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Soil Moisture Monitoring



This book is part of a series providing a comprehensive training resource for irrigation industry participants in New Zealand.

It provides a comprehensive resource for soil moisture monitoring in New Zealand.

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Using soil moisture monitoring for irrigation 1

Good and Best Management Practice for soil moisture monitoring 2

How many soil moisture sensor sites do I need?	3
Where do I install soil moisture sensors within the irrigation system?	3
Why is soil type important?	5
Number of reading points and installation depth	5
Soil moisture parameters	7
Installation of soil moisture sensor	9
Soil moisture data interpretation	9
Do I need to convert my soil moisture data?	10
Do I need to field calibrate the data from my soil moisture sensor?	10
Precision vs accuracy	10
What are the options to capture data from my soil moisture monitoring site?	11

Soil moisture monitoring technologies 12

Guide to soil moisture monitoring options 13

Sensor comparison	13
Sensor type	14
Soil type suitability	14
Does salinity affect my choice?	14
Does temperature affect my choice?	14
Ease of data interpretation	15
What units is the data displayed in?	15
How labour intensive is the soil moisture monitoring method?	15
Does the irrigation system limit my choice?	16
Does crop type limit my choice?	16
Measurement range	17
Measurement radius	17
Data capture frequency	17
Data logging capability	17
Telemetry capability	17
What information do I need from soil moisture monitoring?	17
What other factors affect my choice?	18
Product durability	18
How much maintenance will it need?	18
Cost/benefit consideration	19
Level of expert support with the system	19

Definitions 20

Using soil moisture monitoring for irrigation

The increased investment in precision irrigation infrastructure and control systems, coupled with a need for operators to be more accountable for their water use and nutrient loss, decreasing annual volumes and necessity for managing irrigation cost against production profits is resulting in an increase in the adoption of soil moisture monitoring. However, the use of soil moisture monitoring for irrigation decision making is not a simple task. Operators must choose the right method for their soil, land use activities and irrigation system type. This sits alongside ensuring correct location, installation, calibration and display of soil moisture data to ensure accurate information when making irrigation management decisions. Accessing, managing and understanding soil moisture data is important in irrigation scheduling. If soil moisture monitoring is to be used successfully each of these aspects must be carefully worked through.

This document aims to give the irrigating farmer (operator) the tools and information required to take charge of soil moisture management.

Good & Best Management Practices

	GOOD MANAGEMENT PRACTICE This refers to the <u>minimum</u> standard required to achieve good decision making from soil moisture monitoring.	BEST MANAGEMENT PRACTICE (Note: all GMP elements have been adopted plus the items listed below) This refers to the standard that would allow the <u>maximum</u> benefit to decision making from soil moisture monitoring.
Definitions	- An irrigation system is defined as irrigation application methods of the same type that can be managed together (i.e. apply the same depth at the same time). - The definition of a crop type is of similar water use requirements and similar root zone depths.	
Sites	- One soil moisture monitoring site per irrigation system and/or crop. - The site is located in the soil type with the lowest water holding capacity, but that soil type is representative of at least a quarter of the irrigated area.	
Depths	Each site collects data from minimum one (shallow rooted and pasture) or two (permanent crops) depths within the root zone.	+ An additional sensor located below the active root zone to monitor drainage events. + Accurate identification of the root zone to enable precise irrigation management. + Each site collects data from minimum two (shallow rooted and pasture) or three to five (permanent crops) depths.
Set up	- The data from the sensor is graphed so trends can be identified and implemented in irrigation scheduling. - Soil moisture data must be set up with relevant soil moisture parameters of Field Capacity and Stress Point.	+ The soil moisture parameters are assessed by an industry expert.
Data	- It must be possible for the user to calculate soil moisture deficit from the data provided. - Data is not displayed as an average of several sensor sites nor across a time period.	+ The data collected from various depths across the root zone is added to display a total sum of soil moisture content, not averaged. + For calculating the soil moisture deficit for scheduling, the most recent data should be used.
Maintenance	The soil moisture monitoring site is maintained – by changing batteries, cleaning solar panels, and other necessary upkeep – and protected to ensure data quality, and to prevent soil deterioration that could compromise sensor performance.	
Installation		+ The soil moisture monitoring site is installed by a suitably qualified person. This is a specialist area, ideally the person installing the equipment can show some credentials.
Training	The operator receives some basic training in interpreting the soil moisture data and its implementation in irrigation scheduling.	+ The operator receives comprehensive training in interpreting the soil moisture data and its implementation in irrigation scheduling. + All staff in charge of irrigation management receive on-going upskilling in irrigation management and soil moisture monitoring, such as an industry approved training course where the participants receive certificate of completion.

How many soil moisture sensor sites do I need?

The number of soil moisture monitoring sites required to meet Good Management and Best Management Practice is based on the key parameters of the irrigated area, specifically;

- the irrigation system type,
- soil type(s), and
- the number of crops being irrigated.

One irrigation system is defined as irrigators of the same type that can be managed together (i.e. apply the same depth at the same time).

The definition of a crop type is of similar water use requirements and similar root zone depths.

Where do I install soil moisture sensors within the irrigation system?

