FARM

beef+lamb new zealand

FACT SHEET

APRIL 2017

SOIL CHARACTERISTICS IMPORTANT TO MANAGEMENT

Farmers should be familiar with several soil characteristics if they are to manage their soil effectively. Key soil attributes include texture, structure, porosity, water-holding capacity, drainage class and organic matter content, as well as chemical fertility and fertiliser management, and plant nutrient requirements.

TEXTURE

Soil texture refers to the size of the particles that the soil is made up of (particles are generally < 2mm) (these are the larger particles such as gravel that can be additional textural qualifiers (Table 1). Mineral soils are mixtures of coarse sand particles, finer silt, and very fine clay, and can be classified on the proportions of each of these they contain. Texture can be approximated in the field by the behaviour of moist soil when worked in the hand (Table 2).

Table 1: Particle size classes (mm diameter)

Fine earth fraction	
Coarse sand	0.2–2 mm
Fine sand	0.02–0.2 mm
Silt	0.002–0.02 mm
Clay	<0.002 mm
Large particles	
Boulders	>200 mm
Very coarse gravel	60–200 mm
Coarse Gravel	20–60 mm
Medium Gravel	6–20 mm
Fine Gravel	2–6 mm

Table 2: Field texture assessment of moistened soil

Feel and sound class	Field soil and plasticity	Cohesion texture
Gritty and rasping sound	Cannot be moulded into a ball	Sand
	Will almost mould into a ball but disintegrates when pressed flat	Loamy sand
Slight grittiness, faint rasping sound	Moulds into a cohesive ball that fissures when pressed flat	Sandy loam
Smooth soapy feel, no grittiness	Moulds into a cohesive ball that fissures when pressed flat	Silt loam
Very smooth, slightly sticky to sticky	Plastic, moulds into a cohesive ball that deforms without fissuring	Clay loam
Very smooth, sticky to very sticky	Very plastic, moulds into a cohesive ball that deforms without fissuring	Clay

Fact sheet 150

STRUCTURE

Soil structure describes the way in which the soil particles bind together to form aggregates.

Unstructured soils are either single-grained, like recently deposited sand, or massive, like compressed clay. Soil structure is developed through natural processes (e.g. wetting/drying, freezing/thawing cycles). Plant roots are also important as they can break up large soil aggregates and bind together small aggregates. Organic matter (derived from plant roots and soil) in combination with microbial activity provides adhesive materials to stabilise aggregates, and reduces the extent they break when they are wet or under pressure. This is why soil structure is usually improved under long term pasture where carbon returns and microbial activity tend to be in sufficient. Soil structure can be destroyed by excessive cultivation when the soil is either too dry or too wet, or by the process of compaction.

A well-structured soil will provide a favourable medium for root growth, and a good balance of air and moisture in the soil. It will also allow water to enter and move through the soil easily, thereby reducing run-off and erosion during heavy rain. Soils with coarse soil structure (e.g. large blocky and prismatic structures often associated with a high clay content) will exhibit preferential flow drainage characteristics that can rapidly transport water and contaminants such as faecal microorganisms through the soil profile.

ORGANIC MATTER

New Zealand mineral soils contain 3 to 20% organic matter, mainly formed from dead plant material. Peats and other organic soils contain much more. The major effect of soil organic matter is to stabilise soil structure, but it also facilitates the supply of plant nutrients and stores moisture. Organic matter deactivates many organic compounds (e.g. pesticides), hence application rates of soil-acting agricultural chemicals must be increased in soils high in organic matter.

The organic matter level in soil remains fairly constant if the vegetation cover and land use remains unchanged. However, activities such as clearing of native bush and soil cultivation, can lead to a decline. Including a period of pasture in a crop rotation, adding farm dairy effluents, ploughing in crop residues and green manure crops, and establishing crops by minimum cultivation and direct drilling, can all increase organic matter levels in the soil.

POROSITY AND WATER-HOLDING CAPACITY

Texture and structure both affect a soil's water-holding properties. Sands have large pores between the particles, and these drain quickly after rain or irrigation. Poorly structured clays have many very small pores and, although their total pore space may be greater than that of sands, water percolation is very slow. A well-structured soil (e.g. loam) has an arrangement of both large and small pores. The larger pores (macropores) drain quickly and provide air for plant roots and soil micro-organisms while the smaller pores (micropores) drain more slowly and supply water to plant roots.

After heavy rain or irrigation, water drains rapidly from the large pores under the influence of gravity. As the soil water content falls, progressively drainage slows. After two or three days, the drainage rate is insignificant compared with the rate at which water is being removed by the vegetation growing in the soil (i.e. evapotranspiration). However, if further water was added at this point, then further immediate drainage would result. The moisture content at this point is called field capacity. Without additional rainfall or irrigation inputs, the soil water content continues to fall as vegetation takes up water. The drier the soil becomes, the more energy is required by the plant to extract water from the small pores within the soil matrix. Eventually the necessary energy required by the plant to extract water will be too much at which point the plant will begin to wilt. The soil water content when the plants wilt and do not recover is called permanent wilting point. In practice, crop or pasture productivity is reduced well before permanent wilting is reached. The amount of water that a soil can hold between field capacity and permanent wilting point is called its total available water (TAW). The TAW provides a useful metric for comparing the ability of different soils to supply water to crops. Plant available water (PAW) takes into account the available water capacity for a given depth of plant roots (or depth to a certain soil horizon) and provides a volume of water expressed as mm depth between field capacity and permanent wilting point. Soils with a low plant available water may require irrigation inputs to sustain high production during dryer periods and provide greater resilience against droughts.

