TOIP Pty Ltd
Telemetry Over Internet Protocols

Technical Document
Soil Moisture Probes and Data Interpretation

Version 4.1
March 2025

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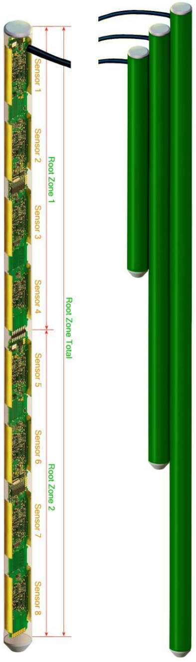
1 Soil Moisture Probes and Data Interpretation

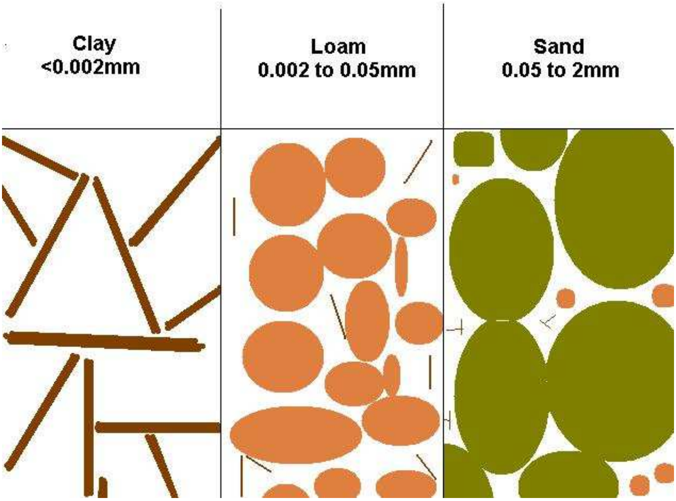
A Capacitance sensor monitors changes in the dielectric properties of the soil to provide users with continuous monitoring of soil moisture. Some sensors also measure soil salinity and soil temperature. Sensors are typically built into a probe which can return moisture levels through the soil profile.

Although some of the images depicted in this document are of the EnviroPro, the concepts apply equally to all of the capacitance sensors e.g. Sentek, AquaCheck, EnviroPro.

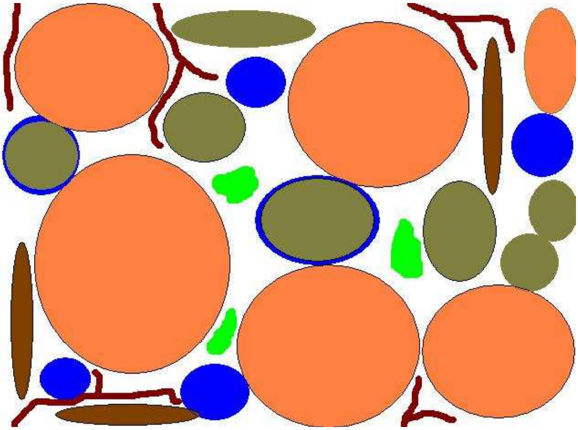


2 Basic Soil Water Relationships

Soils are normally made up of particles of various sizes. The ratios between the small, medium and large particles determine whether the soil is classified as a clay, a loam, a sand, or some sub-classification of each. The distribution of particle sizes in turn impacts on both the soil's water holding capacity and how easily the water can be accessed by a plant.



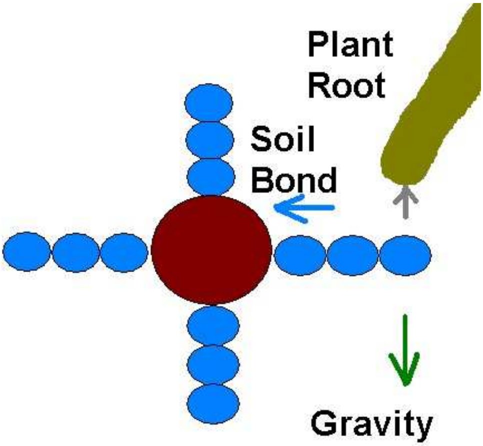
Water coats the soil particles and occupies the pore spaces between them. Water is easily drawn away from the large soil pores but is difficult to remove from around the particles.



The way the water behaves can be explained by considering 3 separate forces acting on it:

- Soil bond: the strength of the force the soil particle is exerting on the water to hold it in place. The smaller the particle, the tighter the bond
- Gravity: when the soil reaches saturation, the forces holding the water to the soil are lower than the pull exerted by gravity, so the water drains through the soil profile
- Matric potential: this is a measure of the suction force exerted by the roots of the plant to draw moisture away from the soil.

When soil is dry, the only water being held is that which is closely bonded to the soil particles. As water is applied, it starts to fill the soil pores. However as more and more water is applied, the force holding it to the soil weakens. Eventually the force of gravity exceeds the force holding the water to the soil and the water is lost through the soil profile as drainage.



If a droplet of water is released onto a dry soil surface, some water will be drawn down by gravity. The dry soil particles around the area will however exhibit a strong attraction to the water molecules and the water will be drawn out in all directions. Eventually the forces in the soil will reach equilibrium and the water will stop moving. Each new drop of water added changes the balance of forces, driving the soil to a new equilibrium. The wetter a soil is, the faster the soil water levels will change.

The aim of irrigation management is to keep the level of water in the soil below the onset of drainage (saturation) and above the onset of stress. There are exceptions to this rule: for instance in applying deliberate water stress to maximise fruit quality in red wine grape production.

