AquaSpy®

Technology & Reporting Overview

Contents

What We Measure

AquaSpy uses an innovative layer by layer vertical approach to measuring soil moisture, salinity, temperature, as well as root zone activity.

What separates the AquaSpy probe from the others?

Most growers and researchers ask if we have volumetric water measure which is a horizontal way of measuring the amount of water in the soil. Instead, AquaSpy uses a vertical, layer by layer approach to understanding the available moisture and how well the crop is consuming it, meaning we give growers more than just a simple look at moisture in the soil. We also give them insights into how well the crop is consuming that available moisture at each layer and if it's ready for more. We can actually see where the active root zone is and what's happening there.

AgSpy Crop Intelligence Software

AgSpy intelligent software and proprietary algorithms turn AquaSpy probe signals from each layer of soil into actionable metrics and graphs. AquaSpy probe sensors independently send out electrical signals every few minutes to all 12 layers of soil. These are transmitted hourly to the Cloud where crop-specific AgSpy intelligent algorithms turn those multiple signals into actionable metrics and graphs. Our proprietary YES! Score tells the grower how well their plants are responding to crop management.

Does AquaSpy measure volumetric soil water content (VWC)?

No. We have developed a simple, hands-free layer by layer approach to understanding how much moisture a crop needs at each stage of the growing season.

How do researchers measure volumetric soil water content (VWC)?

Fundamentally, measuring soil moisture in inches / mm cannot be done in any reliable, convenient way. To calculate VWC effectively you would need to collect multiple soil samples from the field about the size of a coffee cup, weigh that soil, then dry it in an oven for several days (1 – 3). You would first calculate the gravimetric content by subtracting the weight of the original sample from the weight of the dried one and divide that result by the weight of the dry sample. Once you have that number you need to adjust it according to the density of your soil. Of course, in real life, that's a very time and labor consuming way to figure out what's going on in the field, and in essence you'd only be measuring just the top layer or two of soil, when in practice, knowing what's happening at the active root zone would be more useful.

How does AquaSpy measure soil moisture?

AquaSpy uses a vertical approach to assessing soil moisture by sending signals out at 4" (12cm) depth intervals in the root zone. The applied technology in the probe is RF Spectroscopy. Essentially, it functions as a complex permittivity sensor. We send out a signal into the soil and we are looking at the reflected signal. We can discern the phase and amplitude which in turn is an expression for the moisture and electrical conductivity. We also have a temperature sensor with each of the 12 sensors.

Measuring permittivity rather than volumetric water amounts allows us to give a view deeper into the soil and deliver that information to the grower in just a matter of minutes, without the grower having to visit the field or do any programming. Our sensors continuously gather data layer by layer, and then we apply intelligent algorithms that process all of that data and deliver it via the Cloud right to a desktop or

mobile device in understandable charts that tells exactly what's happening in the soil and plant roots hour by hour.

What is permittivity?

Permittivity is the ability of a substance to store electrical energy in an electric field. Air, water, and soil all have different permittivity.

Think of a capacitor that stores energy in an electric field. There are the two conductors (plates) and there's an insulator in between them which is a non-metallic substance. We are measuring the air, water and soil. The permittivity of air = 1 (very low), water = 81 (very high), dry sand = about 7, clay = about 20 to 25. We look at these changes layer by layer so we have an understanding of what's happening in the active root zone and also below it since our probes have multiple sensors spaced 4 inch (12 cm) apart.

How does AquaSpy measure using permittivity?

We are measuring how effectively we can transmit a signal and what's interfering with it, that is, the water / moisture content. The amount of water will impact the shift of the signal.

The reflected signal is dampened by soil and it is phase shifted a few degrees. We can separate those two, so we can also see the electrical conductivity (EC) component which informs us about the salinity of the soil.

The measurement is affected by three variables: moisture, soil type and temperature. The largest component is moisture. Some manufacturers will ask the grower to input the soil type in an attempt to calibrate the soil variable out of the equation. The problem with this approach is that there is not a consistent soil profile all the way through the layers of soil.

