

WHAT IS A HEALTHY SOIL



A Natural
Heritage
Trust
funded
project

Pam Pittaway
National Centre for Engineering in Agriculture,
University of Southern Queensland, Toowoomba



A healthy soil is sufficiently biologically diverse to regulate the availability of nutrients for plant growth, and the activity of soil animals and microbes to promote a healthy root system.

What Makes a Soil Healthy?

Organic matter is the cornerstone of a healthy soil. Plants can grow in the absence of organic matter, as in hydroponics, but nutrients must be replenished continuously, and plant pathogens must be excluded. Organic matter favours the activity of **beneficial organisms** which outcompete pathogens, and organic matter is nature's **slow-release** fertiliser (Figure 1).

As organisms grow, nutrients absorbed from the soil are locked up in their cells, **unavailable** for plant growth. Minerals in the form of waste products are released as part of growth, and on death, their tissues are decomposed by other organisms leading to the excretion of more minerals now **available** for plant growth. Like humans, most soil organisms depend on sugars and starches (**organic carbon**) to fuel growth. In the process, these compounds are transformed into energy and carbon dioxide (a gas). Carbon dioxide represents a net loss of **organic carbon** to the system, as does the harvesting of plant and animal produce. In many cropping soils in Australia, the **organic carbon** levels have declined over time. As a consequence, some **soil physical, biological and chemical properties** have also declined.