GENERAL PRINCIPLES

There are some basic principles that apply to all crop types and irrigation systems when selecting a representative location for a soil moisture monitoring site, these are:

- Stay away from the edges of the crop.
- In the same row of the sown crop, not in between rows.
- Avoid high traffic areas, e.g. gateways and the main path of vehicles, including compacted wheel tracks locked into GPS traffic management guidance systems.
- Avoid elevated areas where redistribution of precipitation may occur.
- Avoid low spots where water may pond or redistribute into.
- Avoid areas where water may run off tracks and across the monitoring site.
- Avoid areas where stock gather.
- Avoid areas which are influenced by factors such as shading from buildings or fences.
- Avoid areas where soil management is different to the irrigated area.
- Avoid areas where crop growth is atypical of the irrigated area.
- Never use fence lines as locations for soil moisture monitoring sites as these are not representative of the irrigated area.
- Select a site with cell phone reception if the telemetry communicates via cellular network.
- Select a site with internet availability if telemetry is communicating via this platform.
- If soil moisture monitoring equipment requires power, ensure the site is suitable for a solar panel (orientation, shade, etc).

The location of the soil moisture site will depend on the irrigation system it is installed within.

For **centre pivot irrigation**, sensors should be placed in a location that receives an average irrigation application rate measured across the pivot length. The first 1/3 of the pivot length should be avoided as application rates are low, the last 1/3 of the spans should be avoided as application rates can be so great they exceed soil infiltration rates.

Never install a soil moisture monitoring site under a corner arm or end gun. This is because the irrigation application depth is variable, and different from the average depth found beneath the pivot spans.

For **variable rate irrigation**, sensors should be located within each of the management zones ensuring to avoid zones that are programmed to be “dry”.

Micro-sprinkler irrigation (micro-jets, mini-sprinklers and drippers) systems require precise selection of monitoring sites. The soil moisture content between emitters can vary significantly, from very wet at the emitter itself to much drier in between. In coarse soils, the lack of lateral spread (sideways movement) of water will accentuate this point.

The soil moisture monitoring site should be placed within the wetted area but 100–300mm away from any emitter. The actual spacing depends upon soil type. For coarse textured soils, the sensor needs to be located closer to the emitter. On these soils the wetted mass is more cylindrical in form beneath the dripper or emitter and installing the sensor halfway between drippers or emitters is unlikely to intersect or sample the wetted mass. The exception to this rule is where the wetted strip is continuous.

Soil moisture sensors must not be installed directly beneath an emitter.

The site must be in the plant row (not in sward) and 300–500mm from vine or tree.

For berries (raspberries, strawberries and blackcurrants) the site must be 200–300mm from the bush.

If bulbs and strawberries are grown in mounds, the site must be in the mound.

Hybrid crops (male and female), the sensor must be in the reproductive plant (female) rows.

Fixed grid and overhead sprinkler irrigation – Site must be away from an individual sprinkler and ideally in an overlap area (within the wetted footprint of more than one sprinkler). In orchard setting, it is not necessary to locate it in the tree row, provided there is evidence of root growth in the selected site.

Water redistribution as a result of the impact of wind is a common issue for these systems. If possible, select a sheltered site.

Sprayline (sideroll, hand shift, endtows and K-Line irrigation) often have uniformity issues as a result of sprinkler placement challenges, management practices and poor design. These irrigation systems also typically operate in highly variable landscapes (slope and aspect). A portable sensor can be a good solution for this scenario as this allows multiple readings to be taken over an area. The measuring site and installation site (if using) should be between pods and ½ way of wetted radius.

Lateral systems (linear move systems) – Select a site along the length of the lateral, avoiding wheel tracks, hydrants, overhang and gun.

For **travelling irrigators (guns and rotorainers)**, site should be located away from the overlaps between runs and not at the beginning or end of a run. The site must be more than the wetted diameter away from the end or start of the run and no closer than 20m from the outside of the irrigation footprint. This is due to water redistribution as a result of the impact of wind and the outside of the wetted area often receives highly variable amounts of water.

Why is soil type important?

Soil type has a significant influence on irrigation depth, particularly the frequency and therefore amount of irrigation.

