What is a Healthy Soil?

FACT SHEET 11

The concept of soil health is used to describe the condition of a soil. The three key aspects of soil health are the biological, physical and chemical characteristics. A healthy soil will have all aspects functioning well to promote optimal plant growth. Seven steps to improved soil health are summarised here.

Importance of soil health

The soil is the most basic resource in any primary production endeavour. The health of all aspects of the soil will determine the productive potential of a crop, pasture or any ecosystem. More than its value from a purely production perspective, soil is the source of human survival, it is the basis of civilisation.

In natural and managed environments the living system that is the soil sustains plant and animal life, health and production. The soil is the source of fertility, nutrition, germination and regeneration of all forms of life. It is the site for storage and filtering of water as well as enhancing both water and air quality.

Soil provides habitat for soil organisms and these diverse communities have additional vital roles including detoxifying elements, control of pests and disease and recycling of nutrients. The health of a soil in any situation will determine how effectively each of these functions is performed.

Figure 1: The conversion of sunlight energy into plant material is the first step to improve soil health.

Seven steps to soil health

Although achieving optimal soil health is not a linear process the starting point for improvement is a constant. All soil life and soil processes depend on plants to provide the essential resource of carbon as the primary source of energy.

1. Photosynthesis - the conversion of sunlight energy, water and CO2 into carbon compounds is the first step to soil health. Every living organism relies on this process. While ever the sun shines there is potential to improve soil health. Since a significant proportion of the products of photosynthesis exist below ground in the root systems of plants, maximising green leaf production will increase root density and influence soil processes.

Perennial grasses have approximately 50% of the total plant biomass contributed by the root system. The production of exudates from plant roots are vital for soil life. The carbon compounds flowing from plant roots provide the source of nutrients and energy for soil microbes in the rhizosphere, the basis of the soil food web. Depending on soil conditions, plant roots have the capacity to penetrate deep into the profile enhancing soil structure.

Plant roots are the most effective soil conditioning agents ever created

Increasing the photosynthetic capacity of an area can be achieved by increasing;

- the diversity of plants with different growth cycles i.e. warm season and cool season production.
- the density of plants. A greater number of plants per unit area will provide a more consistent level of groundcover and maximise photosynthetic area.
- leaf area. Plants with relatively broader leaves have greater potential to harvest more sunlight.

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2. Soil carbon has its origin in plant products in the form of root exudates and material from plant roots and shoots. Root exudates are responsible for the liquid carbon entering the soil system, the most active component of the soil carbon cycle. Plant based material provide a longer term store depending on its composition, condition and rate of decomposition. The other main sources of soil carbon such as humus and microbial biomass are also ultimately derived from the products of photosynthesis.

Soil carbon and soil organic matter (which consists of about 58% carbon) are key indicators of soil health. As soil carbon is the primary food source for soil biota it will be a first limiting factor for biological activity and population growth. A measure on your soil test, carbon levels of at least 5% are ideal in clay soils and in sandy soil the target should be at least 3% carbon.

Soil organic matter increases the cation exchange capacity of soil and is an important source of nutrients such as nitrogen, phosphorus, sulphur and trace minerals. Increasing soil organic matter is the most effective method of increasing the natural fertility of inherently poor soils.

Figure 2: Soil organic matter (58% C) increases soil fertility, soil biological activity and soil physical characteristics.

Increasing soil organic matter also has the effect of increasing the water holding capacity of soil. When present as humus it can hold up to four times its weight in water. Increasing plant available water has the potential to increase plant and root growth and improve soil structure.

The most effective method to increase soil carbon is to grow more plants to increase the rate of photosynthesis

3. Soil biology is dependant on a constant source of soil carbon, primarily from plant roots, as a food source and habitat. In return, microbes cycle nutrients through the soil and increase plant uptake by increasing nutrient availability. The majority of micro-organisms reside in the rhizosphere, immediately adjacent to the plant root. The higher the amount of root biomass present, the higher the number of soil biota that may be supported in any environment.

