WATER MANAGEMENT

Understanding Soil-Water

Introduction

Soil-water relationships determine the available water in the soil for plant use. Understanding these relationships is critical for best irrigation practice. This Environment Topic describes the principles and terms used by irrigation consultants in irrigation decision-making.

Soil physical properties

The main factors controlling soil-water are soil texture and soil structure.

Coarse textured sandy soils generally allow fast water movement and have low water storage. Fine textured silt and clay soils have much slower water movement and retain more water.

However, in fine textured clay soils much of the stored water is not available for plant use as it is too tightly held by the soil. Medium textured loam soils tend to provide the best plant available water storage.

The differences in movement and storage for each soil are due to the soil pores, which are the fine interconnecting gaps between soil solids. Fine pores *(micro-pores)* hold water; larger pores *(macro-pores)* act as the soil drainpipes.

Well-structured soils have a network of interconnected macro-pores and micro-pores. This allows good water entry and drainage of excessive water while still retaining a good supply of water for plants. Poorly structured soils have too few, or too many excessively large pores. These soils are either prone to be water logged or are drought prone.

Soil organic matter content influences soil- water properties partly through its' effect on structure. Generally, increasing organic matter increases the soils' ability to retain water.

Soil-water properties

Two important soil-water properties are water storage and water movement. One way to understand these properties and the terms used to describe them is to think of the soil as a big sponge as illustrated in *Figure 1.*

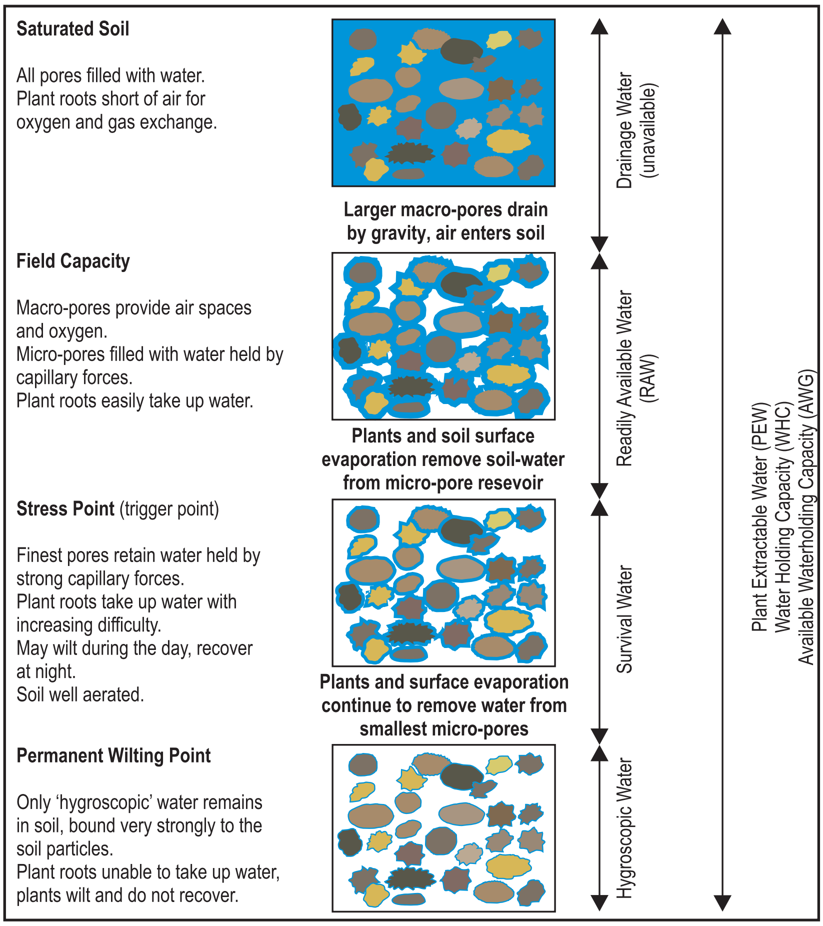


Figure 1: *Soil - water storage and movement*

Water storage

If you completely saturate a sponge, or soil, all the pore spaces become filled with water. Quite quickly the larger pores drain, allowing some air back into them.

The water that gravity drains from these large macro-pores is called *gravitational water*. Because gravitational water drains away quickly it is not available for plants. Once this easily lost water has drained away the soil is said to be at *field capacity*. Field capacity is defined as the amount of water in the soil two days after the soil has been saturated.

If the sponge is squeezed, more water is removed. Initially it is quite easy to squeeze water out, but as water is lost, less and less water can be squeezed from the sponge. Ultimately you can't squeeze any more water out but the sponge will still remain damp.

This also occurs in the soil. The plants can at first take up water easily, but then it gets progressively harder. Once plants can no longer extract water, the soil is said to be at *permanent wilting point*. Plants that wilt will not recover, even overnight. At this point only some moisture remains. This *hygroscopic water* is held so tightly on the soil particles that plants cannot take it up.