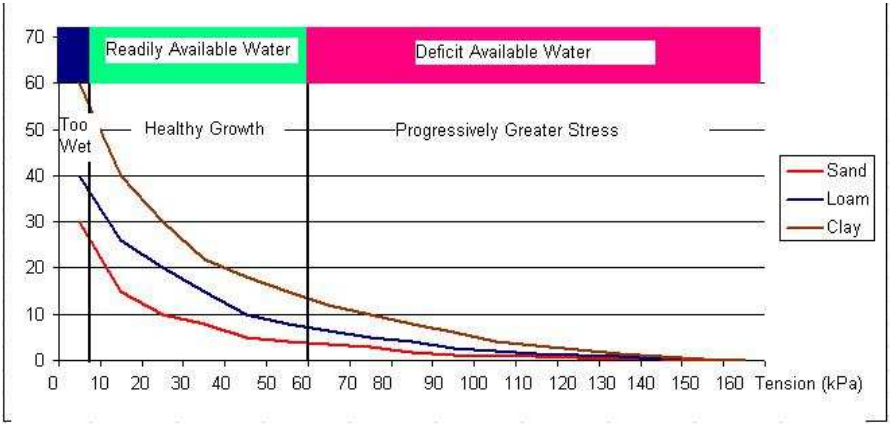
The level of moisture in the soil can be expressed in two ways:

- Soil water tension

    - Matric potential sensors measure the force binding the water to the soil. Matric potential is expressed as a suction or negative tension and is measured in kilopascals (kPa)
- Soil water content
    - Volumetric sensors measure the quantity of water in a given volume of soil (Some systems measure gravimetric soil water content, which is the ratio by weight of water in a given weight of soil). Volumetric soil moisture content is expressed as a percentage.

For each soil type a unique relationship exists between the two measures. When graphed, it is designated as the “soil water release curve”. Samples of the soil are placed in containers of a known volume. The samples are then weighed. The samples are then placed on a pressure plate apparatus where suction is applied to draw away the moisture. The sample weights are taken at a number of tension values. The wet and dry weights and sample volume are used to determine the percentage of moisture in the soil at each point and this is then plotted against the tension values.

Generic soil water release curves are available for a number of common soil types. The difficulty in using these has been that most common soil volumetric sensors (capacitance probes) were not capable of accurately measuring moisture content: they could measure it with high repeatability, but the value given bore little resemblance to the real moisture level. The Theta Probe, HydraProbe and AquaFlex sensors, as well as some of the newer potted capacitance probes, can return accurate, real (absolute rather than relative) soil moisture readings. Tension figures can then be inferred with reasonable certainty form the soil water release curves.



Irrigation managers, are interested in a few key points on this curve:

- Saturation: assumed to occur at a tension of -8 kPa
- The onset of stress: where this point occurs is a function of plant physiology. In annual crops it may occur at -20 kPa whilst in permanent crops it may occur at -40 or -60 kPa
- Wilting point: the point from which the plant can not recover.

Although a soil calibration can show the total amount of water which can be held in the soil (the total available water or TAW), irrigators are normally interested in what can be held between the point of saturation and the onset of stress. This is defined as the readily available water (RAW). Water obtained once the plant is in stress is defined as the deficit available water (DAW).

Although soils with a higher clay content generally hold more water, much of it is too tightly bound to the soil particles to be available to the plant. In general, clay loam soils make the best growing soils as they have the highest ratio of available water. In light soils, irrigation events must be relatively short and must be applied frequently. In heavier soils, irrigation can be applied for longer (because the soils hold more water) and the interval between irrigation extended.

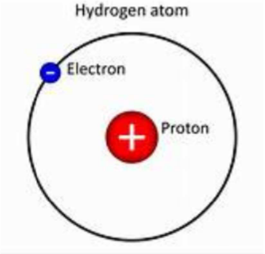
The rate at which irrigation is applied is also important. Different soils have different infiltration characteristics. Water passes rapidly through light textured soils and slowly through heavy soils. If water is applied at a rate above the infiltration rate, it will pool on the surface. If the site is sloped, water will run away down the slope, leaving some areas dry and others waterlogged. The rate at which irrigation is applied is usually measured in mm per hour. A soil survey will identify the typical or actual infiltration rate for the soil sample. A rough estimate can be made by welling up an area of dry soil with the rim of a plastic bucket, then applying a couple of litres of water. An hour later, a hole can be dug and the depth to which the water infiltrated measured. When designing an irrigation system, a designer will choose emitters whose application rate is less than the infiltration rate.

The faster the water moves vertically, the less the lateral spread. In very sandy soils, water can move as far as 1cm in a minute – or 60cm per hour. Whereas in heavy clay soils, the infiltration rate may be as low as 1cm per hour. When using individual emitters such as drippers, the spacing between emitters must be altered to suit the rate at which water is moving laterally. It is thus common to see emitters spaced very close together (300m) in a light sand and further apart (1m) in heavy clay soils.

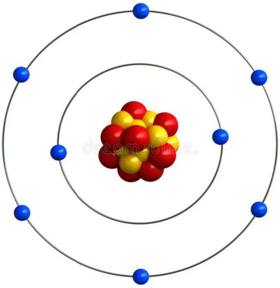
2.1.1 Water Molecules

Water consists of molecules of hydrogen and oxygen: one atom of oxygen binds to two of hydrogen. The electrons around an atom rotate in orbits, much the same as the way the planets rotate around the sun. The orbits are not circular, but elliptical. There are two competing forces in play: firstly the force from the proton in the nucleus which is pulling the electron towards it and secondly, the centrifugal force exterted by the electron as it rotates at the speed of light around the nucleus, which is pushing the electron away. As the electron orbits, the two forces are kept in balance.

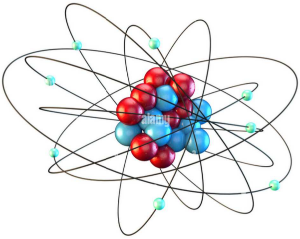
Unlike the sun, the nucleus of an atom has electrons rotating in many different zones or bands. The first band (closest to the nucleus) can hold two electrons: with two electrons in this first orbit, the repellant forces they exert (Like particles repel one another) push any further electrons away. As they rotate they will always be in a position furthest away from each other. In a completely symmetrical system, they would take up positions opposite from one another in a circular orbit. But because the nucleus of an atom is not symmetrical and the orbit of the electrons is elliptical, the relative position of the two electrons changes continually, with them maintaining maximum distance from one another. The resulting pattern looks more like a V around the nucleus.



