Does the Geometry of Soil Moisture Probes Affect Their Accuracy?

The CropX probe most accurately reflects actual soil moisture content

Background

Preferential flow refers to non-uniform flow of water through soil, where water moves through preferred pathways in soil, bypassing most of the soil.

This phenomenon can bias the measurements of soil moisture sensors and is well documented in the literature. The extent the of interruption depends on the geometry of the sensor and method of installation.

Tube-shaped probes are inserted directly into a drilled hole, or with an addition of slurry of a mixed soil. The disturbed soil around the probe creates preferential flow pathways along the probe and allows water to flow along it. Therefore, sensor readings will not accurately represent the actual soil moisture in the undisturbed soil but will rather represent a biased soil moisture value. When water flows through the preferential flow paths along the probe, sensors along the probe may detect an increase in water content while, in fact, water did not reach that same depth of the soil or will reach the same depth at a later time.

Such biased readings might significantly affect irrigation management decisions and results in inefficient irrigation.

CropX has developed a unique, patent-pending, probe design that eliminates the negative effect of preferential flow on the accuracy of soil moisture sensors.

The CropX Probe

CropX developed a revolutionary soil profile moisture probe with patented spiral geometry that allows fast and easy installation, spatial accuracy and unbiased results due to the prevention of preferential water flow around the probe. ADR moisture sensors are located on a wing-like spiral, connected to the main tube body. The probe is screwed into a narrow-drilled hole and so the spirals (carrying the sensing electrodes) cut into a relatively undisturbed soil, not affected by preferential flow pathways created by the drill and the tube.

Studies show that the CropX probe is superior to other commercially available probes

The objective of our studies was to examine the effect of the probe geometry on water flow around the sensors and the corresponding readings. The assumption is that the unique geometry of the CropX sensors minimizes preferential flow effect and, therefore, results in readings that precisely represent the actual moisture in the soil.

Our studies show that the CropX spiral sensor is superior to other commercially available sensors in representing soil moisture in undisturbed soil, where the plants absorb water from. We performed three sets of experiments in order to test the effect of probe geometry on sensor readings:

- Computer simulations comparing different commercial probes and their geometry.
- Comparing CropX probes with spirals to CropX probes without spirals.
- Comparing probes with spirals to tensiometers.

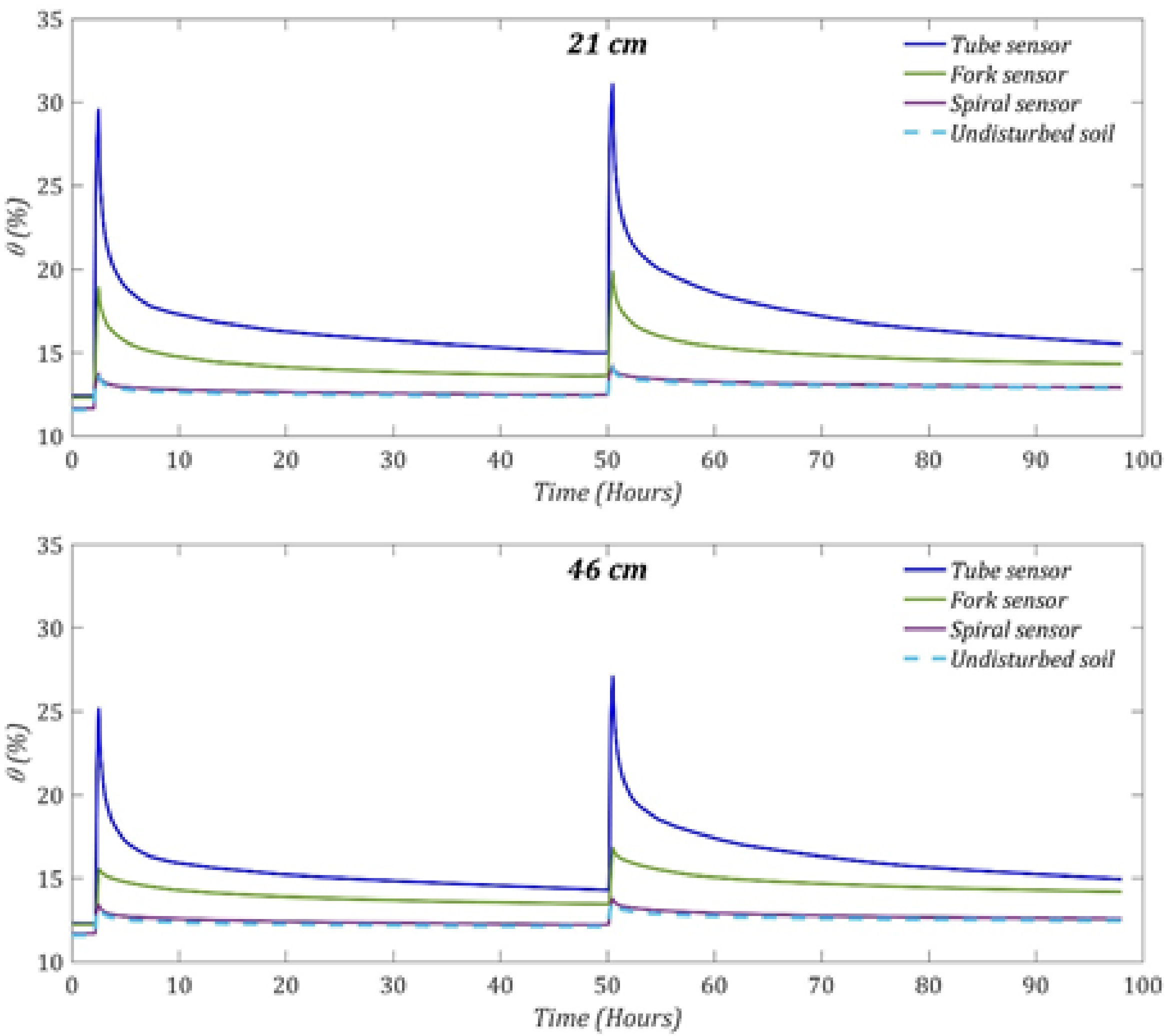
Results of the field trials we conducted support the computer simulations.

