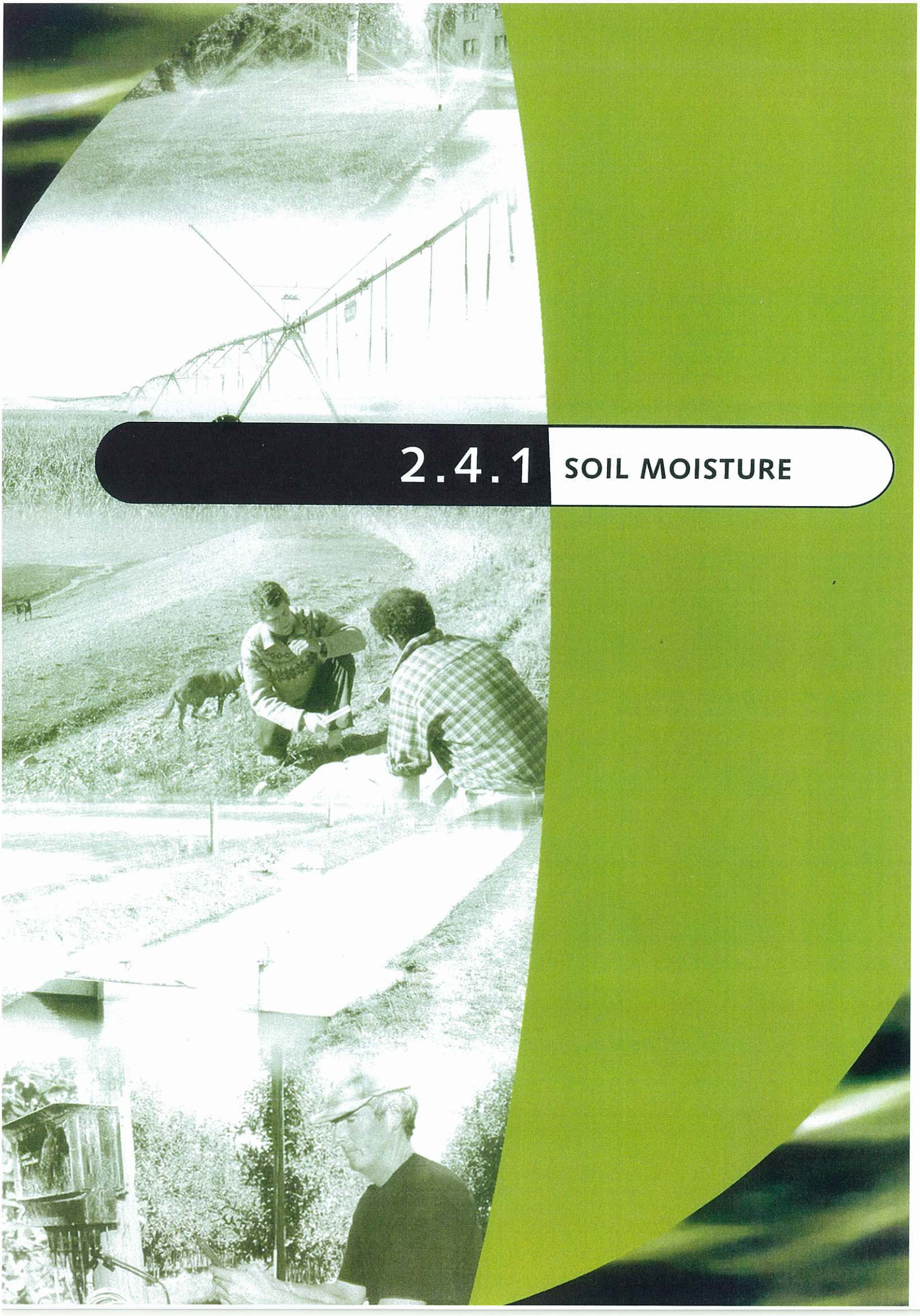

2.4.1 SOIL MOISTURE

Soil moisture measurement – General information

Soil water is an extremely important component in plant growth. To optimise growth, it is necessary to regularly measure soil water content. Properly used, **soil water measurements can be used to answer key irrigation management questions, such as:**

- When to turn irrigation on?
- When to turn irrigation off ?

Why measure soil moisture?