We have adopted a different approach where we are using the combined moisture value as a **relative value**. We automatically look for drainage after irrigations and establish a **field capacity for each layer** (we call that 100). Based on that field capacity, we use an extensive crop specific statistical method to estimate the "empty" point (we call that 0). In this case it is not truly empty, but the plant's daily consumption has reduced to about 50%. Now we have the operating range of each sensor and we can report that to the grower.

Does the grower need to calibrate the probe?

We calibrate the probe in the factory and due to our method, you will not need to calibrate in-situ. We also provide pre-calibrated crop templates so all you need to do is select crop date and plant date.

Why is a Slurry needed in the install?

For our longer probes, we recommend you use a slurry when you insert the probe into the field. Now that you better understand the permittivity of air versus soil or water, it's easy to understand that you want to ensure there are no air pockets around the probe.

What is Full Point or Field Capacity?

Consider the top 4" layer on its own. That **layer** is at field capacity (or "full point") when this occurs:

- Sufficient water has been applied to cause the layer to release water to the layer below.
- Once the water application has stopped and the 4" layer stops draining to the layer below, the layer has reached field capacity.

Field capacity is calculated for **each layer** and we calculate if the irrigation reaches to the layer below.

The general term that a field is at “field capacity” is fairly misleading. Does it mean that the soil is at capacity all the way to the ground water table, 2 feet, in the active root zone or just the top 8 inches? That is why we have chosen to look at this in the active root zone where it matters to the plant.

Summary Chart

Each crop has its own unique growing patterns and input needs throughout the season. We’ve studied how crops like to be treated during the season.

Because AquaSpy measures layer by layer and continually learns throughout the season, we’ve been able to develop specific crop templates that mean you, the grower or agronomist don’t have to do any manual programming or adjusting. Just pick the crop type from the menu upon install and the crop-specific green band will guide you throughout the season. Stay inside the green band of the summary chart for the optimum crop health and yield.

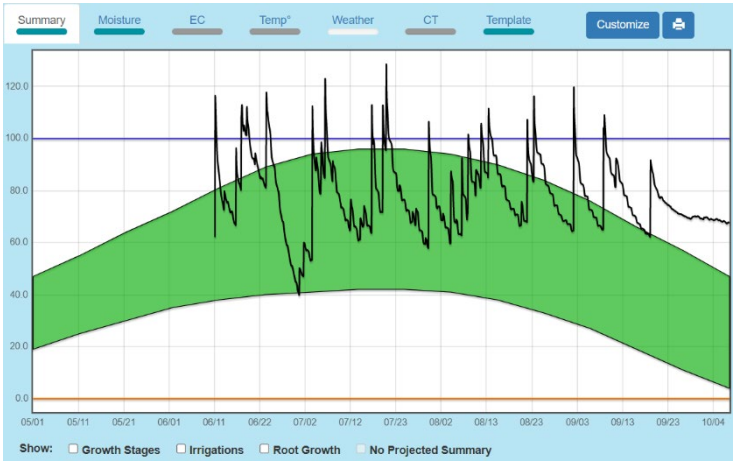
Full and Refill Points:

Blue: Upper Control Limit = Full Point 100%

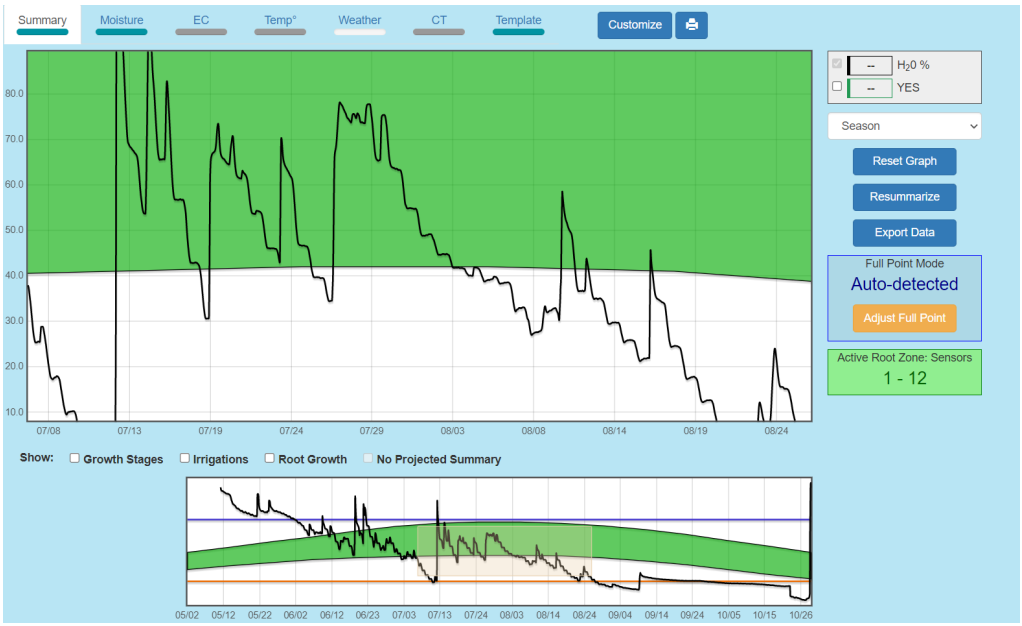
Black lines = Average Output

Green Band: Optimum Performance Range

Orange: Lower Control Limit = Refill Point 0%

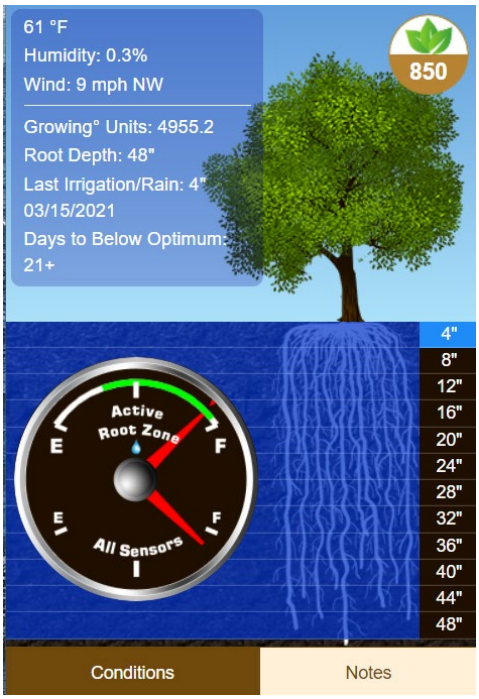


You can zoom into any area on the chart by highlighting and selecting it. Reset with the button on the right.



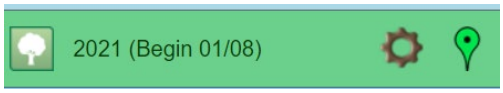
What is the Fuel Gauge?

The Fuel Gauge on the left side of the screen gives you a snapshot of the environment at this moment. You will see a crop image, growing units, root depth, last irrigation date, how full is the active root zone, how many sensors are active, and a projection for the number of days before the line hits the refill line. The blue highlight shows the depth of the latest irrigation was detected. The top section shows the local



weather. The notes tab shows the events logged for the sites. You can adjust these or add notes here that might be helpful to load later.

In the upper section, pin color tells you that status of the field.



Green: You are in the Optimum (Green) band

Blue: You are above the full point

Yellow: Caution, the soil moisture is between optimum band and refill

Red: Time to irrigate, moisture is at the refill point

YES! Score

The YES! Score in the upper right of the fuel gauge ranges from 350 – 850 and tells you how well you are staying in the green band. Grower validated yield data shows that there is a strong correlation between a high YES! Score and optimum yield.

