

# **Examining Water Stress in a Vineyard Using Hyperspectral Imagery Collected from a UAV**

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International Diffuse Reflectance Conference

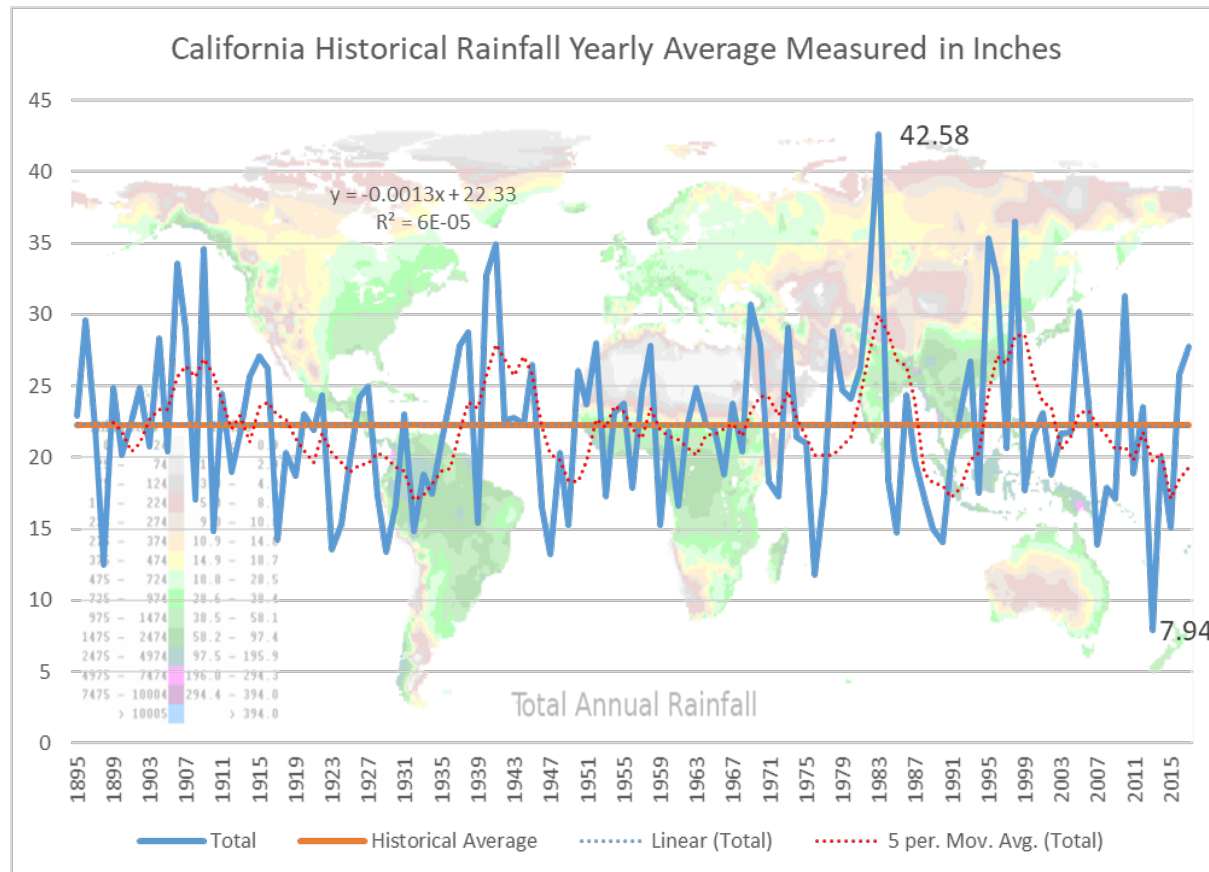
Chambersburg, PA

August 2, 2018

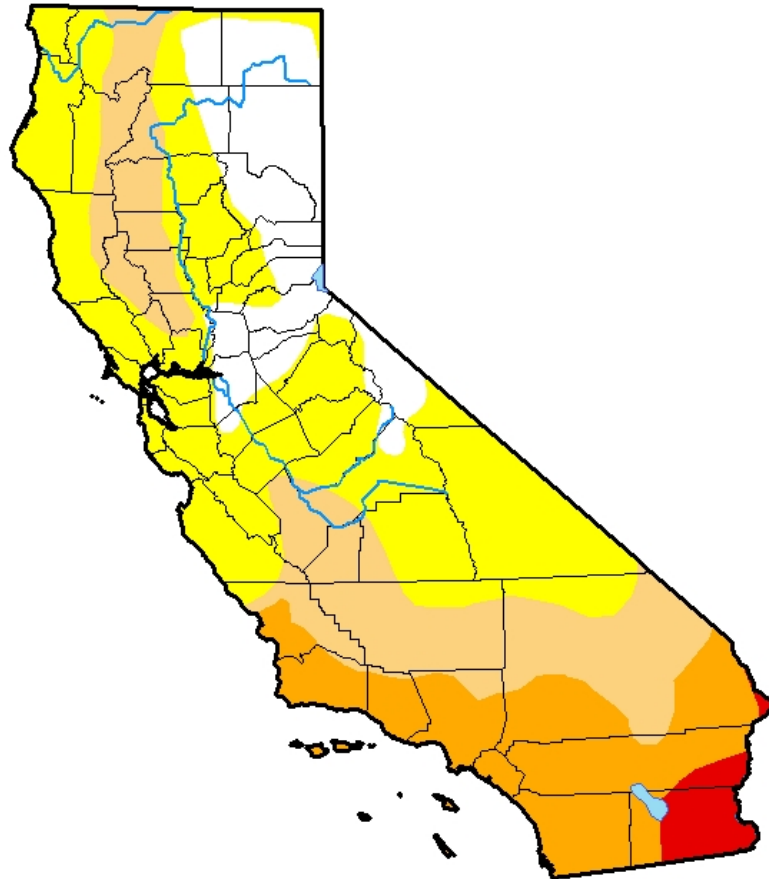
# Agenda

- Why Study Grapes and Water Stress
- Data Collection and Data Analysis
- Key Result of the Data Analysis
- Summary and Conclusion

# California has been experiencing below average rainfall for the last several years



# U.S. Drought Monitor California



**July 10, 2018**

(Released Thursday, Jul. 12, 2018)

Valid 8 a.m. EDT

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
<b>Current</b>	14.85	85.15	44.12	20.75	2.77	0.00
<b>Last Week</b> 07-03-2018	14.85	85.15	44.17	20.75	2.77	0.00
<b>3 Months Ago</b> 04-10-2018	33.85	66.15	37.10	13.77	2.50	0.00
<b>Start of Calendar Year</b> 01-02-2018	55.70	44.30	12.69	0.00	0.00	0.00
<b>Start of Water Year</b> 09-26-2017	77.88	22.12	8.24	0.00	0.00	0.00
<b>One Year Ago</b> 07-11-2017	76.46	23.54	8.24	1.06	0.00	0.00

## Intensity:

<span style="background-color: yellow; border: 1px solid black; display: inline-block; width: 15px; height: 10px;"></span> D0 Abnormally Dry	<span style="background-color: red; border: 1px solid black; display: inline-block; width: 15px; height: 10px;"></span> D3 Extreme Drought