It is the water held between field capacity and permanent wilting point that is available for plants. This is called *plant extractable water* (PEW). It is measured as the soil's water holding capacity (WHC).

An indication of water holding capacities for different textured soils is given in *Figure 2*. These are only a guide and should be determined in the field for specific soil types.

The WHC units (mm/100mm) refer to the millimetres of rain or irrigation that can be stored in each 100mm deep slice of soil. So if most of the plant's roots are in the top 600mm, the amount of water held in the root zone will be six times the WHC. This is referred to as the *available waterholding capacity* (AWC).

About half this water is easily taken up, and referred to as *readily available water* (RAW). Once the RAW is used plants have to work harder to take up water. This increases plant stress and starts to effect yield and quality.

The point at which plant stress begins is called the *stress point*. The aim of most irrigation is to keep soil-water levels between field capacity and stress point (i.e. RAW). The stress point is sometimes referred to as the *trigger point* for irrigation, or the *maximum allowable depletion* (MAD).

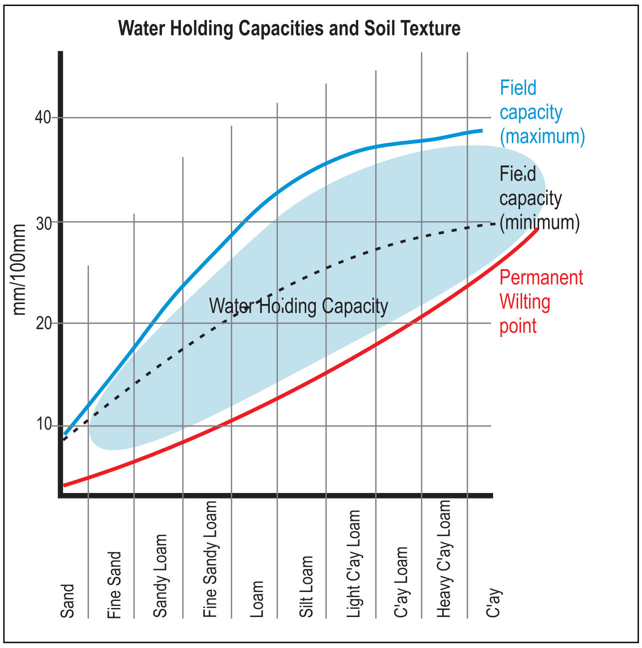


Figure 2: *Water Holding capacities (mm/100mm)*

As an example, *Figure 3* calculates the readily available water for a crop with 600mm deep roots on a silt loam.

Example: Silt Loam, 600mm deep roots

Field Capacity FC (from fig 2)	≅ 35mm/100mm
Permanent Wilting point WP (from fig 2)	≅ 13mm/100mm
Water Holding Capacity WHC	≅ 22mm/100mm
AWC = WHC x root depth	
Available water AWC (22x6)	≅ 132mm/600mm
RAW = ½ AWC	
Readily available water RAW	≅ 66mm/600mm

Figure 3: *A soil-water calculation example using the data from figure 2.*

Water movement

Movement of water into the soil is known as *infiltration*. Movement through the soil is known as *percolation*, and seepage out the bottom as *drainage*.

A number of factors are involved in creating water movement. These include gravity pulling the water down, and capillary forces drawing water into and along pores. In dry soil, capillary forces (the blotting paper or dry sponge effect) are strongest. In wet soil gravity tends to dominate.

Under irrigation the soil surface is saturated. As water is applied, it flows down through the macro-pores and is drawn into the micro-pores. Capillary forces hold the water in the micro-pores until they are full (i.e. field capacity is reached). Additional water can drain down into the next layer through the macro-pores, or spread into adjacent drier soil through capillary action.

Water will only move down through the soil as progressive layers exceed field capacity. This movement can be observed by digging a hole. Because the wet soil is usually darker than the drier soil the extent of water movement will show up as a wetting front.

The wetting front principle explains what happens when soils are irrigated and is illustrated in *Figure 4.*

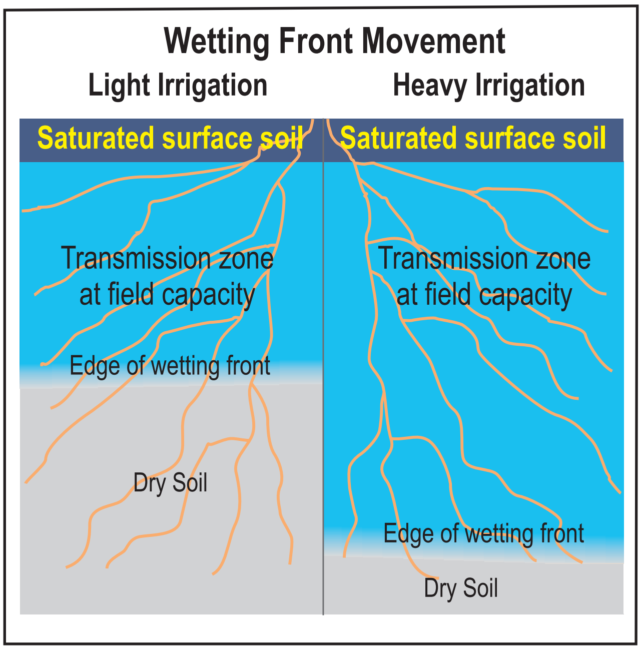


Figure 4: *Wetting Front Movement*

Heavy irrigation applies sufficient water to drive the wetting front to the bottom of the root zone. Light irrigation only re-wets the top part of the root zone, leaving an un-watered zone below. Managing this carefully allows irrigators to take advantage of any rainfall that may occur.

