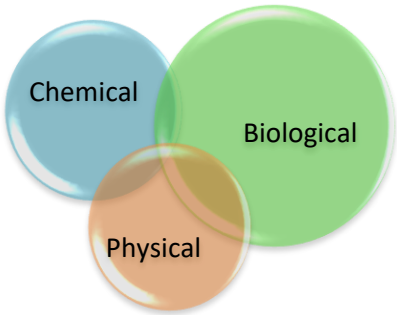
SOIL HEALTH SCHOOL WITH INTEGRITY SOILS, NZ

What is soil? Most simply, soil is a mixture of broken rocks and minerals, living organisms, and decaying organic matter called humus. Humus is dark, soft and rich in nutrients. Soil also includes air and water.

Soil is our most important land asset. Along with sunlight and water, soil provides the basis for: all terrestrial life; the biodiversity around us; the field crops that we harvest for food and fibre. Healthy soils provide ecosystem services, supports healthy plant growth, resists erosion, stores water, retains nutrients, and is an environmental buffer in the landscape.

AIR, WATER AND ORGANIC MATTER (CARBON) are often the major limiting factors for production. Plants and organisms in the soil need air and water to survive and to exchange nutrients and gases.

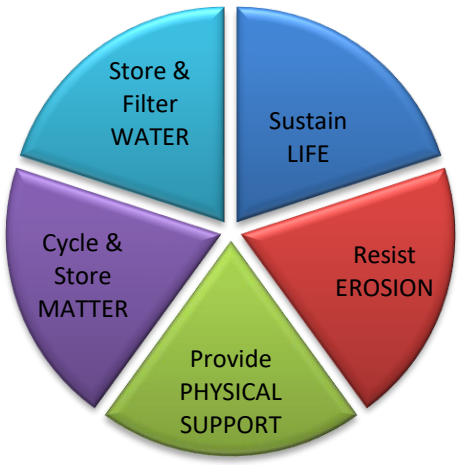


WHAT IS SOIL HEALTH?

Soil health is the condition of the soil in relation to its capability to sustain biological productivity, maintain environmental quality, and promote plant and animal health. Healthy soils are a result of complex interactions between physical, chemical and biological processes.

A HEALTHY SOIL:

- Buffers plants against climactic extremes; temperature, moisture
- Allows water to infiltrate freely and stores water
- Supplies nutrients, water and oxygen for healthy plant growth
- plus plant growth hormones, vitamins and enzymes
- Resists erosion
- Retains nutrients
- Readily exchanges gases with the atmosphere
- Acts as an environmental buffer; detoxify and filter
- Resists disease
- Contains a large and diverse population of soil biota
- Is not acidifying or salinising
- Has a range of pore spaces to house organisms, nutrients & water



Soil health is the balance of natural soil properties, uncontrollable environmental conditions, and management practices: **management has a major influence on soil health.**

The maintenance of good soil quality is vital for the environmental and economic sustainability of farming. A decline in soil quality has a marked impact on plant growth and yield, crop quality, animal health, production costs, water/nutrient holding capacities and the increased risk of soil erosion. A decline in soil physical properties in particular takes considerable time and cost to correct. Safeguarding soil resources for future

generations and minimizing ecological footprints are important tasks for successful long term land management.

SOIL HEALTH IS NOT AN END IN ITSELF

The ultimate purpose of assessing soil quality is not to achieve high aggregate stability, biological activity, or some other soil property. The purpose is to protect and improve long-term agricultural productivity, water quality, and habitats of all organisms, including people. We need more stable and resilient farm ecosystems to reduce our vulnerability to climactic extremes.

GIVE YOUR SOIL A HEALTH CHECK

Do you: Make decisions based on soil conditions (too wet, too dry)?

- Manage for optimum plant recovery and diversity?
- Maintain at least 80% ground cover all year round?
- Minimise cultivation and traffic?
- Monitor soil and plant health?
- Buffer nutrients and Ag chemicals with carbon sources?
- Know how deep crop and pasture roots are growing?
- Know how many pests are grazing on your pasture/crop above and below ground?
- Walk fields and observe soil conditions?
- Think about how to invest in soil health as part of your farming business?

If you answered "no" to any of these questions, your soil may be overdue for a health check.