Moisture Chart

The moisture value you see in the moisture tab is not an absolute moisture value. Rather it's a compound value comprising of two parts – actual moisture plus a value based on the soil. The probe measures permittivity in the soil and the permittivity is affected by both moisture and soil. However, the soil component is largely constant where the moisture component is changing. If we knew the actual soil value we could subtract the soil component, but we don't. The probe is calibrated so a value of 0 is reported then the probe is in air and a value of 100 is reported when exposed to an infinite amount of water. This means that a sensor exposed to wet sand very well can report the same number as a sensor exposed to semi-dry clay. Therefore, we need a different way to look at the numbers.

Instead, we look for the moving part. From that we can find when the moisture level has reached field capacity (we call that 100% or full) and from that value we statically estimate the point where the crop consumption has reached half of maximum (we call that 0% or empty).

Now for each sensor we have a fairly accurate estimate how "full" this level it. We also know how deep the roots are. We could not just average all of those values and present that to you. However, crops behave in different ways. Some crops are very poor at utilizing water at 1m other will happily do so. Therefore, we have developed a crop layer specific water value that assigns a value of water at different layers. Those values are then added together in the "Summary" value.

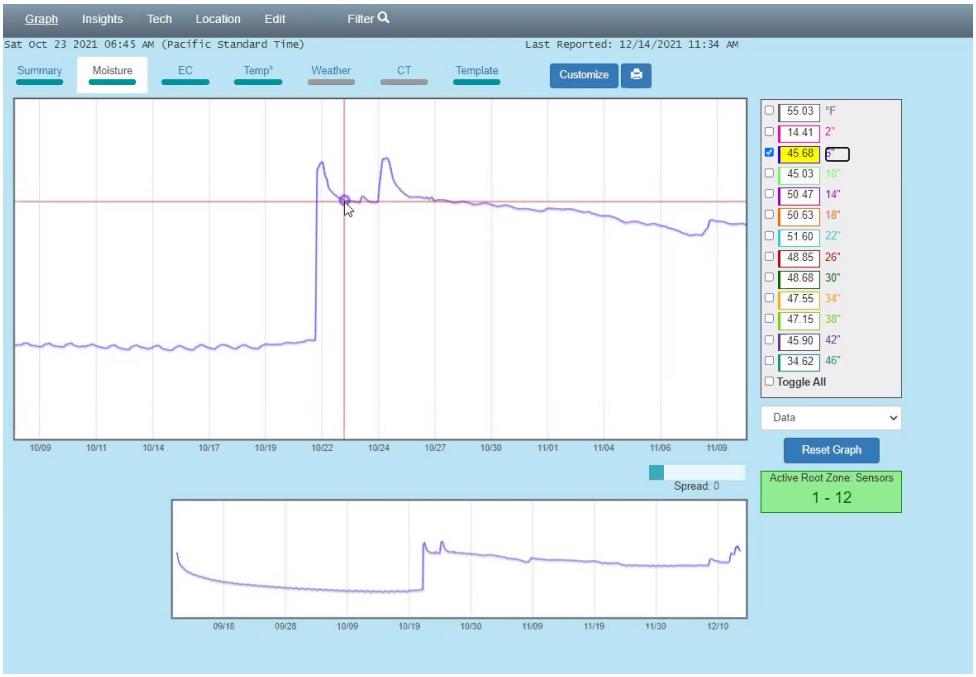
That is why you have a hard time correlating the data you see in the moisture graphs with the value you see in the summary graph. There is a lot of data processing happening in the background.

You can use the data from the field health report if you are just looking for one daily value – a snapshot in time. But if you are looking for trends over time, the graph is better.

However, do keep in mind that for the summary graph, a value of 100% means that the active root zone is at field capacity, 0% means that we estimate that the active root zone is only consuming 50% of the moisture it would have consumed if the field was at field capacity.

You can see the moisture level at each sensor level. Toggle the selector to the right to see each layer. In this example, the first “bump” was moisture above the full point. What we are looking for is the true fill point.

Select 6”. Spike is rain or irrigation. Moisture level increased. Hover over the graph to see the reflected fill at that level on the right side bar (remember this is a relative number on a scale of 1 to 100, rather than inches).

