Using Soil Water Tension To Monitor and Manage Irrigation Easily

Alan Campbell
CEO, SmarterAgGroup
503-502-6302
alan@smartvineyards.net

The SmarterAgGroup

The SmarterAgGroup offers irrigation and weather monitoring systems and data services to growers of vine, tree, and field crops under 3 brands …

SmartVineyards

Smarter Irrigation Management

in Winegrapes and Hops

SmartOrchards

Smarter Irrigation Management

in Apples and Almonds

SmartGrower

Smarter Irrigation Management

in Berries, Onions, and Potatoes

Using Soil Water Tension To Monitor and Manage Irrigation Easily

A Tale of Two Tensions


S12.5
S12.6r Relay
S12.7r Relay
S12.2
S12.9r Relay
S12.1
S12.C Connector
S12.T Transmitter
S12.3
S12.4
S12.8r Relay

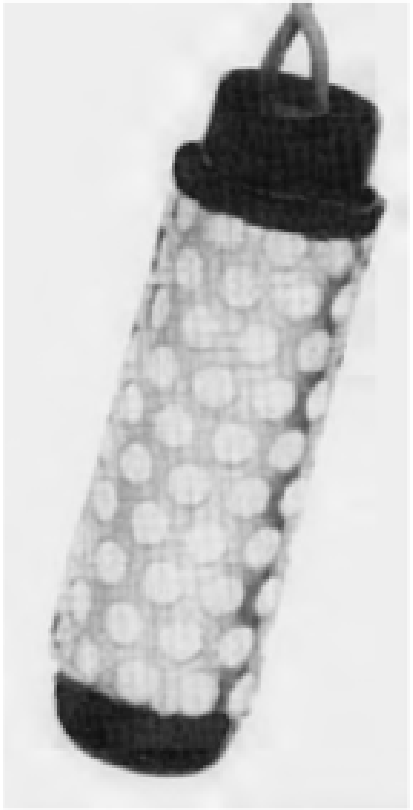
What Is Tension?

- In a soil?
- In a plant?
- How are they linked?
- How is tension measured?
- units: centibars, cbar, cb = kilopascals, kPa

EM 8900 • Revised March 2013

Irrigation Monitoring Using Soil Water Tension

C.C. Shock, F.X. Wang, R. Flock, E. Feibert, C.A. Shock, and A. Pereira



One of the most important tools we have been using at the Malheur Agricultural Experiment Station over the past two decades is the granular matrix sensor (GMS, Watermark Soil Moisture Sensor, Irrometer Co., Riverside, CA), which measures soil moisture. It is only about 3 inches long and normally is buried vertically in the ground.

Like gypsum blocks, GMS sensors operate on the principle of variable electrical resistance. The electrodes inside the GMS are embedded in granular fill material above a gypsum wafer. Additional granular matrix is below the wafer in the fabric tube, where water enters and exits the sensor.

Gypsum dissolved in water is a reasonable conductor of electricity. Thus, when the sensor contains a lot of water, the electric current flows well. When there is a lot of water in the soil, there is a lot of water in the sensor. As the soil dries out, the sensor dries out, and resistance to the flow of electricity increases.

The resistance to the flow of electricity (expressed in Ohms) and the soil temperature are used to calculate the tension of the soil water in centibars (cb). Soil water tension (SWT) is the force necessary for plant roots to extract water from the soil. Soil water tension reflects the soil moisture status. The higher the tension, the drier the soil.

Other devices for measuring soil water tension include tensiometers, gypsum blocks, dielectric water potential sensors, and porous ceramic moisture sensors.

Soil Water Tension, a Powerful Measurement for Productivity and Stewardship

Clinton C. Shock[1,3]
Oregon State University, Malheur Experiment Station, 595 Onion Avenue, Ontario, OR 97914

Feng-Xin Wang[2]
Center for Agricultural Water Research in China, China Agricultural University, No. 17 Qinghua East Road, Haidian, Beijing 100083, China

Additional index words. irrigation, irrigation scheduling, Irrigas, soil water potential, tensiometer, granular matrix sensor, regulated deficit irrigation, dielectric coupled media

Abstract. **A fundamental way to schedule irrigation is through the monitoring and management of soil water tension (SWT). Soil water tension is the force necessary for plant roots to extract water from the soil. With the invention of tensiometers, SWT measurements have been used to schedule irrigation. There are different types of field instruments used to measure SWT, either directly or indirectly. Precise irrigation scheduling by SWT criteria is a powerful method to optimize plant performance. Specific SWT criteria for irrigation scheduling have been developed to optimize the production and quality of vegetable crops, field crops, trees, shrubs, and nursery crops. This review discusses known SWT criteria for irrigation scheduling that vary from 2 to 800 kPa depending on the crop species, plant product to be optimized, environmental conditions, and irrigation system. By using the ideal SWT and adjusting irrigation duration and amount, it is possible to simultaneously achieve high productivity and meet environmental stewardship goals for water use and reduced leaching.**

Irrigated horticulture is essential for human health and welfare. Improved human nutrition can be achieved through improved horticultural productivity and quality, which in turn is often related to irrigation practices. Fresh water for horticulture production is increasingly in scarce supply and facing competition from alternative water demands from cities, industries, and interest groups that want water left in-stream to support fish and other aquatic organisms. Water quality is also becoming more important. It is widely recognized that precise irrigation is a key to high horticultural productivity, efficient water use, and water quality protection.

OPTIONS FOR PRECISE

soil water content or SWT. Soil water content can be determined through gravimetric, neutron probe, time domain reflectometry, or capacitance probe measurements. Measurements of soil water content can be particularly useful when soils are very uniform over large geographic expanses or uniform in nursery container mixes. Measurements of SWT can be determined with tensiometers, gypsum blocks, heat dissipation sensors, granular matrix sensors, psychrometers, and other devices. Measurements of SWT are particularly useful for irrigation scheduling when a SWT irrigation criterion that maximizes crop performance is determined for a given crop in a particular environment. When a SWT irrigation criterion is coupled with knowledge of the soil water-

ψ_a, pneumatic (air) pressure, relating to pressures in the air phase;
ψ_p, pressure potential, primarily resulting from externally applied pressure transmitted through the fluid phase of the soil–water system.

In unsaturated soil, both ψ_p and ψ_a are negligible. If the soil depths are roughly the same, ψ_g can be ignored. Therefore, of the various components of the soil water potential (ψ) that are responsible for the water-holding capacity of soils, the matric potential and ψ_s are most often considered as being sufficient to describe the water potential in partially saturated soil under constant uniform temperature and in the absence of externally


S12.5
S12.7
Relay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EXHAUST
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S12.5
S12.7
Relay


S12.5
S12.7
Relay

Some crops are managed at …

- Low tension
  - e.g. onions, potatoes, young winegrapes
- High tension
  - e.g. winegrapes
- Others ?
  - e.g. hops, apples, blueberries; almonds

For each crop …

- There are two tension limits
- In the soil and in the crop
- A low tension and a high tension limit

These limits change through the season

Examples: onions, potatoes, winegrapes

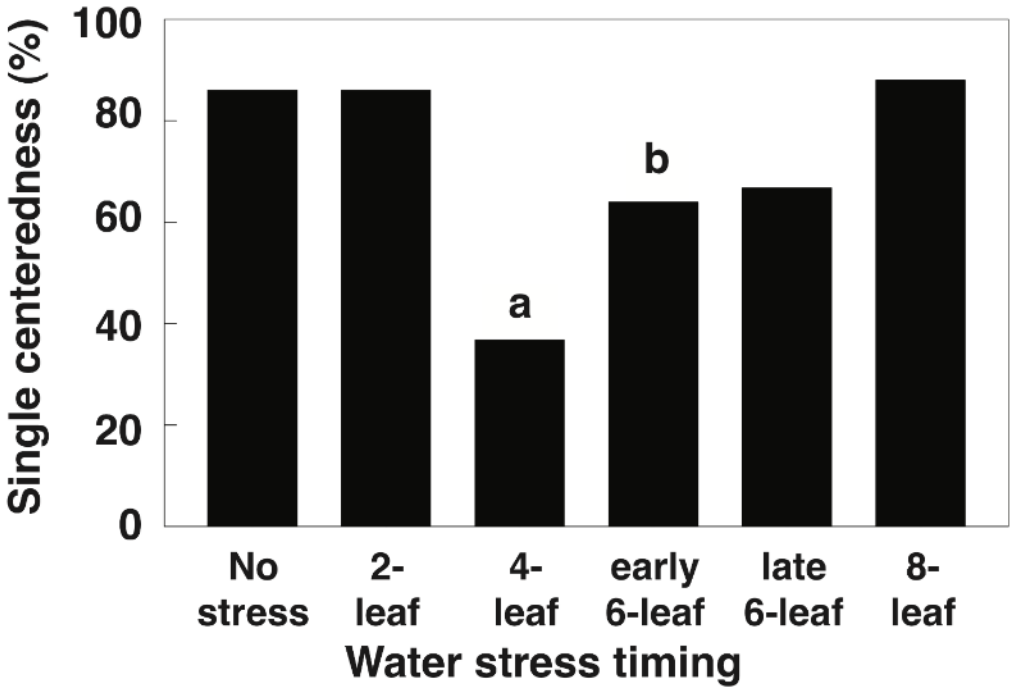


Figure 5. Onion single centeredness in response to short-duration water stress at different onion development stages (2005). Mild water stress to onions was achieved by allowing SWT to reach 60 cb before resuming irrigations. Bars with different letters (a, b) are significantly different with 95 percent confidence.

