
- Topsoil is being lost 100 times faster than it can be made
- The glaciers in New Zealand are periodically stained by red and black 'dust' from Australia

As the future of humanity depends on stopping this degradation, the remainder of the book focuses on how this can be done. Instead of over-clearing, over-grazing, and over-ploughing, land managers need to understand the complex biological world beneath their feet and then implement management practices that work with rather than against nature.

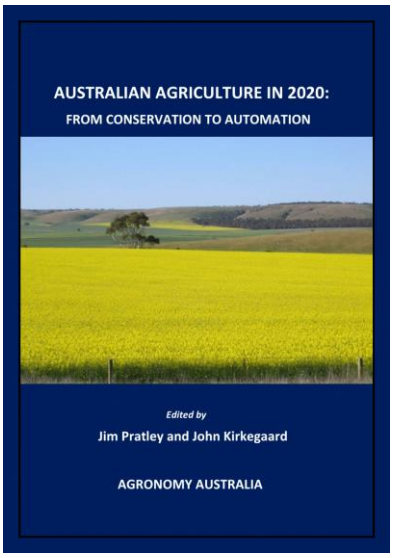
Lowenfels J and Lewis W (2010) *Teaming with microbes: a gardener's guide to the soil food web*. Timber Press, Portland, 184 pp.



Most people are not aware that a large proportion of the living things on earth are found in soil. There are billions of organisms in a teaspoon of healthy soil but because a microscope is required to see most of them, they are generally ignored. 'Teaming with microbes' provides an easily read overview of the fascinating world beneath our feet. It starts with the smallest and most abundant microbes in soil (bacteria and archaea), moves on to the larger but still microscopic organisms (fungi, algae, protozoa, nematodes and microarthropods) and then covers the larger animals (e.g. earthworms and arthropods). More importantly, it explains how to foster these organisms in your garden so you will finish up with vigorous, high yielding plants and a healthy soil.

One important point to note is that farmers should not be put off by the fact that the title contains the words 'Gardener's guide'. They should read the book and learn about the vital role soil organisms play in keeping plants and soil healthy. Farmers will not be able to use some of the soil restoration practices that can be used in a garden, but after reading the book they will start thinking about how their farm management practices can be modified to obtain the benefits provided by an active and diverse soil food web.

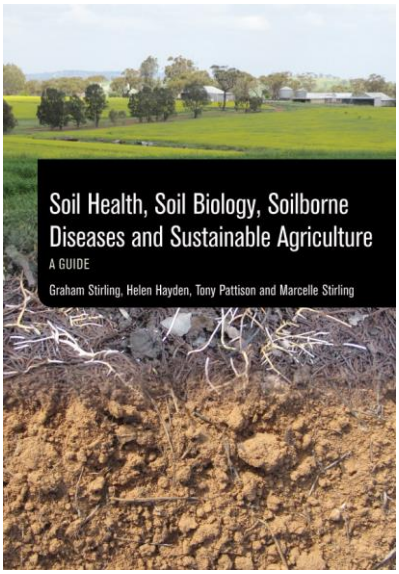
Pratley J & Kirkegaard J (2020) *Australian agriculture in 2020: From conservation to automation*. Agronomy Australia and Charles Sturt University. 458 pp.



In the 1960s and 70s, agricultural fields in Australia were cultivated excessively and so soil erosion and land degradation were major problems. In the next forty years, most Australian grain growers overcame these problems to some extent by adopting three practices (no-till, retention of crop residues, and diverse crop rotations). These practices are the key components of Conservation Agriculture and a multi-authored book edited by Pratley and Kirkegaard (2020) provides an integrated account of how this new farming system evolved.

Chapter 15 of this book (Harnessing the benefits of soil biology in conservation agriculture) shows that the move to Conservation Agriculture not only increased yields but also provided a range of other benefits. Some of the more important were 1) improvements in soil structure and stability; 2) increases in the particulate organic carbon pool that sustains microbial activity; 3) greater nutrient mineralisation; 4) enhanced disease suppression; and 5) increased carbon turnover and sequestration. However, as this farming system is dependent on herbicides, pesticides, and fertiliser inputs, further research will be required to improve its sustainability.

