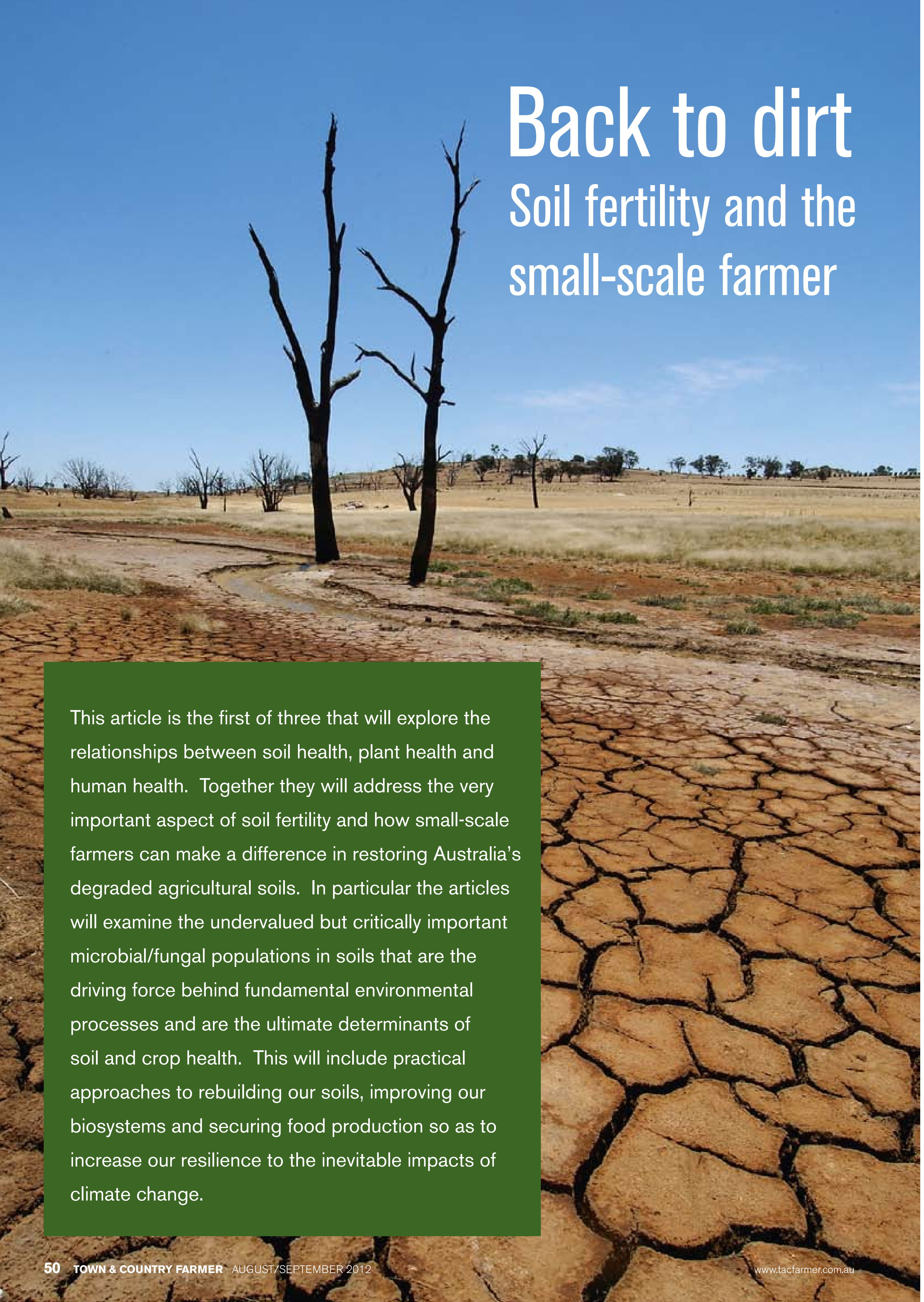


Back to dirt

Soil fertility and the small-scale farmer

This article is the first of three that will explore the relationships between soil health, plant health and human health. Together they will address the very important aspect of soil fertility and how small-scale farmers can make a difference in restoring Australia's degraded agricultural soils. In particular the articles will examine the undervalued but critically important microbial/fungal populations in soils that are the driving force behind fundamental environmental processes and are the ultimate determinants of soil and crop health. This will include practical approaches to rebuilding our soils, improving our biosystems and securing food production so as to increase our resilience to the inevitable impacts of climate change.