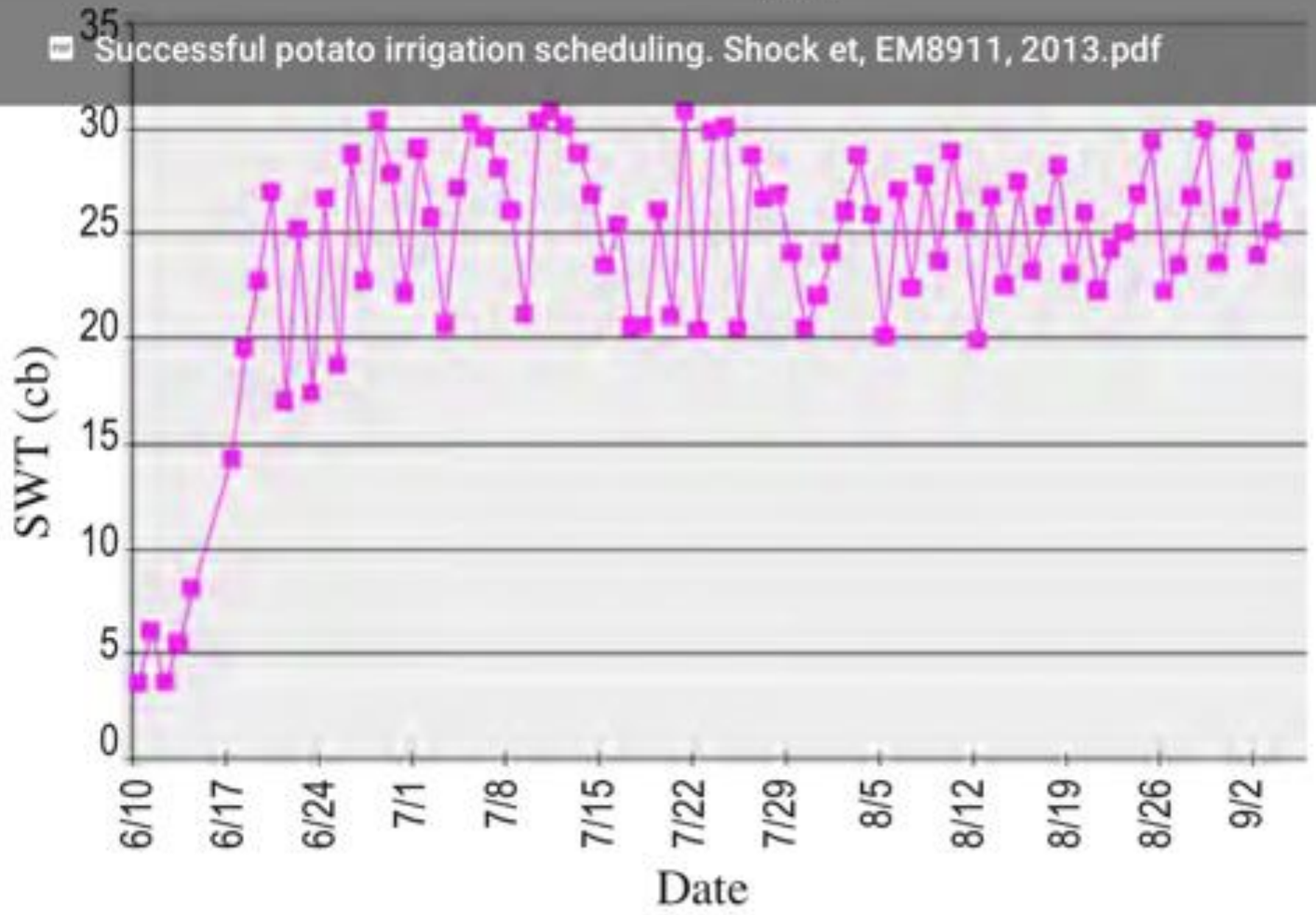
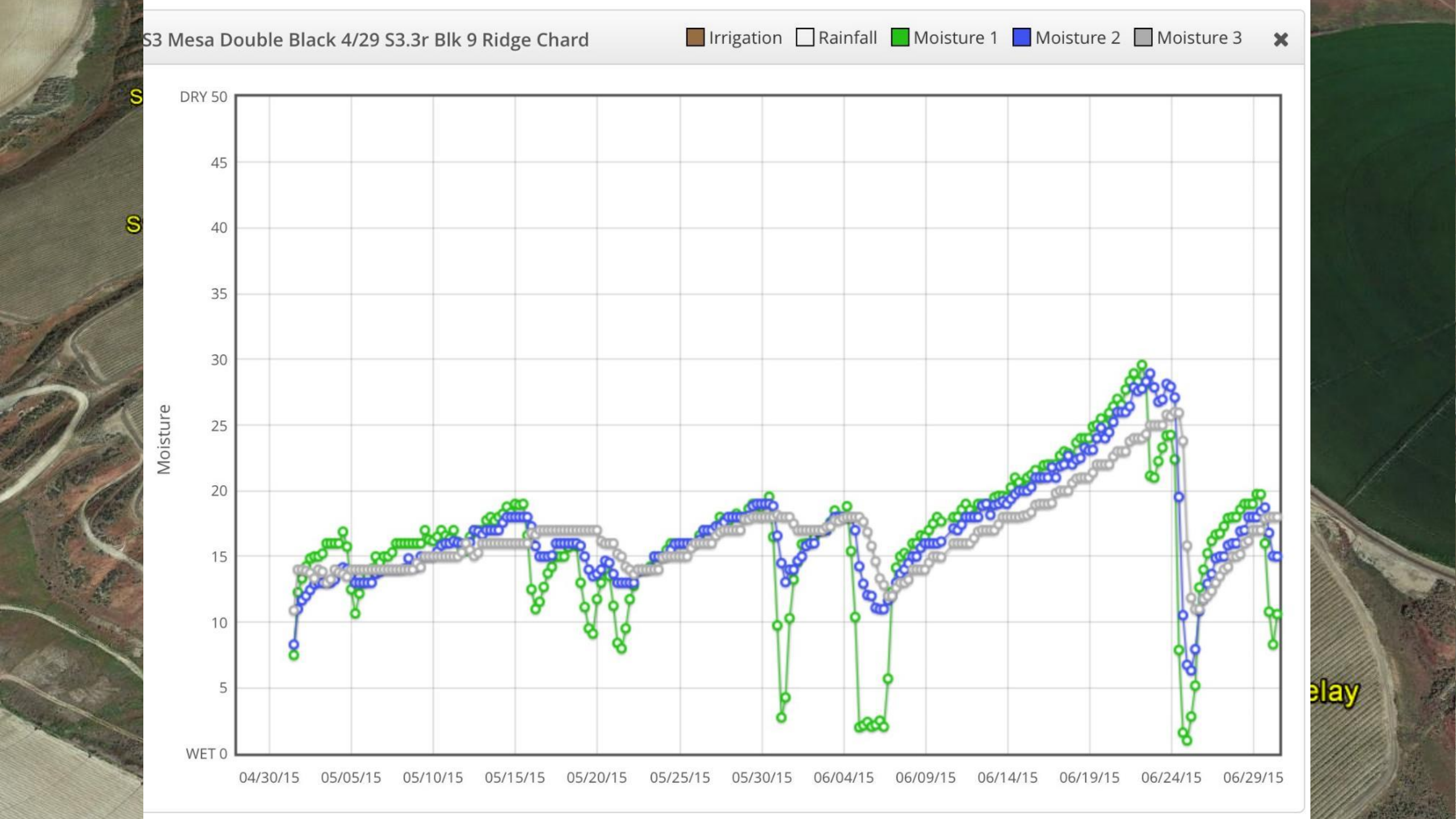


Figure 2. Drip-irrigated potato with small drops in soil water tension following irrigations on silt loam at Ontario, OR. Irrigations are much more frequent. They maintain an average SWT wetter than 30 cb and do not saturate the soil.


S3 Mesa Double Black 4/29 S3.3r Blk 9 Ridge Chard
Irrigation
Rainfall
Moisture 1
Moisture 2
Moisture 3
DRY 50
45
40
35
30
25
20
15
10
5
WET 0
Moisture
04/30/15
05/05/15
05/10/15
05/15/15
05/20/15
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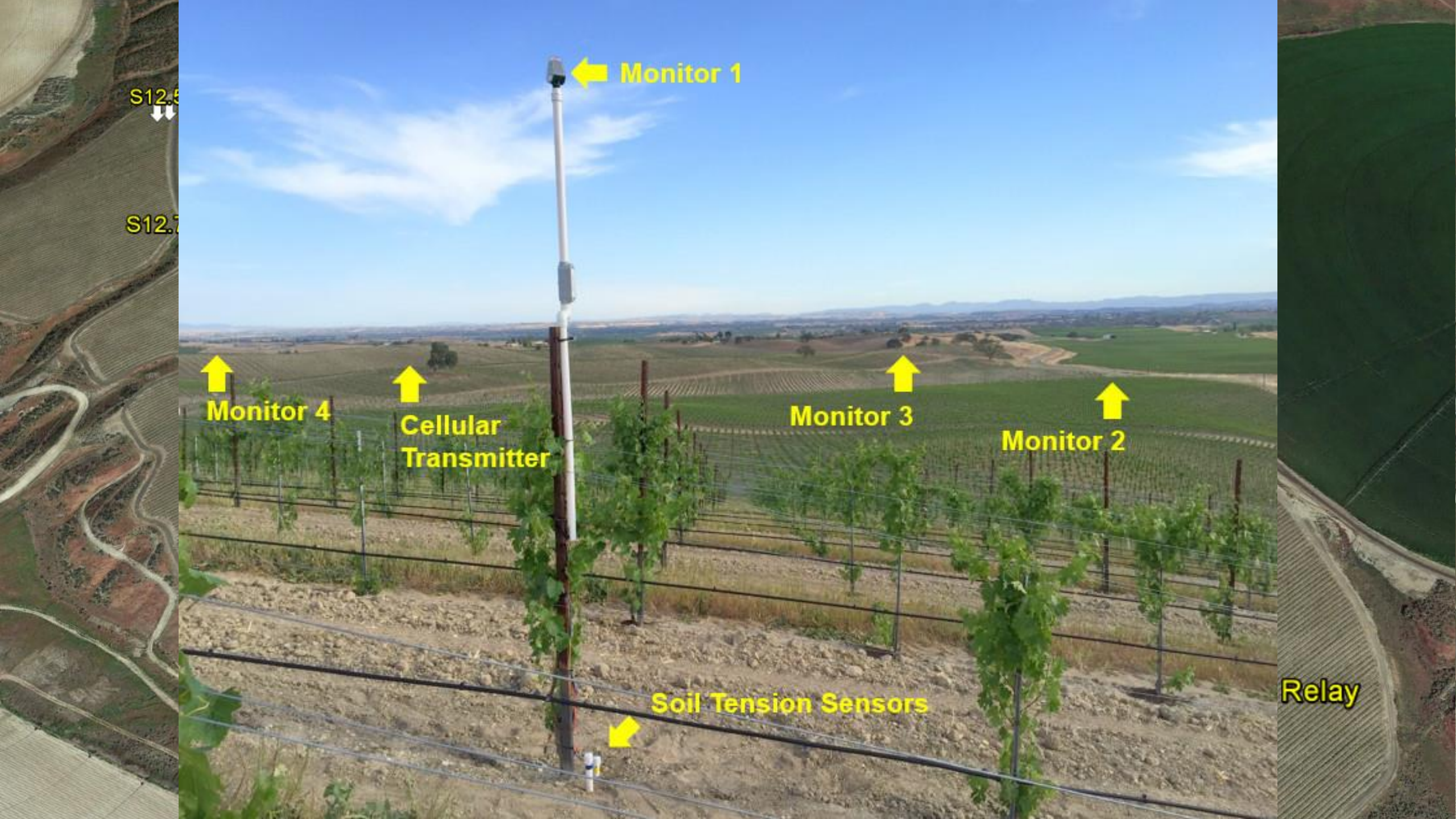
06/29/15

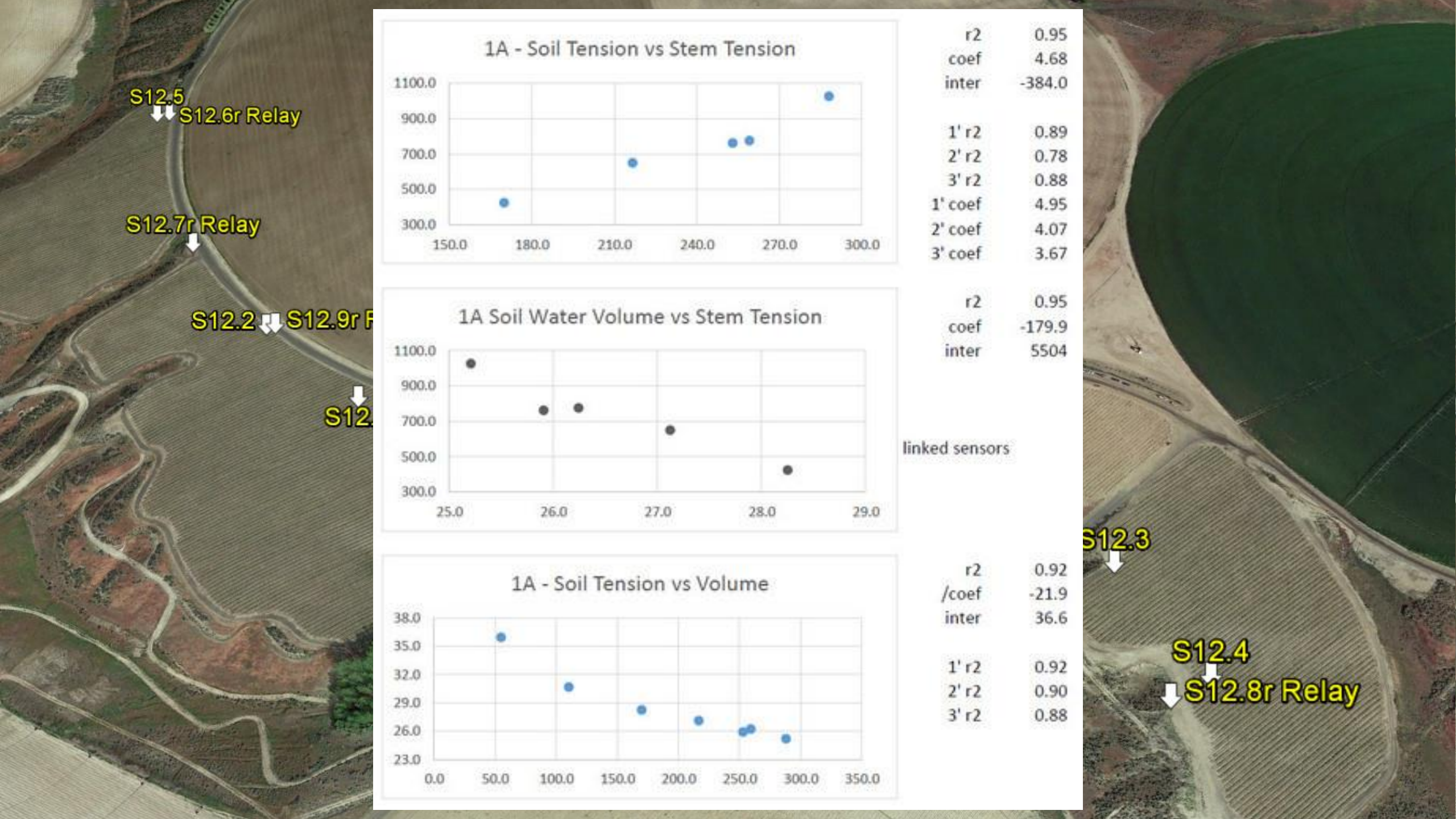

Monitor 1
Monitor 4
Cellular Transmitter
Monitor 3
Monitor 2
Soil Tension Sensors
Relay

Manage Soil or Crop Limits?