Computer Simulations

Water flow in the soil and around the sensors was simulated by the Hydrus 3D software. The simulations were performed using different soil textures: loamy soil, silty loam, sandy loam and 2 types of silty clay loam.

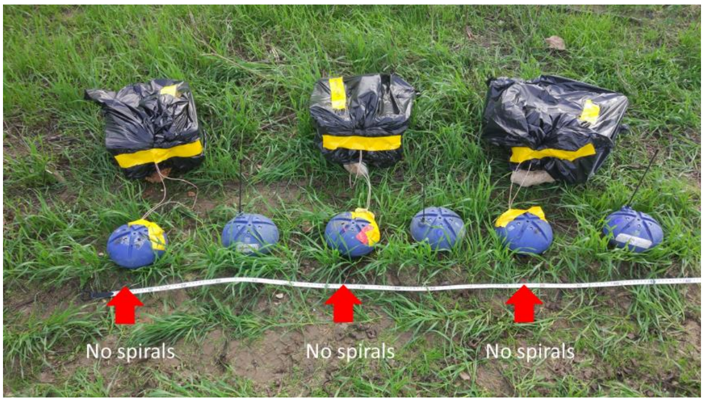
Overall, 20 different simulation have been performed in every soil type giving a total of 100 simulations. The evaluation of soil moisture in the undisturbed soil was made by setting observation points far from the sensor at the same depth.

Moisture readings of the CropX spiral sensors at both the 21cm and 46cm depths agreed closely with the undisturbed soil moisture following an irrigation. The tube and fork type sensors exhibit a much higher "spike" in moisture readings immediately following an irrigation compared to undisturbed soil.

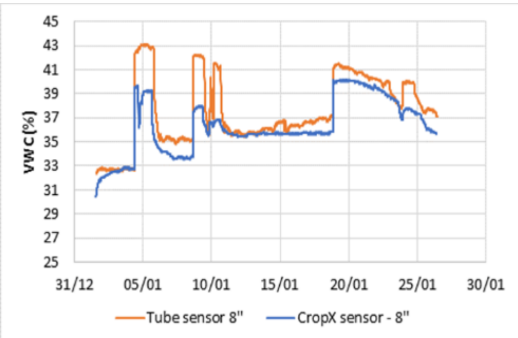


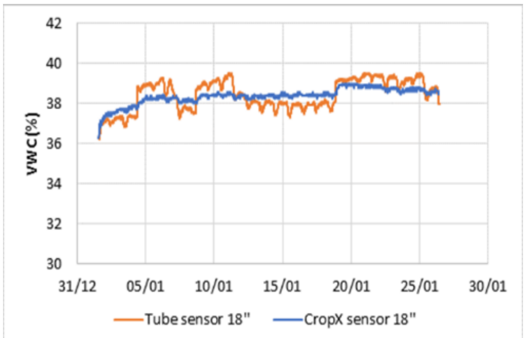
Field Trial - CropX probes with spirals vs. probes without spirals