10 STEPS TO OPTIMAL SOIL HEALTH AND RESILIENCE

1. **Avoid costly production losses through building on local knowledge** - Find a mentor: a successful farmer, regenerative farming consultant or join a discussion group.
2. **Benchmark:** measure where you are now; soil mineral, biology, leaf tests and photographs.
3. **First do no harm:** reduce and then eliminate products that blow the microbial bridge; soluble N and P, glyphosate, fungicides. Buffer chemicals with microbial foods (e.g. Humic/fulvic acid) while in transition
4. **Observe:** pests, weeds and diseases are all indicators for imbalances.
5. **Address major limitations;** air, water, foods and minerals: 1. Drainage, 2. Soil structure 3. Decomposition 4. Review soil chemistry.
6. **Apply** broad-spectrum products which feed biology and address major nutrient deficiencies.
7. **Health:** Ensure crop and animal health needs are being met, if not, use free choice minerals and foliars
8. **Implement** practices that increase photosynthesis, rooting depths and soil carbon.
9. **Monitor and observe changes:** Brix, EC, pH, photographs. Adjust programme as required.
10. **Encourage biodiversity above and below ground:** herbal leys, fodder crops, inter-planting.

VISUAL SOIL ASSESSMENT or VSA Method.

Often, not enough attention is given to:

the basic role of soil quality in efficient and sustained production;
the effect of the condition of the soil on the gross profit margin;
the long-term planning needed to sustain good soil quality;
the effect of land management decisions on soil quality.

Visual Soil Assessment is based on the visual assessment of key soil 'state' and plant performance indicators of soil quality, presented on a scorecard. With the exception of soil texture, the soil indicators are dynamic indicators, i.e. capable of changing under different management regimes and land-use pressures. Being sensitive to change, they are useful early warning indicators of changes in soil condition and as such provide an effective monitoring tool. The VSA looks at the following characteristics:

Soil indicators	Plant indicators
Soil texture	Clover nodules
Soil structure	Weeds
Soil Porosity	Pasture growth
Number and colour of soil mottles	Pasture colour and urine patches
Soil Colour	Pasture utilisation
Earthworms	Root length and density
Soil smell	Area of bare ground
Potential rooting depth	Drought stress
Surface ponding	Production costs to maintain stock
Surface relief	

Sampling Guidelines

It is important to gain as much information about the area and soils as possible. Indicators of soil quality must be evaluated within the context of site and climatic characteristics.

Important: When, where, and how deep to sample and how many samples to take is primarily dependent on the questions being asked or problems being addressed by the farm or land manager. Timing of sampling is important, because soil properties vary within a season and with management operations, such as tillage. In general, for the overall assessment of soil quality, sampling once a year will allow for the detection of long term changes in soil quality. A good time of year to sample is when the climate is most stable and there have been no recent disturbances, e.g after harvest or the end of the growing season. Record the site using a GPS.

Where to sample? An important consideration in determining where to sample in a field is the variability of the area. Soil properties naturally vary across a field and even within the same soil type. Soil variability across a field is also affected by management operations. Avoid areas such as stock camps, troughs and gateways.
VSA booklets, written by Graham Shepherd are available online from Landcare Research: *www.**landcareresearch**.co.nz/**research**/soil/**vsa**/fieldguide.asp* or can be ordered from:

