Bioeconomy Science Institute™

Te Uru Kahika Regional and Unitary Councils Aotearoa

Physical properties of soil

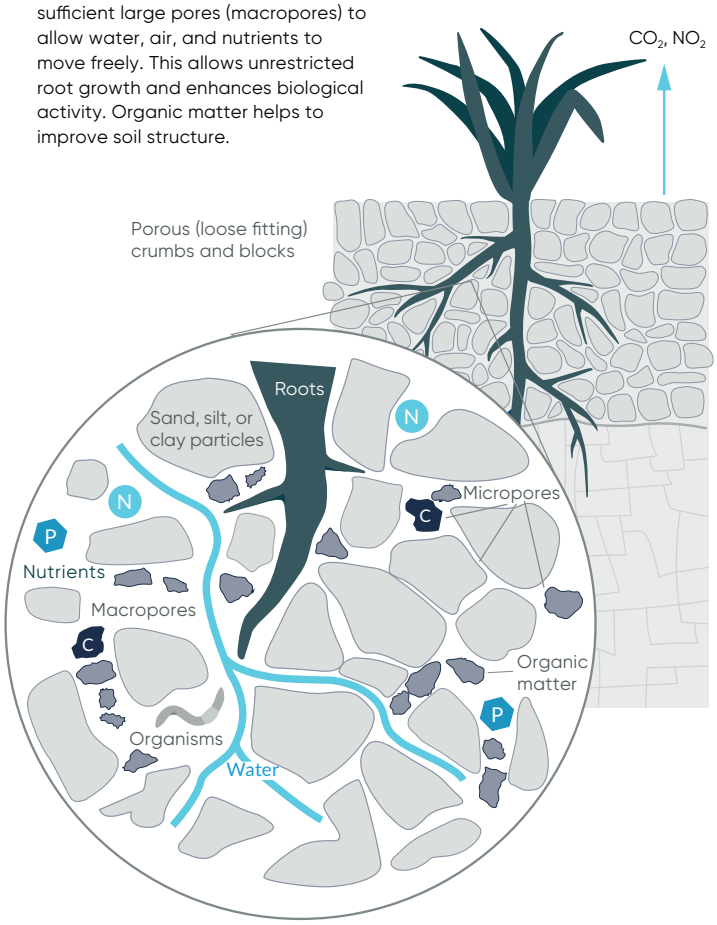
This factsheet contains information on physical soil indicators used for *State of the Environment (SOE) monitoring and reporting*, for local policy-makers such as councils, land managers, and the general public.

Soil structure is important for soil water drainage and storage, root penetration and plant growth, crop and pasture yields, air movement (including oxygen and greenhouse gases), and environmental performance. Organic matter helps to improve soil structure. Good soil structure helps our environment through improved water quality, reduced greenhouse gas emissions and minimising soil erosion.

Soil structural degradation through **compaction** is a key issue, where soils become less friable, have larger, more massive clods, reduced root development, and reduced soil biology such as earthworms. Compacted soils are prone to increased overland surface water flow runoff, which can increase erosion, and reduced water infiltration. This may produce lower crop yields. In New Zealand, pasture production has been estimated to decrease by an average of 2.5% for every 1% reduction in macroporosity.

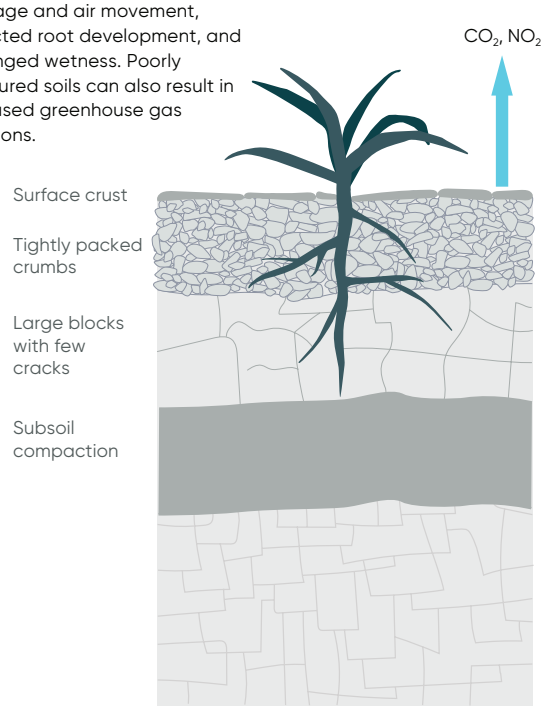
Well-structured soils

are easily crumbed, containing sufficient large pores (macropores) to allow water, air, and nutrients to move freely. This allows unrestricted root growth and enhances biological activity. Organic matter helps to improve soil structure.