- Crop and soil tensions are linked
- Crop tension adjusts to soil tension
  - until crop tension limits are reached

Manage soil tension to manage crop tension

- “Smart Irrigation Management”



r2	0.95
coef	4.68
inter	-384.0
1' r2	0.89
2' r2	0.78
3' r2	0.88
1' coef	4.95
2' coef	4.07
3' coef	3.67

r2	0.95
coef	-179.9
inter	5504

linked sensors

r2	0.92
/coef	-21.9
inter	36.6
1' r2	0.92
2' r2	0.90
3' r2	0.88


Google Earth
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Search
Search
ex: 37 25.818' N, 122 05.36' W
Get Directions History
Places
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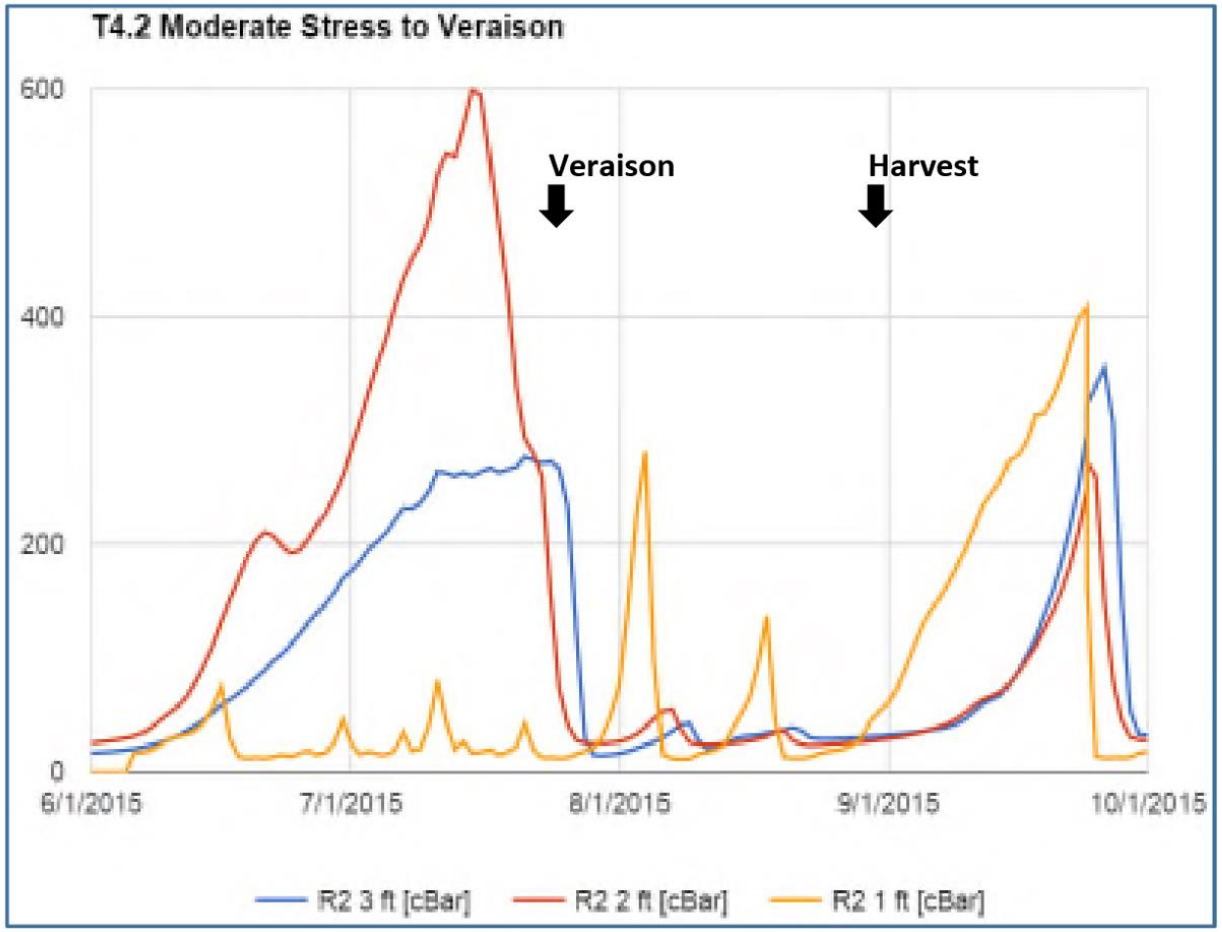
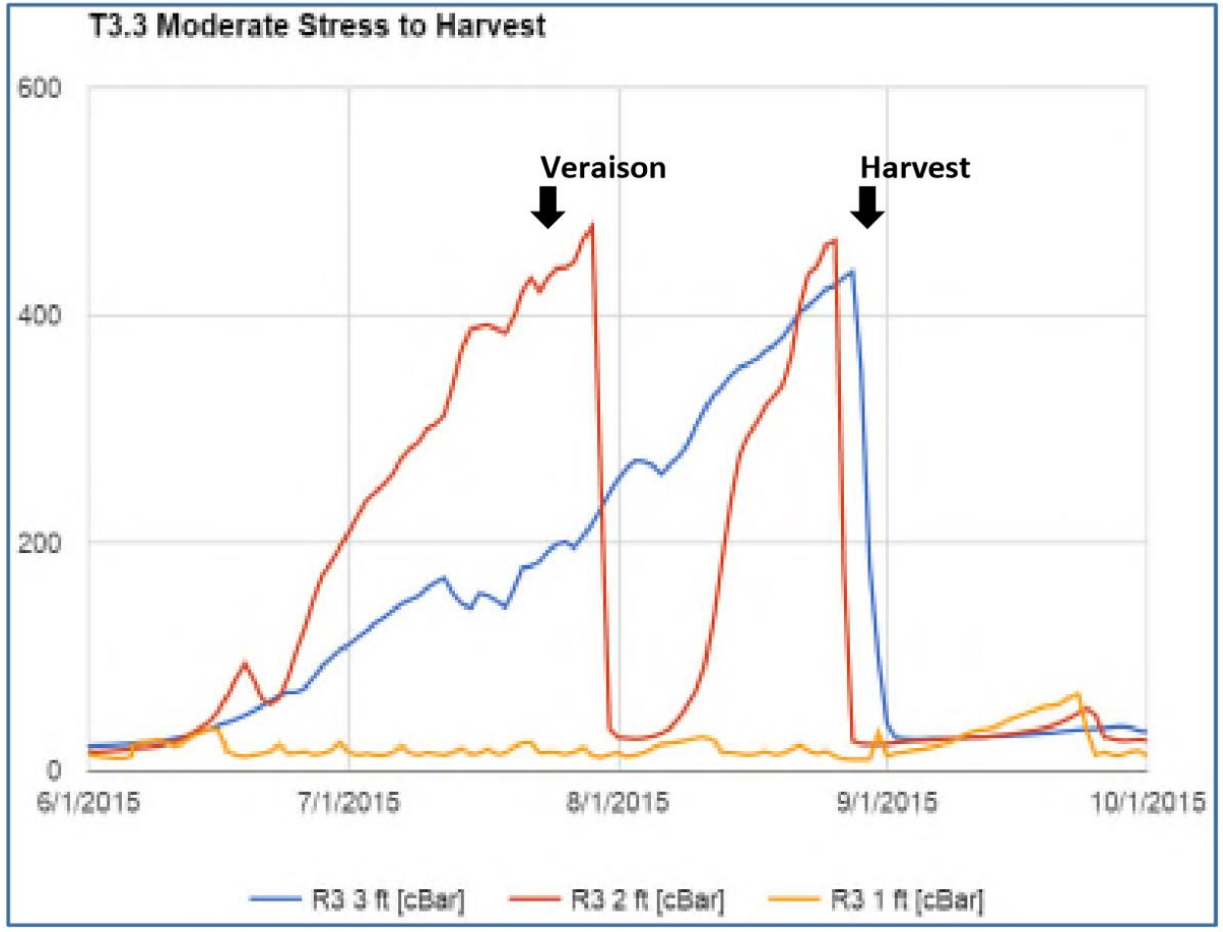
Columbia Crest - icons and installation p...
Columbia Crest
Columbia Crest - Icons
Chardonnay research block WSU
Columbia Crest - Icons
T0.1, S11.1
T0.2, S11.2
T0.3, S11.3
T0.4, S11.4
T1.1, S11.5
T1.2, S11.6
T1.3, S11.7
T1.4, S11.8
T2.1, S11.9
T2.2, S11.10
T2.3, S11.11
T2.4, S11.12
T3.1, S11.13
T3.2, S11.14
T3.3, S11.15
T3.4, S11.16
T4.1, S11.17
T4.2, S11.18
T4.3, S11.19
T4.4, S11.20
11.L Link
S11.B Base
Columbia Crest - Installation photos
2nd 1-9999
Mercer
Angiolina Farm
Angiolina to North
Layers
Earth Gallery
Sign in
11.L Link
T1.1, S11.5
T2.4, S11.12
T2.2, S11.10
T0.2, S11.2
T0.3, S11.3
T0.1, S11.1
T2.3, S11.11
T2.1, S11.9
T4.4, S11.20
T4.1, S11.17
T3.2, S11.14
T4.2, S11.18
T1.4, S11.8
T1.2, S11.6
T3.3, S11.15
Google earth
Tour Guide
1996
lat 45.955701° lon -119.614712° elev 631 ft eye alt 1188 ft


S12.5
S12.7
Relay

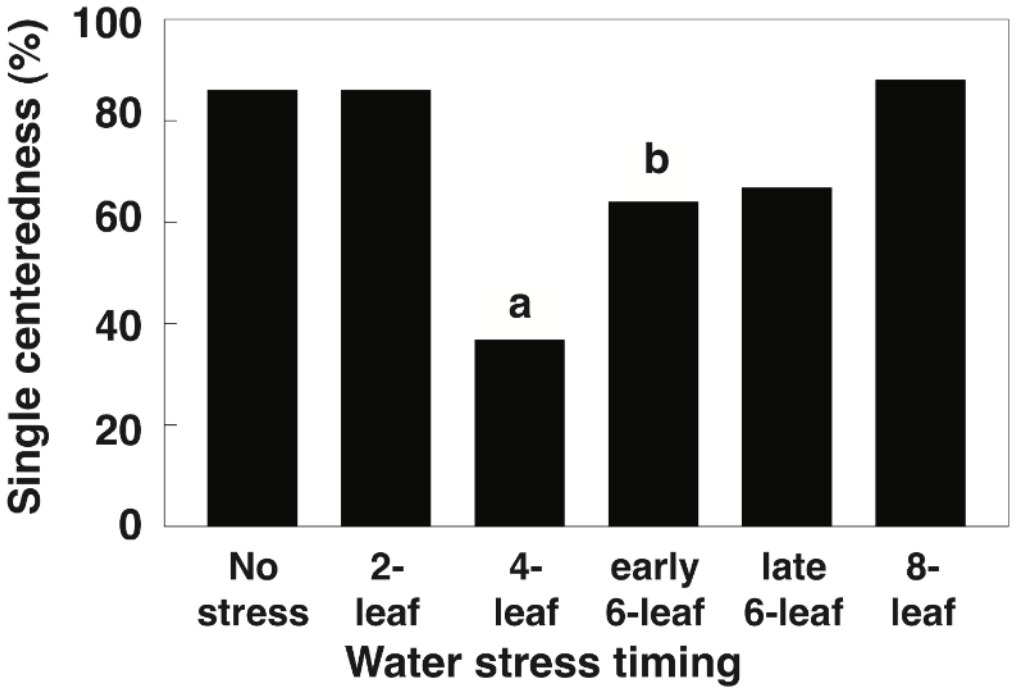
Two examples from the WSU irrigation trial of soil water tension at 1’, 2’, and 3’ closely tracking vine stress:





Why change tension limits?