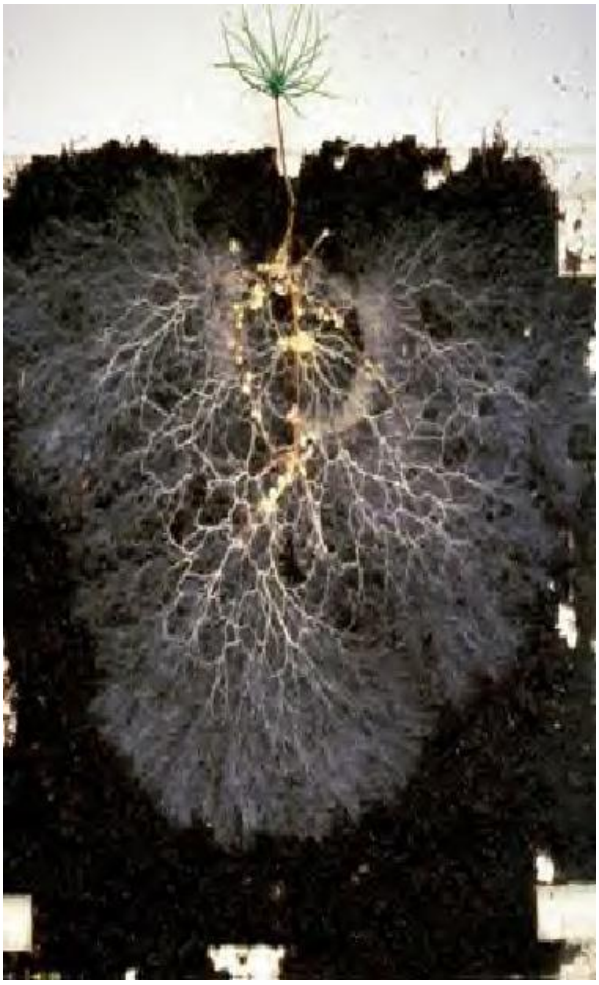
gshepherd@bioagrinomics.com

SOIL MICROBES AND THEIR ROLES

Organism	Description	Role in soil	Foods or inoculation
Bacteria	Bacteria are the oldest, the simplest, and the most numerous forms of life. Supressed by dry conditions, acidity, salinity, compaction and low organic matter.	Make the smallest micro-aggregates, **NUTRIENT RETENTION,** N-fixers. Decomposers. Disease suppression, plant growth promotant molecules, antibiotics, mineral solubilization, Induced Systemic Resistence (ISR), metal binding, improves stress resistance.	Aerobic compost tea, good compost. FEED: Nitrogen: green plant materials. Simple sugars, simple proteins, simple CHO. Molasses, fruit juice, seaweed,
Actinomycetes	Long chains of bacteria	Produce antibiotics; disease suppression, nitrogen cycle, humus formation, give soils their 'healthy smell'.	Eat complex foods such as chitin (e.g. insect shells, fungi) and cellulose. FEED: mussel shells, shrimp, woodier plant materials.
Fungi Saprophytes =decomposers Mycorrhizae **(AM)** (*=Fungus root)* plant symbiote.	Grow from spores. Contain long strands of various lengths = hyphae. Supressed by soluble fertilizer, compaction, herbicides, cultivation, waterlogging, salinity , many 'icides and low organic matter.	Fungi (and bacteria) are the primary decomposers of organic matter. Make organic acids. Disease suppression, **NUTRIENT RETENTION** and solubilization, make the large soil crumbs, **EROSION CONTROL,** insect bio-controls.	FEED: Carbon: wood, paper, cardboard. complex sugars, complex proteins, fish oils, fish hydrolysate, cellulose, humic acids.
Protozoa	Single celled organisms. 3 gps: Flagellates, Amoebae Ciliates	Consume bacteria and fungi- cycle nutrients. Make air passageways. Important food source for micro-invertebrates. **NUTRIENT CYCLING**	Aerobic compost tea, good compost, straw infusions.
Nematodes	Non-segmented worms. One of the simplest animal groups. Most are beneficial.	Nematodes generally eat bacteria, algae, fungi, protozoa and each other. **NUTRIENT CYCLING.** Release N, P, S and micronutrients during their digestive process.	Aerobic compost and compost teas. Vermicast. Encourage good diverse bacterial/fungal populations to feed nematodes.

SUMMARY: Without bacteria and fungi – most inorganic nutrients added will just wash away!
Without protozoa and nematodes – nutrient cycling from bacteria and fungi to the plant will not occur.
How about the microarthropods and earthworms? Diversity is KEY.

Mycorrhizae



'Endo' Vesicular Arbuscular mycorrhizal (VAM) are symbiotic fungi which directly infect pasture roots. 90% of plant species have this relationship- the only species that don't rely on this fungi are brassicas, lupins, amaranthus and chenopodium families- this includes fat hen and pigroot- common cropping weeds.

Plants provide the fungus with its sole source of food (as liquid carbon sugars) and the fungus provides the plant with soil-derived nutrients, namely P and Zn, plus N and trace elements to the plant. Mycorrhizae play essential roles in plant nutrition, as evidenced by their beneficial effects on pasture growth, phosphorus nutrition, and water relations. The length of these external hyphae is typically one to two orders of magnitude higher than that of roots. As such, they significantly increase the absorptive surface area of the root system and enhance the ability of grasses to utilize nutrients and water from the soil solution. VAM have also been found to protect the roots from disease and create an induced defence response against pest attacks.

VAM exude a substance called glomalin into the soil, glomalin is an important component of stable soil carbon resulting in better soil structure, water and nutrient holding capacities and higher organic content.

