Choosing a Wireless Field Monitoring System

Six Important Considerations

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Introduction

Commercial growers are increasingly using in-field monitoring technologies to collect localized weather data for driving operational decisions. Likewise, researchers studying agriculture, climate, and ecological systems are increasingly looking for monitoring solutions to collect high-resolution environmental data over an area. With the introduction of wireless field monitoring systems, both growers and researchers can now more effectively and economically monitor highly-localized environmental conditions, as compared to traditional weather stations or stand-alone data loggers. Insights gleaned from localized data are vital for better crop and greenhouse management, and environmental research.

Overview of Wireless Field Monitoring Systems

While weather stations typically include a data logger with wired connected sensors mounted to a metal tripod, wireless field monitoring systems expand upon those station capabilities to include wireless sensors that are deployed over a spatial area. As a result, wireless sensor networks provide continuous monitoring of field conditions over a much wider coverage area than that of a stand-alone monitoring solution. Data is transmitted wirelessly from the network of sensors in the field to a central data gateway or station, and then to the web, eliminating the need to run cables that could interfere with crop operations.

Advantages of Wireless Field Monitoring Systems

Many high-value crops are sensitive to microclimate variations such as temperature, rainfall, and soil moisture, which directly affect quality and profitability. Growers of these types of crops can benefit from a wireless field monitoring solution that covers the critical areas in their fields, enabling them to be proactive and extra diligent in mitigating risks associated with insufficient water, excess heat, mildew, mold, and frost, which can impact their yields.

For researchers, wireless field monitoring systems that provide more comprehensive data can be beneficial for gaining more insights and more definitive conclusions.

Due to cost and practical limitations, growers who use weather stations typically only have one or two units deployed in their fields, limiting their monitoring range to those one or two spots. This is sufficient where field conditions are uniform, but in settings where conditions are variable, the ability to monitor a greater number of points throughout the growing area enables better-informed decisions that more accurately reflect the diversity of the environment. Wireless sensor networks allow growers to not only monitor multiple locations in their fields, but also to do it cost-effectively, because they can funnel data through a single web-enabled station.

Monitor a wide area with a wireless field monitoring system.

With wired stand-alone data loggers, growers can also monitor many points in their fields. However, stand-alone loggers require the grower to manually download data, eliminating the ability to make decisions in real time, such as with frost alarms. Wireless sensors—which can be now obtained at costs similar to data loggers—enable growers to receive data through the web and conduct near real-time monitoring, without having to visit the field.

Addressing Commercial Agricultural Challenges

To increase the efficiency of agricultural operations and stay competitive, growers face pressure to minimize input costs and maximize yield. At the same time, water and pesticides—two of the highest input costs—are under greater scrutiny as governments and consumers place higher priority on sustainability. Field monitoring systems can go a long way to helping address these and other challenges.

Protecting Against Climate Hazards

In many areas, growers must manage against climate hazard risks such as frost and dry soils, which can impact yields. Frost is an especially serious concern that can potentially cause partial or total loss of crops.

Hills, valleys, and other variations in topography—which affect the amount of sun, shade, and wind exposure—can produce diverse microclimates across an agricultural landscape and greatly influence if and where frost will occur. For example, low points in a valley—where cold air will settle—create conditions that are more prone to frost formation. Valleys also tend to shelter against stronger winds, which is another factor that increases the risk of frost. Similarly, soil moisture can vary dramatically based on topology, soil types, and irrigation system variation.

Look for a system that allows you to visualize conditions across diverse microclimates.

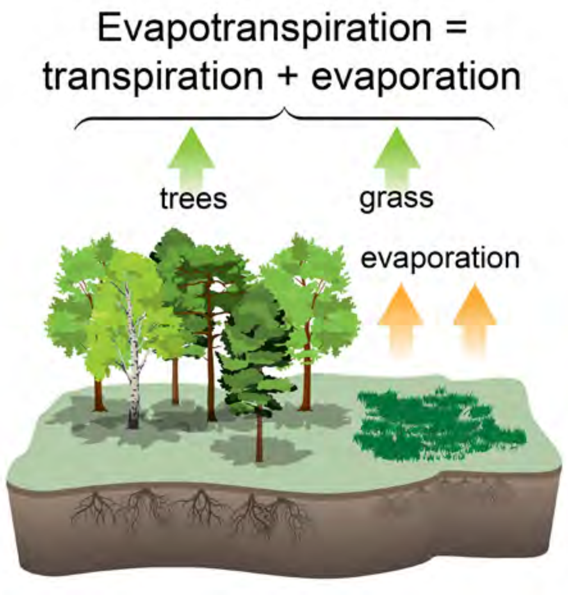
These combined factors drive the need to monitor multiple locations to safeguard crops against both frost and dry soils. Wireless sensor networks, which monitor conditions across multiple points in agricultural fields, including areas where climate hazard risks are higher, can inform growers in real time where attention may be needed.