- Through the season?
- e.g. onions
  - leaf and bulb growth, single centeredness, dry down
- e.g. winegrapes
  - canopy size
  - berry size; berry and wine quality



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SensMit [S12.1]

View in Mesh Analyzer | Configure | Manage Alerts

Moisture | Temperature | Diagnostics

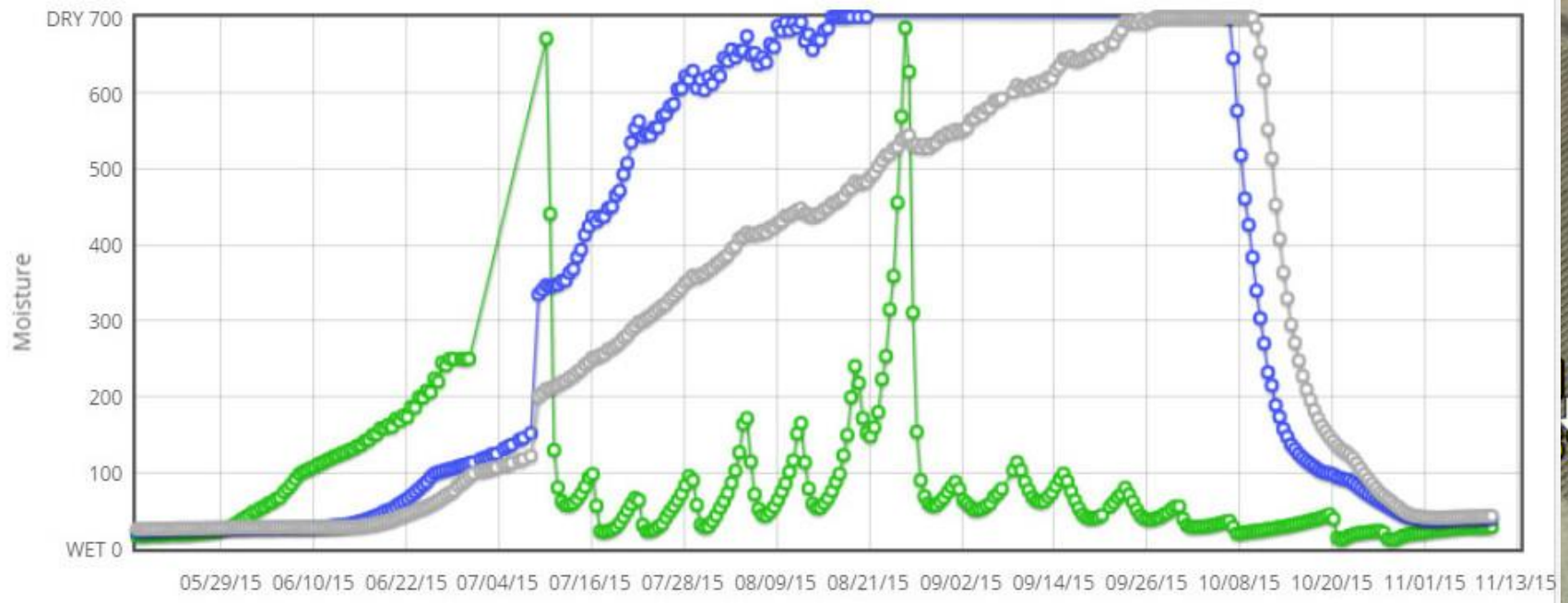
Moisture Data | Custom | Max: 700 cB | Filter outliers | Wet Up

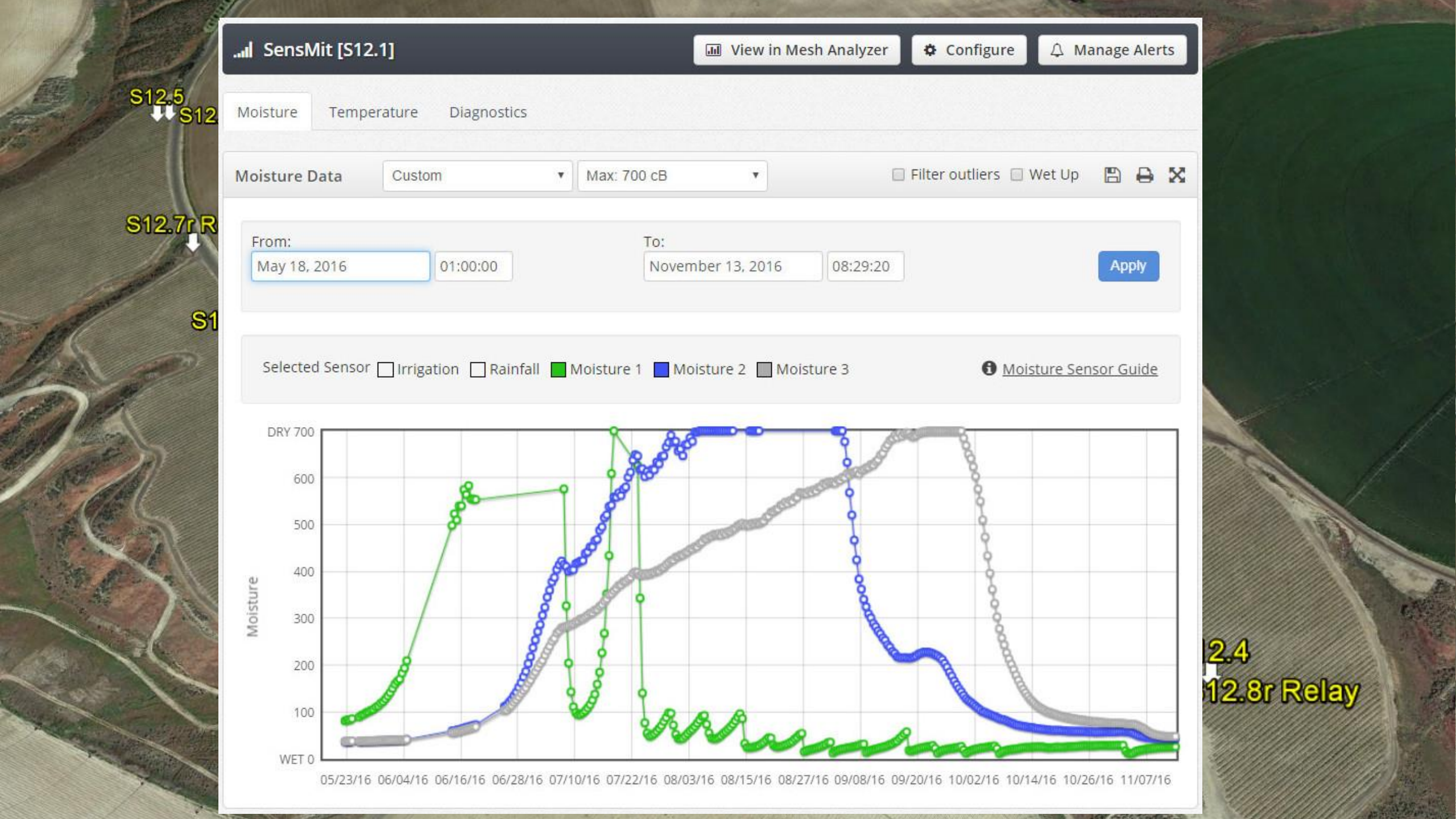
From: May 18, 2015 01:00:00

To: November 13, 2015 08:29:20

Apply

Selected Sensor | Irrigation | Rainfall | Moisture 1 | Moisture 2 | Moisture 3 | Moisture Sensor Guide





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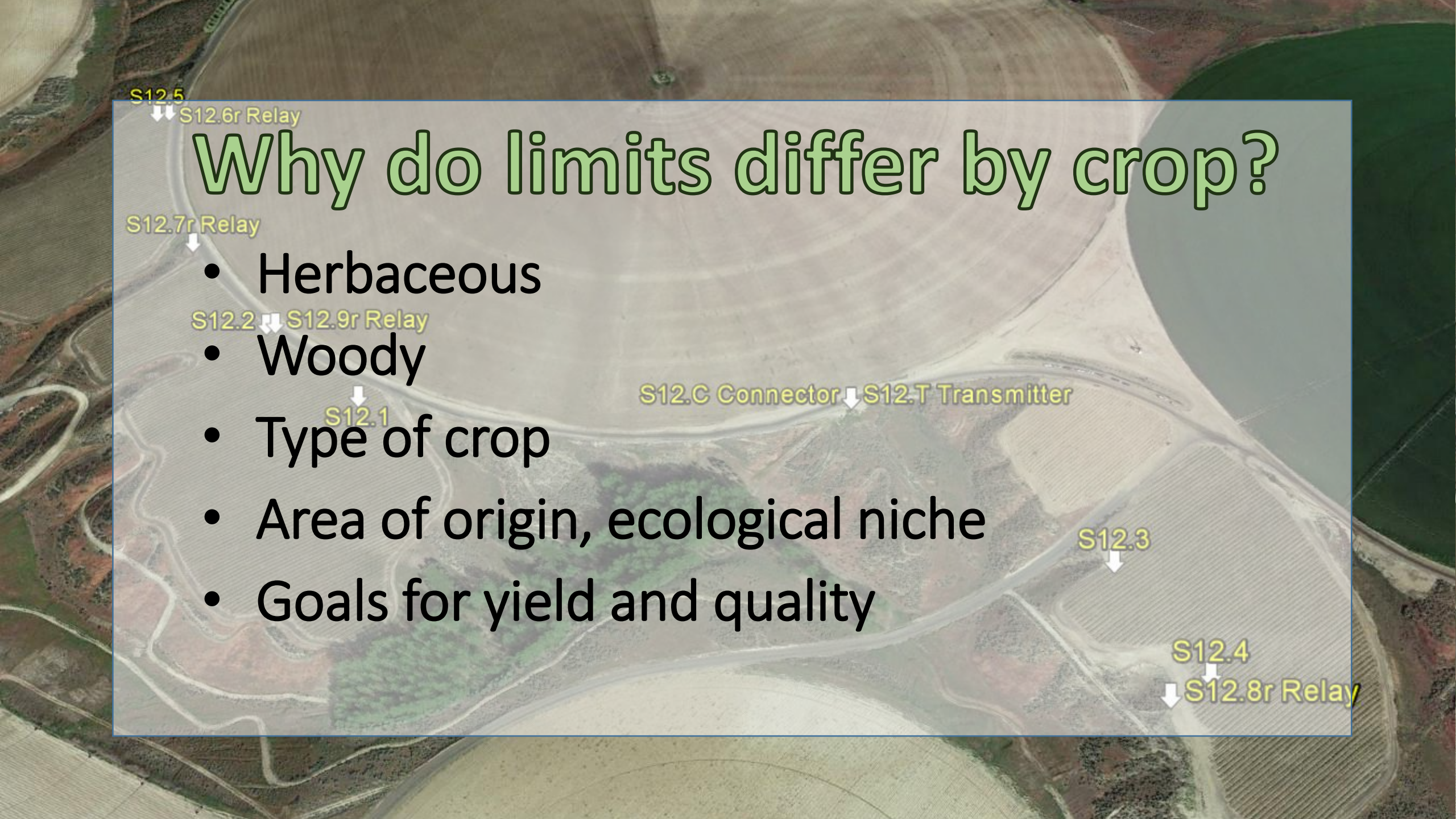


Why do limits differ by crop?

