Soil Water

FACT SHEET 10

Soil water is intimately related to soil physical characteristics as a result of the influence of porosity on water flow and water holding capacity of a soil. Water gives life and the greater the water storage capacity of a soil the greater the potential biological activity and plant growth.

The water cycle

The water cycle describes the process where the Earth's constant amount of water falls as precipitation, then either evaporates from the surface, is processed through plants via transpiration, is stored in soil or groundwater, or flows directly into water bodies such as rivers, lakes and oceans where it again evaporates and through condensation forms clouds and potentially falls again as rain.

The water cycle has a significant impact on the climate on Earth and the soil and ground cover conditions have a vital role in ensuring the effective function of the water cycle.

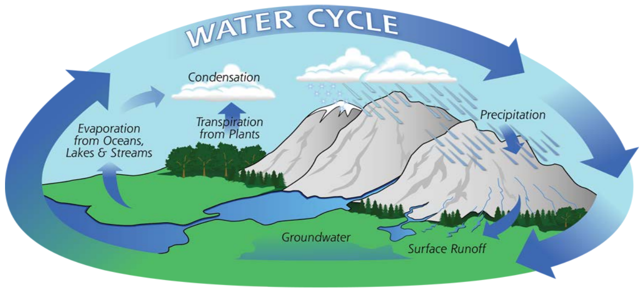

Figure 1: The water cycle.

A raindrop contacting the land surface has a limited number of pathways that it may travel and contribute to the cycle. On contact with the surface it may;

- infiltrate into the soil, be taken up by a plant and transpired back to the atmosphere, stored for a period in the soil profile or flow through to groundwater,
- evaporate directly from the soil surface or
- move across the soil surface as runoff, often carrying soil particles and causing erosion.

The potential path of each raindrop is significantly influenced by soil conditions. From a primary production perspective the soil conditions will also determine the probability of that raindrop contributing to plant production and the likely conversion efficiency of rainfall into plant biomass.

Groundcover

Groundcover is simply a first step to ensuring a healthy soil and efficient water cycling. In the high rainfall zone of the Northern Rivers region nothing less than 100% cover, 100% of the time is an acceptable level of groundcover to ensure optimal soil health and the effective function of the water cycle.

Complete groundcover is not an unattainable goal. The natural state is for soil to be covered. Groundcover may be contributed by living plants, all forms of plant litter or organic matter, rock or manure. Any material that covers the surface and limits the potential of movement of soil particles constitutes groundcover.

In addition to prevention of the movement of soil particles groundcover modifies soil conditions in the following ways;

- The amount of herbage mass present influences the temperature and diurnal change in temperature at the soil surface which impacts plant growth.
- The type, diversity of plant species and plant condition will impact soil structure (including bulk density and porosity) through their root systems and the soil biota those roots support.
- Through the impact on soil structure the groundcover will influence soil water infiltration and the water storage potential of soil.
- Maximum groundcover will increase the potential of water movement through plants via transpiration, where it contributes to plant production rather than being 'lost' via evaporation or runoff.
- Diversity of plants with different growth cycles ensures living groundcover for the maximum period.

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Water movement through soil

Water enters the soil primarily through precipitation. Ideally, the majority of rainfall infiltrates into soil and accumulates into soil pores. The better the soil structure the more water will infiltrate into the soil and be available for plant growth or stored in the profile. Some will drain or percolate into groundwater.

The amount of water retained in the profile depends on a range of factors including;

- **soil texture and structure,** the higher the soil porosity the greater the soil water holding capacity
- **soil depth**, the depth of topsoil
- **soil chemistry,** in particular the proportion of the dominant cations through their effect on the cohesion of clay particles
- **soil biology**, the burrowing activity and numbers of biota providing channels through soil, increasing porosity
- **plant species present** their density and growth cycles. Actively growing plants utilise available water drying the profile. More plants growing per unit area utilise more water, create higher groundcover and slow water movement across the surface.
- **topography** or position in the landscape will influence soil depth. Water retention is more likely to be higher on flats (deeper topsoil) than on hillsides and slopes.
- **rainfall and climate** - the intensity and distribution of rainfall will influence soil water retention. The intense rainfall events frequently experienced in the Northern Rivers region often results in runoff which may lead to erosion and flooding.

When water falls on the soil surface faster than it can infiltrate into soil it pools and eventually flows over the surface. The magnitude of the runoff depends on how much water the soil can hold (influenced by factors listed above) and the slope of the land. The speed of the runoff will depend on the slope and surface conditions, primarily groundcover. The amount of groundcover in terms of herbage mass and the density of plants, the number of living plants per unit area, will act to slow the rate of water movement across the soil surface.