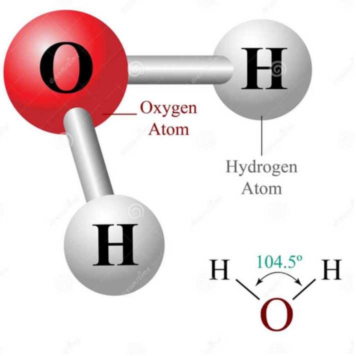
A hydrogen atom, with one electron in its orbit is very reactive – it is holds a strong attraction to other electrons which come past it.. Helium atoms, which have 2 electrons and protons are in comparison very stable: the force from the two electrons pushes any new electrons away. Lithium, which has 3 electrons and protons, has 2 electrons in the first band (like Helium) and a 3rd rotating much further out in a second elliptical orbit. The distance from the nucleus to the second band is such that the repellant forces from electrons in the first band, the attractant forces from the nucleus and the centrifugal force from the electron's movement once again balance each other out. Lithium is very reactive (think lithium batteries) as there is room for up to 8 electrons in rotation in the band and the atom keeps on attracting more until the band fills (a Neon atom is stable because its band is full).



An Oxygen atom has 8 electrons in total: 2 in the inner band and 6 in the outer. There is thus room for 2 more electrons in the outer band. In many simple diagrams, the oxygen atom is shown with the electrons in neat circular orbits. This is to make it easier for students to visualise rather than to understand what actually happens.



In reality, the picture is more complex and the bands much further apart. The dots for the electrons, protons and neutrons would be pinpricks on a large page if drawn to scale. And the positions of all the electrons is governed by the need to keep all those competing forces in balance.

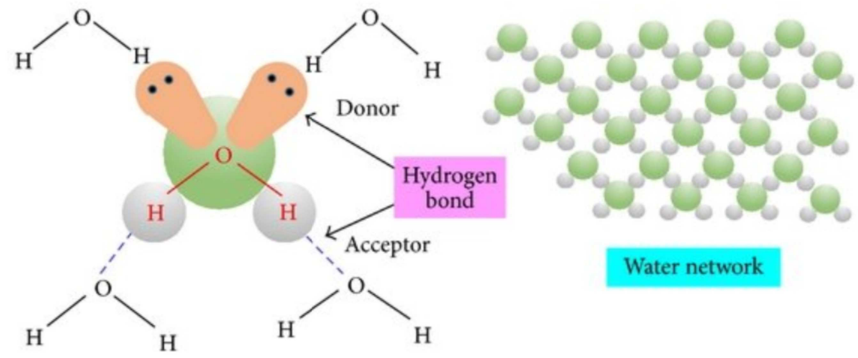


Two atoms of hydrogen share their electrons with that of the oxygen atom, to make water molecules: H_2O. The orbit of the electron from the hydrogen atoms now takes in the oxygen atom. The force which binds the electron to the hydrogen atom is much stronger than the force which shares it with the oxygen atom, so if you apply enough energy, you can separate the water back in to hydrogen and oxygen (you generate hydrogen by applying electrical energy to the water).

2.1.2 Polarisation in Water

In water, the two hydrogen atoms are not directly across from one another. Rather that take up a position which keeps all the competing forces in balance: forming a V, with the oxygen at the centre and the hydrogen at the points of the V. In drawings of a water molecule, they are always depicted as 3 neat spheres. But in effect, there is a massive amount of empty space between them.

Because of the asymmetry, a water molecule is polarised: the oxygen end takes on a negative charge and the hydrogen ends positive. Water molecules can line up, with the hydrogen end of one molecule attracted to the oxygen end of its neighbour. So in the liquid form, you end up with a 3 dimensional structure with all the molecules lining up.



When you put the positive pole of one magnet against the negative pole of another, they stick together; but if you try and put the negative poles together they repel each other. The force you apply to bring the two together is overcome by a force trying to push them apart. If you apply a sufficiently large magnetic field to the water molecules, you can change the direction in which the molecules align. Energy is required to do this, so the process consumes energy. When the force is removed, the electrons will go back to their “normal” orientation. As water is heated, the molecules get increasingly excited and begin vibrating against one another, eventually reaching a point where they break free – turning to vapour.

If the direction of the force being applied has its direction continually changed (exciting it with an AC or alternating current rather than a DC or direct current) the molecules will move at the same rate, with energy being used with each transition. The rate of change of the force is known as its frequency.

3 Capacitance Sensors

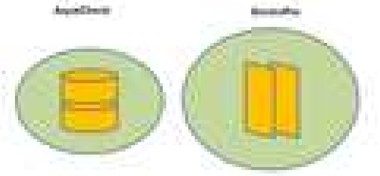
Capacitance probes use this principle to estimate how much water is in the soil. If you apply a force from a high frequency alternating current (or AC) source, the water molecules will switch polarity with every cycle, storing and hen releasing energy as they do so. If the electric field which is generating this force, is applied to the soil, it will polarise the moisture held in the soil. The more water that is present in the soil, the more energy will be stored. If the soil is very dry, there are fewer water molecules and hence less energy can be stored.

The ability of a material to store electrical energy is referred to as its capacitance (or C) and each different insulating material can be allocated a “dielectric constant” or “relative permittivity. The latter term expresses the energy storage ability compared to that of a vacuum. Conductive materials do not store energy like this, instead the electrons are free to move from one atom to the next, conducting electricity from one point to another. Conductors have a relative permitivitty of 0 i.e. they can’t store any energy.

But this principle has limitations. Firstly, the concept applies to materials which are insulators which do not conduct electricity. Distilled water is non conductive, but as soon as any salts are added, it begins to conduct electricity. The act of conduction means that the ability to store energy is reduced: the rest leaks away as conduction through the ground. Secondly, the soil molecules change the behaviour of the water: if the soil molecules are themselves polarised, they will apply a strong polarising force to the of the water molecules. In heavy clay soils, the relative permittivity of the soil can be much higher than that of water – making them look “wetter than wet”, or giving an indicated moisture reading of over 100%. Thirdly, each soil is different – not just in the type of molecules present, but also through the presence of different types of molecules as well as the presence of stones and organic material and of holes through the soil profile as a result of ants and root growth. But as long as these factors are all kept in mind, the measurement of permittivity (the soil’s energy storage) over time, has proven to be a robust method of determining moisture content.

3.1 Capacitance Probe Design

In most probe designs the sensor element is made up of a pair of concentric rings (stacked one above the other) or a set of flat plates mounted either side of the tube. The plates make up the capacitive leg of an "L-C oscillator". In this type of electronic circuit, the frequency at which the oscillator runs, is governed by the ratio of C and L. If either the L (inductive) component or C (capacitive) component changes in value, the frequency of the circuit changes. In a typical soil moisture sensor, theL component is fixed and the capacitance component changes with changes in the dielectric (energy storage) properties of the material inside and outside of the rings. Changes in the frequency of the circuit are then used to derive a figure for the moisture content of the soil.