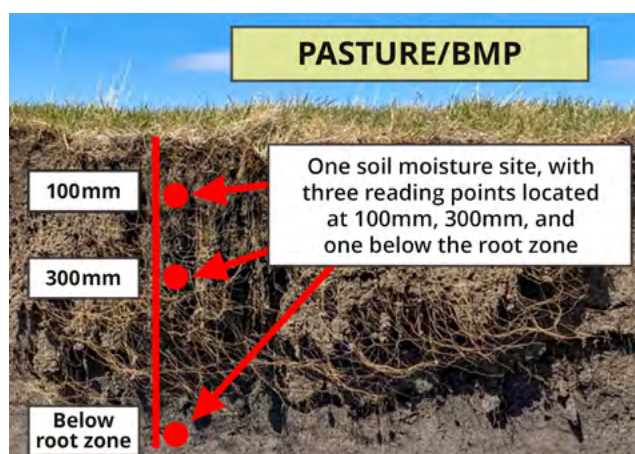
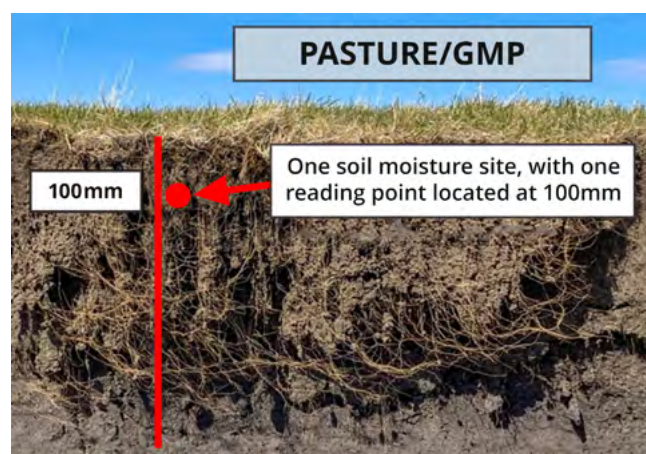
Light soils are typically free draining and have low available water holding capacity. Heavy clay and clay loam soils are less free draining and have high available water holding capacity. Therefore, the light soils (coarse textured soils) will require an irrigation event more frequently than a heavier soil (fine textured soil), similarly the light soils can accommodate a smaller applied depth before field capacity is breached, when compared to heavier soils.

When one irrigation system irrigates more than one soil type it is important to manage the irrigation system (irrigation scheduling) to the soil with the lowest water holding capacity. This will ensure the crop grown on the soil with the least amount of readily available water does not come under stress and the applied depth will match the deficit in all the irrigated soils.

As the soil with the lowest water holding capacity can be challenging to irrigate to, the guideline is to select the soil with the lowest water holding capacity provided it represents 25% of the irrigated area.

Number of reading points and installation depth

The placement depth of soil moisture sensors should correspond to the crop's root zone depth. Sensors must provide data that reflects both the soil moisture deficit and the effectiveness of irrigation events. The number of sensor reading points and their installation depths help the operator determine the appropriate irrigation depth and timing, ensuring water is applied efficiently and reaches the active root zone.



GOOD MANAGEMENT PRACTICE**NUMBER OF READING POINTS AND INSTALLATION DEPTH
PER SOIL MOISTURE MONITORING SITE**

	How many sensors	Suggested depth	Comments
Pasture	Minimum of 1 soil moisture reading points.	The first sensor located at 100mm	- The temperature reading from the 100mm sensor can be used for farm management as this is the standard measuring depth for soil temperature. - Ensure the logger (if using) can accommodate several sensors (if using multiple individual sensors). - Do a cost comparison between vertical sensor probe with multiple reading points vs multiple individual sensors installed at different depths.
Arable crops	Minimum of 1 soil moisture reading points.	The first sensor located at 100mm.	
Trees and vines	Minimum of 2 soil moisture reading points.	The first located at 100mm, the remainder at 100mm–200mm spacing.	

BEST MANAGEMENT PRACTICE**NUMBER OF READING POINTS AND INSTALLATION DEPTH
PER SOIL MOISTURE MONITORING SITE**

	How many sensors	Suggested depth	Comments
Pasture	Minimum of 3 soil moisture reading points.	The first sensor located at 100mm, subsequent 100mm–200mm below. Last sensor located below root zone (dig hole to determine root zone)	- The temperature reading from the 100mm sensor can be used for farm management as this is the standard measuring depth for soil temperature. - Ensure the logger (if using) can accommodate several sensors (if using multiple individual sensors). - Do a cost comparison between vertical sensor probe with multiple reading points vs multiple individual sensors installed at different depths.
Arable crops	Minimum of 3 soil moisture reading points.	The first sensor located at 100mm, subsequent 100mm–200mm below. Last sensor located below root zone (dig hole to determine root zone).	
Trees and vines	Minimum of 4 soil moisture reading points.	The first located at 100mm, the remainder at 100mm–200mm spacing. Last sensor located below root zone (dig hole to determine root zone).	

Soil moisture parameters

For soil moisture data to be of value it must be displayed with soil moisture parameters relevant to the data (field capacity, refill point and stress point).

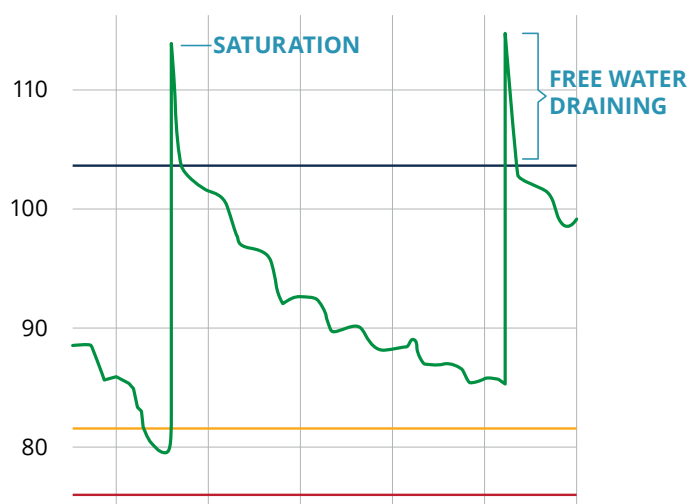
When soil moisture data is displayed as a graph the vertical axis shows the soil moisture status and the horizontal axis shows time.