By ALISON POULIOT

WHAT'S GOING ON WITH OUR SOILS?

Dirt is not a thing and soil is not just dirt. Soil is a dynamic and highly interconnective and interactive web of relationships that form the foundation of our agricultural systems, of life. It drives physical, chemical and biological processes and represents the greatest concentration of biomass on the planet. Yet over the last century, our failure to fully appreciate the critical importance of these connectivities has led to a rapid decline in the fertility of our agricultural soils.

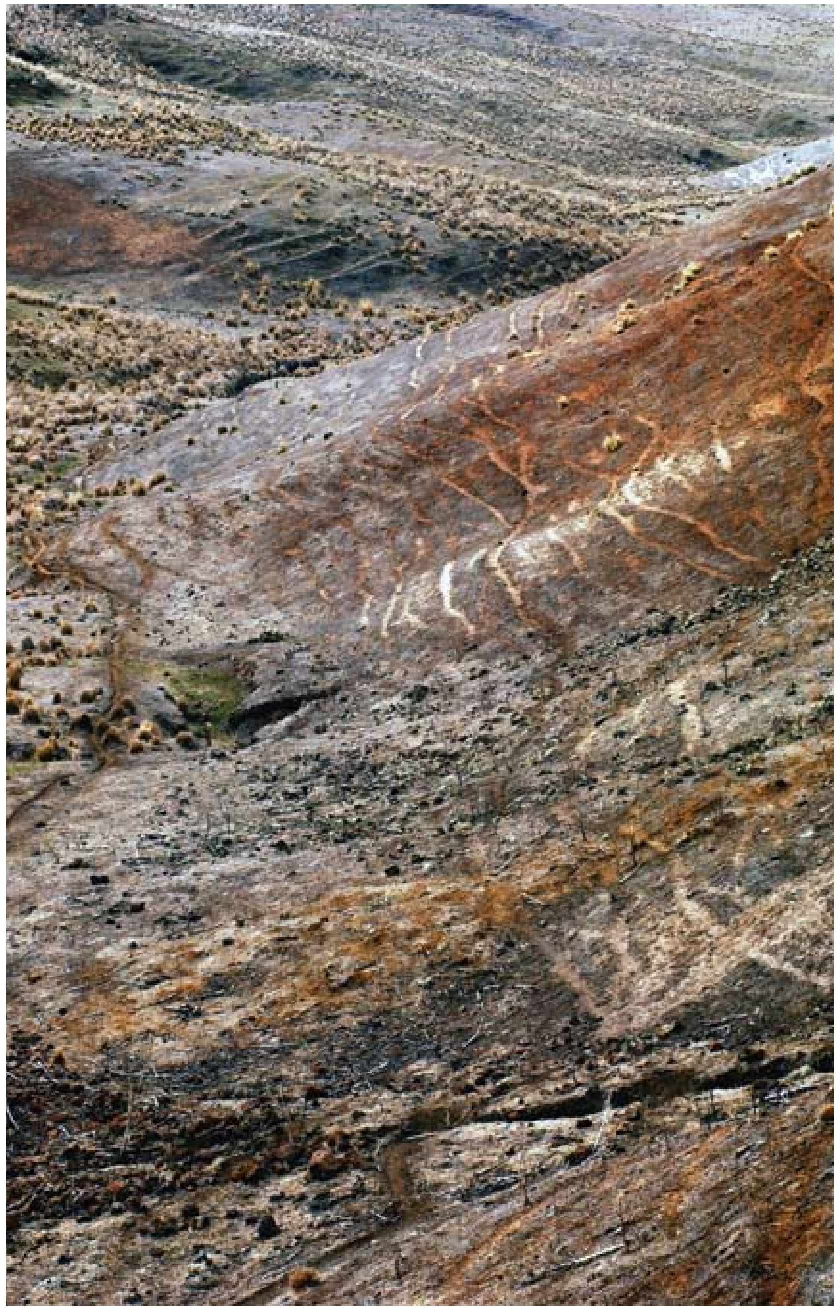
In Australia, indeed in many countries, we've attempted to increase agricultural yields through the application of oil-based fertilisers, irrigation, biocides and have bred plants that are adapted to these conditions. While these approaches achieved their aim of increasing productivity and allowing us to sustain a larger population, we must examine the real costs – to our soils, to our environments, to our society and to our health.