Reducing Water Use

Globally, water scarcity is a growing concern. With agriculture accounting for over 70 percent of freshwater use in most regions of the world and approximately 80 percent in the United States, growers face increasing social and regulatory pressure to incorporate more efficient water-management practices.

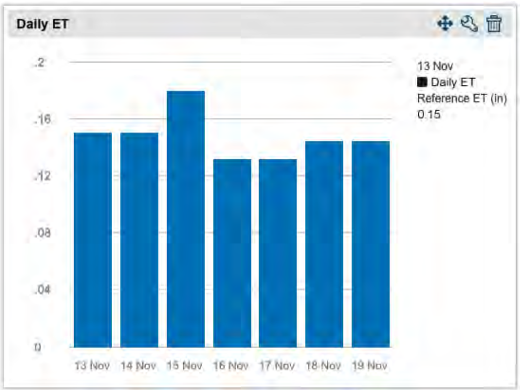
Another driver for minimizing water usage is the rising cost of water, including the energy costs associated with conveyance. However, growers can't risk cutting water use to a level that will impact their yields. That's why it's increasingly important for growers to optimize their irrigation methods.

Wireless sensor networks deployed across an agricultural operation can measure soil moisture to determine where irrigation should be applied and how much water should be used. By irrigating only the areas that need water, growers can cut usage and reduce operational costs without sacrificing crop yields.



Growers can also reduce their water use by using evapotranspiration (ET) to manage irrigation. Some wireless field monitoring systems provide reference ET, which can be multiplied by crop coefficients to determine crop water use. Growers only need to irrigate as needed to make up the difference between the rainfall received and the water used by crops.

Minimizing Pesticide and Fungicide Use



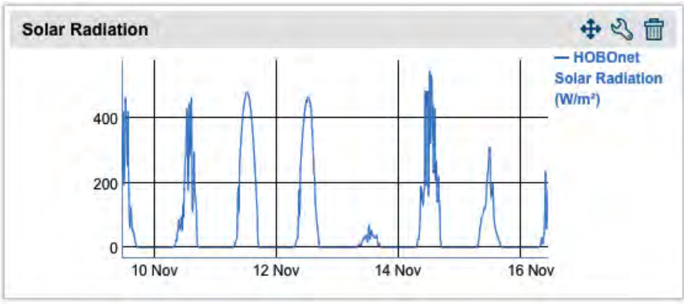
Pesticide and fungicide use represent one of the highest operational costs for growers. Applications can run as high as $100/acre per application, with some crops requiring multiple applications to prevent crop loss due to hazards such as mildew, mold, or insects.

The risk of disease and pests is a function of exposure to environmental factors such as temperature, humidity, and leaf wetness. By monitoring these conditions over time, growers can assess the probability of disease or pest emergence occurring in their crops and use these estimates to help optimize their treatment applications—employing pesticides and fungicides only as needed to prevent outbreaks.

By using pesticides and fungicides only as needed to prevent outbreaks, growers may be able to eliminate one or two applications per growing season, resulting in substantial savings. By eliminating just one spraying per season, a typical 100-acre vineyard could save up to $10,000. Moreover, by reducing spraying applications, growers will also be decreasing the amount of pesticides and fungicides that get released into the air and soil, allowing for improvements from a sustainability perspective.

Improving Harvest Timing and Crop Quality

The timing of a harvest is often critical to attaining the highest potential in crop quality. For vineyards in Portugal, as an example, the timing of grape harvests can make the difference in how the wine is rated, which in turn can dramatically influence the per-bottle-price that consumers are willing to pay. Portuguese vineyards are known to time their harvests based on the sugar content, pH, and feel of the grapes, in addition to the color of the leaves and climate conditions during ripening. For instance, rain before a harvest is not favorable as moisture dilutes the sugar content, causing flavor loss. But while rain and temperature are the biggest drivers in harvest timing, solar radiation can also impact how the grapes ripen.



Solar radiation graph over 6 days.

Vineyards—and especially those with microclimate variations—can benefit from wireless sensor networks to more thoroughly track rain, temperature, relative humidity, and light throughout different areas. In doing so, owners will be able to gain a more accurate understanding of conditions throughout the entire vineyard, helping them to develop a better model for timing their harvests.