Management has a significant influence on many of the factors that effect water retention in soil.

Soil water pools

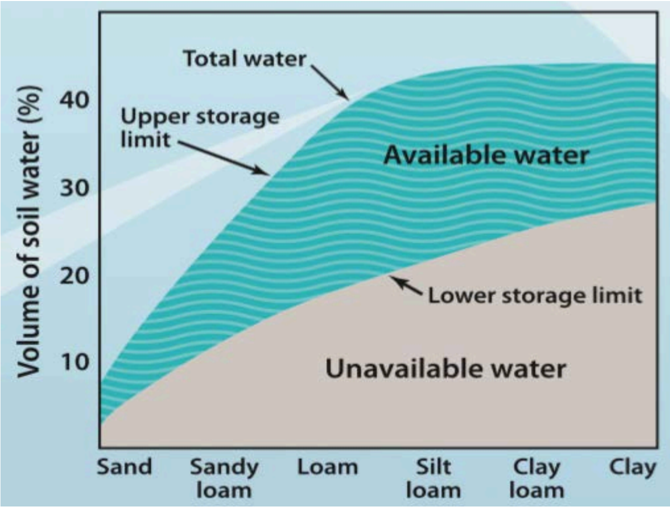
There are three primary ways that water moves through or is held in soil.

Gravitational water – water infiltrating through soil from rainfall or runoff drains freely through larger macropores under the influence of gravity. This water does not stay in the soil for long periods and does not directly contribute to plant growth.

Capillary water – some of the water entering the soil is retained as a film on the surface of soil particles within aggregates. It is held due to surface tension and can be utilised by plants and soil biota. This pool is referred to as *Plant Available Water.*

Hydroscopic water – is held tightly to soil particles and between clay layers in small micropores and is generally not available to plants.

More information on soil porosity and soil structure is provided in Factsheet 9 of this series



Source: soilquality.org.au

Figure 2: Relative amounts of water available for plant growth and unavailable in different textured soils.

Different soils depending on their texture, structure and organic matter content have different capacity to hold and release water. Clay soils have greater water holding capacity than sandy soils which tend to drain more freely. Organic matter significantly increases the water holding capacity of soil and when present as humus it acts as a sponge in the soil, holding up to 4 times its weight in water.

Soil organic matter present as humus can hold 4 times its weight in water

Plant available water

Plant available water is the difference between the maximum amount of water the soil can hold, defined as field capacity and the permanent wilting point.

The soil may be described as a water reservoir for plants. When a soil is **saturated** all pores are filled with water - the reservoir is full and no air remains. The water in macropores drains rapidly or percolates below the rootzone before plants can use it.

Field capacity is the point where the water has drained from macropores and the remaining water stored is available for plants. Larger pores are filled with air and water and smaller pores are still filled with water. Soil water may drain to field capacity within hours in sandy soils and in fine textured clays drainage may take 2-3 days.

Permanent wilting point is the point at which plants can no longer extract water held in micropores measured to the maximum rooting depth. Over time plants utilise the stored water or it evaporates from the surface. If no additional water is supplied to soil it dries. At a certain point if available water is not sufficient to meet a plants needs it wilts and eventually dies. At this point soil water content is called the permanent wilting point.

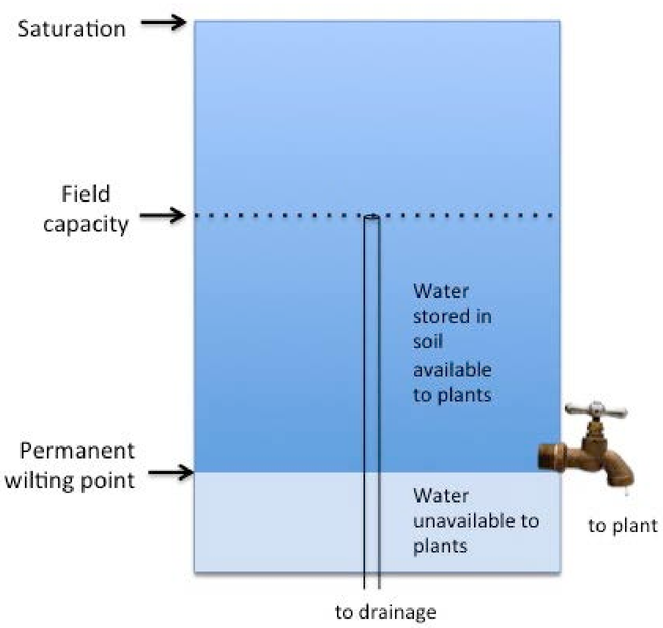


Figure 3: The soil as a reservoir, plant available water is that amount between field capacity and the permanent wilting point.