Because soil moisture is:

- The only source of water for plant growth
- The primary recipient of rainfall and irrigation water
- The major influence on nutrient availability to plants
- An important determinant of soil temperature, aeration, and nutrient leaching.

What is in the soil?

Soil is a delicate balance of four major components: solids, water, air, and organic matter. Any volume of a silt-loam soil typically consists of about:

- 45% solids (the soil particles)
- 30% water
- 20% air and
- 5% organic matter.

For optimum plant growth, it is necessary to maintain both water and air (oxygen) content within certain ranges.

What do you need to know about soil moisture?

For proper decision making, there a several aspects of soil moisture one must understand:

- *Field Capacity* is the amount of water in a soil when gravity drainage stops. Water is held as a film on particles and in capillary-size openings in the soil.
- *Permanent Wilting Point* is the amount of water left in the soil when plants are wilted day and night. If water is not added, the plants will die.
- *Available Water* is the amount of water plants can extract from a soil profile between the limits of field capacity and permanent wilting point.
- *Readily Available Water* is the amount of available water a plant can extract before growth is limited because of the difficulty of extracting the remaining available water. It is different for every combination of soil and plant. Each plant has a different level of ability to overcome the suction that holds water to the soil particles.

When to measure soil moisture?

Measurement must be done routinely and carefully:

- As soon as growth commences in the spring.
- As soon as the crop is sown in the spring.
- When the soil water is likely to be at field capacity.
- Continuously, if you have an electronic soil moisture monitoring system. Otherwise, at least once per week.
- Just before an irrigation application.

June 2001

Using soil moisture measurements

Growers need to know the condition of the soil they are dealing with, in order to maximise the profitability of each crop grown. If a crop is irrigated, one of the most important soil conditions to know is the soil water content.

The saying, "You can't manage what you don't measure", is particularly appropriate for irrigated agriculture.

There is no value (only unnecessary cost) in applying more water than the soil can hold. The only reliable way of knowing how much water can be stored in the soil at the time of irrigation is to measure the soil water content and compare it to the water content of the soil when it is "full", i.e. at field capacity.

If a crop is not irrigated before the critical soil water deficit is reached, yield loss will occur. If soil water content is not monitored – that is, regularly measured – a grower is taking unnecessary risks with yield (reduced income) and with water wastage (extra cost). In the absence of monitoring, the grower has little option but to irrigate to a timetable intended to avoid soil water stress. He or she would then have no certainty as to whether the irrigation has achieved the goal of avoiding soil water stress, or whether too much water has been applied.

Benefits of measuring soil moisture

- Minimises or eliminates soil-water limiting conditions.
- Only the amount of water required by the plant is applied.
- Minimises nutrient leaching.
- Optimises crop yield and quality.
- Maximises the benefit of rainfall and irrigation.
- Minimises environmental impacts.

General procedure for using soil water measurements

- There are many methods for measuring soil moisture. They are described in additional sheets in this section.
- Determine the maximum level of plant available water that can be stored in the root zone for your particular soil. (See Section 3.1.4.)
- Determine the remaining amount of readily available water that can be used by the crop before the critical deficit is reached. (See Section 3.1.4.)
- Estimate the average daily crop water use from the soil water measurements, or from published evapotranspiration (ET) data.
- Estimate the days before the next irrigation must be complete, by dividing the remaining amount of readily available soil water in the root zone by the estimated crop water use.
- If the decision is to irrigate now, the net application depth required to restore soil water to field capacity is calculated by subtracting the measured soil water content (mm) from the maximum level of plant available water (mm).
- If the decision is to wait until the critical deficit is reached, the net application depth required to restore soil water to the full point is equal to the critical deficit.

If either rain or hot, dry conditions are forecast, you should consider adjusting this estimate of the time till the next irrigation must be complete.