Stirling GR, Hayden HL, Pattison AB, Stirling AM (2016) *Soil Health, Soil Biology, Soilborne Diseases and Sustainable Agriculture. A guide.* CSIRO Publishing, Melbourne, 275 pp.



This book is an educational resource that aims to improve farmers' understanding of how soils function. It takes a holistic and science-based view of the soil and argues that agriculture will only survive in the long term if soils are farmed in ways that not only repair historical damage but also improve their physical, chemical, and biological properties. Given the role of soil organisms in improving soil structure, cycling nutrients, and reducing the impact of soilborne pests and diseases, this can only be done by considering the biology of the soil.

One of the most important messages from the book is that the problems which arise when crops and pastures are being grown cannot be solved individually. Instead, an integrated, whole-system approach is needed, in which a range of practices are used to develop a resilient field ecosystem that is capable of coping with the climatic stresses and pest and disease pressures that are an inevitable component of agriculture. Thus, the 'silver bullet' solutions commonly used in modern agriculture are ignored, because these so-called 'remedies' are usually purchased inputs (e.g. fertilisers or pesticides) that target only one component of the problem.

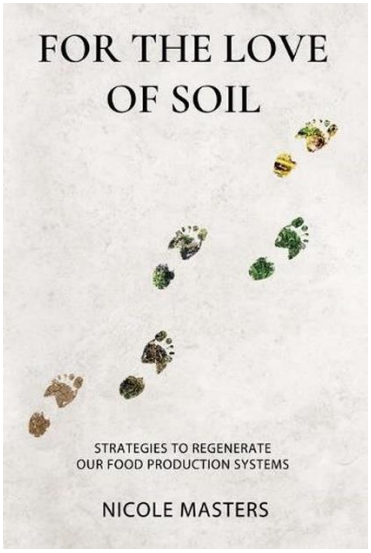
The other important point about the book is that it is educational rather than prescriptive. It does not attempt to provide specific recommendations on how farmers can improve the health of their soils, optimise soil biological processes, or reduce the impact of soilborne diseases. The organisms in soil are influenced by their environment, while the practices which can be used to modify the soil biology will depend on soil type, climate, the principal crop, economics, the level of management inputs, and many other factors. Thus, it is impossible to be prescriptive about the farming systems best suited to a particular location or production goal. Instead, the book focuses on the key practices that a farmer might consider including in a program to improve a soil's biological status and reduce losses from soilborne pests and pathogens. Case studies are also provided to show how growers in various industries have been able to modify their practices to improve the health of their soil and develop a more sustainable farming system.

Sustainable agriculture has been defined in various ways, but the essence of the concept is that agricultural ecosystems are managed in ways that:

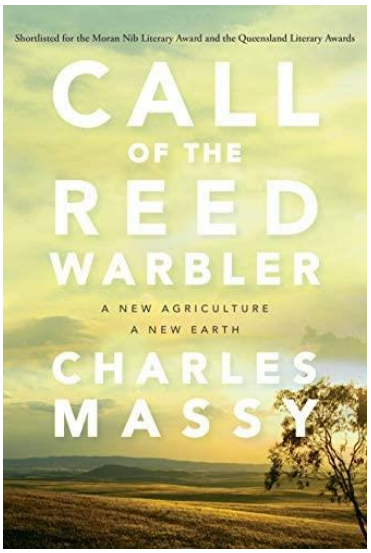
- Maintain the soil resource so that it remains productive in the long term
- Ensure above- and below-ground biological biodiversity is maintained
- Maintain the economic viability of farming enterprises
- Allow agricultural production to continue indefinitely without harming the wider environment

Given the above, the following books are worthwhile reading, as they promote an alternative approach that is usually termed Regenerative Agriculture.

Masters N (2019) *For the love of soil. Strategies to regenerate our food production systems*. Printable Reality, New Zealand, 285 pp



Massy C (2020) *Call of the Reed Warbler. A new agriculture. A new earth*. University of Queensland Press. 528 pp.