Vigorous root systems will more likely form symbiotic relationships with mycorrhizal fungi. These organisms are important contributors to the soil carbon pool as well as increasing the plants ability to obtain water and nutrients, particularly phosphorus and nitrogen.

Figure 3: Mycorrhizal fungi hyphae connecting plant roots

Soil micro-organisms are predated by other microbes and this process encourages microbial population growth and nutrient cycling. As microbial populations increase, populations of the larger predatory organisms increase. The movement of larger organisms through soil creates channels through the profile, increasing porosity which improves water infiltration rate.

While microbes and microbial activity are difficult to measure directly in the field, the presence of larger organisms such as earthworms will provide a good indication that healthy populations of other forms of soil biota are present.

Microbes also produce mucilaginous substances which bind soil particles enhancing aggregate stability and water holding capacity of soil. Increasing these aspects of soil structure will provide conditions that stimulate biological populations. Soil aggregates providing habitat and soil moisture, the latter being a critical factor in stimulating biological activity.

4. Soil physical characteristics are strongly influenced by soil texture but any soil may be improved by increasing organic matter and improved biological activity. Both will have the effect of improving soil structural characteristics such as porosity and bulk density.

Soil structure effects the water holding capacity of soil and soil moisture is a primary influence on soil biological activity. The greater the capacity to store plant available water the more productive that soil environment will be. Soil moisture content also has an inverse relationship with soil strength. Where higher soil moisture conditions are present plant root growth is less likely to be limited.

A soil penetrometer will give a measure of the force required to penetrate soil to depth. If you can't easily push a penetrometer or a long shafted screwdriver or wire into soil plant root growth will be unlikely.

5. Soil water infiltration and plant available water are influenced by soil structure and soil organic matter content. With an increased rate of infiltration and water holding capacity more water is available for plant uptake and growth and soil biological processes. Increasing soil water infiltration will also reduce the amount of water moving off the soil surface.

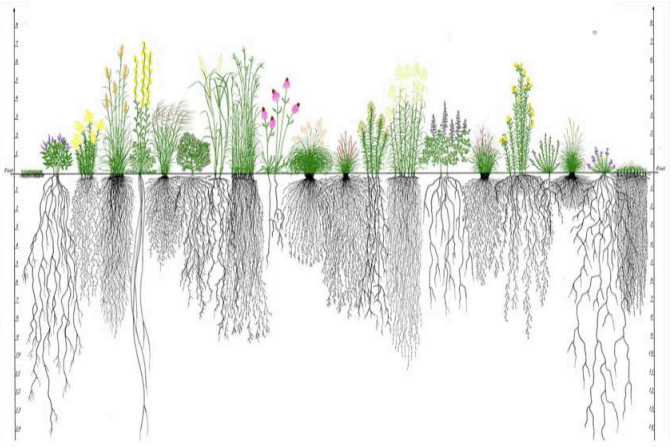

Figure 4:
Deep rooted perennial plants enhance soil structure and soil water infiltration.

Associated with runoff are soil particles and nutrients. Reducing potential runoff by increasing soil water retention will mitigate the risk of flooding and erosion damage so common with intense rainfall events.

A simple field measurement can be made using any cylindrical shape pipe or tube to around 150mm diameter and 12-15cm long placed around 2-5cm into soil. Pour a known amount of water (e.g. 500ml) into the cylinder and measure the time it takes to disappear. Using this method a soil water infiltration rate of around 10ml/second is ideal.

6. Soil chemistry will be strongly influenced by soil type and the origins of the soil. Clay soils with higher cation exchange capacity are inherently more fertile than sandy soils.
The potential to increase soil fertility using natural processes starts with increasing photosynthetic capacity of a site which allows an opportunity to increase the input of soil carbon and organic matter.

Increasing plant growth increases root biomass and the associated biology will enhance the potential nutrient cycling as well as water holding capacity and soil structure. All of which combine to increase the potential fertility of a soil.

Soil chemical analysis gives the best indication of the fertility status of your soil. The ideal levels for each element will vary for different soil types. Factsheet 3 of this series provides more information on aspects of soil chemistry.