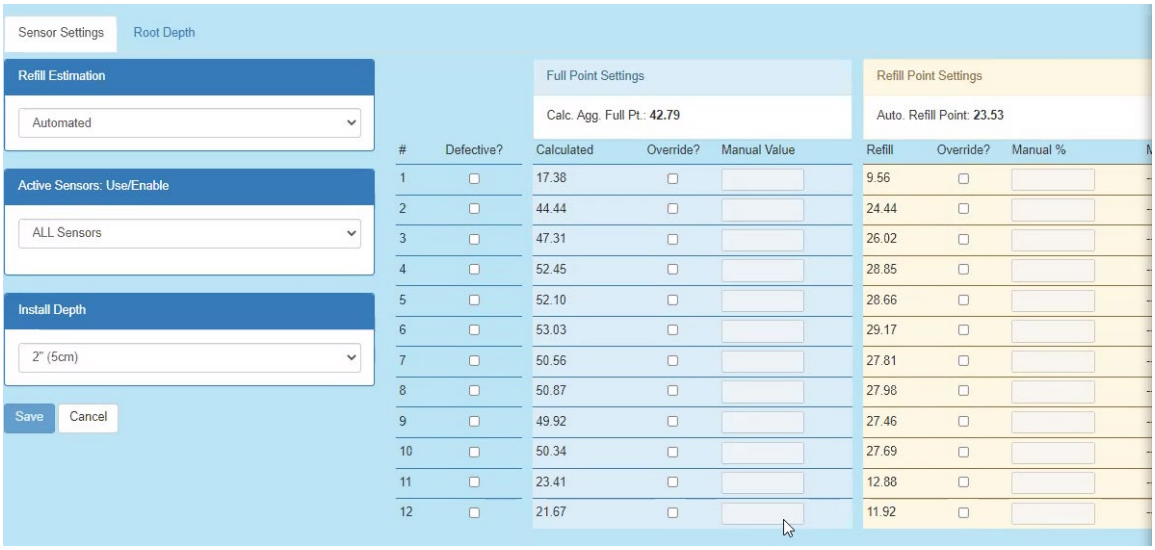


TIP: you can click and zoom in on any section of the chart. Click Reset Graph on the back to go back to regular view.

It is like a pasta strainer. You fill it then it starts to drain.

We can confirm this by turning on the next toggle and seeing that water came to the blue layer but not to the green layer so it was not a fill.

Go to the Tech Tab and see 47.31 full point at that peak. The calculated refill 26.02.



If the fill point is 44, the refill is 24 (about half). We do this for each sensor and that's what makes the green band. It answers, how well is the plant pulling moisture from the ground? Corn is lazy and doesn't do it very well. Almonds are good.

Water at the top has more value than water from down at the bottom.

So when researchers want "inches of water available" that's ignoring how valuable it is at a specific layer.

What's the refill point when you reach 50% consumption?

Tip: Stepping is the consumption by the roots.

The calibrating of the probe, does it matter?

No. Not at all. Notice we don't have numbers on the left side of the graph. This is a dynamic range. Could be 20, 40, 80, it doesn't matter.

Measuring EC

We measure Bulk EC. Bulk EC is the total amount of EC in the soil including dissolved in the solution and solid particles. Contributors are Ions of any sort, salt, fertilizer, etc. It is modified by moisture and temperature. The higher the temp, the higher the perceived electrical.

There is an organic component that's influenced by temperature and season. The ionic activity is slow in the winter and spring when it is cold. Also rain has pushed the salt down. Organic matter is dormant.

We use this for determining "bad EC", that is, when there is a yellow line or band and it is above the recommended line, the salinity is unacceptable for that crop type's health. You can click on EC to the right and see that value.

Summary EC value – for value in the active root zone, EC is more for the detrimental influence to the plant at the top level.