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Overview of different methods of soil moisture measurement

There are a large number of soil moisture measuring methods available on the market today. They generally fall into the following categories:

1. ***Gravimetric*** - direct method of manual sampling and oven drying (traditional laboratory method).
2. ***Soil suction*** – measures how hard it is for a plant to abstract water from the soil. Examples: Tensiometers, Irrometer
3. ***Electric resistance*** – electrodes connected to a porous block. The electrical current through the block changes with moisture content. Examples: Gypsum block, Watermark
4. ***Capacitance probes*** – the capacitance of the soil changes with water content. Examples: WTL Probe, Enviroscan
5. ***Neutron thermalisation*** – water scatters and slows down the movement of neutrons, which can be detected. Example: Troxler or CPN 503DR
6. ***TDR (time domain reflectometry)*** – measures speed of propagation of a signal that depends on the dielectric constant of the soil. Example: CS615 probe
7. ***TDT (time domain transmission)*** – measures speed of propagation of a signal that depends on the dielectric constant of the soil. Example: Aquaflex
8. ***Thermal dissipation methods*** – measures heat dissipation in soil, which depends on water content. Example: AquaSensor
9. ***Soil thermocouple psychrometers*** – sensors mounted in ceramic cups that measure the energy status of the soil solution. Not common.

Issues to consider when selecting a method

- Reliability – Acceptable accuracy, repeatable results, low maintenance?
- Robustness – Suitable for the conditions it will be used under?
- Fixed or portable – Left at one site or used at different sites?
- Stand-alone – Do you need any other equipment?
- Ease of installation – Important if portable. Usable in stony soils?
- Operating range – Will it work over the range of soil moistures you expect?
- Calibration – Do you need to calibrate? If so, who does it?
- Point source or averaging – Volume of soil measured. Do you need multiple sites?
- Single or continuous readings – Depends on what you want.
- Additional information – Soil temperature, conductivity?
- Single depth or multiple depths – Depends on crop and soil type and on needs.
- Interpretation of data – Can you do it yourself? Is help provided?
- Cost – Very wide range.

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Soil moisture measurement – The feel method

This is the most simple method of soil moisture measurement, and is as old as the practice of irrigation. There are more reliable methods available now. Some of these are described on the following sheets.

Benefits

- Provides a guide as to when irrigation should occur.
- With experience, can improve crop yield and quality.

Advantages

- Very simple.
- Inexpensive.

Disadvantages

- Subjective (different answers by different people).
- Depends on grower's experience.
- Crop root zone is rarely sampled.
- Requires many samples in a field.
- No measure of the amount of water in the soil.
- No measure of the amount of irrigation required.
- No real predictive element.

How to use the feel method

- Squeeze a handful of soil from the root zone three or four times, attempting to make a ball.
- Assess the soil moisture, based on the soil's ability to bind together:

No ball formed:

- too dry, and irrigation is long overdue

Weak ball formed:

- needs irrigation now

Firm ball formed:

- probably OK, but will need irrigation "soon"

Moisture on hand:

- close to field capacity, and no irrigation required at present

Water visible, soil oozes:

- too wet, above field capacity, and no irrigation required at present.

June 2001

Soil moisture measurement – The gravimetric method

This is a simple and accurate method of soil moisture measurement, but is time consuming.

It is the standard for all other methods of soil moisture measurement.

Benefits of measuring soil moisture

- Minimises or eliminates soil-water limiting conditions.
- Only the amount of water required by the plant is applied.
- Minimises nutrient leaching.
- Optimises crop yield and quality.
- Maximises the benefit of rainfall and irrigation.
- Minimises environmental impacts.

Advantages

- Accurate and relatively simple.
- Directly measures the amount of soil moisture.

Disadvantages

- Destructive, because the soil is removed for measurement.
- Requires laboratory and soil sampling tools.
- Takes at least 24 hours to get results.
- Must also know soil bulk density (weight/unit volume).
- Requires several samples to obtain a representative measurement of soil moisture conditions in a paddock.

How it works

Soil samples are taken from different depths at several locations in a field, and the volume of water in each sample is determined by measuring the change in sample weight brought about by drying the sample.

How to use the gravimetric method

1. Take soil samples.
2. Weigh the sample before any drying occurs.
3. Dry in an oven at 104°C for 24 hours.
4. Reweigh the sample.
5. The percentage of water in the sample, by weight, is calculated using the following equation:

$$\frac{\text{Wet weight} - \text{Dry weight}}{\text{Wet weight}} \times 100$$

6. To obtain the volumetric soil moisture content (V%), multiply the number obtained by the soil bulk density.

Related information

For a more detailed description of the procedure, refer to any agronomic or soil science (physical properties) text.

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Soil moisture measurement – The tensiometer method

This is a relatively simple method of soil moisture measurement, and is commonly used to manage irrigation in some areas of New Zealand. It is one of two common methods, along with the electrical resistance method, of measuring soil water potential.