<span style="background-color: orange; border: 1px solid black; display: inline-block; width: 15px; height: 10px;"></span> D1 Moderate Drought	<span style="background-color: darkred; border: 1px solid black; display: inline-block; width: 15px; height: 10px;"></span> D4 Exceptional Drought
<span style="background-color: darkorange; border: 1px solid black; display: inline-block; width: 15px; height: 10px;"></span> D2 Severe Drought	

The Drought Monitor focuses on broad-scale conditions.  
Local conditions may vary. See accompanying text summary  
for forecast statements.

## Author:

Brian Fuchs  
National Drought Mitigation Center



<http://droughtmonitor.unl.edu/>

# California Wine Regions



# Water Usage for Grapes

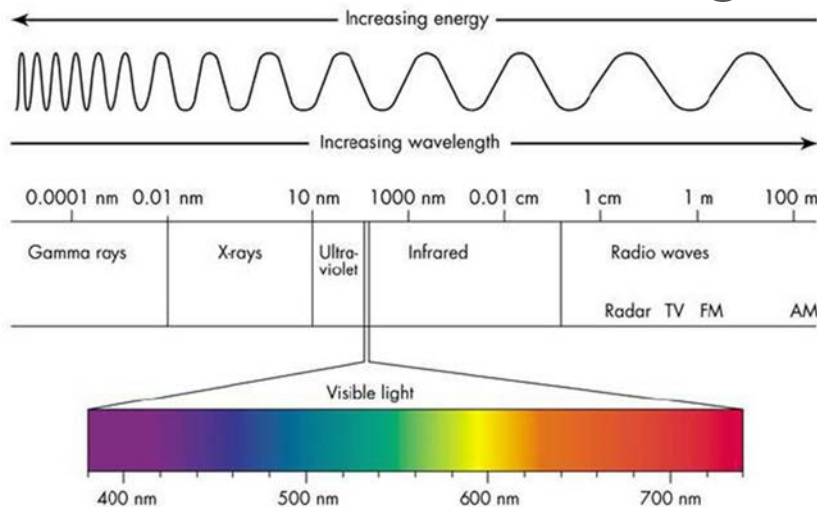
	<b>Acres (1,000)</b>	<b>Acre-feet per Acre</b>	<b>Acre- Feet (1,000)</b>	<b>Tons of Grapes per Acre</b>	<b>Gallons Water/Ton (1,000)</b>	<b>Gallons Water/Gallon of Wine*</b>
North Coast	132	0.7	93	4.4	52.5	309
Central Coast	91	1.4	27	5.7	80.1	471
Delta	86	1.35	116	10.6	41.3	243
S.J. Valley	129	2.4	307	14.6	53.2	313
Total California	459	1.45	667	8.75	54.1	318

\*~170 gallons of wine per ton of grapes

Source: Daniel Sumner, UC Davis Ag. Issues Center, Wine Industry Symposium, Sept. 26, 2016

# Research Question

- Can hyperspectral imagery collected from a drone be used to detect water stress in a vineyard that would compete with current methods of detecting water stress?