Key Factors to Consider with Wireless Field Monitoring Systems

This white paper provides an overview of the wireless field-monitoring alternatives available today, and is intended to help you determine the best system for your needs, based on your unique application requirements. Highlighted in the following pages are six important factors to consider when selecting and deploying the most optimal solution. These factors are:

1. Ease of deployment
2. Wireless sensor coverage
3. Actionable information
4. Alarm notifications
5. Maintaining complete historical data
6. Total cost of ownership

1. Ease of Deployment

When evaluating different wireless field monitoring systems, you should be mindful of the deployment process required with each option and prioritize solutions that minimize complexity.

To avoid difficulties with deployment, you can instead opt for a solution that provides simple, push-button configuration for adding sensors.

With some systems, the wireless nodes need to be programmed as part of the setup, requiring you to dedicate time to understand this process or seek outside help. Due to the deployment complexity of some systems, certain suppliers also offer installation services as a separate cost.

To avoid difficulties with deployment, you can instead opt for a solution that provides simple, push-button configuration for adding sensors. Moreover, nodes that come with sensors already connected are much faster to deploy as compared to those that require programming for each sensor connection. Wireless sensor networks that have an intuitive, user-friendly interface for mobile devices or laptops also make for a simpler configuration.

Look for wireless sensors that are small and that have integrated solar panels for easy deployment.

For deploying wireless field monitoring systems, you should also consider:

- **Solar panel configuration.** Most wireless nodes use solar panels with rechargeable batteries. Sensor nodes that have built-in solar panels can be deployed faster than those that require you to connect and mount external panels.

- **Transmitter size.** Transmitters that are small can easily mount on a PVC pipe or a fence post. Larger transmitters may need a tripod, which can be a problem for deploying in some crops. In evaluating the transmitter size, consider the machinery that is used to manage crops. The smaller the transmitter, the easier it is to mount, so as to not interfere with operations.

- **Mounting flexibility.** You should also consider how easily the transmitters can be mounted. A transmitter that can be attached with zip ties or a couple of screws will save time compared to those that require bolts or U-bolts.

2. Wireless sensor coverage

In evaluating different options, carefully consider the type of wireless system in order to better evaluate whether the wireless sensors will have the range to cover all the sites you need monitored, while providing the reliability to ensure you can view conditions and receive notifications during critical times.

Wireless frequency used. As compared to options that use 2.4 GHz, wireless sensors that use transmissions in the 900 MHz range for communication are better suited for transmitting through and around vegetation. This is especially important as the crops grow, and more vegetation is present to interfere with communications. Rain can also interfere with wireless communications (water attenuates wireless signal strength). Wireless signals in the 900 MHz range will be less attenuated than signals in the 2.4 GHz range.

Mesh networks allow "hops" to obtain a wider coverage area.

Star vs. mesh network. Both of these networks use a web-enabled, central receiver to consolidate data from the wireless nodes. With a star network, all of the wireless nodes communicate directly to the central receiver. As such, the maximum range that can be monitored in any direction from a station is limited by the wireless range of that sensor.

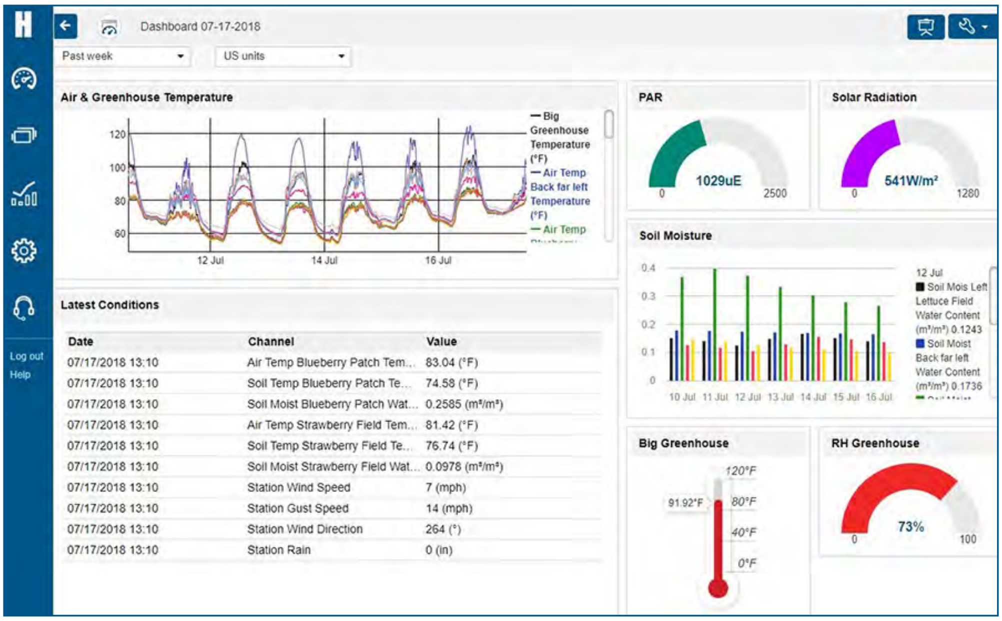
Mesh networks, on the other hand, have nodes that can relay signals from other nodes. These networks allow multiple "hops" (a hop counts as one transmission step between two nodes, or from a node to a central receiver), so that you can obtain a wider coverage range. Also, repeater nodes can be added as needed for longer distances. Additionally, mesh networks offer a more robust wireless network by allowing signals—and the transmission of data—to take alternate paths back to the central station in the event that a sensor goes offline, thereby providing redundancy and greater reliability. When looking at mesh networks, one of the specifications to check is the number of hops back to the receiver that they support, as this will determine the maximum coverage range.