Poorly structured soils

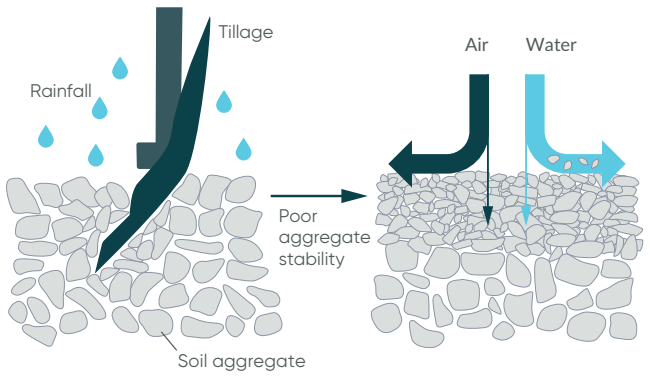
are dense and firm and have poor drainage and air movement, restricted root development, and prolonged wetness. Poorly structured soils can also result in increased greenhouse gas emissions.



Testing for soil physical structure

For State of the Environment (SOE) monitoring, air-filled porosity – sometimes referred to as macroporosity – and bulk density are commonly used indicators of soil physical health; these indicators are also used for soil management research. Aggregate stability may also be measured and is particularly useful to characterise the soil physical health of cropping soils.

- Air-filled porosity is the volume percentage of large soil pores larger than 30 µm (measured at -10 kPa matric potential).
- Bulk density is a measure of the density of soil (i.e. how loose or compacted the soil is).
- Aggregate stability describes the ability of soil aggregates (i.e. soil crumbs) to resist breakage.



In soils with poor aggregate stability rainfall and processes such as tillage reduces soil aggregate size and consequently soil porosity.

Surface sealing arising from reduced aggregate size blocks air and water flow through the soil increasing surface sediment run-off.

Aggregate formation in poorly structured soils.

Degraded soil structure is typically indicated by low air-filled porosity, high bulk density, and low aggregate stability.

Reference ranges used for SOE reporting are used to assess whether soils are within acceptable limits. These values often vary by land use and by soil order or grouped soil orders.

Air-filled porosity

A limited number of studies are available to quantitatively relate air-filled porosity measurements to negative effects for different soil orders. Some soils are more vulnerable to compaction – e.g. Ultic, Podzol, Pallic, and Gley soils – and require more careful management.

Bulk density

Bulk density is not particularly sensitive to changes in soil physical condition or the influence of land management practices. Pumice, Organic, and Allophanic soils typically have low bulk densities. Other than for these soil orders, soil texture may have a greater influence than soil order. High bulk density can be a physical barrier to root growth.

Aggregate stability

In New Zealand, aggregate stability is typically measured by wet sieving and expressed as a mean weight diameter (MWD) of the aggregates. Aggregates larger than 1.5 mm MWD are of minimal concern for soil structure.

Managing soil structure

Best management practices can help restore and maintain good soil structure.

- **Reduce mechanical impacts:** Limit vehicle and machinery traffic, especially in wet conditions. Avoid over-cultivation and deep tillage, especially over the longer term.
- **Manage grazing pressure:** Reduce stocking density in wet paddocks to avoid pugging. Rotational or deferred grazing can help minimise further damage in recovering areas.
- **Encourage plant growth:** Cover crops and growing plants add organic matter to the soil via litter and root inputs. This can increase porosity and stimulate burrowing by soil fauna.

This factsheet is part of a series produced in 2025 by the Bioeconomy Science Institute, for the Regional Council Land Monitoring Forum.