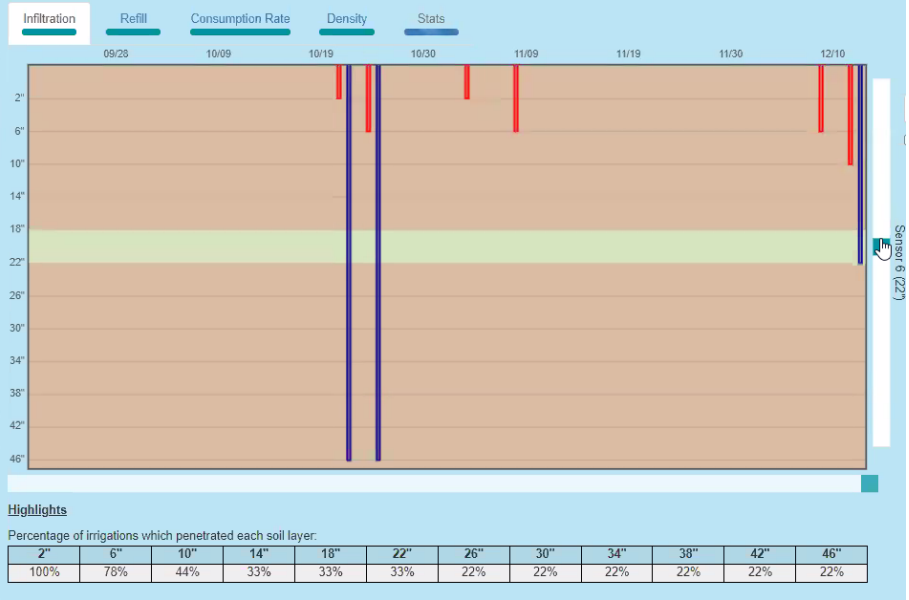
Insights Reports

INFILTRATION

The bar graph displays how deep your irrigations have penetrated over the course of the season. Each irrigation detected by the system is indicated by a vertical blue bar.

By moving the slider on the right side of the graph, you can set a target depth to see how many irrigations reached that depth.

Assume you have a target and you can see how deep an irrigation has hit that target. Select your sensor level by moving the slider on the right. Here we are looking at sensor #6 and can see 3 irrigations reached this level or below (blue bars) this but 6 did not (red bars).



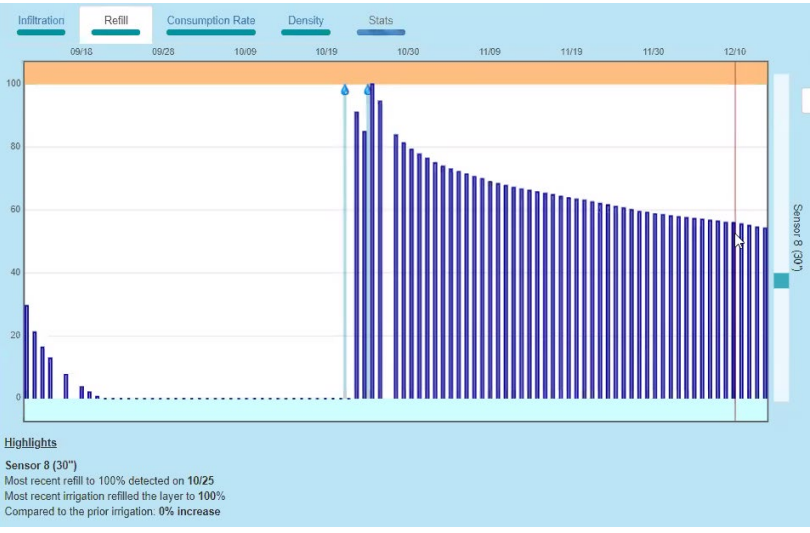
The table at the bottom illustrates the percentage of irrigations penetrating to each sensor depth.

In this case, 33% reached the 22” level.

REFILL

Use this graph to evaluate, layer by layer, how effectively moisture is replenished during irrigations. When you have an irrigation, did it fill to the profile? Use the slider on the right side to select each of the layers. A value of 100 indicates that the layer was refilled to field capacity (full point); a value of 0 indicates that the layer was depleted to our estimated refill point.