The charts below show a typical soil moisture trace from a remote soil moisture sensor where a reading is recorded every 15 minutes.

Below is a basic explanation of the soil moisture parameters which form the basis of irrigation scheduling from this data.

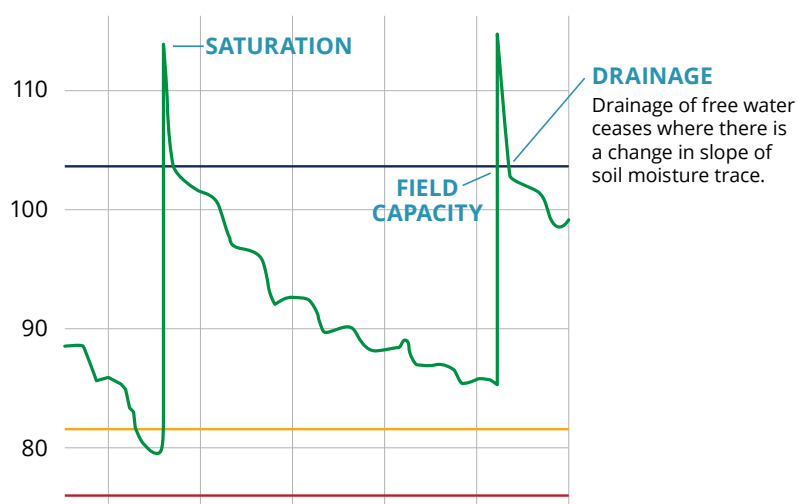
SATURATION

Spikes above field capacity indicate water is lost through the profile, this may be a saturation event or near saturation event. This will result in drainage of water and nutrients. During periods of saturation, roots and microorganisms are deprived of oxygen, this restricts growth, compromises soil health and loses of nutrients. If conditions are prolonged roots will be at risk of rotting, prolonged saturation can lead to plant loss.



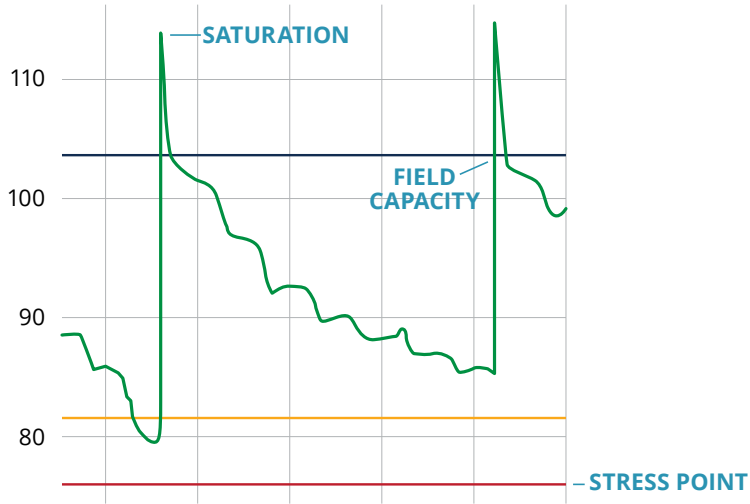
FIELD CAPACITY

Water is held at sufficient tension to overcome gravity. Irrigation application should not refill the profile to the field capacity, but rather aim a few millimetres below the field capacity.



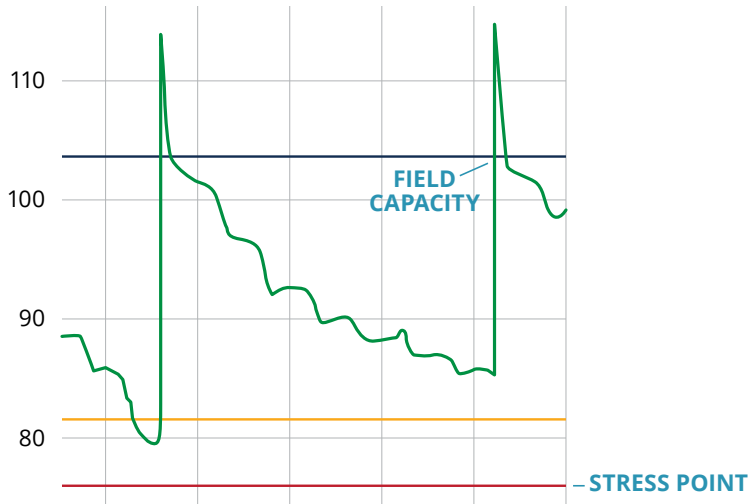
STRESS POINT

At stress point water is held at tensions too great for plants to meet potential evapotranspiration rates. That the soil moisture content has reached the stress point will be demonstrated by a change in water use, i.e. a change in slope of the soil moisture trace. Irrigation should commence prior to the crop coming under stress.



GOOD SOIL MOISTURE TRACE

A soil moisture chart should have correct soil moisture parameters (field capacity and stress point). The soil moisture status line should illustrate the changes corresponding to daytime and nighttime and there should be a vertical response to precipitation.