3. Actionable information

More than receiving raw data, you need a solution that will allow you to make the best decisions. In this regard, you should seek out a wireless field monitoring system that allows you to better visualize conditions across your fields and provides actionable information in a form that can directly be used to make decisions. This can be clearly communicated in real time through either:

• A map view, which shows current sensor readings on a map

• A dashboard view, which offers a customized view of the most critical parameters and can include visual gauges that show current values, or graphs for viewing trends or recent historical data



Systems with a dashboard enable instant visualization of your data.

A well-designed dashboard, for example, would enable you to view your operation and understand where attention is needed, such as spots that are abnormally cold or dry. When considering systems, you should look for ones with dashboards that offer:

• Compatibility with the platforms you use in the office and the fields, including laptops, desktops, iPads, or smartphones

• Ability to integrate data from multiple stations and networks into views that clearly show the most critical information needed to make decisions

You should also search for software that can leverage climate data to inform you when actions need to be taken, such as irrigating your crops or applying pesticides. Common software tools that are used include:

• Evapotranspiration (ET) to determine crop water use to help decide when irrigation is needed; ET is also an important parameter for hydrological modeling and applications such as water resource management

• Growing degree days to determine when plants or pests are reaching critical growth or development stages

• Crop disease models to calculate the risk of disease or pest emergence and the optimal time to apply pesticides or fungicides

If the vendor’s software does not include the ability to process data to the form that is required, you may be able to feed your sensor data into software available online to derive decision-making parameters. Examples include:

*Integrated pest management software from the Network for Environment and Weather Applications

**The DEGDAY Excel application from the University of California, Davis for calculating degree days

*\ http://newa.cornell.edu/
** http://biomet.ucdavis.edu/DegreeDays/DegDay.htm

4. Alarm Notifications

An important feature for crop management is the ability for a system to provide notifications when conditions reach critical levels. For this reason, consider a solution that provides alarm notifications. When evaluating options, it's important to look for a system that can detect alarm conditions based on sensor readings or calculated parameters.

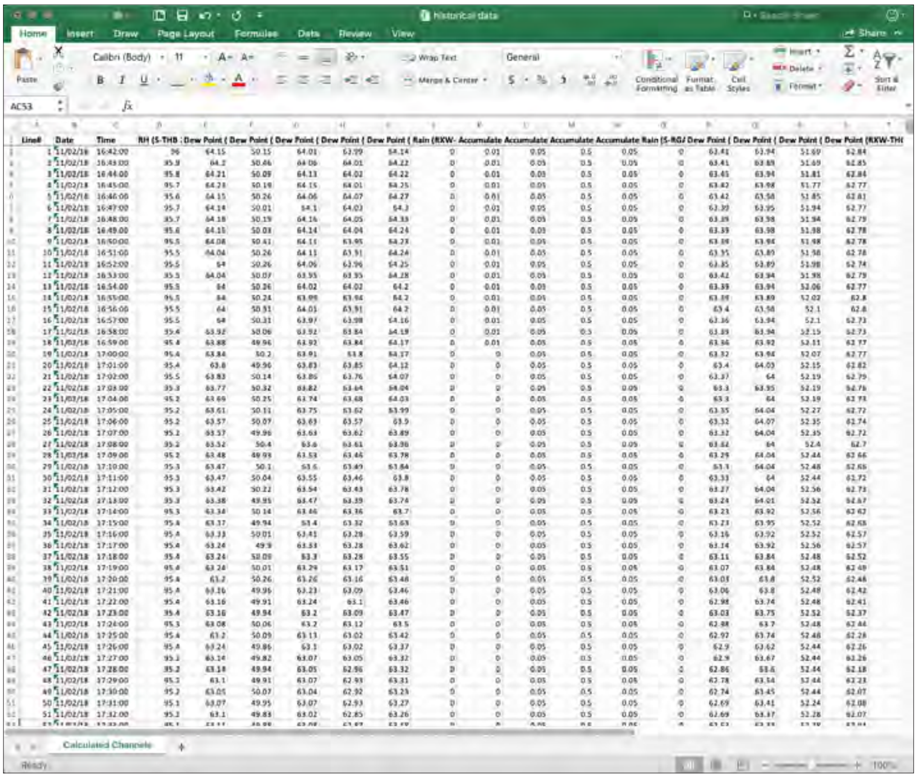
Look for a system that can provide real-time alarm notifications of critical conditions.