## Why study grapes?

- Grapes represent an interesting crop to study for water stress because vineyard producers would like to control the stress of the plant during the season
- Wine grapes are a high value crop that has the profit margins to adopt this technology
- Current method of measuring water stress is time consuming and expensive



## Equipment Used for the Study

- Yamaha RMax Helicopter
  - 16 kg payload capacity
  - 2-stroke, horizontally opposed 2-cylinder engine
- Corning Shark HSI
  - 60 bands
  - 400 – 1000 nm
  - Full FOV 52°
  - ~ 9 pounds



- PMS Instrument's Model 600 Pressure Chamber
- 13x11x10 inches (14 lbs)
- 40 bar max (1 MPa = 10 bars)



## Flight Specifics

- Flights occurred between July 12, 2016 to September 2, 2016 (8 usable flights)
- Two sets of altitudes were flown (~105-110 feet AGL and ~80-85 feet AGL)
- Due to the size of the vehicle, a COA was required for the flights
- Flights typically occurred between 11am and 1pm



## Field Specifics

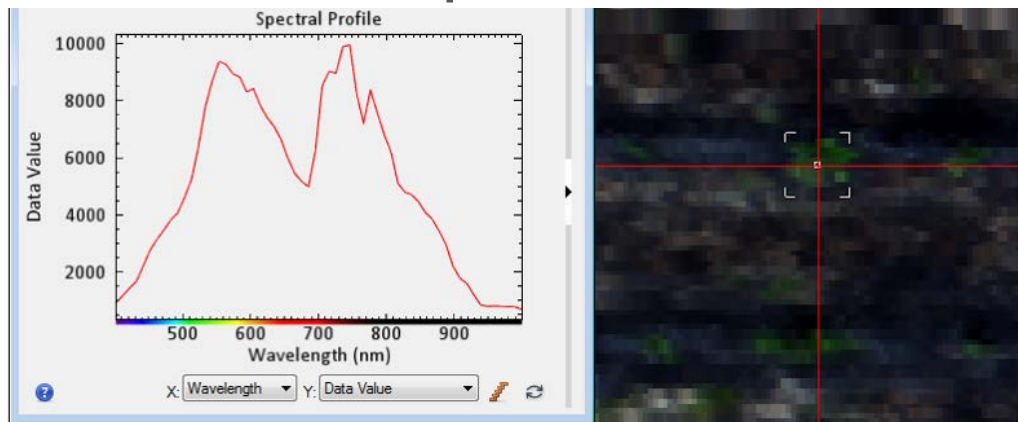
- Data was collected on an on-campus 17 acre vineyard
- Vineyard is a dryland operation with negligible watering
- ~45 random sample locations were generated
- Two leaves for each plant were placed in a silver colored bag and left on the plant for ~1 hour

- After 1 hour, leaves were cut and then placed into a pressure chamber
- Pressure was slowly increased until water was seen coming from the stem



## Data Analysis

- Analysis of imagery data was conducted using Harris' ENVI software
- Nine pixels were extracted from the hyperspectral imagery corresponding to where the leaf samples were collected



- Pressure bomb readings were broken up into 4 regions
  - No stress (less than 10 bars)
  - Mild stress (between 10 – 12 bars)
  - Moderate stress (between 12 and 14 bars)
  - High stress (between 14 and 16 bars)
- Averages of each bands DN (provided by the HSI camera) was calculated for each stress level

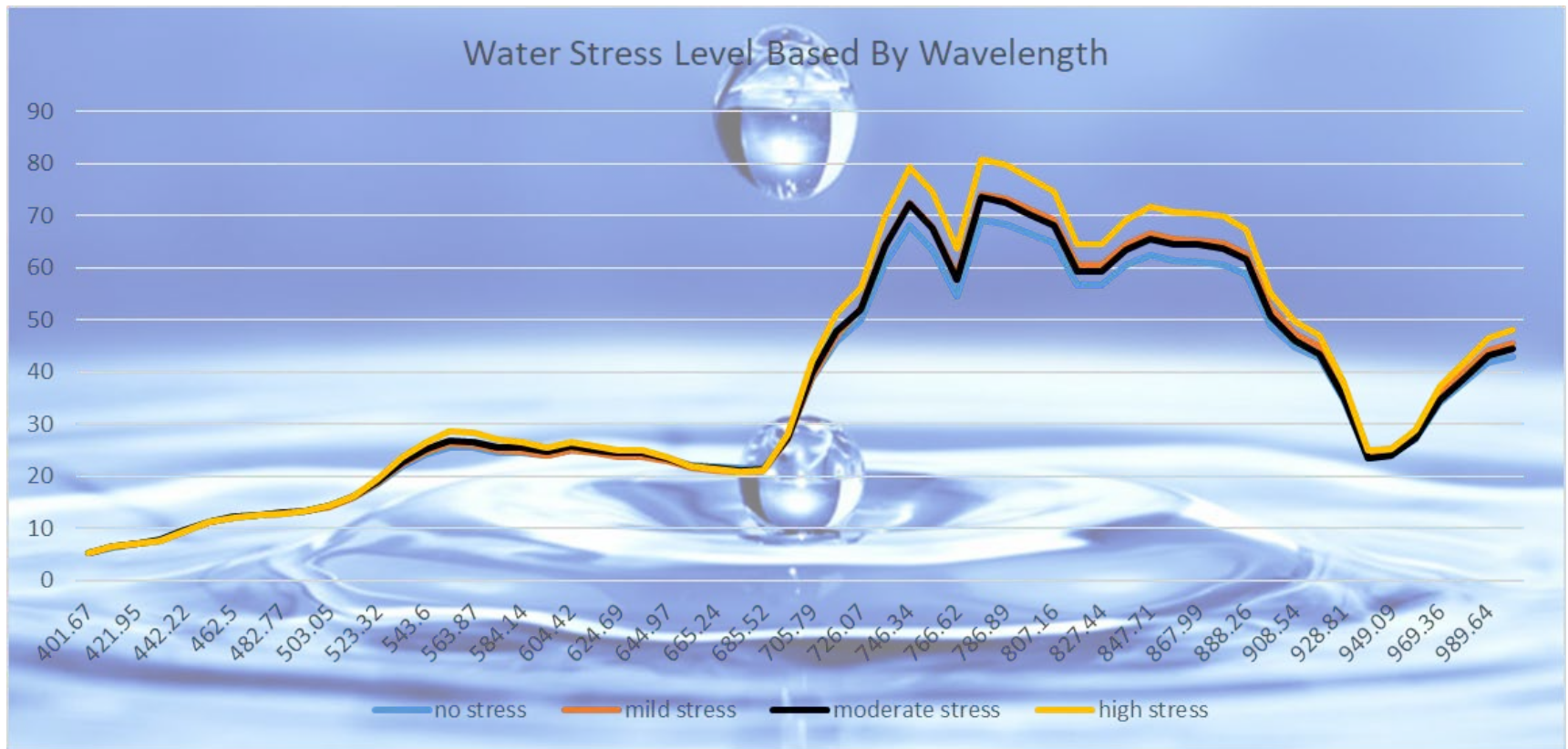
- An F-test was used to see if the variance within the stress categories were homoscedastic or heteroscedastic for each band
- An appropriate student T-test was used to see if there was a significant difference in the means between the different stress level categories for each band