Manufacturers have adopted a number of different formats for their sensor design. The original Sentek probes used a 50mm PVC tube, which was installed into the ground (and plugged at the bottom). A plastic rod, with sensors installed at several depths, would be lowered into the column. The primary issue with this design has been the tendency for moisture to build up inside the column (either from leaky bottom stoppers or due to thermal cycling drawing in additional air as the probe heats and cools).

The electric field exerted by the sensors extends only 10 or so mm from the plates, but falls off in an exponential fashion. Much of the effective area is thus taken up by the air gap between the sensor and PVC tube and the PVC tube itself. Any air gaps in the soil or the presence of rocks or organic material will also change the measurement area.

The AquaCheck was the first product to adopt a sealed design and a slim-line" (34mm) format and was subsequently followed by the EnviroPro (38mm). The slimline probes can utilise a thinner wall tube and minimise the gap between the sensor and wall, thus giving a bigger effective measurement area. By sealing the probes and filling them with resin, the need for preventative maintenance is removed and reliability increases dramatically.

At the time of manufacture, probes are typically calibrated to a standardized soil media and it is the accuracy of the sensors in this media which is given in the sensor specifications. The accuracy in a given soil type will depend on how well the calibration (either the default or one added in software) matches the characteristics of the soil.

Capacitance sensors must be considered a “relative” instrument. They lack absolute accuracy (the value given could vary by up to 100% from the real value) but are highly repeatable (they will give the same value at the same site in the same conditions).

4 Other Measurement Parameters

4.1 Soil Temperature

Most capacitance probes include a thermistor which measures the temperature at each sensor. Under most conditions, this will reflect the soil temperature.

The temperature sensor range is set to cover that expected in the various applications in which the probes will be used. The upper limit for example allows the sensor to make measurements in compost.

Because the electronics on the probe printed circuit boards are typically potted in resin, it takes time for changes in soil temperature to transfer first through the wall of the PVC tube and then to the sensor where they are detected. This means that it can take some time for changes in soil temperature to be observed on the temperature sensor, especially if the soil temperature changes rapidly (e.g. when rain falls on hot soil).

4.2 Electrical Conductivity

Very early in the development of capacitance probes it was found that the sensors are influenced not just by moisture content of the soil but also by its salt content. The first capacitance based soil conductivity (Soil EC) sensors operated over two frequency bands: firstly one at which the influence of moisture was greatest and salt least, then again at a lower frequency where the influence of water content is lowest and salt highest. Mathematical models then tried to separate the two frequency responses into soil moisture and soil conductivity components. This approach tended to be acceptable in sandy soils but becomes less useful as clay content rises.

One manufacturer uses an alternative approach of looking at the two components of change in the dielectric properties of the soil: a “real” component which reflects the moisture induced change and an “imaginary” component (a phase change or time delay) which represents the salinity component.

The conductivity relationship is however quite complex: conductivity is firstly influenced by temperature, so readings must first be adjusted with information from the thermistor. Secondly, the ability to make a good conductivity measurement is also influenced by moisture content: the higher the moisture content the easier it is to read conductivity. The best conductivity measurements are made using steel pins or rings which are in direct contact with the soil. Inferring the conductivity any other way is fraught.

If a sample of soil is carrying a fixed amount of salt, the concentration will change as moisture is added: i.e. as the moisture content increases, the amount of salt in any given volume of water decreases. But one problem of the salinity measurements made by the capacitance probes, is that as moisture content increases (e.g. with irrigation) even though the salt content has not risen, the indicated salinity increases. This is because they are responding to the total quantity of salt rather than the concentration.

Some SWR based conductivity sensors (e.g. Stevens HydraProbe) can measure the bulk conductivity and then, using values of soil temperature and soil moisture, determine the salt burden – a figure which does not change with water content. They can do this because they are able to make a direct conductivity measurement (i.e. measuring the current flow between two conductive electrodes). However because capacitance sensors are not able to measure conductivity directly (i.e. they have no pins in contact with the soil) and because of the interaction between the various factors controlling measurement, they cannot yet provide measurement of salt burden, only of the conductivity at a given moisture level.

Conductivity values from capacitance probes can not be analysed as a trend. Instead, you must identify points in time where the moisture content is the same and then, look at the change in indicated conductivity from one point to the next.

The relationship between bulk conductivity and true pore water conductivity is also site specific. To convert the indicated EC to pore water conductivity, the values obtained from the probe should be compared with those obtained from soil samples or from a solute sampler. The latter provide a very cheap and simple method of monitoring EC and nitrate levels in the plant root zone.

4.3 Temperature Compensation

Most capacitance probes do not however apply compensation for the change in moisture readings generated when the soil temperature changes. The change occurs because the dielectric properties of all materials are temperature dependent: as temperature increases, the water molecules can move more freely and hence store more energy, which is seen as an increase in capacitance. This is evident as an increase in indicated soil moisture as soil temperature rises. It is particularly noticeable in dryland agriculture over the post harvest period, when the soil progressively dries, but, as it heats, starts to show an increase in moisture. In irrigated agriculture the change is not as pronounced, because irrigation helps keep soil temperature changes to a smaller range. Often the change that does occur is dismissed as “diurnal variation due to capillary rise” rather then rise due to temperature change.

The compensation can be expressed as:

$$\mathrm{SMcomp} = \mathrm{SM} - (\mathrm{SM} * \mathrm{F} * (\mathrm{ST}-\mathrm{Tref})$$

Where

SM	soil moisture reading
SMcomp	compensated soil moisture value
ST	soil temperature reading
Tref	Reference temperature i.e. 15 °C
F	Scaling factor 0.002 to 0.004

As nearly all manufacturers of soil moisture probes have not yet accepted this fact, the compensation must be done externally to the probe. This can be completed in the presentation software or after exporting the data to a spreadsheet.

5 Data Interpretation and Use

5.1 Soil Temperature

Soil temperature provides useful information for the management of crops, particular in the areas of germination and nutrient uptake. Soil temperature also has an impact on root growth as perennial plants emerge from senescence.