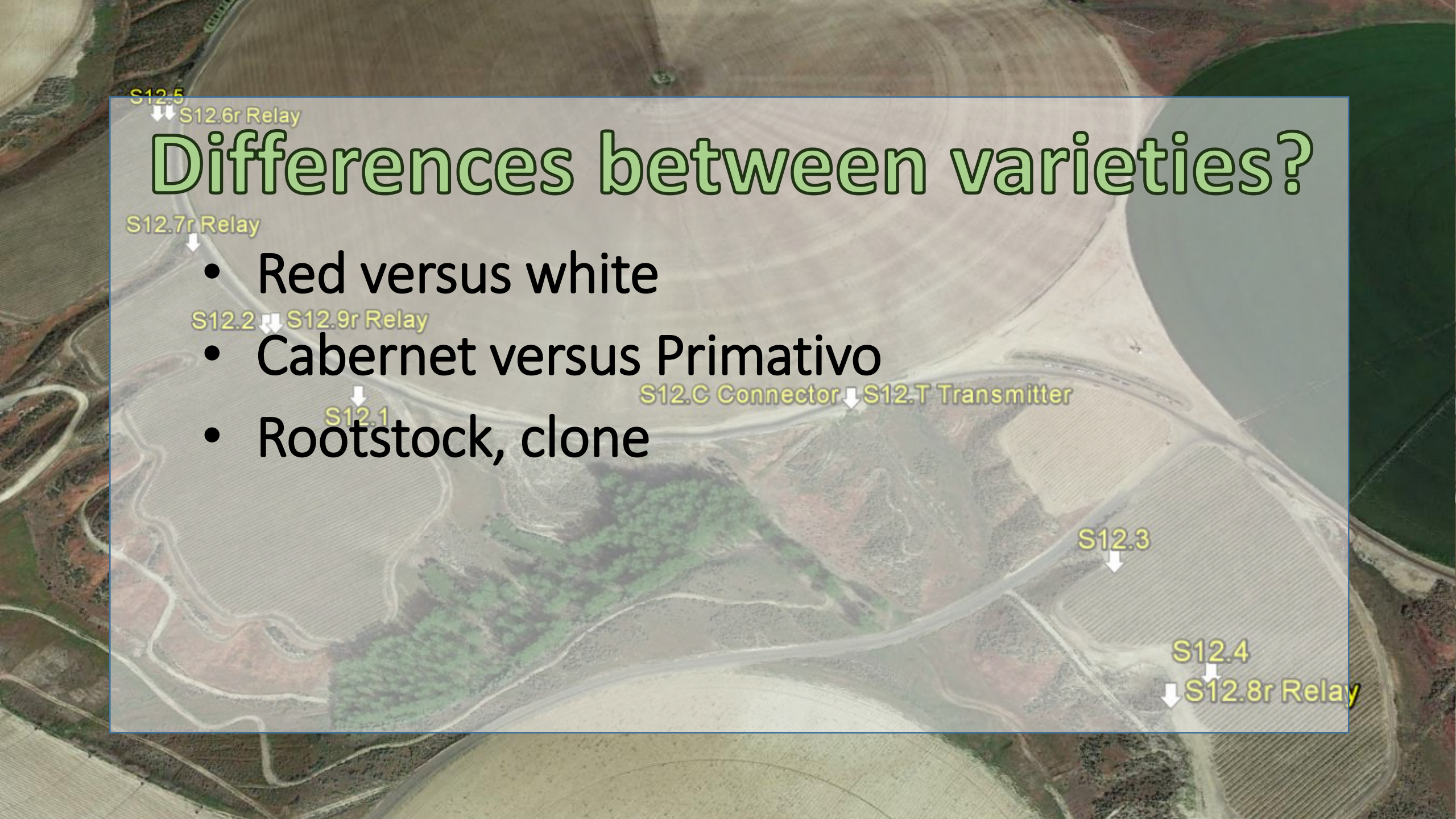
- Herbaceous
- Woody
- Type of crop
- Area of origin, ecological niche
- Goals for yield and quality

Why do limits change?

E.g. Winegrapes

- Growth stops
- Cells harden
- Solutes increase

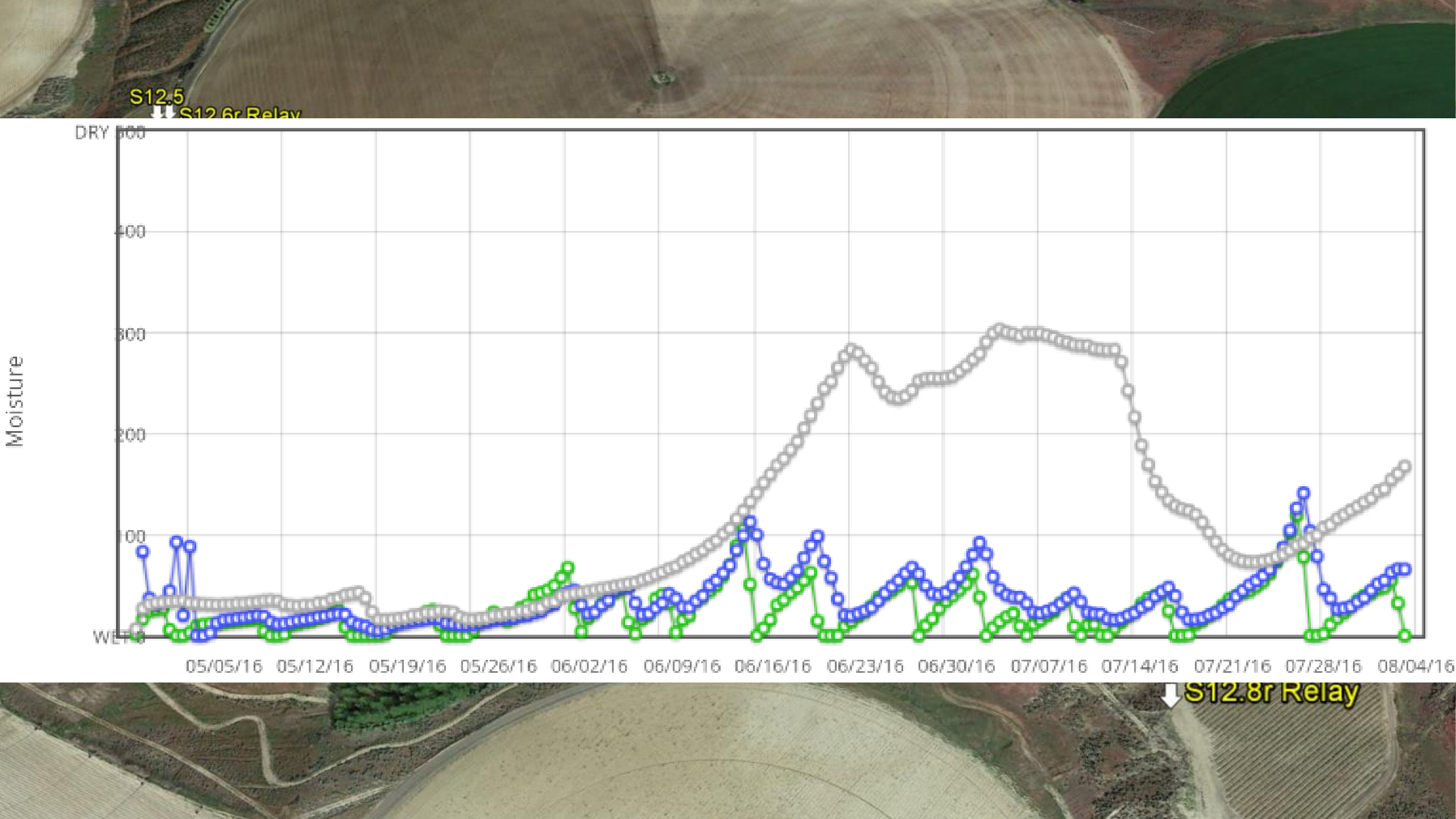
Tension used to effect each in turn



Differences between varieties?

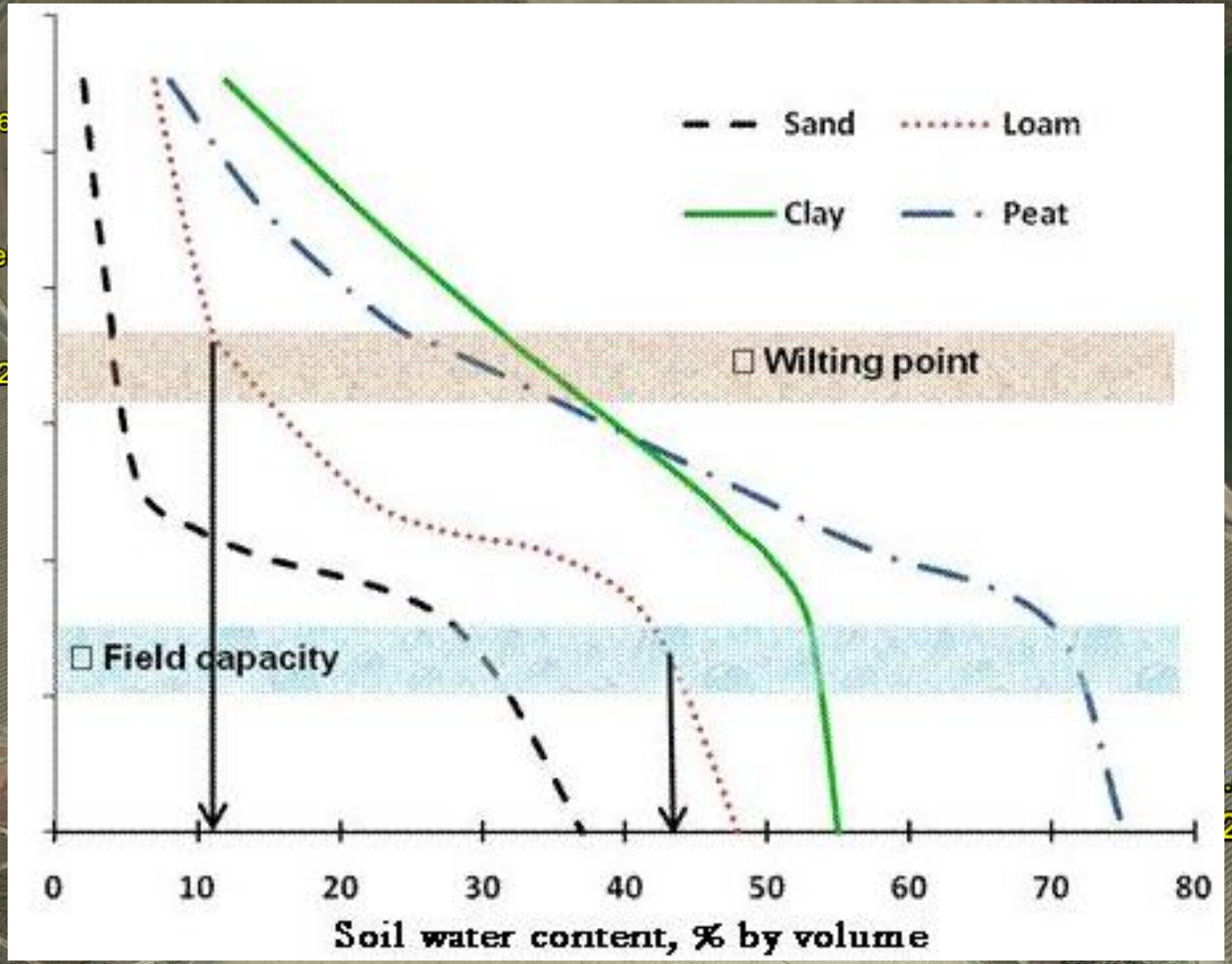
- Red versus white
- Cabernet versus Primativo
- Rootstock, clone


S12
S12
r Relay


S12.5
S12.6r Relay
DRY
400
300
200
100
Moisture
05/05/16
05/12/16
05/19/16
05/26/16
06/02/16
06/09/16
06/16/16
06/23/16
06/30/16
07/07/16
07/14/16
07/21/16
07/28/16
08/04/16
S12.8r Relay

Differences between Soils?