Installation of soil moisture sensor

Most permanently installed sensors rely on perfect sensor-soil contact (defined as no air gaps between sensor and soil) for accurate results. It is recommended only experienced service providers install permanently installed sensors. Neutron probe access tubes are installed by the provider and do not require perfect contact with soil. Portable sensors, like a handheld sensor require no installation but need perfect soil contact when inserted.

The key considerations for sensor installations are:

- Ensuring perfect contact between soil solution and sensor device (where applicable).
- Ensuring there is no pathway for water (irrigation or rainfall) to flow directly to the sensor (preferential flow paths).
- Ensure that the cable is situated below the sensor in the cable trench. This is so water will not track down the cable to the sensor and give a false reading.
- Ensuring soil backfill does not collapse around installation site leading to a depression for water pooling and ponding, forcing a false reading (this includes removing any air-gaps around sensor casings or cables).
- Ensuring any soil removed during sensor installation is repacked in the same layers so it is representative of the soil profile (horizon order, and density). It is important all dug soil is placed back in the hole or trench.
- Ensuring the soil surface around the sensor is not altered during installation process, this is to ensure it represents the irrigated area in terms of structure, topography and crop health. Surface disturbance could affect soil infiltration rate, redistribution and pooling of precipitation.

For optimal outcomes permanently installed sensors should ideally be installed in the autumn or winter. This allows for soil particles to settle around the newly installed device. Post settling there should be no air gaps between sensor and soil, ensuring reliable readings from the installed device.

In arable situations where the device is installed in spring as crops emerge, device selection is important. Selecting a device which requires minimal soil disruption, such as a vertically installed probe, or a soil moisture method which requires no settling (neutron probe) is advisable.

Soil moisture data interpretation

Initial training in interpreting and analysing the soil moisture monitoring data is essential. More comprehensive or intermediate level training is recommended to derive the best benefit from the soil moisture data.

The data provider should offer an initial interpretation session. Alternatively, third parties can offer this training as well as an integrity check of the soil moisture data.

The information from soil moisture monitoring sensors is most useful when presented as graphs or line charts, this makes it easier to identify trends.

Most data providers and soil moisture monitoring services present the data in a graph format. For other products (handheld portable sensors), you will need to manually enter data into a spreadsheet to develop a line chart helpful in identifying the trends.

Regardless of how data is presented, initial training in interpreting and analysing the data is essential.

Poorly presented soil moisture data and lack of training in correct interpretation and implementation of the data are the key reasons why operators stop using soil moisture data in irrigation scheduling.

Therefore, if there is no support provided from soil moisture data providers, you should reconsider purchasing the equipment.

Do I need to convert my soil moisture data?

All soil moisture data needs to be presented in units that aid in irrigation scheduling. It is therefore essential to apply a calculation to the data (e.g. TOPP equation) that converts it from raw data (e.g. dielectric permittivity) into v% or mm.

This calibration is essential for soil moisture data, irrigation systems, and rainfall to be in same units.

This calibration is essential for the soil moisture data to provide value to the irrigation scheduling process.

Do I need to field calibrate the data from my soil moisture sensor?

Field calibration turns the soil moisture data from v% into true v%.

It is not essential to field calibrate the soil moisture data. For day-to-day irrigation management decisions, actual v% soil moisture is less important than where a current soil moisture measurement sits in relation to the field capacity and stress point for the measured data.

Field calibration is necessary if you want to know actual soil moisture content, such as:

- Precisely matching irrigation and rainfall depths with changes in soil moisture content.
- Quantifying drainage from the root zone
- Using the measurements for nutrient drainage and data input such as Overseer.

Many remote soil moisture sensors cannot be field calibrated as only one calibration can be applied to the data. Many soil moisture sensors (vertical probes) represent several soil types, but only one calibration can be applied to the data, making one sensor display true v% while the rest are not.

Having the soil moisture data displayed correctly (correct units and soil moisture parameters) is of greater importance and value than field calibration.

Precision vs accuracy

Different sensor types and technologies offer different levels of precision. This refers to how similar, closely repeated measurements are to each other. This is different to accuracy and unless the technology has been field calibrated it is not known if the measured V% is the true soil V%. This means it is possible for the measurements to be very precise but not very accurate.

The level of sensor precision often relates to cost, device type and correct installation.

What are the options to capture data from my soil moisture monitoring site?

There are three main options to capture data from a sensor:

- Manual readings
- Data loggers that are manually downloaded
- Data loggers that are telemetered to a computer network or the cloud.

A continuous record of soil moisture can offer close to 'real-time' soil moisture status information.

Good quality loggers have a date and time stamp and will continue logging during power outages ensuring data is not lost. Loggers can be manually downloaded.

There are various telemetry solutions available including radio, internet or cellular communication.

The optimal solution depends on the nature of the site and access to required communication options (e.g. cellular network).

Portable manual sensors can be an option with no cellular connectivity or soil moisture services on offer. A good quality portable sensor will log the data with a time, date and location stamp which can then be downloaded.

For good decision making, trends (water use) need to be identified. If a soil moisture reading is provided intermittently (e.g. weekly) the readings must be combined with water budgeting (change in soil moisture status, rainfall, and applied irrigation). For a neutron probe service this must be part of the service and result in a calculation of daily water use. This process must be replicated by the operator who chooses to use a handheld soil moisture monitoring device. It is important to note if a handheld sensor is used there is a significant time commitment involved in acquiring the weekly readings. This time commitment should not be underestimated as readings throughout the winter will be required to accurately determine field capacity for the monitoring sites.