As profiling capacitance probes provide temperature measurement through the full soil profile, you can examine soil temperature at any or all levels in the root zone.

5.1.1 Nutrient Uptake

Farmers must often choose between the application of ammonium nitrate or Urea. Of the nitrogen in ammonium nitrate half is present as nitrate (which is available directly to the plant) and half as ammonium (which must be converted to nitrate by soil microbes before becoming readily available to the plants). Urea is cheap and easy to apply, but should be incorporated into the soil as quickly as possible: 2/3 of the Urea-N resent will be hydrolyzed to ammonia-N within 24 hours but some of this will be lost as ammonia gas (de-nitrification) reducing the efficiency of the urea as a fertiliser. The bacteria which convert the nitrogen are more active at high temperatures, so losses increase with temperature. But the mineralisation process stops in low temperatures, so urea should not be applied when soil temperatures are below 7 °C at a depth of 10cm.

Plotting soil temperature on a graph and adding a threshold with colour bands above and below the threshold allows for simple determination as to whether the temperature is high enough to allow mineralisation. An alarm can be added to the presentation software to alert users when the threshold is reached.

5.1.2 Phenological analysis

Plants which shut down over the cooler months, will typically undergo a root growth surge just before entering senescence and then again once they emerge.

The soil conditions at these times have an impact on root growth and hence the amount of biomass produced. There are thresholds at both the low and high temperatures and at different stages of the growth cycle: the temperature in cold areas must rise to a species specific threshold before root growth can occur; overly high temperatures at these times can restrict root growth and hence biomass accumulation.

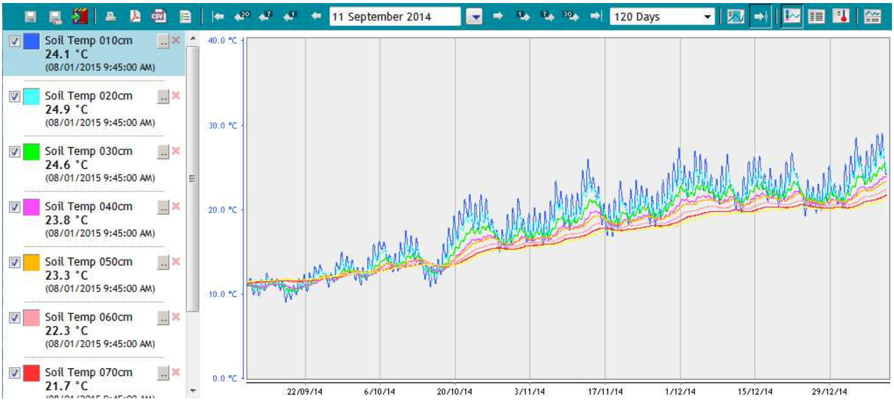
Research on Maize has also shown that dry matter yield and nutrient uptake were higher at soil temperatures above 28 °C than they were below 22 °C (Hussain and Maqsood, 2011 p1).

Careful analysis of soil temperature trends will not just help identify when plants go in and out of senescence, but also whether the timing is going to be beneficial or not.

5.1.3 Long Term Analysis

Plotting soil temperature over longer time frames provides a good basis for evaluation of changes in root zone conditions over a growing season.

The 10cm sensors show the greatest amount of movement – with a clear diurnal pattern – but the daily changes are superimposed on shorter cycles which follow the 1 to 2 week weather patterns and then again on longer seasonal patterns.



11 September 2014

120 Days

☑ 🟦 Soil Temp 010cm
24.1 °C
(08/01/2015 9:45:00 AM)

☑ 🟦 Soil Temp 020cm
24.9 °C
(08/01/2015 9:45:00 AM)

☑ 🟩 Soil Temp 030cm
24.6 °C
(08/01/2015 9:45:00 AM)

☑ 🟪 Soil Temp 040cm
23.8 °C
(08/01/2015 9:45:00 AM)

☑ 🟧 Soil Temp 050cm
23.3 °C
(08/01/2015 9:45:00 AM)

☑ 🟥 Soil Temp 060cm
22.3 °C
(08/01/2015 9:45:00 AM)

☑ 🟥 Soil Temp 070cm
21.7 °C

It is also useful to add rainfall totals to soil temperature data, so that the cooling effect of rain events can be examined. This is best done using daily rainfall totals.

5.2 Soil Moisture

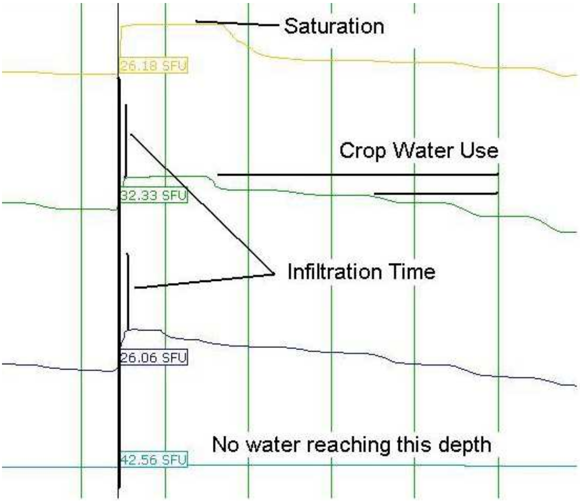
Soil moisture monitoring provides critical information for crop management in both irrigated and dryland farming.

5.2.1 Monitoring Irrigation Events

An irrigation event usually displays a set of similar characteristics:

- A rapid rise in soil moisture at the surface
- Infiltration down through the profile at a rate determined by both the soil's current water status and its texture (infiltration rate increases as relative water content increases and decreases as the clay content rises)
  - This is evident as a delayed rise in moisture level at the next sensor in the profile
- A sharp fall off at the end of irrigation as the soil quickly drains
  - At the top sensors you will see a rapid rise in water level, a peak when irrigation stops and then a rapid fall
- If a sensor climbs and stays at that level for a period of time, it is likely that the soil at that depth is saturated and water is being lost through the profile as drainage. This behaviour is not often seen in micro irrigation but is common in flood/surface irrigation.