You should also consider where the alarm conditions are detected, as this influences the alarm response time. Systems that use web-based alarm detection require that data is first uploaded to a website before the readings are checked against the alarm limits, which means the alarm response could take as long as the upload rate plus the maximum internet-latency time. As a better option, consider seeking a system that checks alarm conditions from within the station. This provides faster response times because the station connects to the internet as soon as an out-of-limit condition is detected, instead of waiting for the next scheduled connection. As soon as the station connects, the alarm notification can be sent to you, typically as a text message or email.

Another aspect to consider is whether a system can also be set up to trigger a relay. As an example of this feature, a system that sends a frost alarm when a low temperature threshold is reached would at the same time close a relay that turns on an irrigation system, spraying the crops to provide protection from freezing.

One further element to seek out with alarm notifications is whether the system provides "hysteresis," such that an alarm can be triggered on one level and be cleared at another level so that you don't receive multiple alarms when conditions are near the alarm threshold. By allowing a system to be more tolerant of conditions that are hovering near the alarm threshold, hysteresis prevents alarms—and systems—from turning on and off repeatedly in a short amount of time.

5. Maintaining complete historical data



Historical data storage enables more informed analysis and planning.

As part of their crop management practices, many growers collect and analyze historical records of their field climate conditions to identify longer-term trends and conditions that may be affecting their yields, enabling for more strategic planning. Historical data is important for conducting analyses that compare crop yields or wine quality with climate conditions over time. For example, long-term temperature data could help a vineyard manager to identify areas in their fields that are historically colder and where more tolerant grapes should be planted.

Historical data is also key for growers who need to have records of climate conditions to protect their interests. Such data can show that a grower only sprayed when conditions did not exceed safe levels, minimizing the chance that pesticide could have drifted into a neighboring field.

If you are currently using or are exploring the use of historical data, it is important to look for a system that ensures complete historical records by retaining data in the wireless nodes until upload is confirmed. In the event of a break in the wireless transmission, such a feature prevents data from being lost. Ideally the system will automatically upload the data from the nodes when wireless communication is restored, or worst case, the data can be offloaded directly from the nodes with a USB cable.

6. Total cost of ownership

When evaluating options in order to determine the best wireless field monitoring system, you should also factor in the total cost of ownership. As part of this analysis, be sure to consider all costs that will be accrued over the life of each different system. These costs can include the purchase of a gateway station, wireless sensor nodes, data service plans, and mounting stands or poles.

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Additionally, consider the costs for installing systems and annual maintenance. Complex systems are going to cost more to install, and paying a little more upfront for a reliable and low-maintenance system can save you money in the long run. Importantly, if a system fails at a critical time, the potential cost of crop damage or loss could be severe.

There may also be costs of ownership implications due to whether the wireless system network is a star or mesh network. This can be especially true if you plan to expand in the future. For example, where a star network may force you to purchase a new station due to range limitations, a mesh network might allow you to simply add more nodes to expand coverage.

Conclusion

Your investment in technology for monitoring the conditions that directly affect the health and quality of your crops is one of the more important decisions you can make. The information and guidance presented in this white paper is intended to help you make the best decision possible when purchasing a wireless field monitoring system, so you can protect your crops and your livelihood well into the future.

About Onset

Onset is a leading supplier of data logger solutions for monitoring climate and crop conditions and improving both indoor and outdoor environments. Based on Cape Cod, Massachusetts, Onset has been designing and manufacturing its products on site since the company's founding in 1981.

Visit Onset on the web at www.onsetcomp.com.

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