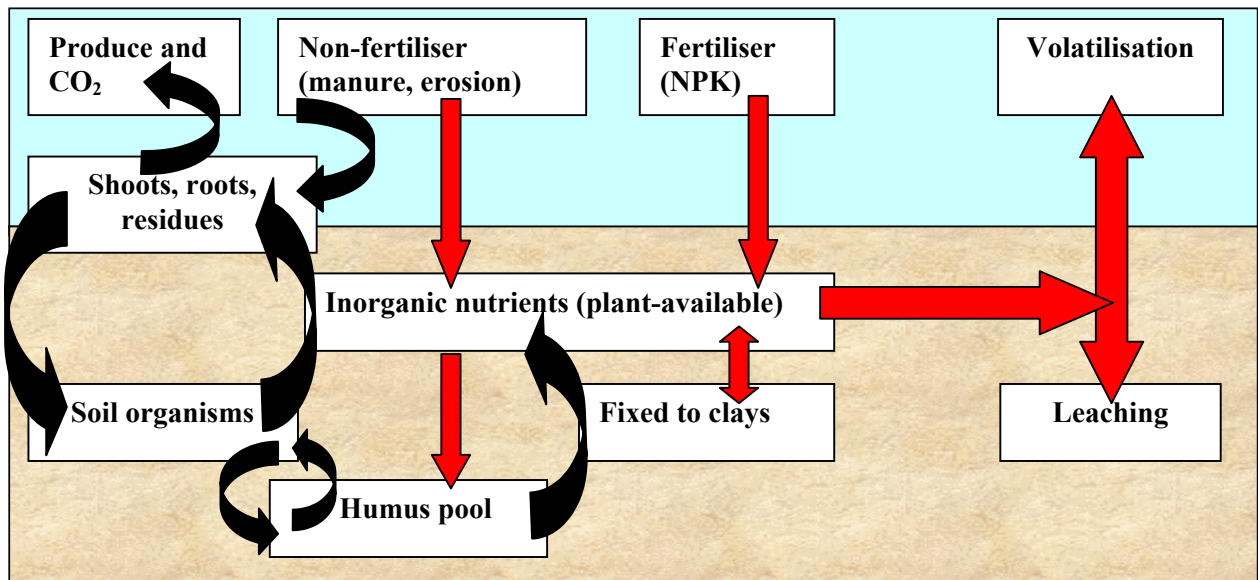
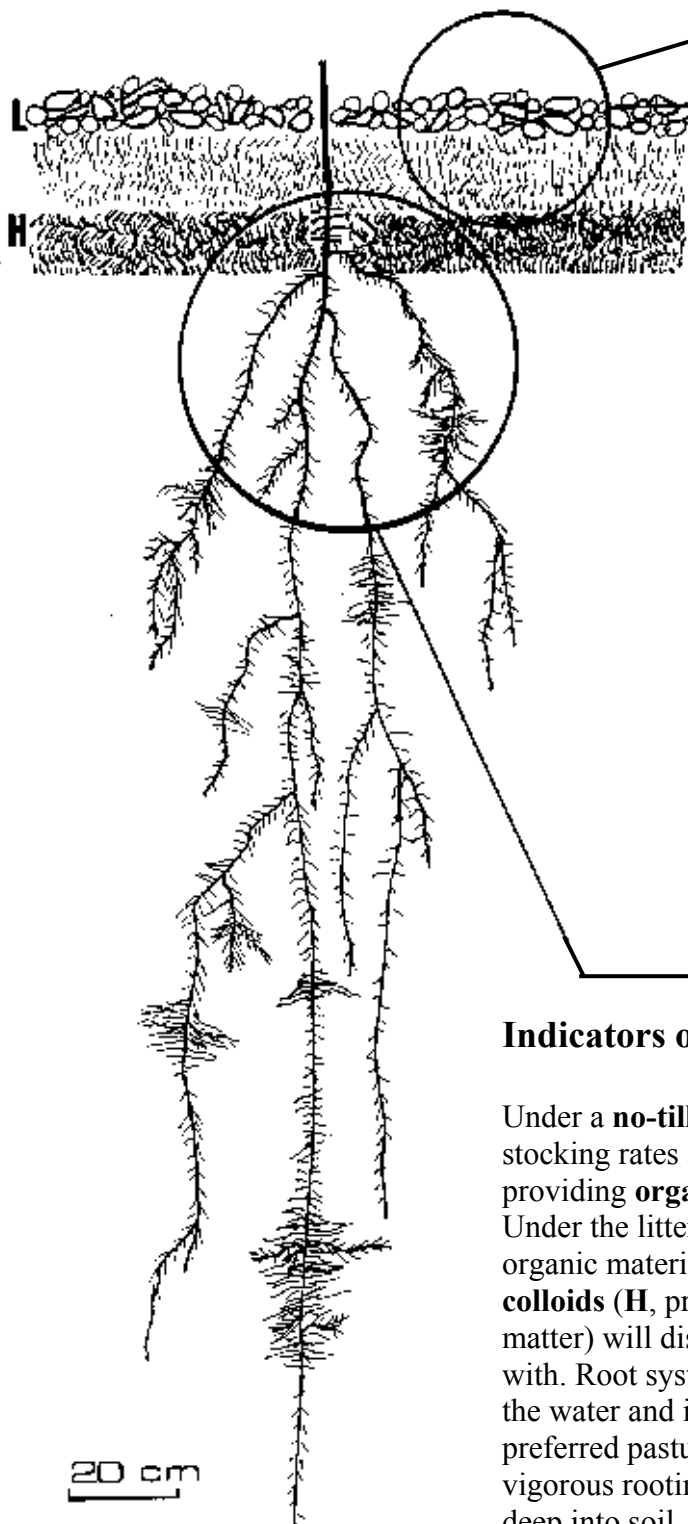


Figure 1 Nutrient dynamics within the soil profile. Straight arrows show inorganic processes, curved arrows show organic processes. Inorganic nutrients in excess of plant and microbial requirements, will be lost via leaching and volatilisation (in the case of N). Humic acids interact with minerals fixed to clays, making them more available to plants.

What is Enough Organic Matter and How do I Get it?

There is no standard figure for **enough**. As a benchmark, check the levels of **organic carbon** in a relatively undisturbed patch of vegetation (remnant vegetation or native pasture with a history of low grazing pressure), on the same soil type. However levels of over 2% have been measured for long-term pastures with well developed **litter layers (L - plant residues)**, under no tillage in Qld.



Animal manures will improve the availability of **P, K and Ca** for plant growth, but the organic carbon component is relatively short-lived (depending on the animal type and feed ration). However manures may be contaminated with weed seeds and pathogens, and high land application rates may lead to P enrichment of local waterways.