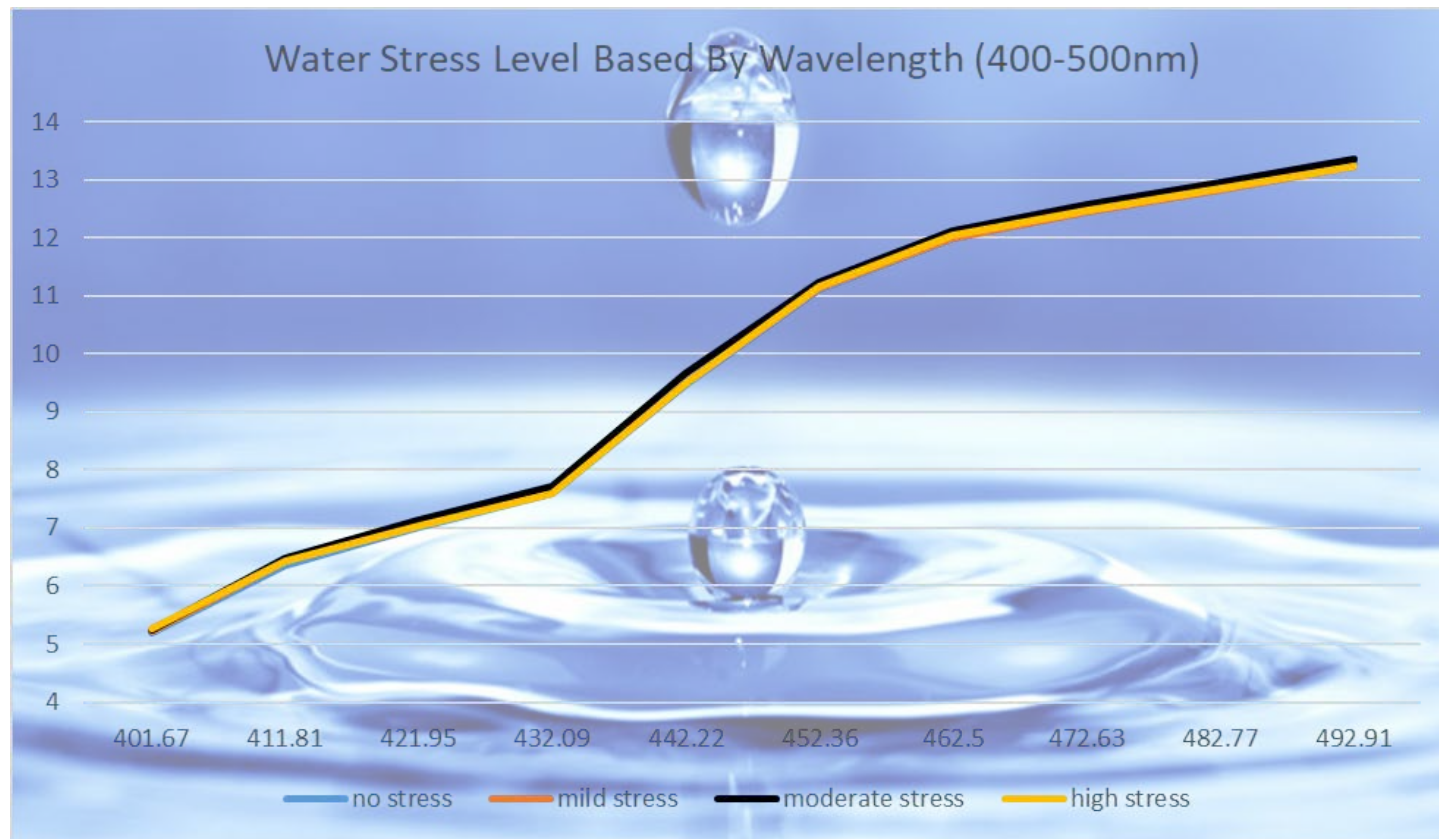


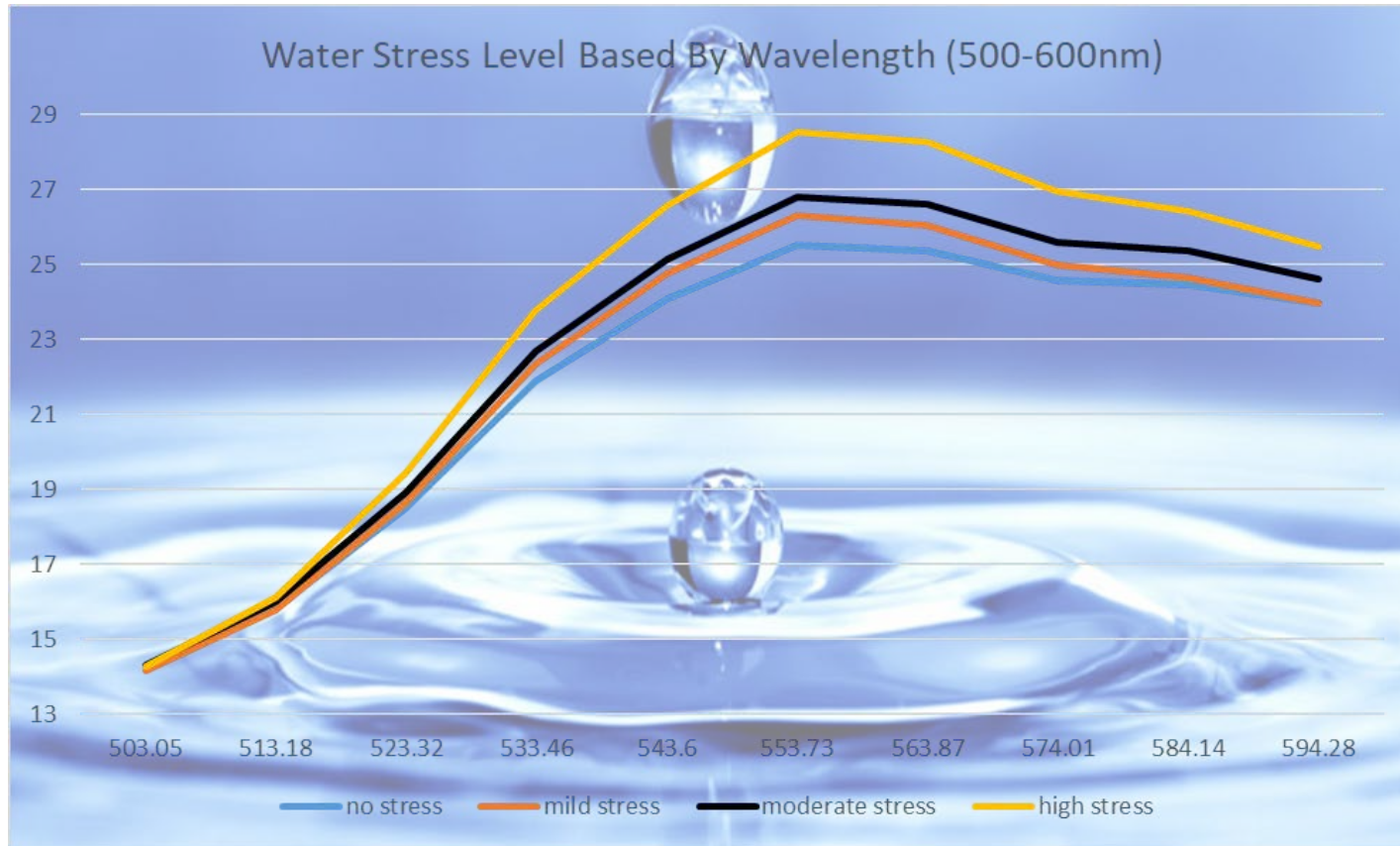
## Results

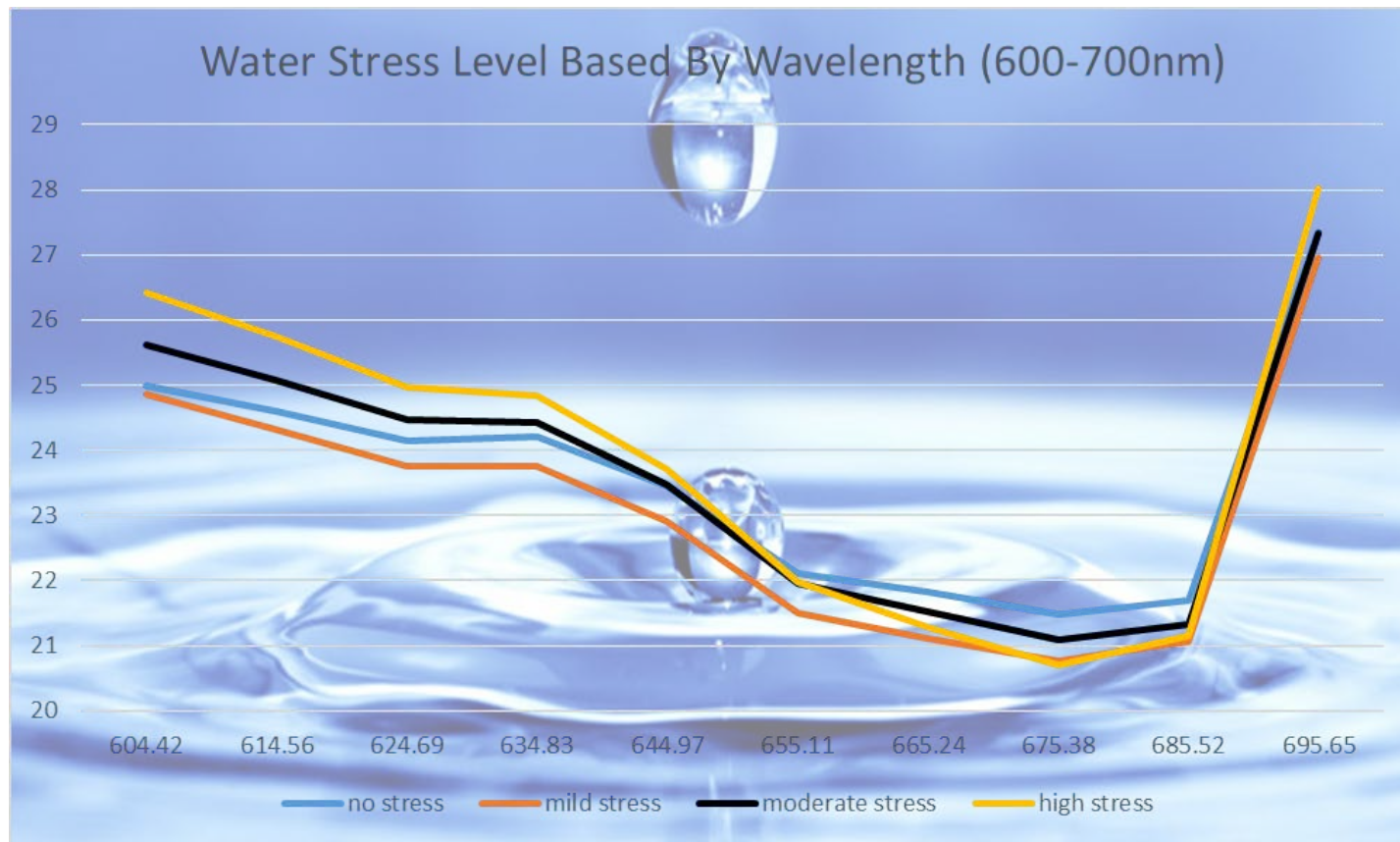
- 339 usable leaf samples were collected and paired with hyperspectral band information

Pressure Chamber Reading	Water Stress Distinction	Number of Observations
less than -10 Bars	no stress	166
-10 to -12 Bars	mild stress	104
-12 to -14 Bars	moderate stress	53
-14 to -16 Bars	high stress	16