Here we are looking at sensor #8. The droplet icons shows when irrigation occurred. Up until the 25th none of the irrigations refilled all the way (100%) to this depth.



CONSUMPTION

The consumption rate is an indication of how much water the crop is using over the season.

A value of 100 corresponds to the maximum consumption in this particular field **to date**; a value of 0 corresponds to zero consumption. (Because of graph smoothing, you will rarely see a consumption of 100%.)

The main graph displays the summary consumption in the Active Root Zone. By selecting an area of this graph with your mouse, you can calculate an average consumption rate over that period. Use this feature to compare different fields over the same time period.

At the top right, you can select either the **Summary** or **Sensors** view. Start with the sensor view. The Sensors view allows you to examine the individual sensor consumption rate. The values on the far right indicate how much consumption was detected for each layer compared to the highest consuming layer. The highest consuming layer is set to 100%; the other values are relative to that.

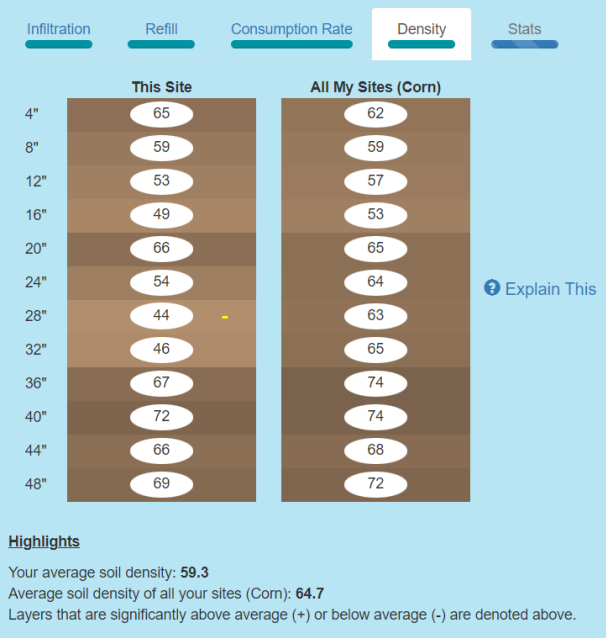
Plant consumed more when we had the irrigation (10/25). The question to ask yourself, is, was this the right timing for high consumption (such as for corn, during tasseling). The only time the lower depths show consumption is right around that big irrigation. It might be that you want to do another deep irrigation at another critical growth stage for that crop.

Next, select Summary and a range of days to see average consumption for that period. Mark an area and you can see the consumption – so you can mark this in the fruiting time, and determine, did I achieve what I wanted? The blue line shows us the average for the marked period. For example with corn, I want the most consumption when there is tasseling.

DENSITY

The density chart compares fill point to your other sites. What's the average field capacity? There are higher numbers in clay. This chart displays the estimated soil density for the current site – layer by layer, and for all your other sites of the same crop type. The soil density value is estimated based on the calculated field capacity for a given layer; use it as a guideline for how much water that layer can hold.

A higher value indicates denser soil with a greater water holding capacity. Watch for low values or values that otherwise seem out of the ordinary; this could indicate a problem with the probe installation, or a poor probe location due to greatly varying soil composition. Sensors with higher or lower than average values are highlighted.



STATS

This table summarizes the key metrics for this site, provides comparison metrics against all of your other sites of the same crop type, as well as other AgSpy sites of the same crop type.

- Days to Root Detection: indicates the number of days elapsed from planting until the system detected root activity at a given depth.
- Average Consumption Rate: the average over all days where consumption was detected.
- % of Days with Consumption Rate Below 50%: the percentage of days out of total days since planting where the consumption rate was below 50%; this indicates that moisture in that layer is depleting.
- # of Irrigations Detected is a simple count of the number irrigations which have been detected in any particular layer.

Weather Tab

NEW water pressure sensors in the weather tab (if you have the weather and water pressure attachments, optional).

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