Much of our industrialised food production in Australia is unsustainable as it relies on oil-based inputs. We have also radically changed our soils with modernised agricultural processes resulting in an endless list of degradations including aridification, oxidation, acidification, salinisation, toxification, accelerated erosion, structural decline and loss of organic content, decline in water retentive capacity, increased vulnerability to pests and disease and overall loss of resilience and productivity.

Furthermore, the viability of smaller scale farming has been substantially reduced through the industrial commodification of food production.[1] We're also seeing a decline in the nutritional quality of our foods and subsequent decrease in human health. As a consequence of our oversight of the importance of soil fertility, our agricultural systems are becoming ever more vulnerable to disease as well as the impacts of larger scale crises such as those imposed by climate change. We now essentially have a dysfunctional agricultural economy driven by dollar values and not nutritional values[2] that is not only seriously degrading the sustainability of our soils and livelihoods but is also eroding the potential for a healthy future.

So-called modern farming practices that involve fertiliser and pesticide application along with irrigation have not only destroyed the vital microbial ecologies of our soils, but are also unsustainable in terms of costs of fertiliser production and water use. While yields have increased, energy requirements for crop production have also increased to an extent where this imbalanced ratio renders the current industrialised farming approaches unsustainable. To push the point further, 'high yields' is something of a misnomer as many 'high yielding variety' plants are technically not in themselves higher yielding, but just more highly responsive to (and dependent on) fertiliser and irrigation.[3]

So what's the good news in all this you may well be asking? There are real, achievable and sustainable solutions. And it is the small-scale farmers that are already and can further make the difference in catalysing change.



DEGRADED AGRICULTURAL LANDSCAPE SHOWING EROSION AS A RESULT OF LOSS OF VEGETATIVE COVER AND GRAZING.

IRRIGATION CAN LEAD TO NUMEROUS PROBLEMS IN SOIL INCLUDING WATER-LOGGING AND SALINISATION BOTH WHICH NEGATIVELY AFFECT VITAL MICROBIAL AND FUNGAL ECOLOGIES.

THE IMPORTANCE OF MICROBIAL AND FUNGAL ECOLOGIES IN DRIVING PLANT HEALTH

Plants require mineral nutrients to survive. Mineral nutrients are present in soils but are not always available to plants in a soluble form. Hence it is the processes that allow the solubilisation of mineral nutrients, making them available for uptake by plants that determine their growth. It is the unseen workings of microscopic organisms, largely bacteria and fungi that solubilise mineral nutrients and allow for their selective uptake by plants.

Fungi form mutually beneficial relationships with plants, called mycorrhizal associations that not only allow the selective uptake of nutrients, but also increase their capacity to uptake water as well as increasing their tolerance to toxins and helping to suppress soil-borne diseases (see info boxes). To truly understand and manage soils one must understand the microbial and fungal ecologies that govern plant growth and hence determine the nutrient integrity of our crop foods. Hence we need to delve into the secretive workings of the rhizosphere – that is, the vastly complex and symbiotic interactions within the sphere of influence of plant roots. It is the fundamental activities of microbes and fungi occupying this realm that ensure the productivity and stability of our agricultural systems.

SUBTERRANEAN INTIMACIES

Many people think of fungi as something they perhaps had for dinner last night, or worse, something growing in the corner of the shower recess. It is true, they both are fungi but they're just the fruit, or reproductive structure of the fungi. The actual fungus 'body' exists as an intertwining matrix of hyphae beneath the soil. An individual hypha is a long branching filamentous cell of a fungus which collectively form the fungal mycelium. They form sheaths around the roots of plants, or enter into the root cells of plants, increasing their surface area and capacity to penetrate more soil in search of water and nutrients. This enlarged root surface area can increase the nutrient uptake capacity of a plant by hundreds or even thousands of times. Despite the common belief that plants can uptake nutrients, the reality is that the vast majority (> 95%) can't do it effectively and selectively without their fungal partners. Plants rely on fungi to cycle, solubilise, access and take up nutrients. Fungi have special enzymes that have evolved over hundreds of millions of years that allow them to break down and solubilise minerals, making them available to plants. These relationships benefit both partners in the symbiosis and in returning the favour the plant offers the fungus a nice feed of sugars that it produce through photosynthesis.