Soil moisture monitoring technologies

A range of sensor technologies are available. They can be split into groups based on how they measure soil moisture content.

DIELECTRIC CONSTANT SENSORS:

Many sensors measure the dielectric constant. Each material in soil has a unique ability to store electrical charge, referred to as its dielectric constant. Air, soil particles and organic matter all have a low (<5) dielectric value but water has a value of 80, therefore as the water content changes, so does the read dielectric constant.

Capacitance – uses the soil as a capacitor element and the soil charge storing capacity to calibrate to water content.

Frequency Domain Reflectometry – also uses the soil as a capacitor to measure the maximum resonant frequency in the electrical circuit and relate the resonant frequency to water content.

Time Domain Reflectometry – measures the travel time of a reflected wave of electrical energy along a transmission line. The travel time is related to the charge storing capacity of the soil and the volumetric water content.

Time Domain Transmissivity – works like the TDR but in a closed loop.

TENSIOMETER

Used to determine the water potential, or soil moisture tension. The readings are in kPa or cba.

NEUTRON PROBE

The neutron probe emits fast neutrons into the soil, when these collide with hydrogen the velocity they travel at changes, they become slow neutrons. The number of slow neutrons detected is a correlation to the hydrogen present in the sampled soil. As water contains two atoms of hydrogen per molecule it is a measure of soil moisture.

Guide to soil moisture monitoring options

The range of soil moisture measurement methods, their benefits, and limitations are summarised in the table below.

Sensor comparison

MOST COMMON PERMANENTLY INSTALLED SENSORS		Tensiometer	Neutron Probe
Soil type suitability	Silt and sandy loams. Air gaps around the sensor can reduce data suitability. These gaps may form in stony soils or when peat and clay soils contract during drying.	All soil types except stony soils.	All soil types. This sensor does not require perfect contact with soil for optimum performance.
Installation ease	This is a specialist area; care should be taken to ensure the installer can show credentials and in-depth knowledge of the importance of correct installation.		
Ease of data interpretation	Easy if presented as v/v% or mm. Ask to see the data display prior to purchasing.	Difficult to relate reading to mm.	Easy. Data interpreted by service provider.
Units	Displayed data should be converted to v/v% or mm rather than displayed as the raw data that is measured.	kPa (cba)	Displayed data should be converted to v/v% or mm .
Labour intensity for correct operation	Low–Moderate for user. Will need to clean solar panel and change batteries, along with regular data integrity checks (especially if consent conditions require continuous data).	Moderate for user. May need daily water refill.	Low for user, High for service provider. Provided access tubes are not damaged.
Readings per sensor	Some sensors offer only one reading per sensor. If you wish/require multiple readings across root zone (e.g. to meet BMP), purchase several sensors or purchase a vertical soil moisture sensor probe with several reading points along its length.	If several readings are required at different depth, additional tensiometers are required.	Several readings per root zone are provided. The number of readings provided can match the individual situation's requirements.
Measurement radius	Varies between brands and models but is generally between 30mm and 100mm. Be aware that the smaller the measuring range the larger the impact of removing stones from the sample area.	≤50mm	100mm (wet soil) – 200mm (dry soil)
Data capture frequency	Can be adjusted to meet requirements. This will affect how often you can adjust your irrigation schedule, and some consent condition require continuous data. The more frequent readings will be more demanding on battery.	Hourly–Daily	5–7 days
Data logging capability	Some consents will require soil moisture monitoring data that is logged and read at pre-determined intervals. Data logging ensures data is not lost.		
Telemetry capability	Some consents will require soil moisture data to be transmitted at pre-determined intervals. This is not possible with neutron probes.		

Setting up a reliable soil moisture monitoring system requires choosing the right sensor for your situation. In addition to the table above further relevant information is discussed in more detail below.

1. In mentioning sensor brands next to operation type does not mean we endorse the brands listed nor do we wish to exclude any, it is just to give the reader an idea of the category some commonly used sensors fit into.

Sensor type

- Time Domain reflectometry (TDR) this includes sensors such as Trime, Trase TDR, Acclima TDR.¹
- Time Domain Transmissivity (TDT) this includes sensors such as Aquaflex, Acclima TDT, Baseline Bi-sensor.
- Capacitance and Frequency Domain Reflectometry (FDR) sensors such as EnviroScan, Aquacheck, EnviroPro, Decagon 5TM, 5TE & 10HS and Aquaspy.
- Tensiometer
- Neutron probes

Soil type suitability

Soil type affect which soil moisture monitoring options are suitable. For example, tensiometer, capacitance, dielectric and time domain reflectometer devices require perfect contact with soil medium and are therefore not suitable in all soil types.

STONY SOILS AND GRAVEL

Dielectric type sensors may not be ideal for this soil type. To obtain perfect contact between soil and the sensor, stones must be removed from the soil directly against the sensor. This will change the measured soil's water holding capacity from what is irrigated and from what the majority of the crop is grown in. If the number of stones removed is significant, then avoid this monitoring method.

Tensiometers are not suitable in stony soils and gravels.