See image above, the actual roots of this conifer only extend a short distance, the rest of what you can see is VAM. The hyphae are much thinner than plant roots- so they can access more water from inside soil particles.

Why are VAM so important?

i. Drought resistance

ii. Nutrient cycling

iii. Major source of P

iv. Build and hold soils together

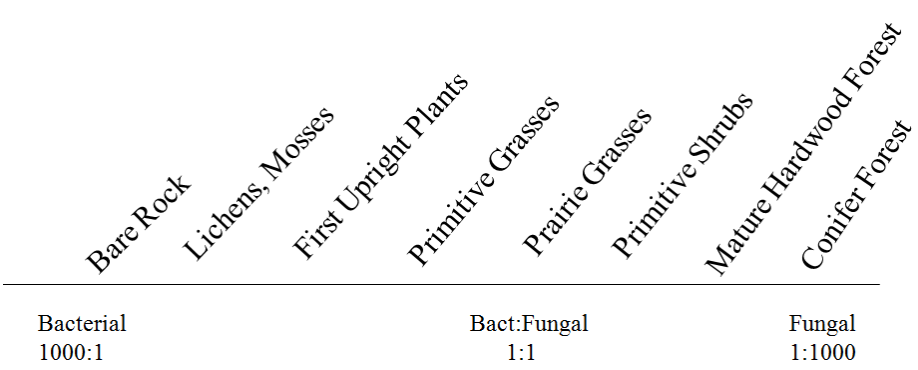
v. Plant health and pest resistance

What on Earth is a Weed?!

In the simplest of terms, a weed is a plant growing out of place; what is a weed for a cattle beast, may not be a weed for sheep, or even a weed in a crop. Weeds are nature's guardians or repairers and the indicators they offer can provide those willing to listen valuable insights into soil health. There are five main (& related) reasons why weeds grow:
1. To quickly protect bare/disturbed soil 2. Low organic matter 3. Balance mineral 4. And microbial imbalances and 5. As a safety valve for toxins.

Many weeds are adapted to colonise disturbed areas and help the soil building process, this is referred to as 'plant succession'. Deep rooted weeds are 'dynamic accumulators" which mine minerals from deeper down in the subsoil, feed micro-organisms and build humus, creating a more favourable soil environment for higher plant species, such as grasses. This is not an overnight process!

How weeds grow, above and below ground, can offer clues to their soil repairing role; scrambling weeds offer protection to soil surfaces and help prevent the loss of valuable carbon. While deep tap rooted weeds, such as dock and Californian thistles (with root depths up to 20 feet deep) provide services; opening up tight soils, transporting nutrients from the subsoil and creating channels for air and water. Shallow roots can indicate high water tables, compaction and overgrazing. Grazing management is an important tool for managing weeds, often shallow rooted weeds prefer set stocking and short covers, as they are outcompeted by grasses with longer grazing rounds.



Disturbance events (pugging, fire, herbicides, waterlogging etc) push environments back to more primitive bacterially dominated states, as fungi are more vulnerable to disturbance events. These imbalances can all create favourable soil conditions for weeds to germinate. Alternatively, by using regenerative soil practices which change the soil environment to suit more advanced pasture species and crops, the weeds are out-competed. When soils become more fungal (or sleepy), fungal weeds germinate- like 'woody shrubs' or species like mullein and foxglove.

<u>Build it and they will come:</u> The weed seed-bank in the soil can be massive; a single ragwort plant can produce 150,000 seeds, viable in the soil for over 15 years. There can also be 400 to 1200 clover seeds in a square meter of soil, yet not a single visible clover. Your management determines what signals the seedbank to germinate.

A large number of weeds indicate low functional calcium, especially coarse grass weeds, while broadleaf weeds can indicate high available potassium and low phosphorus. Some "weeds" act like safety valves to remove high levels of toxins and nitrates out of the soil. They can also quickly cover and remineralise the soil, feed microbes and create ground cover thus fulfilling all five roles at once. Some "repair plants" detoxify soil and remove nitrates out of the soil such as e.g. nettles, fat hen, barley grass and cape weed.

A weed can indicate a number of different environmental factors, so observing the whole picture is vital; dig a hole, observe patterns, record changes, take herbage tests to identify what a weed is accumulating, note previous management or climactic conditions and set up some trials for yourself. This all helps to build your own knowledge bank.