- Sand, silt, clay - texture
- Capillary size distribution - structure
- Water movement, storage, release
- Water retension curve
  - Tension vs volume

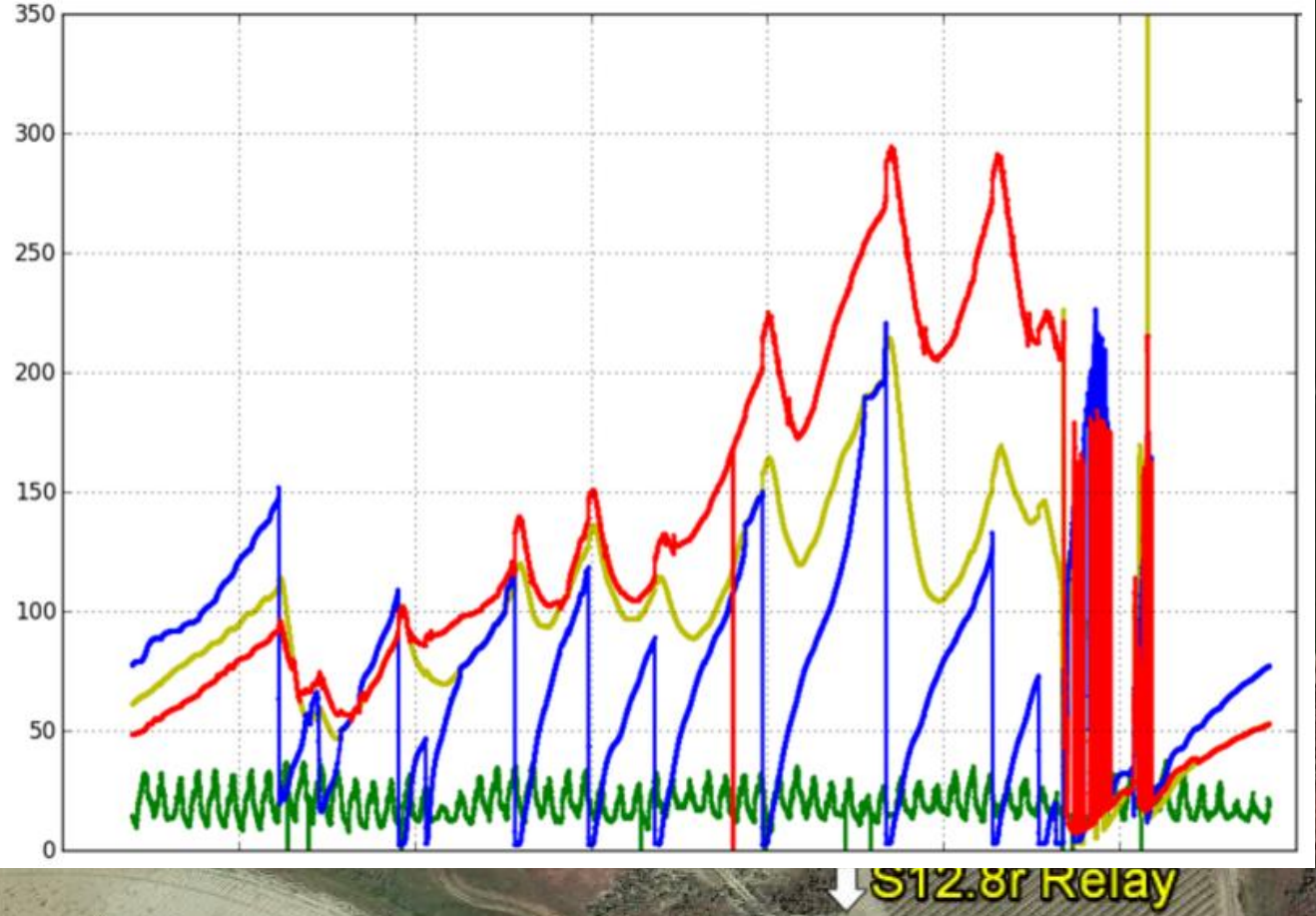

Sand
Loam
Clay
Peat
Wilting point
Field capacity
0
10
20
30
40
50
60
70
80
Soil water content, % by volume

Challenges of Drip Irrigation?

- More complicated that pivot or sprinkler
- Water addition not uniform
- Tension depends on sensor placement
- Consistent sensor placement is important

S12.5
S12.6r Relay

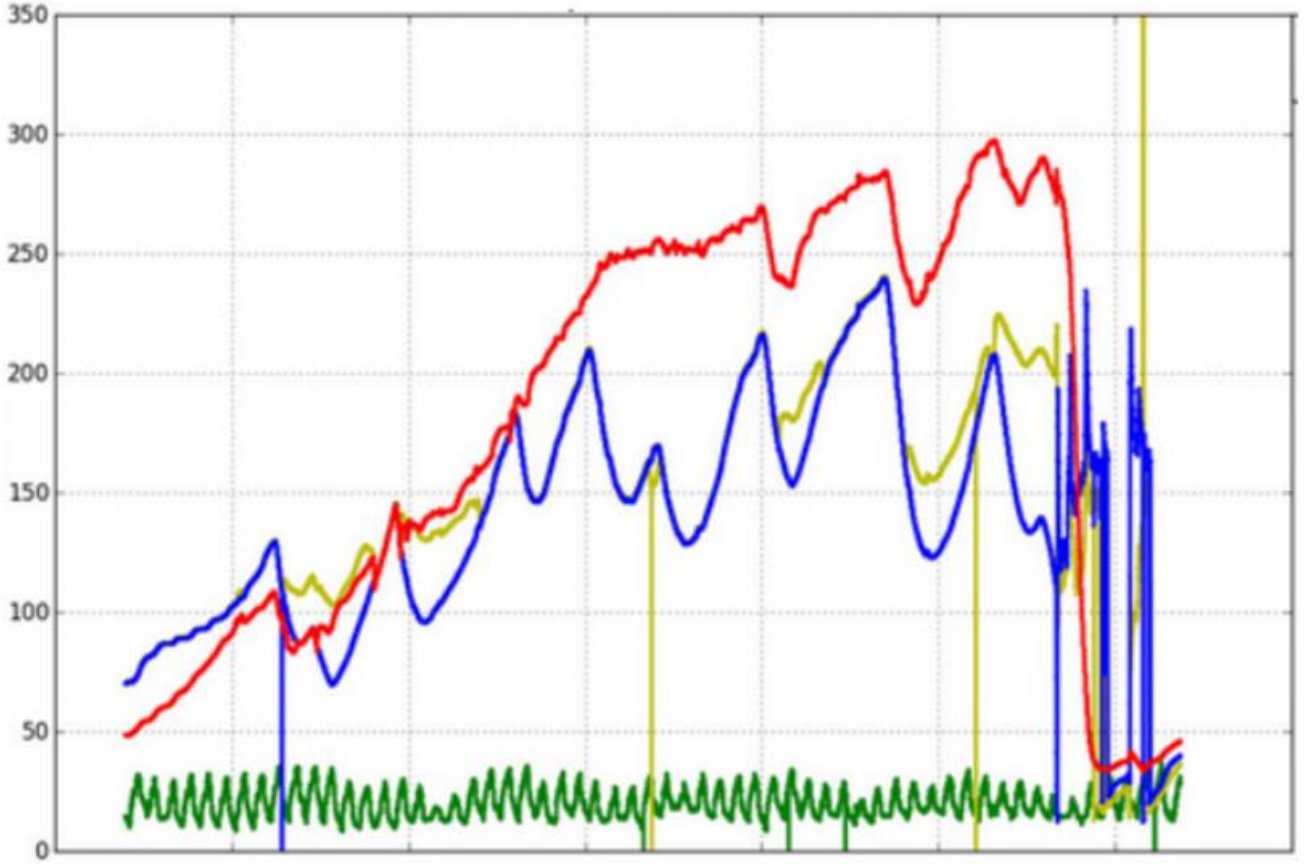
Watermark sensors installed 1”back from drip line



S12.8r Relay

S12.5
S12.6r Relay

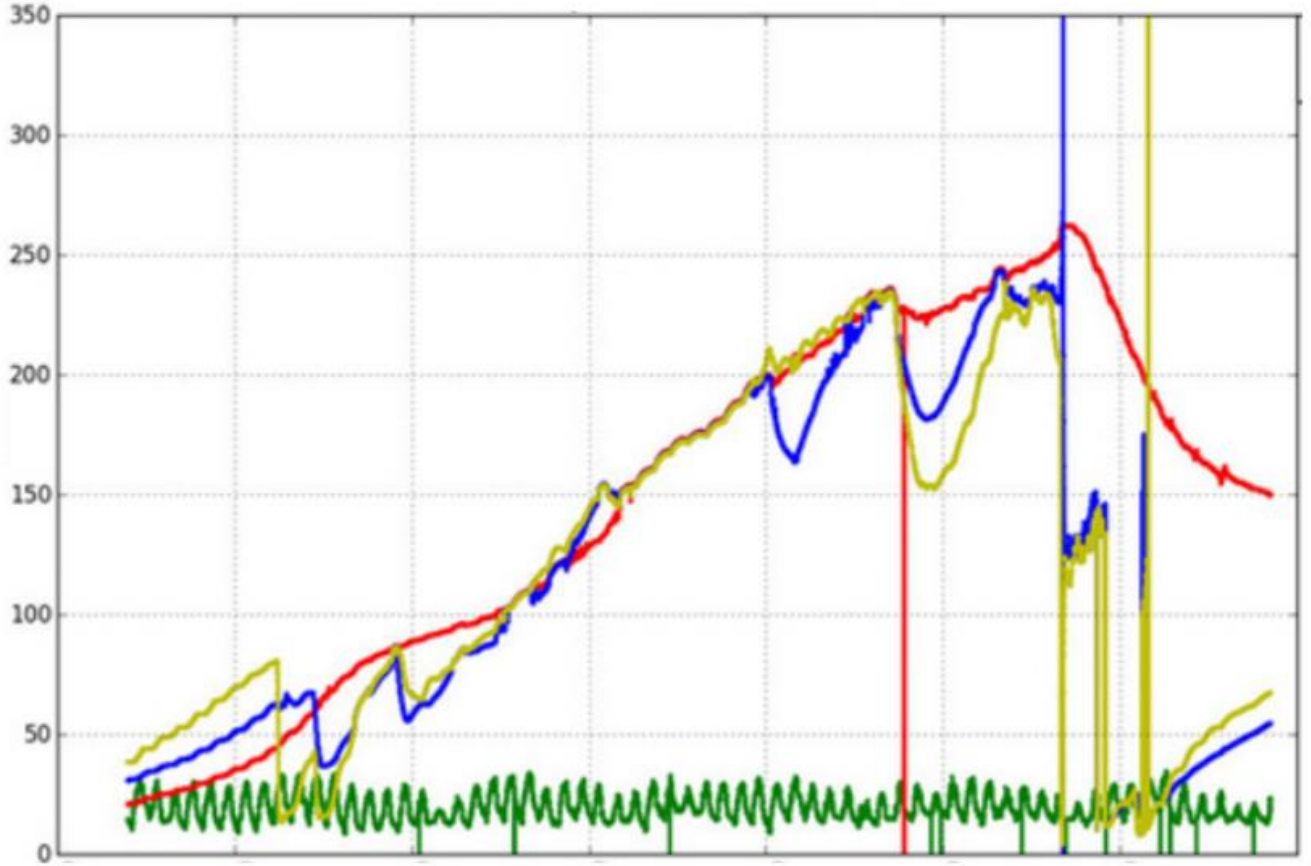
Watermark sensors installed 4” back from drip line



S12.8r Relay

S12.5
S12.6r Relay

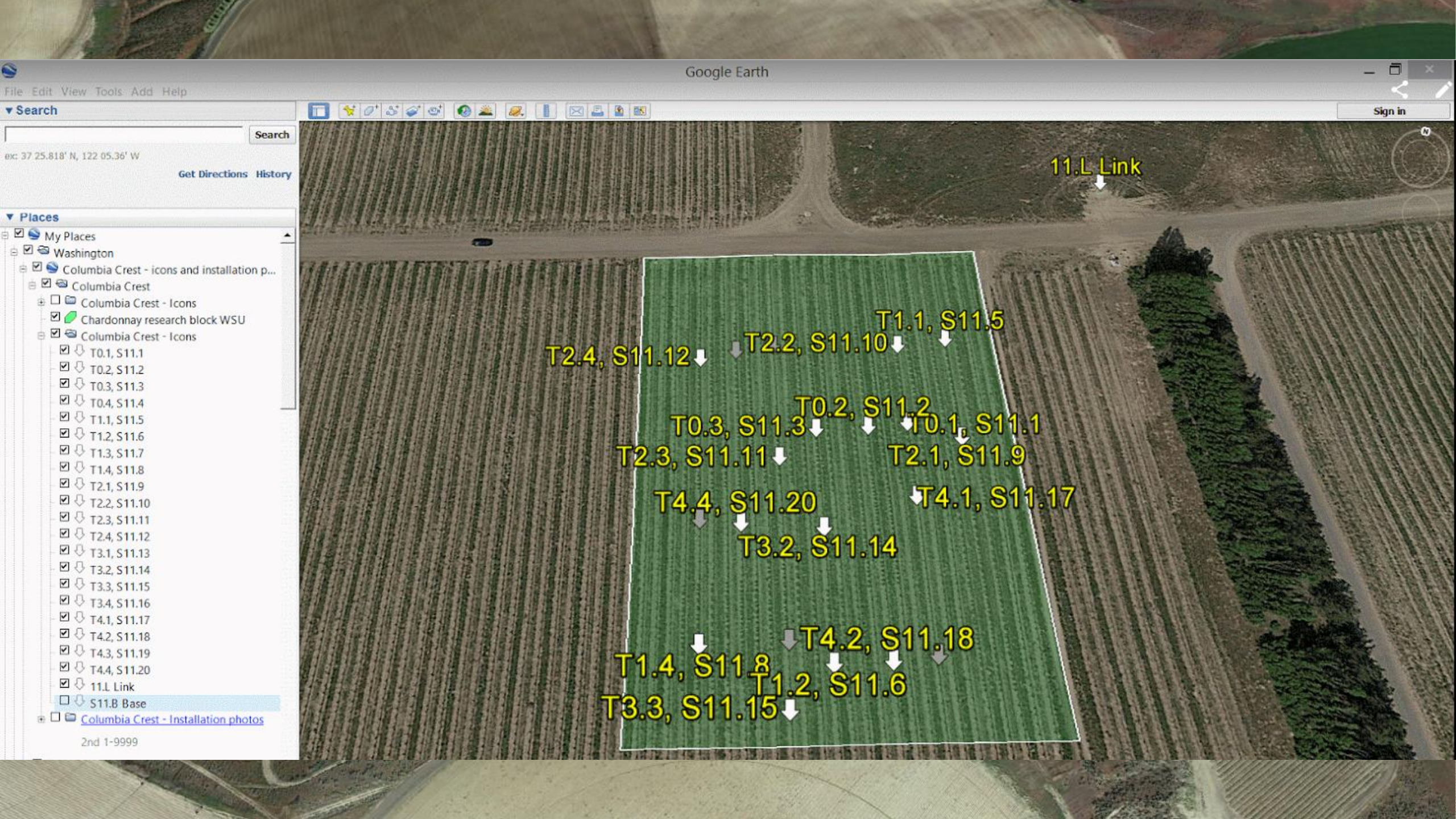
Watermark sensors installed 8”back from drip line