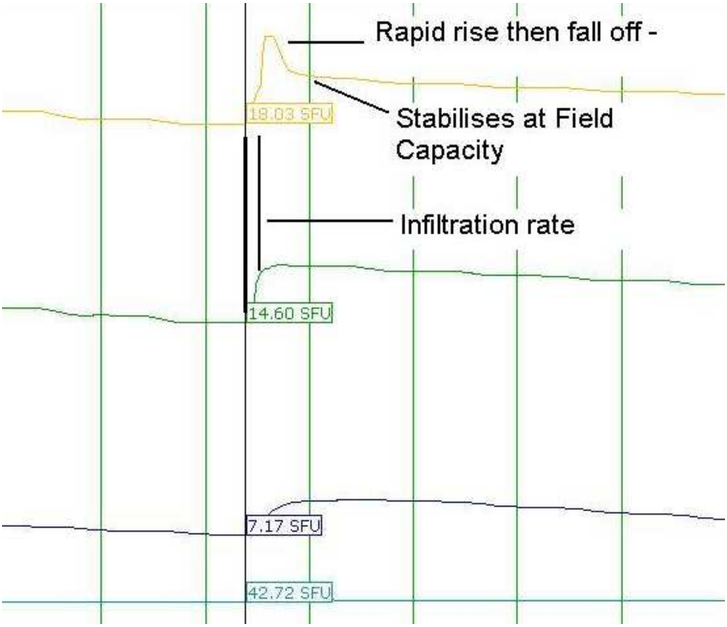
The image below shows a representation of an irrigation event with data from sensors at 10 through 40cm (10cm at top).



5.2.2 Irrigation Depth

If a plant's roots can only draw water to a given depth (whether because of the plant physiology or limitations in the soil structure), it makes sense to irrigate to the same depth. Irrigating to a shallower depth means that the plant's growth will be restricted. It also means that the reserve of water for the plants in the event of a hot spell will be reduce. Irrigating more will waster water (in deep soils) or create waterlogging (in soils with an impervious layer).

To identify the depth of irrigation and its corollary, where in the profile the plants are drawing water from, it is common to look at the data from all of the sensors at the one time – a separate level graph. For clarity, the sensors are all placed on the one graph, but the traces are stacked one on top of the other. The graph thus gives a very clear picture of changes in moisture through the profile.



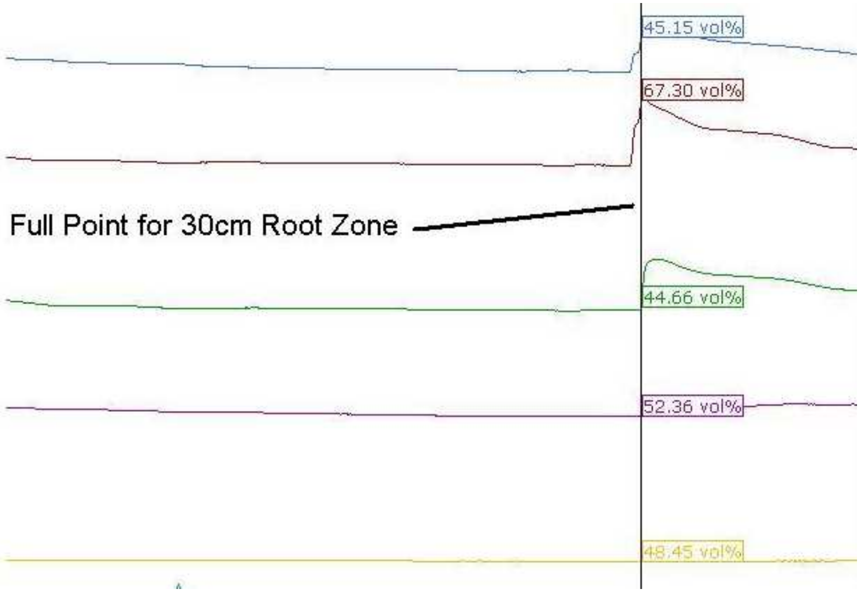
In the above graph, the water reached the third sensor but not the 4th. The top sensor rises quickly at the start of irrigation and then, at the end, falls off quickly with drainage. The water level then stabilises at field capacity and then you start to see daily water use. As you move through the profile you can observe the increase in infiltration time and a slowing in the rate of rise. This is because the soil at depth is often a heavier texture and because as the wetting front moves through the profile it gets weaker.

It is good practice to install a sensor below the root zone. If the water reaches this level, too much is being applied. Ideally this sensor should start at a reasonable moisture level (assuming the profile has been filled by winter rains) and then slowly dry down over the season. It should only rise after prolonged rainfall.

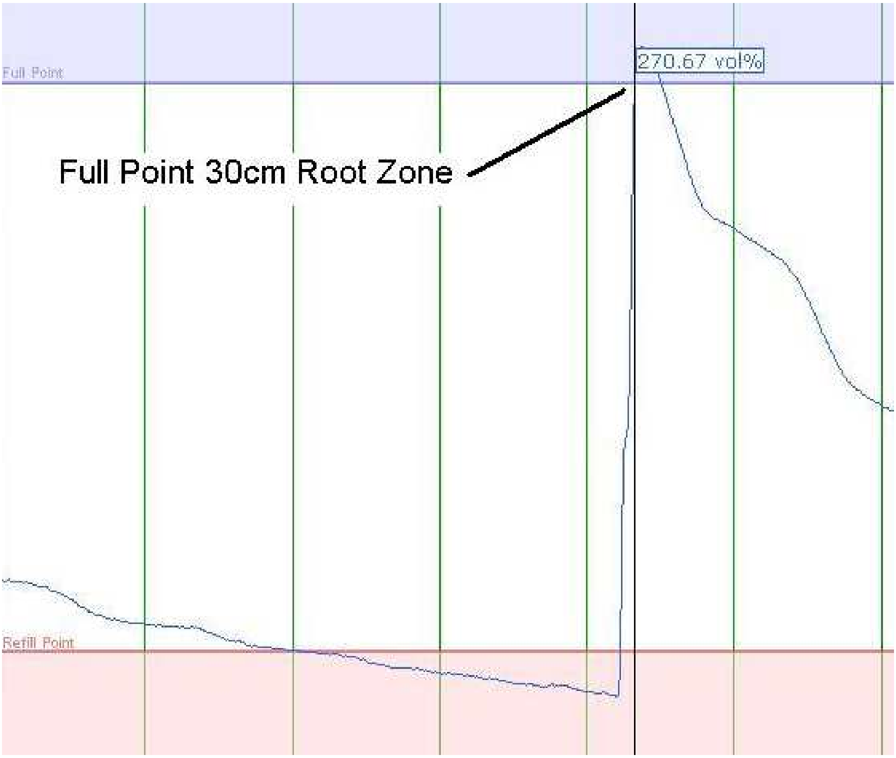
5.2.3 Setting Full and Refill Points

To set full and refill points, the data in the “Separate level” view described above is used to gain insight in to where in the profile water is reaching during irrigation.