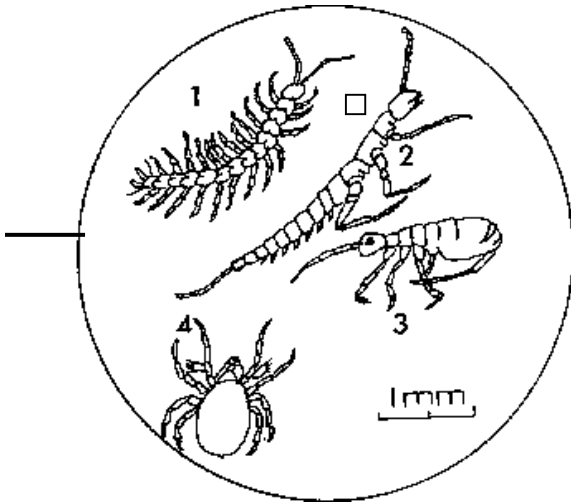
Green manures also provide a short-term organic carbon deposit (improving soil structure), whereas the tougher material in sorghum adds to the longer term carbon pool (a **mulch crop**).

Co-composting animal manure with sorghum stubble or sawdust, not only maximises the storage and slow-release of NPK, but also adds to both the short and longer-term organic carbon pools. Increased organic carbon levels improve soil structure and plant health, and reduce nutrient losses from leaching and erosion

Indicators of a Healthy Pasture

Under a **no-till** pasture management and conservative stocking rates a distinct **litter layer (L)** will develop, providing **organic matter** for soil microbes and soil animals. Under the litter layer fine particles of partially decomposed organic material will collect. Below this layer **humic colloids (H)**, products of the decomposition of organic matter) will discolour the clay particles that they complex with. Root systems penetrate through these layers, tapping the water and inorganic nutrients at depth. Lucerne is a preferred pasture plant due to its **nitrogen-fixing** ability and vigorous rooting system, which can extend several meters deep into soil.

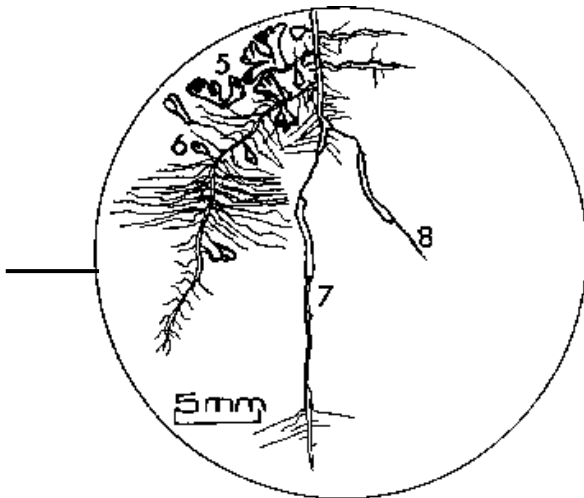
Dry heat extraction of soil animals



In order of abundance, **mites (4)**, **springtails (3)**, **bristletails (2)** and **symphylids (1 –mistaken for small centipedes)** are the most common soil organisms feeding in the litter layer. You will need a tungsten filament lamp (desk lamp), a plastic funnel (175 mm diameter) a glass jar, and an empty milk carton to support the funnel. Cut two circles of 12 mm aperture chicken wire (or gutter guard) to approx. 100 mm to fit mid-way down the funnel. Offset the mesh circles to minimise the hole sizes through which the soil organisms will move (this will reduce the amount of soil falling through). Half fill the jar with water and place it in the bottom of the milk carton.

Place the funnel in the carton so that the barrel is in the jar. Use a spade to cut about a 10cm cube of litter and soil from the pasture. Place this carefully into an ice-cream container for transport home. Avoid breaking up any clods, as this will cause more soil to fall down the funnel. Place the litter/soil sample on the mesh support, then position the lamp in the funnel, as close to the soil (without touching it), as possible. The heat and drying effect will repel soil animals. After 24 or 48 hours, pour the contents of the jar into a white tray or ice-cream container, to observe the numbers and diversity of soil animals present. You may need a magnifying glass (check your local school for a low powered microscope), as most of these organisms will be less than 5mm in length!