SOILS WITH HIGH CLAY CONTENT OR PEAT SOIL

Dielectric type sensors may not be ideal for this soil type if irrigation management allows for the soil to dry and contract from sensor creating air gaps between sensor and soil.

Neutron probes do not require perfect contact with soil medium and are suitable in all soil types, including stony soils, gravels, peats and swelling clays.

Does salinity affect my choice?

As salinity levels increase, the salt changes the electrical conductivity of the soil water and can interfere with the measuring technologies of TDR, FDR and capacitance probes. These sensors sensitivity to salinity is linked to the use of low frequencies, but as measurement frequency increases (above 50Mhz) the influence of salt is reduced. Some TDR sensors contain a range of frequencies (not just a single frequency) in the signal, which can help reduce errors from soil salinity.

Salinity is not a common issue in New Zealand soils.

Does temperature affect my choice?

Some soil moisture measurement technologies are affected by temperature, as the signal travels faster during high temperatures. Most sensor make an auto correction for this.

Ease of data interpretation

Some soil moisture data is easier to interpret than other.

The information from soil moisture monitoring sensors is most useful when presented as graphs or line charts, this makes it easier to identify trends, calculate water use and interpret data.

In most cases when purchasing a soil moisture sensor, the retailer will provide a data management service which presents the data in a graph format available for viewing on their website, app or via email.

For other products, you may need to manually enter data into a spreadsheet to make sense of it, as is the case for handheld probes.

Prior to making a purchase it is important to ask how that data will be collected and presented and what the associated (data provider) costs are.

You need to understand how this works, if any upfront or ongoing costs are associated with it, the knowledge base within the company and how reliable the service is.

Regardless of the option chosen you will need training in interpreting and analysing the data. Check with the supplier whether training is provided, and to what degree. Also check whether you can easily get ongoing support and software updates. These are critical components for learning how the equipment works and what the data is showing and should continue until you are competent in its use. Being unsure of how to make best use of sensors is one of the key reasons why operators stop using monitoring equipment.

Often, a specialist consultant will be useful in helping to understand the soil moisture monitoring data, water and plant interactions. Alternatively, industry bodies run grower support groups where results and other issues can be discussed, either peer to peer or by engaging an expert.

What units is the data displayed in?

It is usually easier to use data for irrigation scheduling if it is displayed in units that are easily converted to millimetres. Most common units are Volumetric soil moisture content (v%), millimetres of soil moisture (mm), or soil water potential (kPa and cba).

How labour intensive is the soil moisture monitoring method?

Soil moisture monitoring that requires the operator to collect information manually are more labour-intensive than those that collect or log data automatically, or where the data collection is part of the service.

Labour availability is often not considered in the purchasing decision, but lack of time or labour is one of the main reasons why manual monitoring sensors are ineffective.

Manually read sensors need to be regularly and consistent, with readings at frequent intervals throughout the irrigation season and at less frequent intervals throughout the winter for the purpose of establishing field capacity. Missed readings result in the inability to calculate water use, making the data of little value in irrigation scheduling.

If you purchase a manually read sensor, you have to commit the labour required to undertake the readings at regular intervals. If you cannot guarantee this labour commitment, then you should select another option such as automatic logging devices, telemetry or a contract service.

Automatic logging sensors can be downloaded periodically in the field or telemetry options can be added that automatically send the data your PC, phone app, a server or the cloud for viewing over the internet.

A contract service can do everything for you, i.e. take the soil moisture readings, provide you with irrigation scheduling advice. Alternatively, the service may process data into an easily understandable form and combine it with forecasting tools that aid in irrigation scheduling.

This service requires less labour investment input in terms of time.

Does the irrigation system limit my choice?

The characteristics of the irrigation system in combination with the soil type should be a consideration when deciding on what soil moisture monitoring method is best suited.

An irrigation system where a long rotation period results in soil drying and contracting between irrigation events can result in unreliable readings from any sensor that relies on perfect contact with the soil to establish the water content.

Does crop type limit my choice?

The crop type results in some important considerations for sensor choice and location:

- For shallow rooted crops one soil moisture sensor installed at one depth is sufficient to meet GMP. Furthermore, the sensor will be installed in the same position for a number of years therefore any soil disturbance and settling period is relative in terms of duration in that location. This allows for a broader range of products. However, if you wish to have several sensors site across the root zone a profile probe might be the cheapest way to achieve this.
- For deep-rooted plants it is desirable to have several soil moisture readings across the root zone. Profile probes best meet the need. Single sensors can also be suitable, but one sensor must be installed at each depth, resulting in increased costs and some telemetry data loggers cannot accommodate multiple sensors.
- Prior to purchasing single sensors make enquiries to ensure the datalogger can accommodate the number of sensors you plan on installing. For short term and annual crops, sensors should ideally be installed after emergence and removed at the end of the season before harvest. Therefore, it is critical to choose a sensor that installs and can be removed with relative ease and minimum soil disturbance.
- Crops that require or are managed with large soil moisture deficits i.e. to force reproductive mode or control vegetative cycles may have soil conditions that compromise reliable readings from devices that require perfect contact with soil to read the soil moisture content. This issue only occurs on soils that tend to change structurally when drying because the drying result in air gaps between soil and sensor. If this is an issue, it may be necessary to choose a monitoring method that does not require perfect contact with the soil.