S12.8r Relay

Smart Irrigation Management

- Deliver sensor data to growers in real time
  - dependable, insightful, actionable
- Use machine learning to analyze the relationships between crop, irrigation, weather, and soil at specific sites.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Columbia Crest - icons and installation p...
Columbia Crest
Columbia Crest - Icons
Chardonnay research block WSU
Columbia Crest - Icons
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T1.1, S11.5
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T4.3, S11.19
T4.4, S11.20
11.L Link
S11.B Base
Columbia Crest - Installation photos
2nd 1-9999
Sign in
11.L Link
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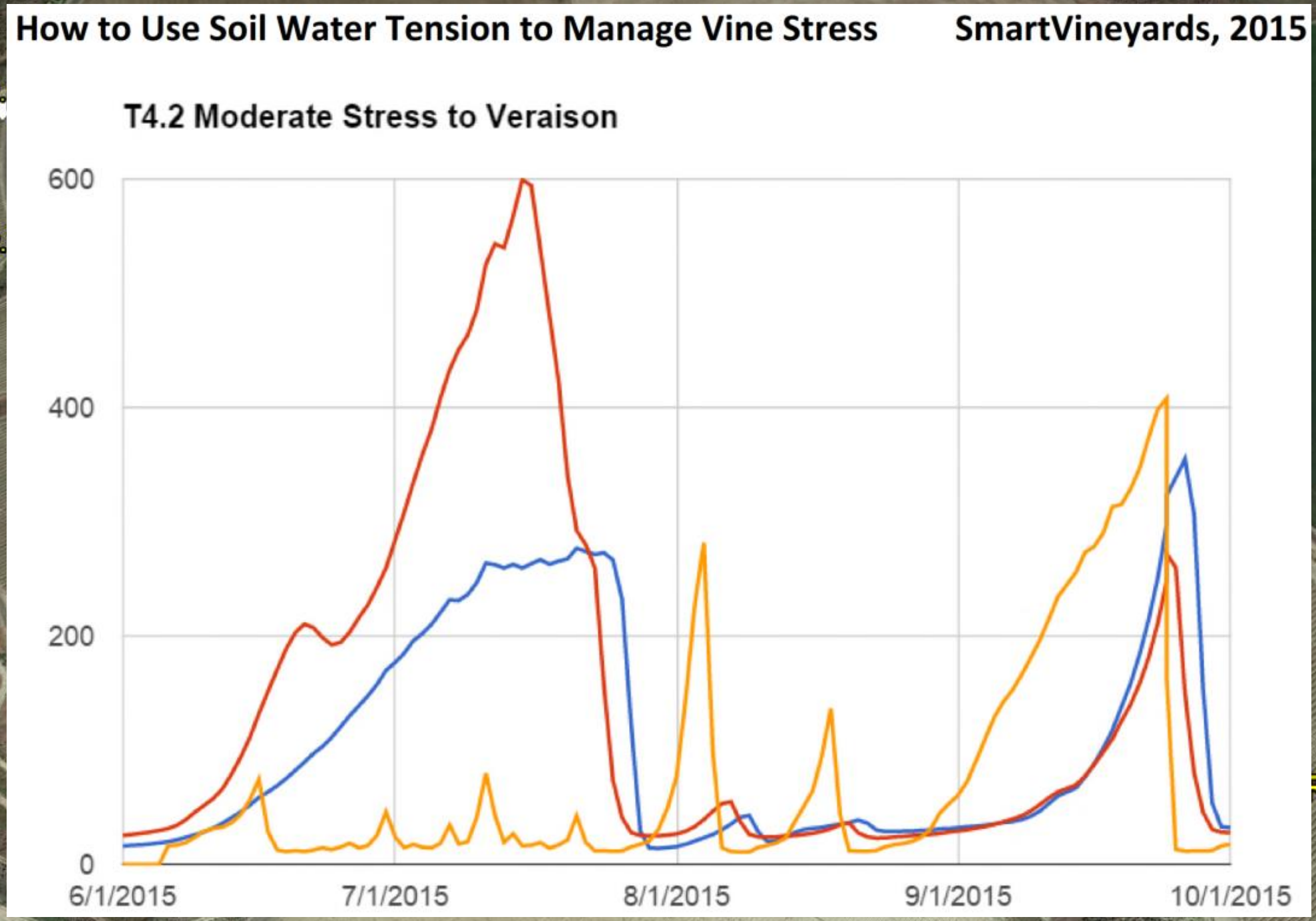
S12.5
S12.7r
Br Relay

How to Use Soil Water Tension to Manage Vine Stress

SmartVineyards, 2015

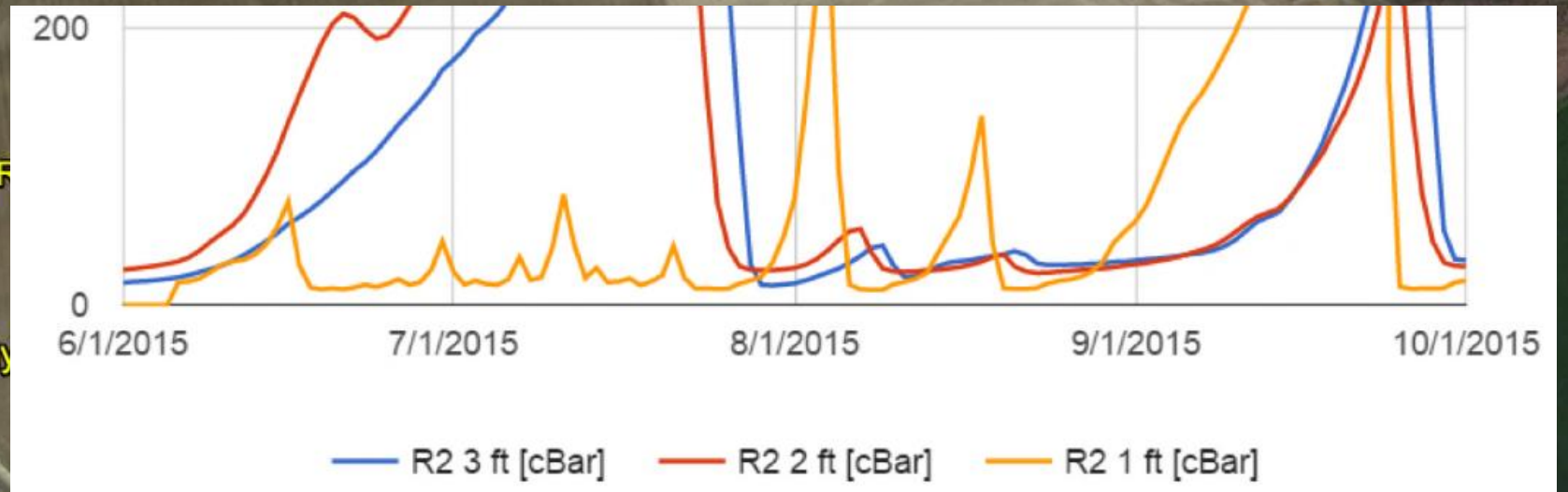


S12.5

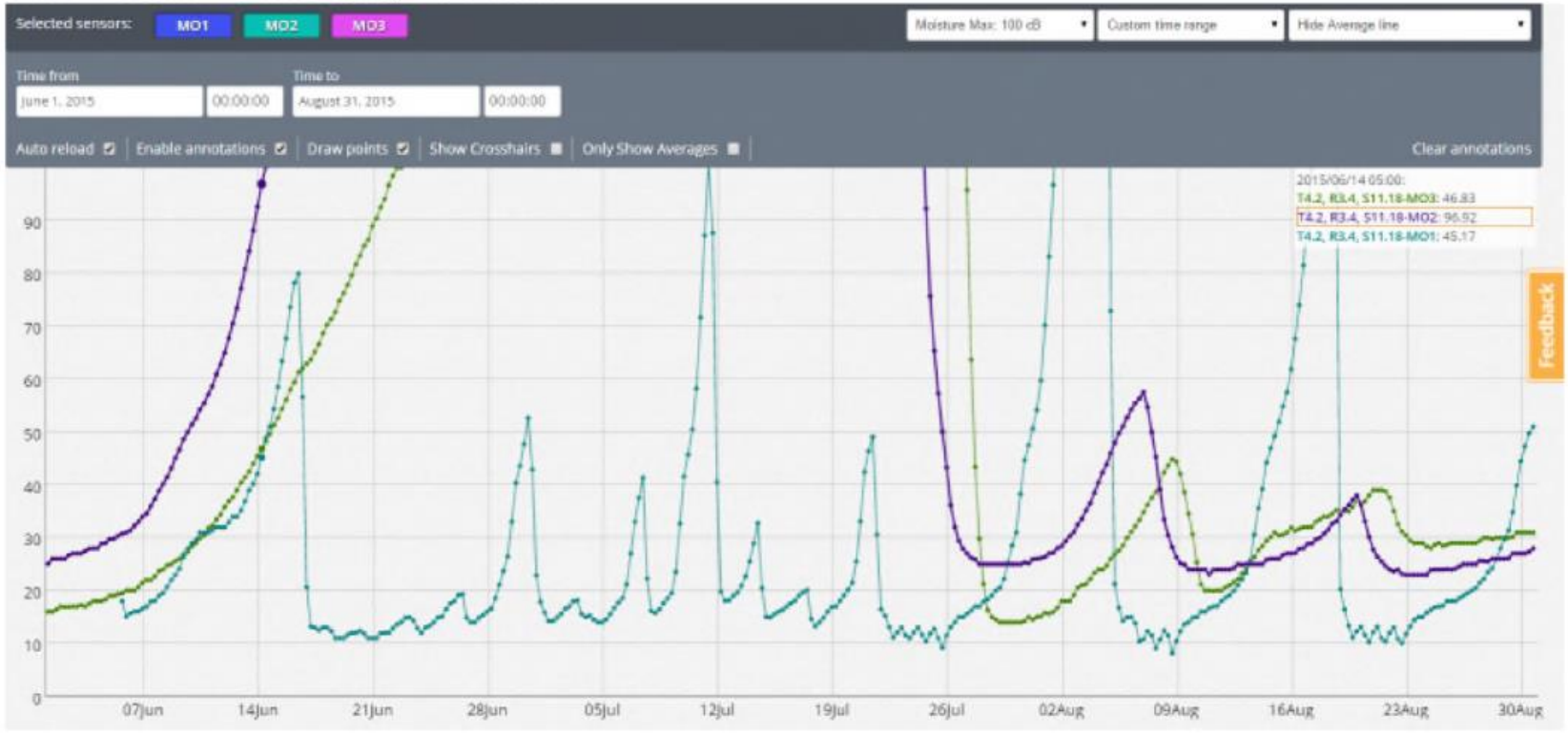
S12.6r R

S12.7r Relay

S12.2



T4.2 Detail – 3 months, 100 cbar



12.4

S12.8r Relay

Smarter Irrigation Management

- Growers set management goals
- Machine learning analyzes sensor data
- Growers given guidance to achieve goals
  - by email, text, or login - with data and analysis
- In vineyards, orchards, or fields
  - for grapes, hops, apples, berries, onions, ...