First off, users can seek out a point in time where the water level at all of the sensors in the root zone has risen to somewhere close to field capacity (below the point where drainage occurs) and mark the date/time where this occurs.



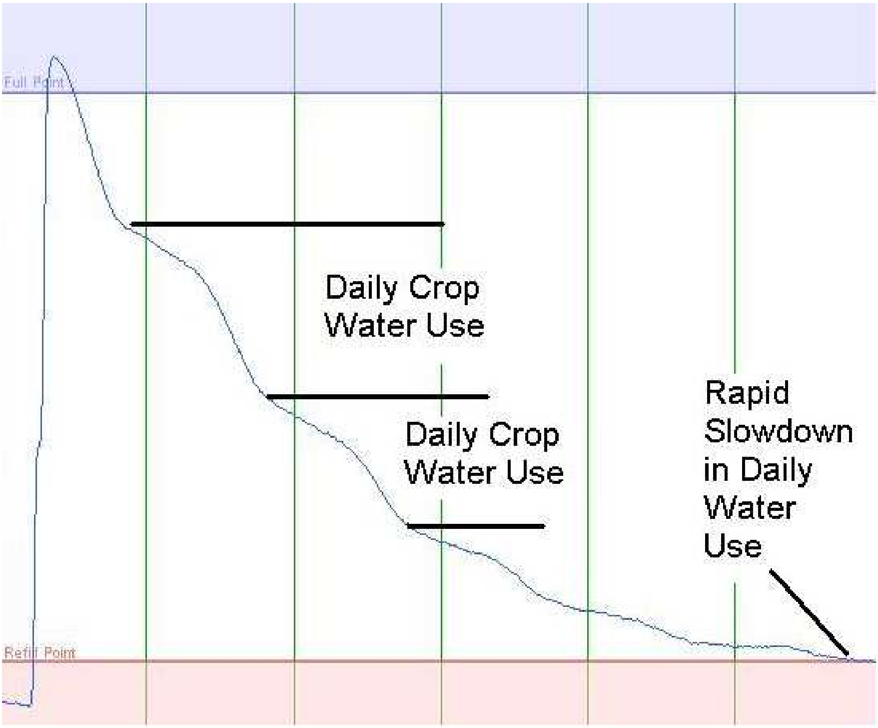
The next step is to create a graph which shows the sum of the soil moisture readings through the profile (or the average). If you have a sensor installed below the root zone, this drainage sensor would normally be excluded from the summed graph. A reference line would then be placed on the graph at the point in time identified in the previous step. This would be used as the Full Point.



The refill point is harder to define. In permanent crops, it pays to review a couple of months (or better still a seasons) worth of data. When the profile is full, the plants can easily obtain moisture. On the summed graph, if you look at the readings at 6:00 pm on successive days, you will see that the step change is fairly large (high daily water use). As water availability falls, so too does the daily crop water use (and hence the size of the steps. Initially the slowdown is fairly linear, then after a period of time, the curve flattens out quickly. The point where this flattening commences is the onset of stress. The refill point should be set at just above this level.

It pays to always err on the conservative side when beginning to use the system: start with a higher refill point and then fine tune it over time.

In annual crops, the task of setting full and refill points is made even harder, as there is no historic data to work from: decisions need to be made from the day of planting. This is why soil tension sensors (matric potential sensors) are much easier to use – the full and refill points can be set immediately in kPa, e.g. Full point -8 kPa, Refill point for permanent crops typ -60 kPa, for annual crops -20 to -30 kPa.



The best approach here is to initially apply a deep irrigation to fill the root zone (typically to 20 or 30cm), then use that information to establish a starting Full Point. While the plants are very small, irrigation should be applied in regular, small events, to keep the profile moist. As the plants grow and harden up, the time between irrigation can be extended. The first planting year will always be the hardest to manage. In subsequent years, information from the previous year can be used as the starting point for each new planting. The newer potted sensors are less susceptible to variation across installations than the larger access tube based units, making it easier to transfer readings from one sensor or one site to another.

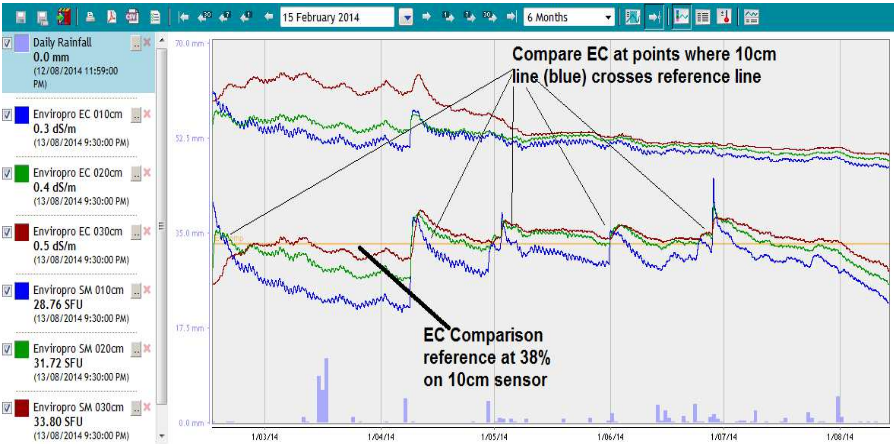
5.3 Soil Conductivity

The salinity sensor on capacitance probes respond to the total level of salt in the soil (the bulk conductivity). This changes as the soil moisture content of the soil changes, which is why users will see changes in indicated salinity as the irrigation is applied.