Soils with higher clay or organic matter contents will have higher field capacities, permanent wilting points and available water capacities than sandy soils; or soils with less organic matter.

DRAINAGE CLASS

Soils differ in their relative drainage rates due to soil textural and structural attributes and also topographical influences. A well-drained soil will achieve field capacity within 24 hours of being saturated once rainfall (or irrigation inputs) stops. However imperfectly and poorly drained soils take longer to achieve the state of field capacity owing to their fine soil texture. Additionally, their poorly drained status may be a result of a slowly permeable layer in the soil profile or a high water table. Poorly drained and imperfectly drained soils can create management challenges related to the risk of soil compaction and pugging from animal treading or vehicular movement. Artificial drainage (such as mole and pipe drainage or open swale surface) can be used to alleviate the effects of wet soils, which will allow them to be more productive and decrease the risk of ongoing soil damage.

pH AND LIME REQUIREMENT

pH is a measure of acidity and alkalinity. Soils typically lie between pH 3.5 (acid) and pH 9 (alkaline). Most plants prefer a pH of between 6 (slightly acid) and 7 (neutral). The pH of acid soils can be raised by adding lime (calcium carbonate), but the amount needed to raise the pH by a given amount differs from soil to soil.

PLANT NUTRIENT ELEMENTS

Plants require about 10 elements in large quantities (macronutrients), and about 8 in small quantities (micronutrients). Of the major elements, carbon, hydrogen and oxygen are obtained from the air, and from water. Others include nitrogen (N), phosphorus (P), potassium (K), sulphur (S), calcium (Ca) and magnesium (Mg). Micronutrients include iron (Fe), manganese (Mn), copper (Cu), zinc (Zn) molybdenum (Mo), boron (B), chlorine (Cl), silicon (Si) and cobalt (Co). Elements such as selenium (Se), sodium (Na) and iodine (I) are not required by plants, but are necessary for the health of grazing animals.

The total quantity of mineral nutrients in the soil depends initially on the composition of the soil's parent rock. The availability of nutrients also depends on the soil's age and weathering processes. In young soils, made up mainly of small particles of unweathered parent rock, many of the nutrients are held in insoluble forms. As the minerals weather, they are converted into more soluble forms, and the nutrients become available to plants. Further ageing may lead to the supply of nutrient in excess of plant requirements and are subsequently leached from the plant root zone.

Only a small proportion of a soil's nutrient element content is available to plants at any time. Some is retained in insoluble minerals, some is held on the surface of clay and organic matter particles, and a small percentage (e.g. 1%) is freely available in the soil solution. There is an equilibrium between nutrients bound to clay and organic surfaces and those in solution. As plant uptake lowers the concentration of nutrients in the soil solution, bound nutrients are released from the soils cation exchange sites on the surfaces replenish it. Soil nutrient availability also varies with soil pH. Some elements are more available in acid soils, some in alkaline soils. Some are most available at an optimum pH, and are less available if the soil is more acid or more alkaline than this.

Under some conditions applied P may become permanently unavailable to plants through phosphate fixation. Soils differ greatly in their tendency to fix P. Analytical laboratories can measure a soil's anion storage capacity (ASC). High ASC soils require more P fertiliser input to overcome a deficiency than low ASC soils. High ASC soils also retain sulphate-S and prevent its loss by leaching.

Nitrogen behaves differently from other nutrient elements. The major reservoir of N is the atmosphere, but N gas cannot be used by plants. In nature, N is fixed in available forms (nitrate and ammonium) by some soil micro-organisms, and by Rhizobium bacteria in nodules on the roots of legumes such as clover. Large quantities of N can also be returned to the soil in plant residues and animal manures. Atmospheric N can also be converted to plant-available forms industrially and applied as chemical fertiliser such as urea. Urea added to the soil in fertiliser is converted to ammonium and nitrate by soil microbes, and plants can take up either form. The nitrate form is not retained on clay surfaces, however, and unless it is quickly taken up by plant roots it can be leached from the soil. In saturated soils, nitrate can be converted by micro-organisms back to N gas, and lost to the atmosphere.

Large amounts of plant nutrients are removed from the land in harvested plant and animal products. Fertiliser management must allow for this, and ensure these losses are replaced.

MORE INFORMATION

For further information, contact:
Dr Dave Houlbrooke
AgResearch, Ruakura Research Centre
Private Bag 3123, Hamilton
Phone 07 856 2836; Fax 07 838 5012

This fact sheet is a revision of the AgResearch AgFACT sheet no. 99 ISSN 1172-2088. Fact sheets are made possible by sheep and beef farmer investment in the industry.