Benefits of measuring soil water potential

- Minimises or eliminates soil-water limiting conditions.
- Only the amount of water required by the plant is applied.
- Minimises nutrient leaching.
- Optimises crop yield and quality.
- Maximises the benefit of rainfall and irrigation.
- Minimises environmental impacts.

Advantages

- A direct measurement of the suction required by plants to extract soil water.
- Relatively simple and inexpensive.
- Measures soil water potential (tension), ie the degree to which soil water is available to the plant.
- Soil water potential can be measured at any depth.
- Provides an indication of when to irrigate.

Disadvantages

- Does not measure the volume of water in the soil.
- Only works in a small part of the range of available water (about 0-80 centibars). The lowest limit for many crops is beyond this (ie drier than this).
- The relationship between the suction and the amount of water in the soil is complex.
- Tensiometers require frequent servicing.
- Only measures in the immediate vicinity of the ceramic cup – several tensiometers are required to obtain a representative measurement of soil water conditions in a paddock.
- May be a time-lag response that could result in over-irrigation.

How it works

- A tensiometer consists of a plastic tube with a porous (ceramic) tip filled with water and inserted in the soil. The system must be sealed and free of air. The soil pore pressure (the force holding the water to the soil particles) is reflected by the water pressure in the tube and is measured by a vacuum gauge.
- The soil tension is read every 2-3 days, and readings from the same depths are averaged.
- When the soil water potential reaches the critical deficit, irrigation should be applied.

How to use tensiometers

- Auger a hole, and insert the tensiometer, ensuring there is good contact between the soil and the ceramic tip.
- In stony soils, a slurry must be used to fill and seal the hole, to ensure good contact between the soil and the ceramic tip.
- Install at least two tensiometers at any given location, one near the top of the root zone and one at the bottom of the root zone.
- Several locations in a paddock must be sampled to provide a good indication of the soil tension condition.

Is something wrong?

- If the tensiometer reading does not change over several dry days, it may need servicing or refilling.
- If the tensiometer reading is zero, it probably has a broken ceramic tip that must be replaced.

Related information

For a more detailed description of the procedure, refer to any agronomic or soil science (physical properties) text, the SOWACS web site <www.sowacs.com> or a manufacturer's handbook.

June 2001

Soil moisture measurement – The electrical resistance method

This is a relatively simple method of soil moisture measurement. It is one of two common methods, along with the tensiometer method, of measuring soil water potential.

Benefits of measuring soil water potential

- Minimises or eliminates soil-water limiting conditions.
- Only the amount of water required by the plant is applied.
- Minimises nutrient leaching.
- Optimises crop yield and quality.
- Maximises the benefit of rainfall and irrigation.
- Minimises environmental impacts.

Advantages

- A direct measurement of the suction required by plants to extract soil water.
- Relatively simple and inexpensive.
- Measures soil water potential, ie the degree to which soil water is available to the plant.
- Soil water potential can be measured at any depth.
- Unlike the tensiometer, can function over the full range of available soil water.
- Provides an indication of when to irrigate.

Disadvantages

- Does not measure the volume of water in the soil.
- The relationship between the suction and the amount of water in the soil is complex.
- Instrument sensitivity may vary, depending on soil moisture content.
- Each sensor requires individual calibration, because of sensor variability and because sensor response varies in different soils.
- Sensors require periodic re-calibration, because calibration changes with time.
- Only measures in the immediate vicinity of the sensor – several sensors are required to obtain a representative measurement of soil water conditions in a paddock.
- It is not highly accurate, so is limited to situations where high accuracy is not required.

How it works

- A porous block is buried in the soil. Water moves in and out of the block until equilibrium with the soil around the block is reached.
- The electrical resistance of the block is read and the soil water potential is estimated, using the calibration equation.
- When the soil water potential reaches or nears the critical deficit, irrigation should be applied.
- Irrigation should be turned off when the soil water potential is returned to field capacity.

How to use electrical resistance blocks

- Insert the block into a hole, ensuring good contact between the block and the soil.
- In stony soils, a slurry must be used to fill and seal the hole, to ensure good contact between the soil and the block.
- Ensure the wires are connected to the block and are protected at the soil surface.
- Install at least two blocks at any given location, one at the top and one at the bottom of the root zone.
- Several locations in a paddock must be sampled to provide a good representation of the soil water potential condition. Up to 12-14 blocks are recommended to characterise the soil water potential in each paddock.