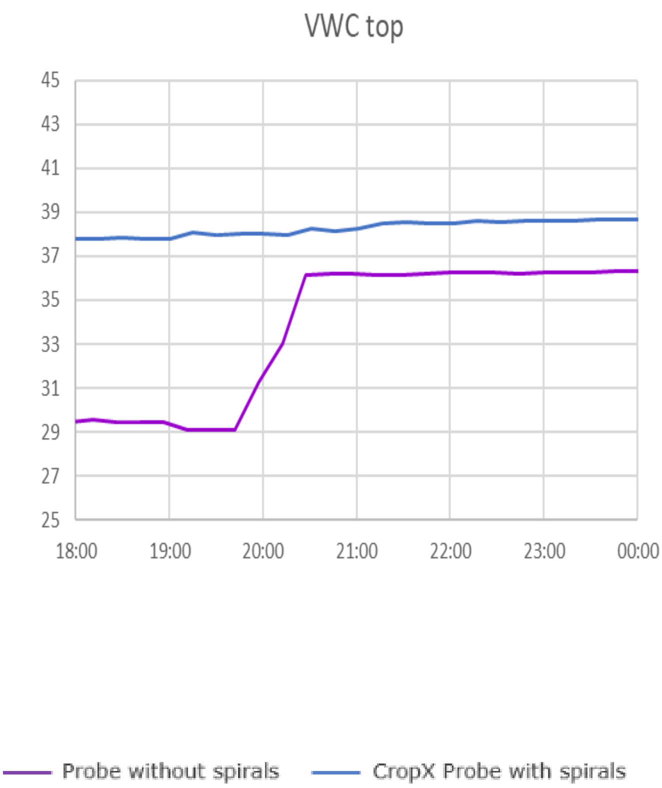
We manufactured 'tube-shaped' probes that do not have the typical spirals design. CropX sensors (electrodes) were installed directly on the probe. This enabled us to evaluate the effect of the probe design, while using the same sensor technology. 'Tube-shaped' probes were installed in different soil types, just next to probes with the original design that includes the spirals.



Probes without the spirals showed a more significant water movement and responded significantly earlier (45-75 minutes) than probes with spirals. Absolute reading of sensors on spirals are higher due to higher soil density in the undisturbed soil.