When interpreting the EC data, you must thus compare readings at points in time when the moisture content is the same. The simplest approach to take is that if for example you are looking at the 10cm EC and soil moisture, that you add a Threshold or horizontal marker at a set moisture level : this should normally be done at a steady point 12 hours or so after irrigation. You can then compare the EC readings each time the moisture is at that level.

In citrus, for instance, most of the active feeder roots are in the top 10 to 20cm of soil. So if looking from a nutrition viewpoint, this is the area of most interest. If instead, you were concerned about the accumulation of salt over time (through irrigating with salty water) you may be interested in looking further down in the root zone.

If the software that you are using to display the data supports this functionality, you should add display of daily rainfall and fertilization events – this may be through either automatically logged readings or through manual entry of readings. If you cannot add fertilization and rain events in the display software, you may need to export the data to a spreadsheet file and perform your analysis in that program.



15 February 2014

6 Months

☑ Daily Rainfall
0.0 mm
(12/08/2014 11:59:00 PM)

☑ Enviropro EC 010cm
0.3 dS/m
(13/08/2014 9:30:00 PM)

☑ Enviropro EC 020cm
0.4 dS/m
(13/08/2014 9:30:00 PM)

☑ Enviropro EC 030cm
0.5 dS/m
(13/08/2014 9:30:00 PM)

☑ Enviropro SM 010cm
28.76 SFU
(13/08/2014 9:30:00 PM)

☑ Enviropro SM 020cm
31.72 SFU
(13/08/2014 9:30:00 PM)

☑ Enviropro SM 030cm
33.80 SFU
(13/08/2014 9:30:00 PM)

Compare EC at points where 10cm line (blue) crosses reference line

EC Comparison reference at 38% on 10cm sensor

The above picture shows data from the 10, 20 and 30cm soil moisture and EC sensors for a 6 month period with the EC sensors at the top and soil moisture at the bottom. The 10cm values are blue, the 20cm green and the 30cm red. At the very bottom of the graph is the daily rainfall total.

A reference line has been inserted at a soil moisture value of 38% on the 10cm sensor. The EC values can then be compared at each time when the moisture equals this value – i.e. where the blue soil moisture line crosses the reference line.

This process can be made easier with some of the more sophisticated data evaluation programs: for instance by setting up a query to extract the EC values each time the soil moisture values are within say +/- 0.2% of the chosen reference; by then saving the results to a new table and then looking at the changes in EC over time.

5.4 Dryland Crops

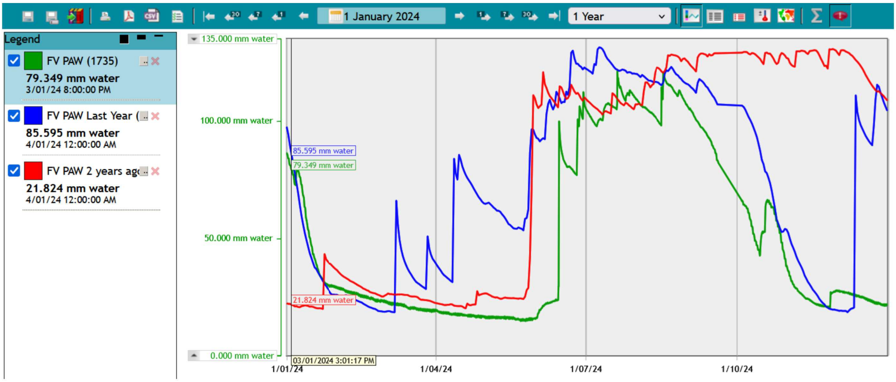
In dryland crops, growers can not control the timing or quantity of their most important input – rainfall. But, as has been proven over many years, soil moisture probes can provide information to assist with vital decision making.

5.4.1 Prior to Seeding

Traditionally growers of dryland broadacre crops would sew their crops when a particular date was reached (e.g. Anzac day) without giving much consideration to what the in field conditions were like. Delaying planting in the hope of rain carries a risk: the longer the seed is in the ground without water, the lower the likely yield. Today it is increasingly common to vary the planting date based on the prior and forecast conditions. If for instance a good rain band is building, farmers will rush out to dry seed prior to the rain's arrival. The window before the rain may however not be long enough to sew the complete area, leaving farmers to wait for the soil surface to dry out enough to move machinery around again – moving machines on wet soil creates un-necessary compaction, plus there is the risk of leaving machines bogged.

In this period, a soil moisture probe can give growers information to help tailor the decision on when to sew. In many winter rainfall areas, rain still falls at the end of summer. Good rains in February or March will not be used by plants and can infiltrate straight into the soil and be held.

A soil moisture probe can answer the vital question of whether there residual moisture in the ground. If so, at what depths is it present? If the probe shows moisture is available at 30cm, then any new rain just has to get the crop going until its roots can reach the stored moisture. If it has been very dry and there is no stored moisture, then the coming rains must feed the complete growth of the plants.



The image above shows a comparison of the plant available water (PAW) at a cropping site over 3 successive seasons. The green line is the current year, the blue line the previous year and the red, two years ago. Clearly the moisture at the start of the season shown in red was vastly less than that of the following years – 50 and 60mm less in fact.

But not only was the moisture pattern vastly different at the start of the season, it was also very different as the season progressed. The current year (green) was marked by a long dry run, whereas the previous year saw a lot of autumn rain, which gave the crop a massive head start.

The end of the graph also tells a very different story: this year the season ended with a bone dry profile, whereas two years ago, it was almost full. That means that decisions on when to plant the next season’s crop were completely different: two years ago, you could plant as soon as a couple of mm of rain were received, but in the current season, growers would be advised to wait for a significant rain event.

5.4.2 Mid Season Decisions

Another critical time occurs mid season, particularly in crops which receive two fertiliser applications. The first is post planting and the second mid season. But what to do if there is no rain and no prospect of rain? Do you abandon the crop and cut it for sileage or apply the fertiliser and hope like hell? Once again a soil moisture probe can help. Referring back to the earlier graph, if you had to make a decision on what to do in the current (green) season in August, you would have been able to see that there was still plenty of moisture left in the profile, so the second fertiliser application would have been worthwhile – giving a good boost to yield.

References

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