7. Biodiversity is an indication of the number of individual species present in a community. By far the greatest biodiversity is found in soil. A teaspoon (1 gram) of healthy soil may contain over a billion individual organisms of many species, most of which likely remain unnamed. It also applies to other types of soil biota, plant species as well as other organisms such as insects, birds, reptiles and herbivores.

Other aspects of biodiversity relating to soil health include;

- the diversity of root structure or architecture of different plants and their capacity to access different regions of the soil profile (Fig 4)
- different plant species will produce different compounds in their root exudates which will favour different species of soil biota
- plants with different growth cycles will extend the period of growth of green leaves, increasing photosynthesis over an annual period
- plants with different growth forms; grasses, forbs, egumes, shrubs, trees all have different root structure and their growth habit modifies conditions at the soil surface which will impact processes deeper in the profile.

The more biodiversity present in any system the more resilient that system will be and the more resistant it will be to change or external pressures. Biodiversity can be easily measured by counting the number of different organisms present. You don't have to know their names, just recognise their differences.

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Question: What is a healthy soil?

Answer:

A healthy soil will have all of these seven components functioning to their maximum potential. As with all other elements in nature, nothing in the soil system operates in isolation. Each process is interdependent on all others for effective function. By actively managing to regenerate your soil and improve soil health the result will be an improvement in all aspects of the soil environment. It will improve the resilience and productive potential of the land.

The figure below attempts to illustrate the complexity of the soil system whereby each element is influenced by and influences all other aspects of soil health.

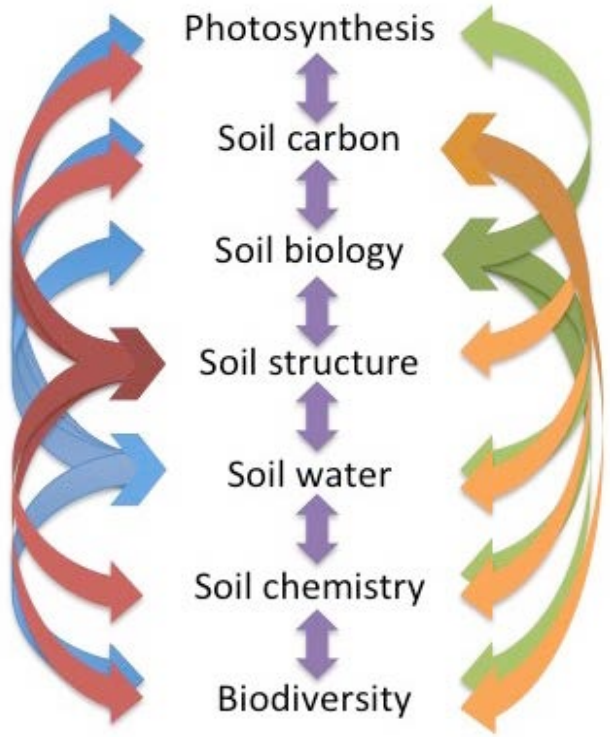

Figure 5:
All elements of soil health influence the effective function of all others.

Measuring soil health

The best way to evaluate the health of your soil is to monitor and measure changes over time to ensure the changes you want are happening in the direction you want. Monitoring can also help to identify which factor is most limiting to achieving optimal outcomes for your soil or allow you to quantify the response to changes in management or addition of any treatment.

There are a range of monitoring protocols available but one of the most user friendly methods has been developed on the North Coast and is freely available from SoilCare. The Soil Health Card is a 10 point checklist that covers all easily measured aspects of soil health. It includes methods to measure;

- Groundcover
- Diversity of soil life
- Soil strength – penetrometer
- Soil water infiltration
- Root development
- Soil structure
- Aggregate stability
- Earthworm numbers
- Soil pH
- Diversity of plant species

Soil monitoring should ideally be conducted twice annually, in spring and autumn a few days after and within a week of at least 25-50mm of rainfall. Try to sample at the same time each year under similar soil moisture conditions. This will provide more comparable results over time.

More Information

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