In contrast, plants that have lost these mycorrhizal associations through soil deterioration and instead are fed synthetic fertilisers don't have the capacity provided by fungi to selectively choose which nutrients to uptake. Fertilisers (predominantly nitrogen, phosphorus and potassium) often lack the many trace nutrients also required by plants. Hence they are not only unable to select what to uptake, but also don't have the capacity to exclude toxic compounds. They can essentially only access those nutrients that exist in soils in a soluble form and have no access to the vast range that they require but can't solubilise. They've essentially lost the regulatory system or quality control system provided by fungi that determine the concentrations, forms, ratios and balances of mineral nutrients that are required. This directly influences the nutrition of plants and therefore the nutrient quality of our food and in turn, human health. Through our desire for high yield (and inevitably short term) agricultural systems, the way in which crop plants access and take up nutrients has been fundamentally changed from a system of symbiotic relationships that has evolved so incredibly efficiently over hundreds of millions of years[4], to one that is inefficient, less nutritional and unsustainable.

As well as those fungi that form mutually beneficial relationships with plants, there are also those that play a vital role in decomposition of organic matter. These decomposers or recyclers, otherwise known as saprobes, secrete enzymes that can break down the indigestible structural proteins of plant matter such as cellulose and lignin. They are also capable of decomposing animal proteins such as keratin (found in hooves, hair and fingernails) and chitin (found in insect exoskeletons). Along with bacteria they perform vital processes of decomposition, converting organic matter into simple molecules and returning nutrients to the soil for uptake by plants.

Imagine soils that are held together by a network, a framework of mycelium, that binds it together, helps it retain water and nutrients and resist disease and environmental stresses, that unites plant, animal and fungal kingdoms providing a fertile and dynamic environment in which to grow our food. Fungi are vital and oft forgotten components of soil and fundamental to the health of our crop plants. The path to improving degraded agricultural soils lies in optimising these symbiotic relationships with plants and their nutrient dynamics.

The next article in the series will examine the role of soil fertility as it relates to human health and how small-scale farmers can make a difference in initiating new and innovative approaches toward rebuilding the fertility and structure of our agricultural soils.

THE LAWYER'S WIG (COPRINUS COMATUS) IS NOT ONLY A VITAL SAPROBIC SPECIES BREAKING DOWN ORGANIC MATTER AND RETURNING NUTRIENTS TO OUR SOILS, BUT ALSO MAKES A TASTY MEAL.

SOIL

WHAT ARE MYCORRHIZAS?

Mycorrhizas (*formerly mycorrhizae*) are the mutually beneficial symbiotic associations that form between the roots of plants and fungi. The word mycorrhiza literally means 'fungus root'. These intimate associations are essential to either one, but usually both partners and play a vital role in nutrient exchange. The predominant role is transfer of mineral nutrients from fungus to plant. The fungus secretes powerful enzymes into the soil that solubilise minerals such as phosphorus, iron and sulphur that are otherwise unavailable to the plant. The plant also often transfers metabolites to the fungus.

Over 95 percent of plants form mycorrhizal relationships with fungi. In mycorrhizal relationships the fungus either enters into the cells of the plant's roots (*endomycorrhizas*) or forms a sheath around it (*ectomycorrhizas*) effectively extending their surface area and increasing the plant's capacity to absorb water and nutrients anywhere from ten to thousands of times.

Undisturbed soils are typically loaded with mycorrhizal fungi but many modern farming practices such as tillage, irrigation, fertilisation and use of pesticides have reduced or destroyed mycorrhizal fungi in agricultural soils.

BENEFITS OF MYCORRHIZAS TO ECOSYSTEMS, PLANTS AND PEOPLE

Some of the many benefits provided by soil mycorrhizas include:

- Nutrient cycling
- Maintenance of soil structure
- Carbon storage
- Increased supply of nutrients to plants
- Greater tolerance to environmental extremes
- Access to nutrients not usually available to plants
- Protection from nematodes and soil-borne diseases
- Improved diversity and stability of soils
- Improved nutritional value of crop plants
- Breakdown of phenolic compounds which can reduce nutrient uptake
- Improved water retention
- Provision of food for invertebrates and mammals from fungal fruit bodies
- Provision of food, medicines and aesthetic values to humans from fungal fruit bodies
- Bio-indicators of environmental quality

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