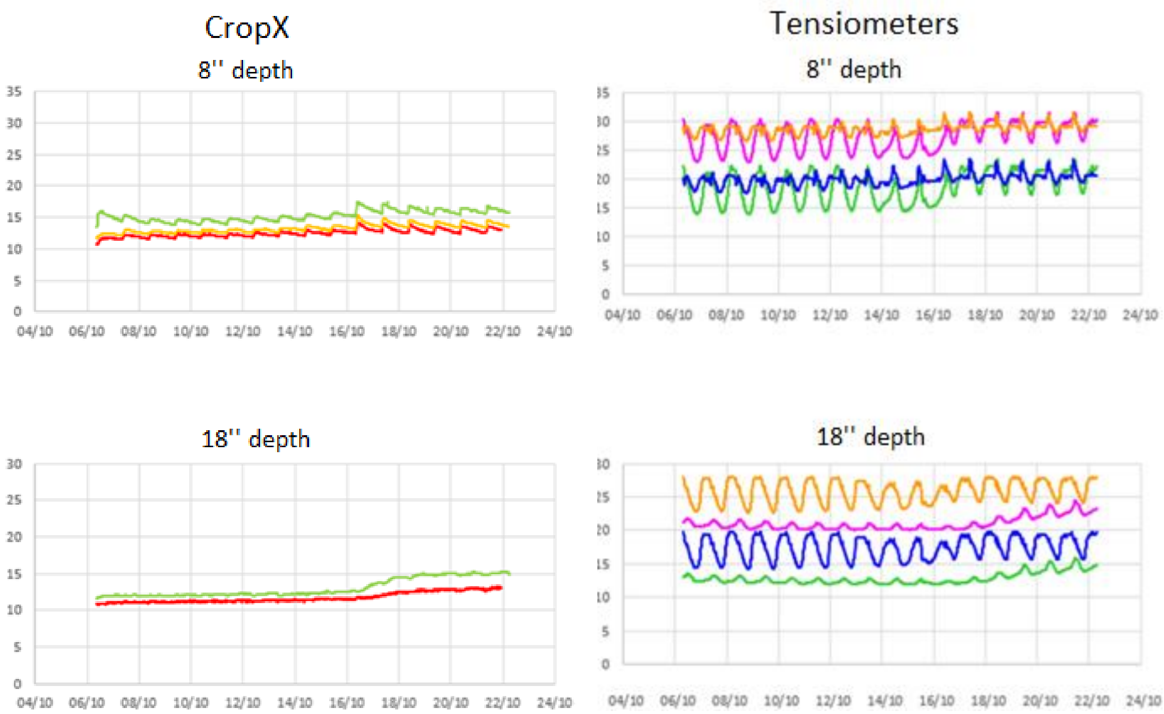


* Tube sensor = CropX probe without spirals

Probes with spirals vs. tensiometers

A trial was conducted in various drip-irrigated crops in Southern Israel. CropX sensor readings were compared to readings of tensiometers.

Volatility of the readings and spike height were much larger in the tensiometers, compared to CropX sensors.



> The larger spikes in the tensiometer graphs are a result of preferential flow along the tensiometer tube. This shows that the unique geometry of the CropX probes minimize result in readings that better reflect the actual soil moisture.

Summary

Preferential flow of water in soil is a well-known phenomenon. When installing soil moisture probes, it is impossible to avoid disturbing soil structure around the probe. As a result, preferential flow paths are formed in the immediate surrounding of probe. The increased water flow around the sensors may bias their readings and, therefore, the irrigation management decisions.

Our studies show that probe geometry may significantly affect the accuracy of the soil moisture sensors. Probes with a geometry that that minimally disturb soil structure, such as the spiral design of CropX probes, are found to be superior to other commercially available probes and provide more accurate readings that closely represent the moisture content of the soil.

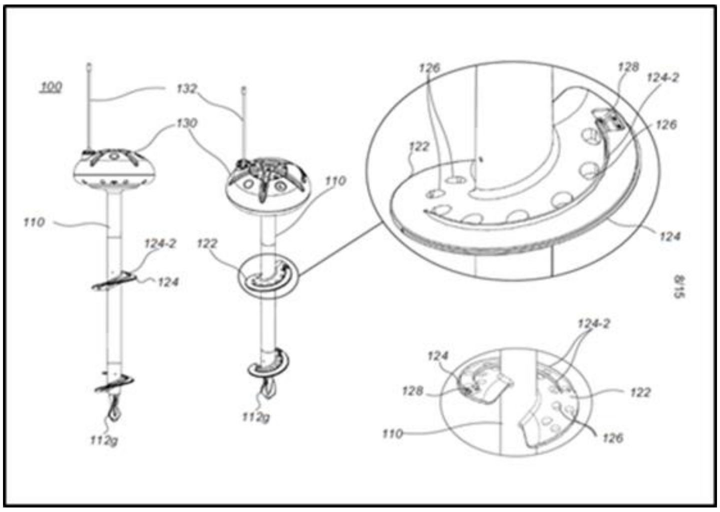
Appendix – Preferential flow and what CropX does to prevent it

True soil sensing means accurately measuring natural water flow through soil. However, Installation of all commercial soil sensors has been scientifically proven in many published papers to disturb the natural soil structure and affect water flow. In 1997 Rothe et al. published a paper in a leading soil science journal, suggesting that water content measurement is “highly sensitive to installation effects”.

This disturbance causes water to flow along these sensors, painting an inaccurate picture of the actual water resources available to the plants in the soil, suggesting the soil is wetter than it truly is. The biased readings may lead to ill-advised irrigation decisions, typically resulting in under-irrigated fields and loss of yield. When integrating such inaccurate data into big-data systems, the output would be distorted, and essentially, meaningless.

To solve this problem, CropX have developed a revolutionary soil sensor with a patented spiral geometry that allows a fast and easy installation, unprecedented accuracy and unbiased results due to the prevention of water flow around the sensor.

How does it work? CropX’s sensor is screwed into a narrow-drilled hole such that the spirals that are carrying the sensing electrodes cut into undisturbed soil. These unique spirals stop water from flowing along the tube and divert them back to the undisturbed soil through specially designed holes.



More on this preferential flow:

Cornell University Dept. of Environmetal Engineering - Preferential Flow

Walker et al. - In situ measurement of soil moisture: a comparison of techniques - Journal of Hydrology, 2004

Kogelbauer et al. 2015 - Preferential percolation quantified by large water content sensors with artifactual macroporous envelopes

Rahav et al. 2017 - Induced heterogeneity of soil water content and chemical properties