Both books start with the assertion that industrial agriculture is problematic for several reasons.

- The predominant objectives are to maximise production and profit
- The production system is underpinned by intensive tillage, monocultures, application of synthetic fertilisers, dependence on fossil fuels, intensive irrigation, chemical pest and weed control, manipulation of plant and animal genomes, and the factory farming of animals
- Management practices are implemented without regard for their unintended, long-term consequences
- The ecological dynamics of the agroecosystem are not considered

The alternative approach (Regenerative Agriculture) is not fully defined, but terms such as "bringing vibrant life back to the land" or "a focus on mimicking natural systems" are sometimes used. Thus, regenerative agriculture is seen as 'actively rebuilding or regenerating an existing system towards full health'. In contrast, the authors maintain that sustainable agriculture is doing nothing more than 'maintaining the same'.

The aim of Regenerative agriculture is to 1) ensure plants capture as much solar energy as possible; 2) maximise water infiltration, storage, and recycling; 3) produce biologically active soils that contain and recycle a diverse range of minerals and chemicals, and 4) maximise the biodiversity and health of the ecosystem. These objectives are achieved by continually maintaining ground cover; minimising soil disturbance; increasing diversity using trees, native vegetation, crop rotation and cover crops; incorporating livestock into the system; and reducing the use of artificial fertilizers.

Both books provide many examples of people who have used regenerative agriculture techniques to improve their farming operation and their lifestyle. However, the authors point out that one of the biggest determinants to success is the persons mindset. Successful regenerators try something new, assess the outcome, and implement changes if benefits are observed. They are then prepared to repeat this process year after year, so there is a continual process of learning and updating. Successful regenerators are also passionate about soil. They recognise that soil is a vital living ecosystem and that plant nutrition and pest control is mediated through and by the soil's biology. This knowledge is used to continually optimise inputs and modify management practices.

SCIENTIFIC PAPERS AND REVIEWS

Soil health, soil biology and sustainable agriculture are huge topics and information in these areas can be found in thousands of scientific papers and reviews. However, anyone wishing to check the veracity of a statement or obtain more detail on a specific topic could start by checking the references cited in the books mentioned above, as collectively, they list many important references.

The following references are included here because they are some of the more important papers and reviews that have been published recently.

Baveye PC (2021) Soil health at a crossroad. *Soil Use and Management* 137, 215-219

Bünemann EK, Bongiorno G, Bai Z, Creamer RE, De Deyn G et al. (2018) Soil quality- A critical review. *Soil Biology & Biochemistry* 120, 105-125.

Janzen HH, Janzen DW, Gegorich EG (2021) The 'soil healthy' metaphor: Illuminating or illusory? *Soil Biology and Biochemistry* 159, 108167. https://doi.org/10.1016/j.soilbio.2021.108167

LaCanne CE, Lundgren JG (2018) Regenerative agriculture: merging farming and natural resource conservation profitably. *PeerJ* 6, e4428; DOI 10.7717/peerj.4428

Larkin RP (2015) Soil health paradigms and implications for disease management. *Annual Review of Phytopathology* 53, 199-221.

Lehman RM, Cambardella CA, Stott DE, Acosta-Martinez V, Manter DK. et al. (2015) Understanding and enhancing soil biological health: the solution for reversing soil degradation. *Sustainability* 7, 988-1027

Lehman J, Bossio DA, Kogel-Knabner I, Rillig MC (2020) The concept and future prospects of soil health. Nature Reviews, Earth & Environment 1, 544-553.

Moebius-Clune BN, Moebius-Clune DJ, Gugino BK, Idowu OJ et al. (2017) Comprehensive Assessment of Soil Health. The Cornell Framework. Cornell University, Ithaca, NY

Norris CE, Congreves KA (2018) Alternative management practices improve soil health indices in intensive vegetable cropping systems: A review. *Frontiers in Environmental Science* 6, Article 50, 1-18.

Powlson DS (2020) Soil health- useful terminology for communication or a meaningless concept? Or both? *Frontiers of Agricultural Science and Engineering* 7, 246-250

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