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S12.7
Relay


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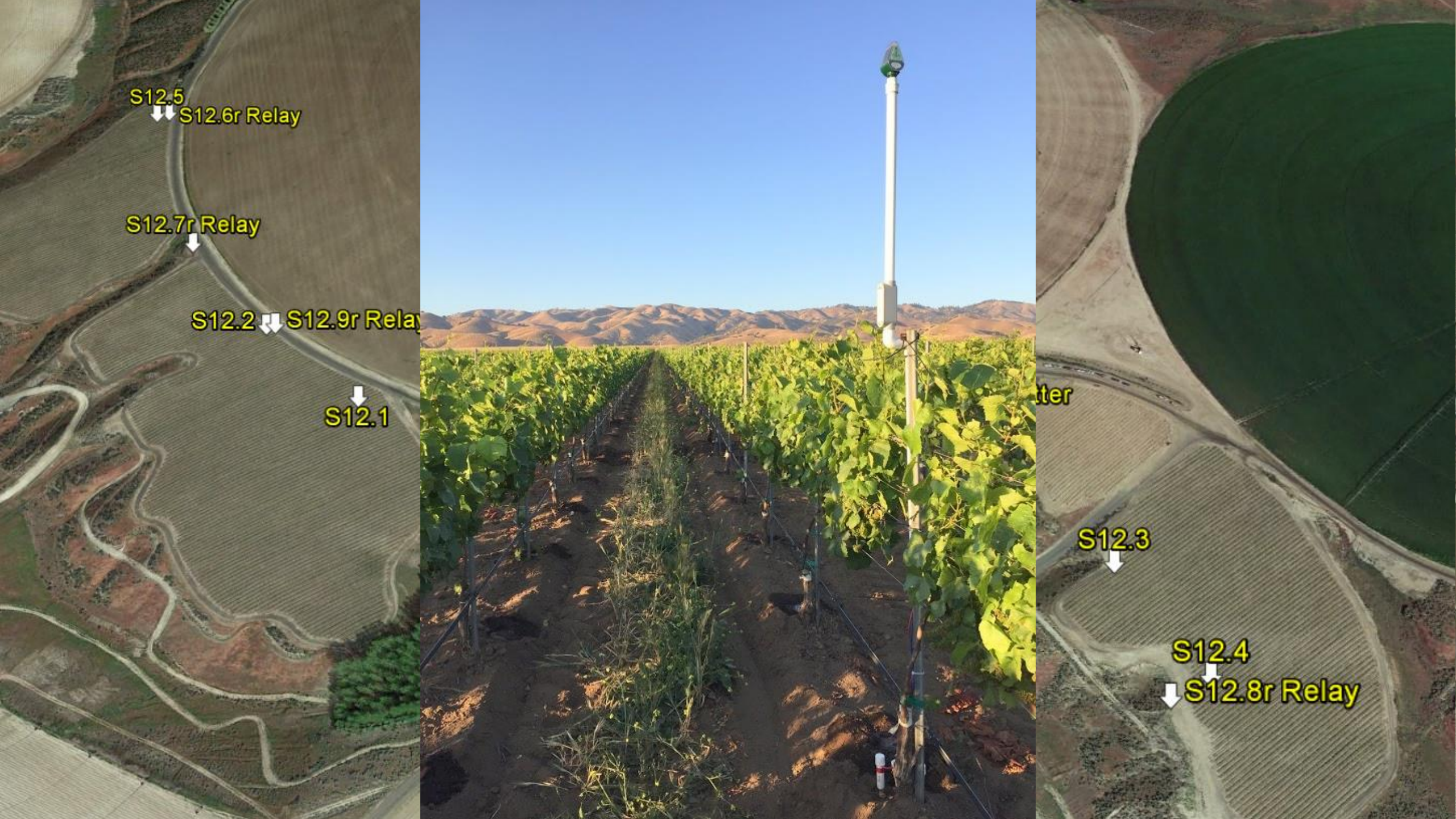
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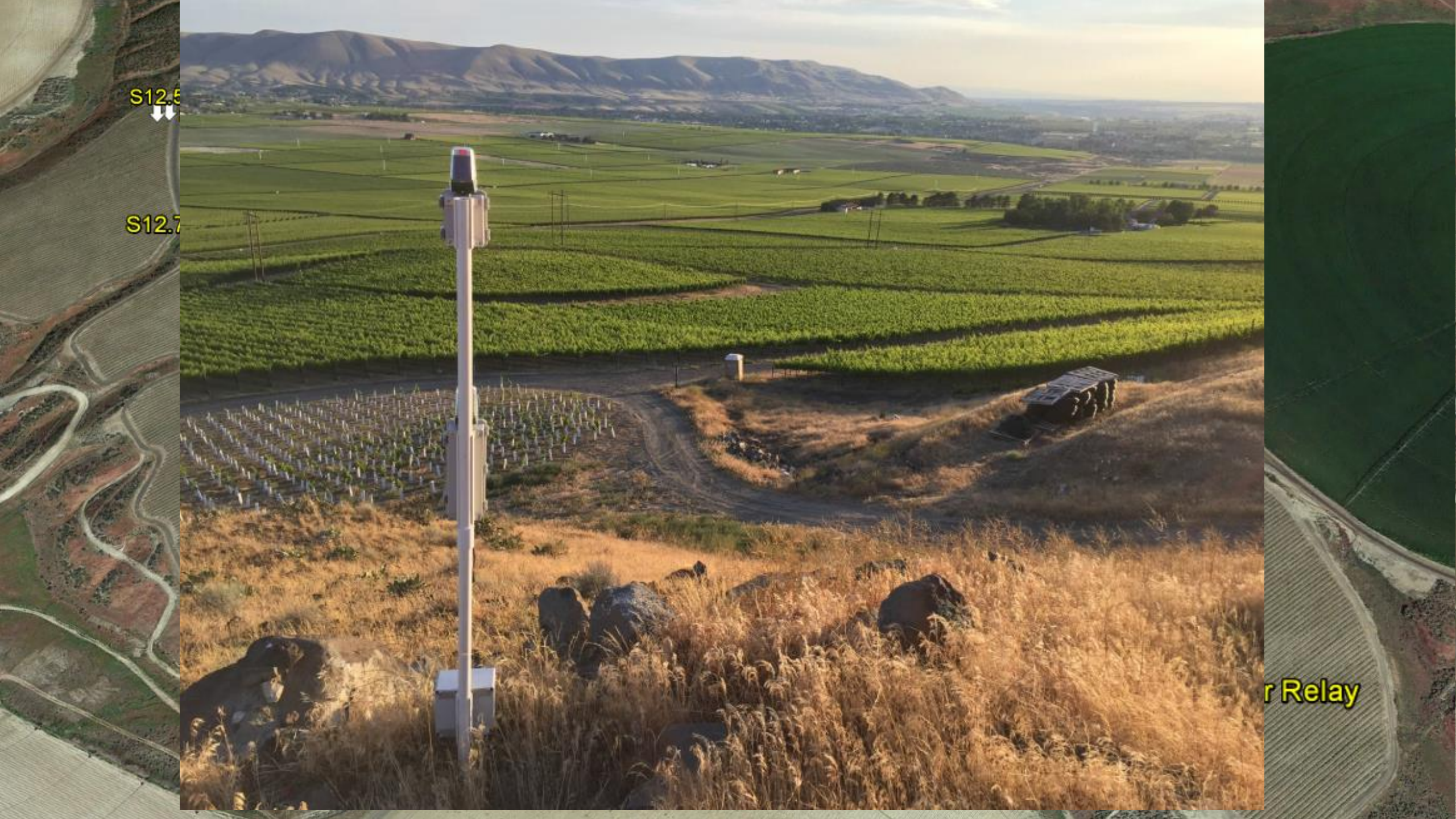
Relay


S12.5
S12.7
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S12.5
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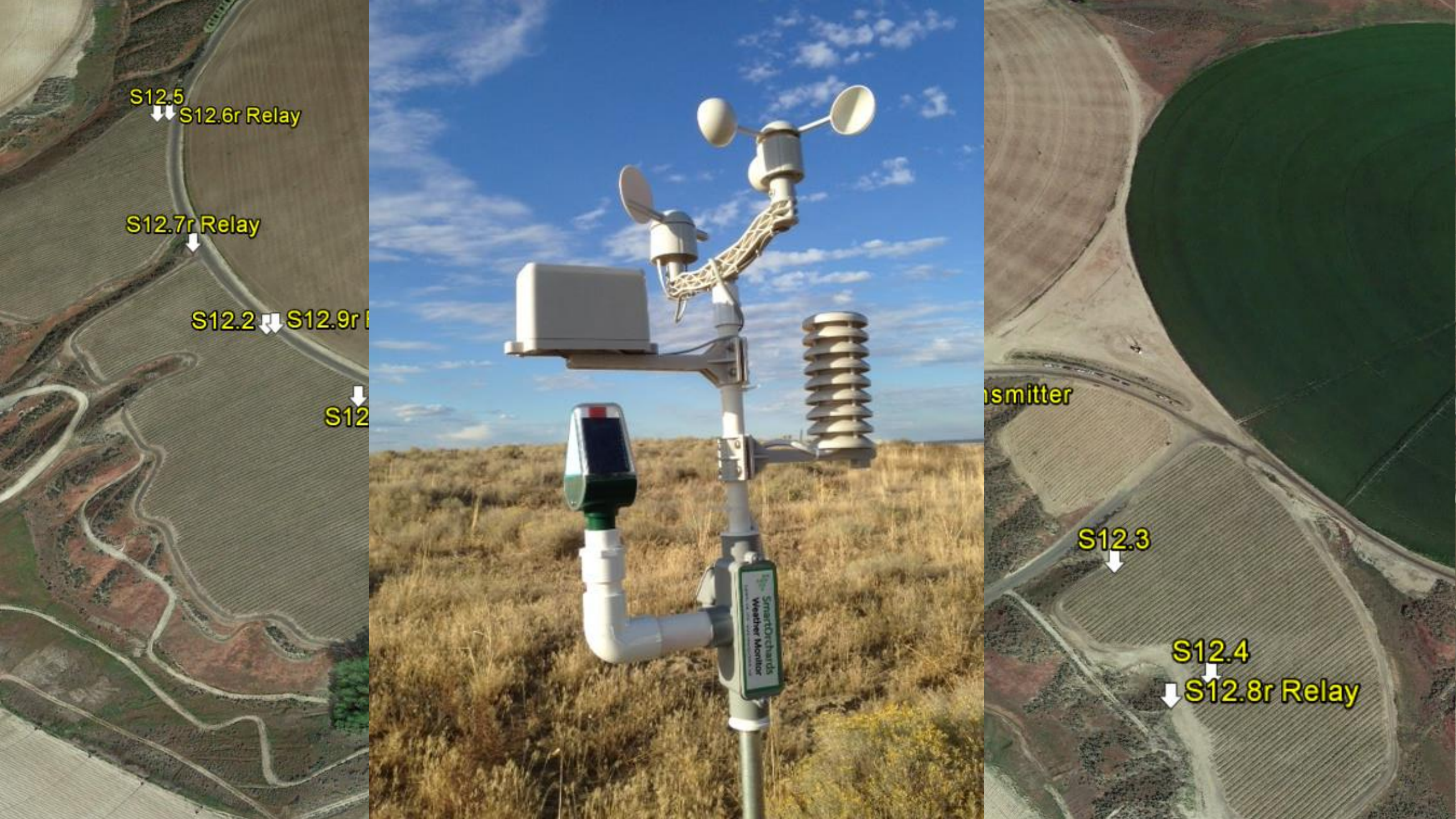
S12.8r Relay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nsmitter
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S12.8r Relay
SmartOrchards
Weather Monitor


S12.5
S12.6r Relay
S12.7r Relay
S12.2
S12.9r Relay
S12.1
S12.C Connector
S12.T Transmitter
S12.3
S12.4
S12.8r Relay

Using Soil Water Tension To Monitor and Manage Irrigation Easily

Alan Campbell
CEO, SmarterAgGroup
503-502-6302
alan@smartvineyards.net