The available water content is significantly influenced by soil texture and structure. Through the impact on soil structure it can be influenced by management.

Table 1: Average available water content in mm water depth per metre soil depth for different soil types.

SOIL TYPE	AVAILABLE WATER (mm/m)
Sand	25-100
Loam	100-175
Clay	175-200

The field capacity, permanent wilting point and plant available water describe the soil moisture characteristics of a soil. They are relatively constant for any given soil, modified only by organic matter content, but vary significantly between soil types.

Soil water and nutrient uptake

Water is not only essential to plant growth it also has a vital role in nutrient uptake. Most plant nutrients are present in the ionic form and acquired by plants through the soil solution (Fig 4). There are three main processes by which nutrients are taken up;

Mass flow is the movement of nutrients into the plant as it absorbs water. This process is responsible for transport of nitrate, sulphate, calcium, magnesium and the trace elements, boron, copper and molybdenum.

Diffusion is the movement of nutrients to the root surface in response to a concentration gradient. Nutrients in higher concentration move to areas of low concentration to create equilibrium. High concentration in the soil solution and low concentration at the roots cause the movement of nutrients to the root to be taken up by the plant. This process is most important for phosphorus and potassium uptake as well as zinc and iron.

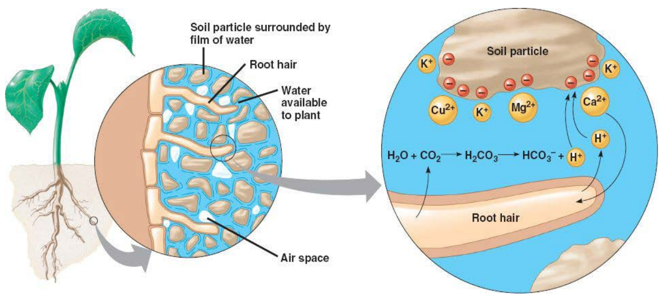


Figure 4: Nutrient uptake from the soil solution

Root interception is where contact is made between the root and soil particles and exchangeable nutrients, primarily calcium and magnesium are absorbed. This process is not directly reliant on soil water.

Water use efficiency

Water use efficiency is a measure of the efficiency of conversion of rainfall into herbage mass. In a crop or grazed pasture situation it is the kilograms of dry matter (DM) produced per millimetre of rainfall.

The majority of soil physical characteristics are not easily measured using field methodology. Water use efficiency is one measure available to graziers and other primary producers that gives an indication of soil health and productivity. Maximising water use efficiency has two basic components;

1. increasing the amount of water entering the soil in any rain event - the infiltration rate and
2. maximising the storage capacity of the soil to increase the amount of plant available water.

Both will be influenced by the soil structure, the porosity and pore size distribution of the soil. Management has a significant influence on all aspects of soil structure. Plant roots, ideally perennial, and the associated soil biology are most effective at enhancing soil structure. Any activity that supports the growth and increased density and depth of plant roots and increasing soil organic matter will result in improvements in soil structure, water infiltration rate and porosity.

Figure 5: Poor groundcover, poor soil structure, water infiltration and water use efficiency.

Less than optimal soil physical conditions reduce water use efficiency and exacerbate the potential for flooding and soil water deficit.

In a region where the annual average rainfall is 1,200mm this equates to 12,000,000 litres of water incident per hectare. In grasslands or pastures with relatively poor soil structure and a water use efficiency of only 6 kg DM/ha/mm the resulting herbage mass produced = 6 x 1,200mm = 7,200 kg DM/ha/mm/year.

Under precisely the same rainfall conditions where water use efficiency could be considered as relatively good and 10 kg DM/ha/mm was produced this would result in 10 x 1,200mm = 12,000 kg DM/ha/mm/year.

Ecologically, economically and socially the difference is significant. More rainfall converted to herbage mass means higher productivity or carrying capacity of land, with associated profitability. Less water running off the land reduces flooding and environmental damage is mitigated. More plant available water also reduces the incidence of drought.

In the high rainall zone of the Northern Rivers region where intense rainfall events are commonly experienced the critical importance of maintenance of soil structural conditions to optimise soil water infiltration and water use efficiency cannot be over-emphasised.

This is number ten in a series of 12 Factsheets which cover a range of topics regarding soil health and soil processes.

More Information

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