Is something wrong?

- If the reading does not change over a week-long period, the block may need to be replaced or the meter checked.
- If the reading is zero, there is probably a broken wire. The wire or the entire block must be replaced.
- If the readings do not seem right, given the prevailing conditions, recalibrate or replace the block.

Related information

For a more detailed description of the procedure, refer to any agronomic or soil science (physical properties) text, the SOWACS web site <www.sowacs.com>, or a manufacturer's handbook.

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Soil moisture measurement – The time domain reflectometry (TDR) method

This is a simple, precise, "state of the art" method of measuring soil moisture.

Benefits of measuring soil moisture

- Minimises or eliminates soil-water limiting conditions.
- Only the amount of water required by the plant is applied.
- Minimises nutrient leaching.
- Optimises crop yield and quality.
- Maximises the benefit of rainfall and irrigation.
- Minimises environmental impacts.

Advantages

- Accurate measurement of the amount of soil moisture.
- Standard calibrations are supplied, but ideally should be checked.
- Simple to operate.

Disadvantages

- Static discharge to the wave guides could damage the sensitive electronic components.
- Operation is adversely affected in highly saline soils.
- Requires several sets of rods to depth-profile the soil.
- Only measures in the immediate vicinity of the rods that make up the wave guide – several measurements are required to obtain a representative measurement of soil water conditions in a paddock.
- The electrical signal can be attenuated in fine textured soils, thereby reducing the reliability of the measurements.

How it works

- A fast electrical pulse is sent down rods of known length in the soil.
- The soil water content affects the speed of the pulse, and the speed is electronically measured.
- The instrument gives a direct reading of the amount of water in the soil, to the depth of the rods.

How to use TDR

- Push the wave guide into the soil (possible with short wave guides in moist and/or friable soil), ensuring good contact between the guide and the soil.
- Ensure the wave guide rods are parallel.
- Connect the wave guide to the meter or instrument, and follow instructions to take a measurement.
- Use at least two wave guides of different lengths at any given location, one sampling the root zone and one sampling beneath the root zone.
- To obtain a depth profile of the soil moisture, several wave guides of different lengths need to be used.
- Several locations in a paddock must be sampled to obtain a representative measurement of the soil water status; for example, up to nine measurements are required to sample the same volume as one neutron probe.

Is something wrong?

- If the instrument will not turn on, check the power supply.
- If readings cannot be made, check that the instrument and wave guides are correctly connected.
- For other instrument problems, consult the supplier or manufacturer.
- If the crop shows signs of moisture stress (too much or too little water), check the calibration of the instrument, and adjust if needed.

Related information

For a more detailed description of the procedure refer to any agronomic or soil science (physical properties) text, the SOWACS web <www.sowacs.com>, or a manufacturer's handbook.

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Soil moisture measurement – The neutron probe method

This is a simple and accurate method. It is sometimes used as a standard for other methods (excepting gravimetric) of measuring soil moisture. Unlike most of the other methods, this method requires engagement of a specialist, for safety reasons.

Benefits of measuring soil moisture

- Minimises or eliminates soil-water limiting conditions.
- Only the amount of water required by the plant is applied.
- Minimises nutrient leaching.
- Optimises crop yield and quality.
- Maximises the benefit of rainfall and irrigation.
- Minimises environmental impacts.

Advantages

- Accurate measurement of the amount of soil moisture.
- Simple to operate.
- Easy depth profile of the amount of soil moisture.
- Unaffected by salts and soil temperature.

Disadvantages

- Neutron probes are expensive.
- Requires calibration, and the calibration should be checked annually.
- Instrument contains a small radioactive source.
- Only measures in the immediate vicinity of the probe – several measurements are required to obtain a representative measurement of soil water conditions in a paddock.

How it works

- Fast particles from a radioactive source are emitted into the soil.
- Water reduces the speed of the reflected particles.
- The number of radioactive particles detected over a set period of time is related to the moisture content of the soil.
- The instrument gives a direct reading of the amount of water in the soil at selected depths, if the calibration is programmed into the instrument.