Excessive irrigation pushes the wetting front below the root zone where it is unavailable to the plants and therefore wasted. It also increases the amount of leaching.

Infiltration rates

Infiltration rates vary greatly between soils. Tight clay soils have very low infiltration and percolation rates whereas sandy soils have high rates. Soils with high organic content such as peat, soils with a thatch of dead organic matter on the surface and some volcanic soils are virtually waterproof when dry. Guidelines on infiltration rates are given in *Figure 5*. Also note, infiltration rates generally decrease as more water is applied.

Estimated Maximum Infiltration Rates (mm/hr)
(Adapted from NZS 5103:1973)

Soil Group	Slope 0°-8°	Slope 9°-12.5°
Sands and light sandy loams uniform in texture	31	25
Sandy loams overlaying a heavier subsoil	20	16
Medium loams to sandy clays over a heavier subsoil	16	13
Clay loams over a clay subsoil	13	10
Silt loams and silt clays	10	8
Clays	6	5
Peat	16	-

Figure 5: *Infiltration Rates*

If water is applied faster than the infiltration rate, it will simply flow to the lowest points and pond on the surface. While the water may soak in over time, the result is very uneven watering. The problem is even worse on sloping sites as water runs off site.

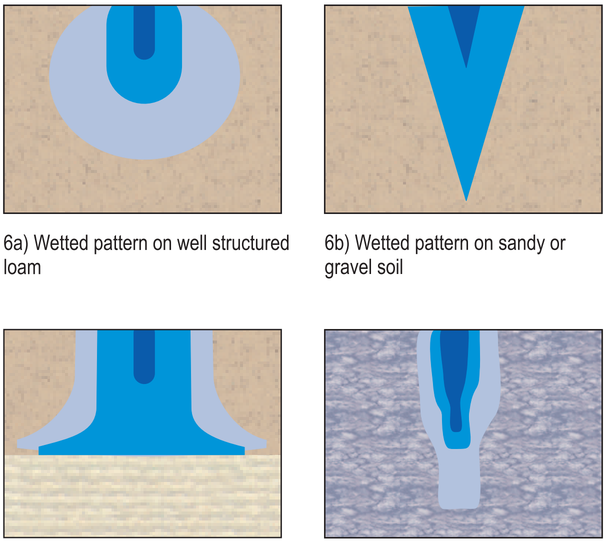
Uneven watering means large amounts of water are wasted and crops are inadequately irrigated. This lack of uniformity is one of the major causes of irrigation inefficiency.

An example of water movement - point source irrigation

Point source irrigation, such as from a dripper, wets only a fraction of the soil surface. A small pond may appear under which there is a saturated zone. Gravity pulls the water downwards while capillary forces draw it sideways into drier soil.

On well structured, loam soils the wetting pattern forms an onion *(Figure 6a)*. On coarse textured soils, gravity dominates and a narrower, deeper wetting zone will be found *(Figure 6b).*

A textural break (from fine soil to coarse or coarse soil to fine) prevents water crossing the boundary, though it may spread sideways. This can result in a perched wetness *(Figure 6c)*. Water cannot cross large air gaps, so wetting patterns on cloddy or gravelly soils tend to be narrow and deep *(Figure 6d)*.



6a) Wetted pattern on well structured loam

6b) Wetted pattern on sandy or gravel soil

6c) Wetted pattern on soil with textural change

6d) Wetted pattern on poorly structured or cloddy soil

Figure 6. *Point source irrigation water movement on various soil types*

Summary

- Understanding soil-water relationships is critical for best irrigation practice.
- The main factors controlling soil-water relate to your soil texture and structure.
- Two important soil water properties to understand are water storage and water movement.
- The balance of micro-pores and macro-pores in your soils determine their water holding capacity.
- Increasing organic matter content can increase the soils' ability to store water.
- The readily available water (RAW) for your crop can be calculated from the soil type, crop root depth, field capacity and permanent wilting point.
- Know your soil infiltration rates. Infiltration rates vary greatly between soils. If irrigation water is applied faster than the infiltration rate, very uneven watering will result.

References

NZS 5103:1973 : Code of practice for the design, installation and operation of sprinkler irrigation systems.

The New Zealand irrigation manual. A practical guide to profitable and sustainable irrigation. A Malvern Landcare Project. 2001. Available from Lincoln Environmental, PO Box 133, Lincoln, Canterbury. Telephone (03) 325 3700. or irrigation@lincoln.co.nz

For further information

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