Measurement range

Some technologies have an upper limit to their soil moisture measurement range even if the soil moisture content is higher, the readings will plateau. This range is generally not limiting for most irrigated soils, but where the technology is used to measure water content in other mediums, such as composts it may be a limiting factor.

Measurement radius

This refers to the amount of soil the sensor gets its reading from.

Data capture frequency

This refers to how often a soil moisture reading can be obtained from this sensor type. Technologies that use telemetry and data loggers can take readings at any frequency. However, soil moisture status does not change over seconds or minutes and batteries tend to run flat quickly if the frequency is too high.

Data logging capability

Some sensor types can log the soil moisture readings.

Telemetry capability

This relates to whether the soil moisture sensor can be linked to a telemetry unit which would ensure the readings are automatically sent to a data provider.

What information do I need from soil moisture monitoring?

Soil moisture monitoring can provide a range of information.

Some give simple 'wet/dry' measurements, which provide a guide to reducing plant stress and minimising irrigation water losses in the field. This type of monitoring would not satisfy GMP nor BMP criteria.

Other soil moisture monitoring systems can gather more information including:

- identification of root zone,
- forecast irrigation depth and timing based on water use (known as irrigation scheduling), and/or
- soil temperature.

What other factors affect my choice?

Other key factors that should be considered include:

- Sensor installation is critical. Of the many things that influence the quality of data, installation is the most important.
- What support is provided?
- Ask your neighbours what they use and learn from local's experiences, what has worked for them in your area?
- Prior to purchasing, ask other people for advice, which could be IrrigationNZ, your Irrigation Scheme, Agronomist or Environmental Consultant.

Product durability

Both portable and permanent products need to be assessed for durability:

- Livestock, pests, machinery traffic and temporary labour can damage fixed sensors. How resilient is the sensor in terms of the equipment itself and its installation?
- Portable products need to withstand potential damage in transport. Does the equipment come with a robust carry case, or do you need to purchase one?
- If the sensor is damaged what support is provided by the supplier?
- Will they repair the damage?

How much maintenance will it need?

To ensure ongoing performance the soil moisture site will require maintenance. It is important to consider this prior to purchasing.

The maintenance can include:

- Solar panel cleaning.
- Battery replacement.
- Maintain soil moisture content to ensure soil does not dry around sensor resulting in air gaps forming.
- Keep stock off equipment.
- Keep stock from congregating at the installation site as this will result in pugging and/or compaction around the site.

Cost/benefit consideration

COSTS

- It is important to consider telemetry as a means of reducing the labour cost of data collection. The trade-off is usually the increased initial purchase cost of the product.
- The annual costs relate to the maintenance both during and after the season, and re-installation costs for annual crops. For this the variation in cost between sensors lies with differing labour requirements and the need for supplier support.
- Several sensors installed at various depths is usually more expensive than a sensor which provides readings across several depths.

BENEFITS

The benefits of installing a soil moisture sensor also need to be considered, these include:

- productivity gains,
- potential energy savings,
- potential water savings,
- avoid drainage caused by irrigation event,
- avoid the lack of growth as a result from over-irrigation,
- avoid nutrient losses as a result of over irrigation,
- demonstrate good environmental management.

There are many cases where a monitoring system has shown financial benefits that far outweigh costs. In most cases external advice or upskilling in correct interpretation of soil moisture data and the link between crop growth stages and irrigation management is required.

Level of expert support with the system

An industry expert in soil moisture measurement in New Zealand typically has 5–10 years of hands-on experience across various soil types and land uses, with proven skill in installing, calibrating, interpreting, and maintaining monitoring systems. They often hold relevant tertiary qualifications and are recognised by industry bodies, councils, or training programmes for their applied expertise.

When choosing a soil moisture monitoring system, ask whether expert support is available from someone with at least 5 years' field experience and recognised training, such as in irrigation performance or soil water management. Reliable expert support ensures your system is correctly installed, calibrated, and interpreted, so the data informs timely and confident irrigation decisions.

Definitions

Full point and field capacity

Terms used to describe the amount of water a soil can hold after gravity drainage.

Stress point and refill point

Terms used to describe the point at which water availability limits plant growth.

Industry expert

An industry expert in soil moisture measurement in New Zealand typically has 5–10 years of hands-on experience across various soil types and land uses, with proven skill in installing, calibrating, interpreting, and maintaining monitoring systems. They often hold relevant tertiary qualifications and are recognised by industry bodies, councils, or training programmes for their applied expertise.

Basic training

Basic training can be provided by the provider, it should include how to log in, an explanation of the data as it is displayed under that log-in. An explanation on how to use the data in irrigation scheduling as in how to calculate irrigation deficit. In addition to this, who to call if something goes wrong.

Comprehensive training

The comprehensive training includes basic soil science, terms and definition of soil moisture parameters.

- How soil moisture parameters relate to soil types.
- Irrigation scheduling from soil moisture data.
- Analysis of soil moisture at depth.
- Identification of active root zone.
- Analysis of irrigation events and effectiveness at depth.
- Comprehensive cover of saturation and the effects.

REFERENCES

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