The soaking method for observing root systems



The best time to look at a root system is after the seedling stage, but before the stresses of flowering and fruiting. Insert a garden fork vertically into the soil, on each of the four sides of the plant. Lever the soil from each side in turn, until it is possible to remove the system as one intact clod. Ease the clod into a bucket, with as little disturbance as possible (excessive force will break the root connections). Immerse the clod in water, and allow it to soak for an hour or two. Water will infiltrate the soil pores, making it easier to wash the roots. Support the root system by putting your hands under the water, under the soil clod.

Gently shake your hands to agitate particles away from the roots. Discard excess soil in the bottom of the bucket, change the water, and repeat the process. After most soil has been removed, place the root system in 2cm of water, on a white tray (eg large white ice-cream container). You should see lots of **finely branched** roots (6), emerging from the main laterals and tap root. Healthy legumes may have **nodules** present (5). However, only those with a blood-red pigment inside, will be actively fixing nitrogen. Unhealthy roots will have few fine roots, with **brown or black** discoloured patches, sections missing from the outer root tissue (7), and evidence of **spear-tipping** (8). The ability of the plant to compensate for and to replace damaged roots, will determine the health status of the plant.

Benchmarking the Organic Matter Status of Your Soils

Organic matter can be divided into the larger fragments or residues of plants and animals referred to as the **litter layer**, smaller living and non-living products of microbial activity, and the more resilient, non-living **humus**. The litter layer protects the soil surface (**reducing erosion**), the microbial fraction aids in binding soil particles together (**improving soil structure**), and humus binds with soil nutrients to increase the concentration of nutrients available for plant uptake (**increasing cation exchange capacity**).

Benchmarking the Litter Layer in Pastures:

Photographic kits are available from some government departments to aid in benchmarking the **percentage cover** of litter remaining after grazing (eg NSW Agriculture Sustainable Grazing Systems Pasture Health Kit). Alternatively, you could construct a 50 cm square wooden or metal template to place on the ground to sample from within. Use your hands to collect the litter layer from within the frame. Document the **volume of litter** by marking off the number of standard cup fulls (500 mL capacity or equivalent) collected from the square. Repeat the procedure at least three times for each paddock, to compare the extent of the litter layer. In guides such as the Sustainable Grazing Systems pasture Health Kit, benchmark figures for protection from erosion in different regions are provided (eg 70% litter cover for the North West Slopes of NSW).

Benchmarking the Organic Matter Content of Topsoil:

The concentration of organic matter is more precisely measured as **organic carbon**. The value for **organic matter** is calculated by multiplying the result for the **Walkley/Black organic carbon** test by 1.72 (allows for the mineral or ash component of organic matter). Soil chemistry laboratories commonly perform two tests for **organic carbon**, the furnace or Leco carbon test, and the acid-extractable or Walkley/Black test. The furnace test can be misleading, as it includes very resilient, biologically inert organic carbon such as charcoal or coal. The more important, biologically active soil fractions (**microbes** and their products, and **humus**) are best measured using the **Walkley/Black** test.

Match the paddock of interest with a second site on the same soil type but lacking a history of cropping, tillage and intensive grazing, to **benchmark** the maximum amount of organic carbon likely to develop within that soil/land use regime. Avoid sampling from old fence lines, yards or roads that are not representative of the management history that you wish to examine. More specific advice on soil sampling is available in publications such as **Soil Matters** (QDPI shop). Brush aside the litter layer before you start sampling. Sample a minimum of 10 to 20 points to a depth of 10 to 15 cm within the soil type and paddock that you are interested in, using a hand operated auger. Bulk the samples from each soil/land use type in a large clean bag (about 2 kg of soil in total), removing any obvious root, manure, or other large, undecomposed organic fragments and mix well. Save half the sample and store in a cool, dry place (reserve sample). Send the rest to the laboratory (preferably a NATA registered lab.) for testing. Include details of the date of collection, the numbers of subsamples mixed and the depth of the sample, and the soil type and land use. The results will be given as **percentage by weight** of oven-dry soil.

Keep records of the **organic carbon** results and your observations on the **litter layer**, to monitor changes over time. In Qld some farmers have recorded increases of 0.5% after adopting reduced tillage and stubble retention for 5 years. Others have observed an increase in the population of small lizards (feeding on soil animals), with the increased litter layer!

Sheet updated 4/2002