How to use the neutron probe

- Install an aluminium access tube in the soil, ensuring it is deep enough to measure throughout the crop's root zone and preferably below the root depth.
- Place the instrument on the access tube, lower the probe to a pre-determined depth and follow the instrument instructions to take a measurement.
- Repeat measurements at successively lower depths to obtain a depth profile of soil moisture.
- A single access tube is sufficient to obtain a depth profile of the soil moisture.
- Several locations in a paddock must be sampled to provide a representative measurement of the soil water condition. At least three or four access tubes or sampling locations are recommended.

Is something wrong?

- If the instrument will not turn on, check the power supply.
- If readings cannot be made, check that the surface instrument and probe are connected correctly.
- If the reading is zero, the cable connecting the two components is broken. Have the cable repaired.
- For other instrument problems, consult the supplier or manufacturer.
- If the crop shows signs of moisture stress (too much or too little water), check the calibration of the instrument, and adjust if needed.

Related information

For a more detailed description of the procedure, refer to any agronomic or soil science (physical properties) text, the SOWACS web site <www.sowacs.com>, or a manufacturer's handbook.

June 2001

Soil moisture measurement - The capacitance method

This is a relatively new technology and varies in its complexity to use. It has some similarities with TDR technology, and is sometimes referred to as Frequency Domain Reflectometry (FDR).

Benefits of measuring soil moisture

- Minimises or eliminates soil-water limiting conditions.
- Only the amount of water required by the plant is applied.
- Minimises nutrient leaching.
- Optimises crop yield and quality.
- Maximises the benefit of rainfall and irrigation.
- Minimises environmental impacts.

Advantages

- Accurate measurement of the amount of soil moisture, subject to correct installation.
- Standard calibrations are supplied, but ideally should be checked.
- Simple to operate.
- Most can be connected to a data logger.

Disadvantages

- Static discharge could damage the sensitive electronic components in some instruments.
- Some instruments are expensive.
- Capacitance type instruments vary in their level of accuracy and ease of operation.
- Readings are strongly influenced by moisture content and air gaps in the soil close to the electrodes. Good sensor/tube/soil contact is essential for reliable readings.
- Soil salinity and temperature affect operation, and the instrument should correct for these. The lower the operating frequency, the greater the susceptibility to soil salinity.
- If the instrument requires a plastic access tube, this is difficult to install in stony soil without significant soil disturbance.
- The region of influence around the sensor is typically small: 20-30 mm beyond the access tube or sensor.
- Only measures in the immediate vicinity of the instrument – several measurements are required to obtain a representative measurement of soil water conditions in a paddock.
- Some instruments require specialist installation and removal. If connected to a data logger, considerable lengths of cable may need to be laid in the field.

How it works

- The capacitance of soil varies as the moisture content changes.
- The speed of an electrical pulse travelling down electrodes placed in the soil depends on the soil's capacitance.
- Capacitance instruments measure the travel speed and convert this to a soil moisture measurement, using a calibration equation.
- The instrument gives a direct reading of the amount of water in the depth of soil between the electrodes.

How to use capacitance instruments

- Insert the sensor probes into the soil. For some instruments, this requires installation of a PVC access tube. The sensor is lowered down this tube.
- Contact between the sensor, or the sensor access tube, and the soil must be perfect. This is crucial for this method.
- In stony soils, a slurry must be used to fill and seal the access tube hole, to ensure sensor/tube contact with the soil.
- Connect the sensor to the meter or instrument (where appropriate), and follow instructions to take a measurement.
- Use at least two sensors of different lengths at any given location – one sampling the root zone and one sampling beneath the root zone.
- For those instruments that use an access tube, a depth profile of the soil moisture is possible with a single access tube.
- Several locations in a paddock must be sampled to obtain a representative measurement of the soil water condition. Because the measurement zone typically extends just a short distance (20-30 mm) from the sensor or access tube, at least three or four locations should be sampled in a paddock.

Is something wrong?

- If the instrument will not turn on, check the power supply.
- If readings cannot be made, check that the instrument and sensor(s) are connected correctly.
- If an erroneous reading is obtained, there could have been a "cave-in" outside the access tube. The sampling location will need to be moved and re-established.
- For other instrument problems, consult the supplier or manufacturer.
- If the crop shows signs of moisture stress (too much or too little water), check the calibration of the instrument, and adjust if needed.

Related information

For a more detailed description of the procedure, refer to any agronomic or soil science (physical properties) text, the SOWACS web site <www.sowacs.com>, or a manufacturer's handbook.

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