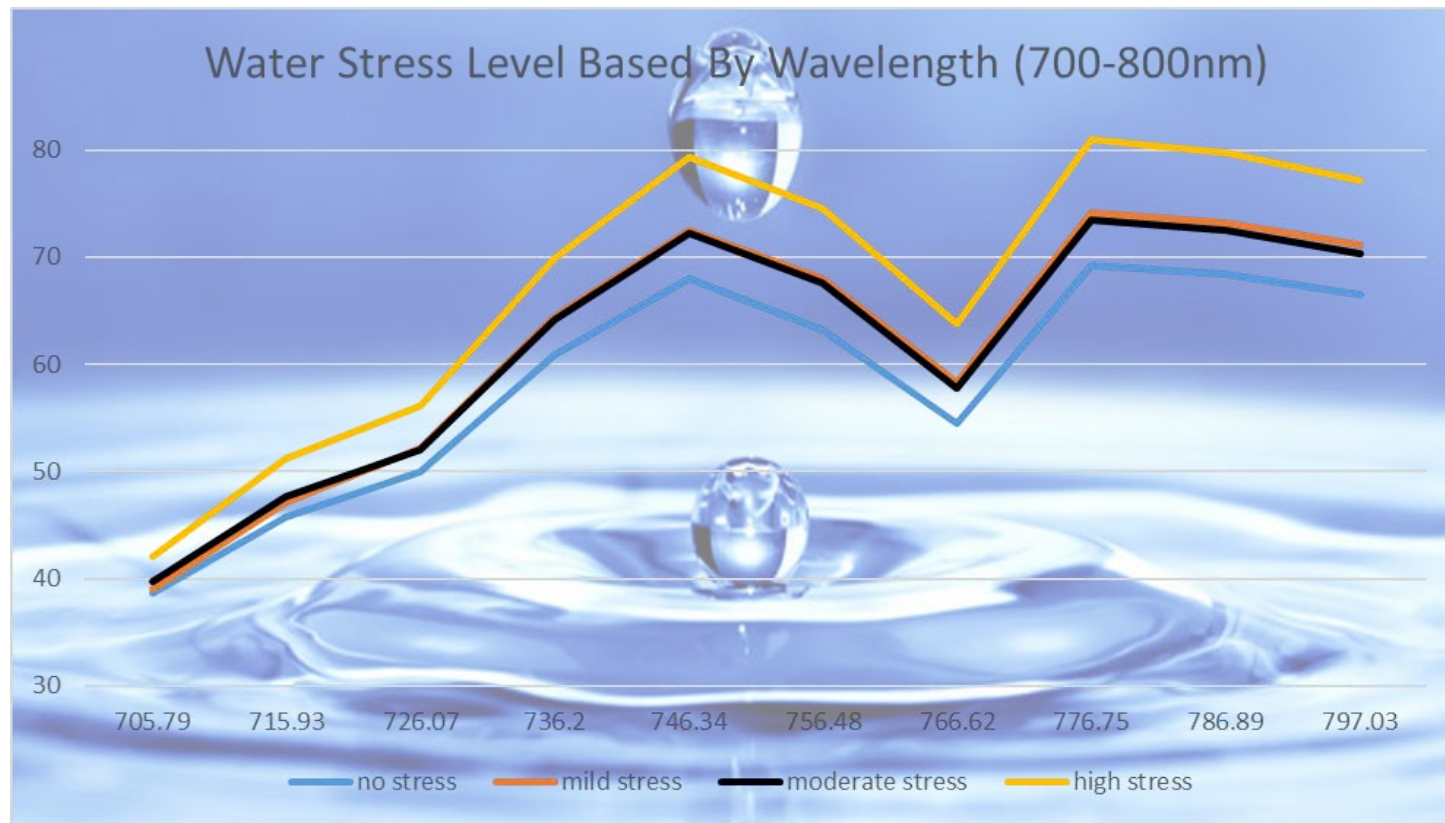


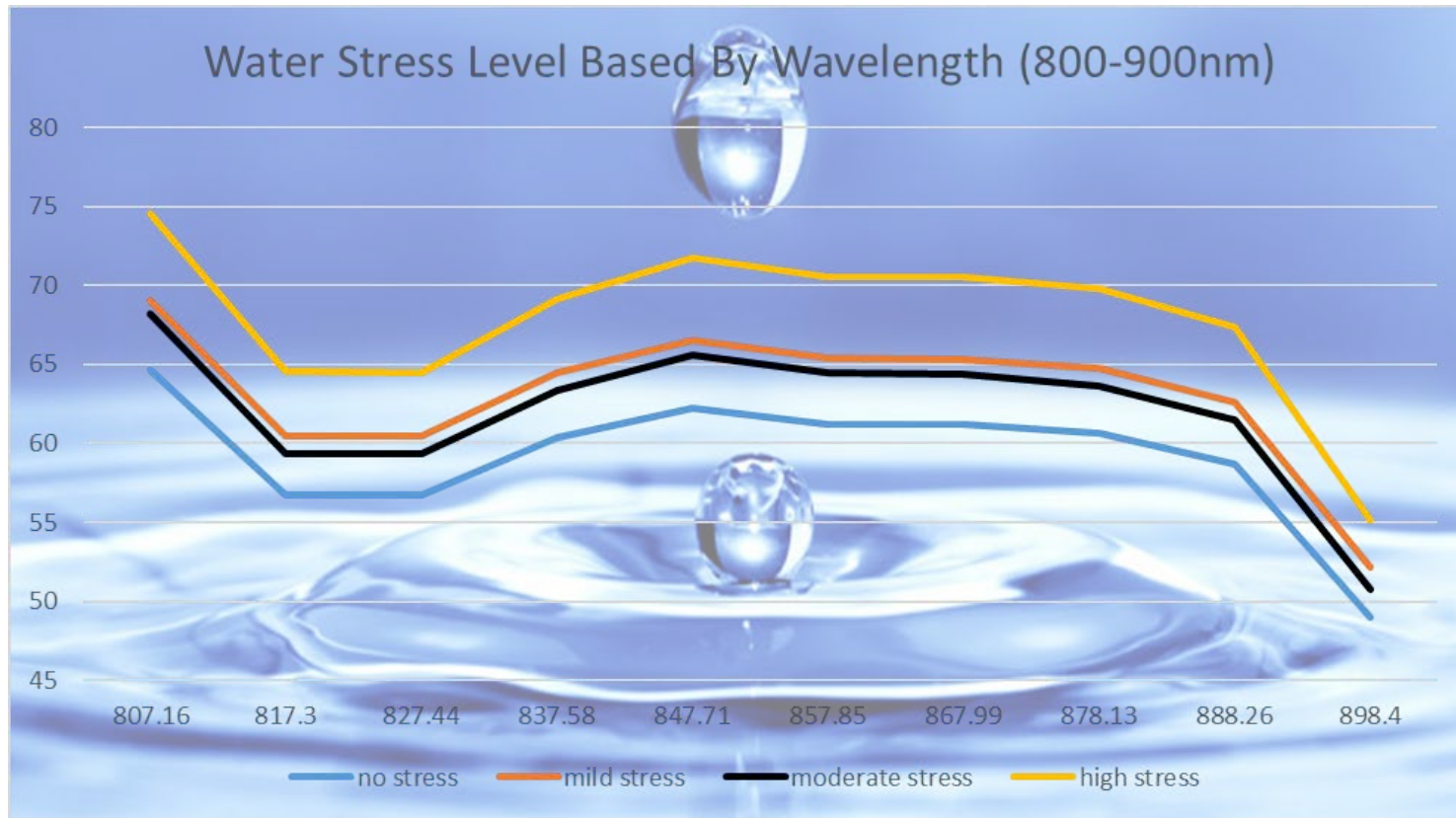


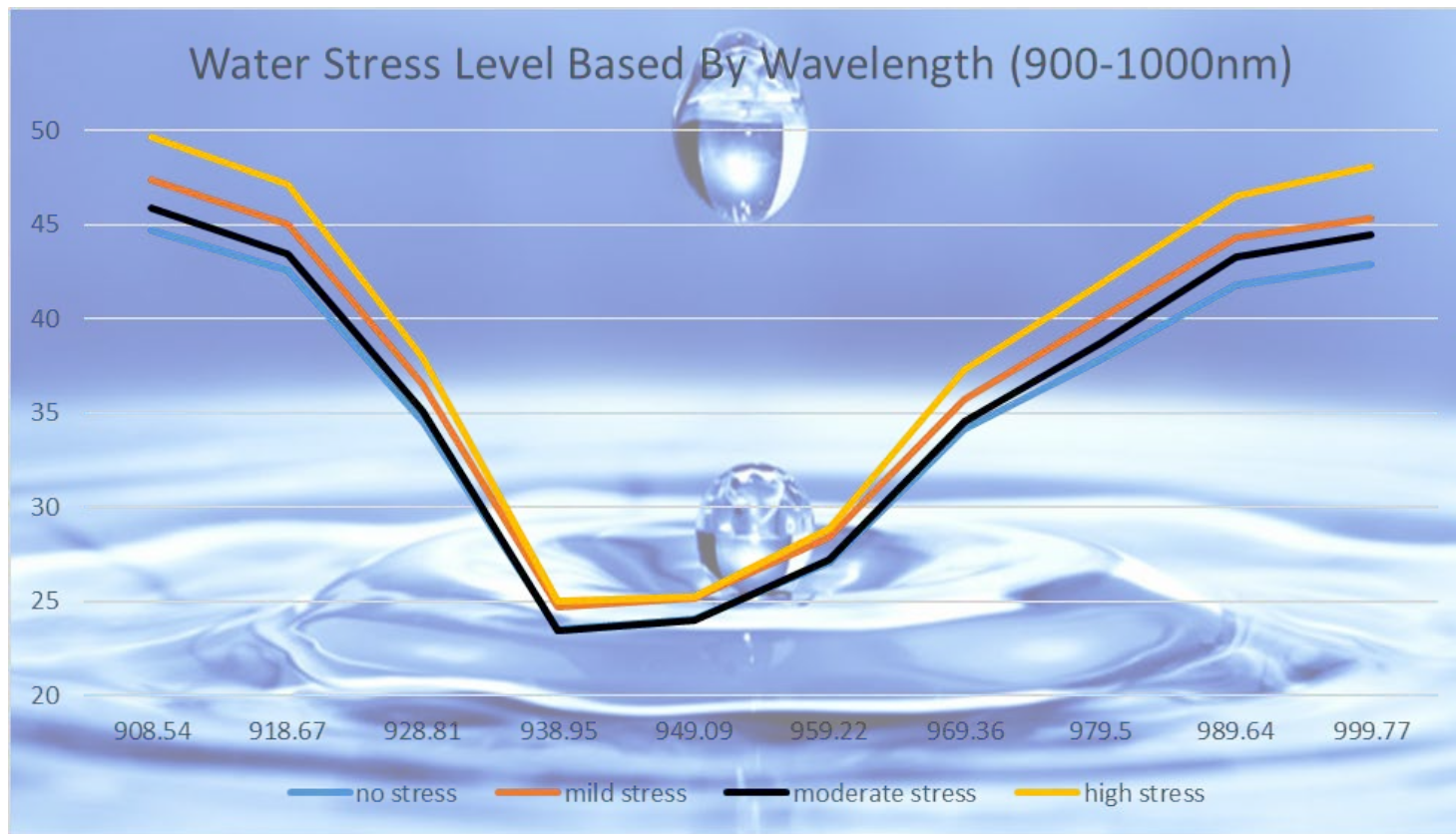














- Looking at Pearson Correlation Coefficients for pairwise comparison of the bands shows:
  - There are high correlations ( $\rho > 0.7$ ) between bands that are within 300 nm of each other
  - There is low correlation ( $-0.043 < \rho < 0.106$ ) between actual pressure bomb readings and the band readings

- Low stress vs. mild stress statistically different band readings
  - Alpha = 0.1:
    - Bands 736.2, 746.34, 766.62, 776.75, 786.89, 797.03, 807.16, 817.3, 827.44, 837.58, 847.71, 857.85, 867.99, 878.13, 888.26, 898.4, 908.54, 918.67, 979.5, 989.64, 999.77
  - Alpha = 0.05:
    - Bands: 756.48

- Low stress vs. high stress statistically different band readings
  - Alpha = 0.1:
    - Bands 553.73, 563.87, 715.93, 726.07, 817.3, 827.44, 837.58, 898.4, 989.64, 999.77
  - Alpha = 0.05:
    - Bands: 736.2, 746.34, 756.48, 766.62, 776.75, 786.89, 797.03, 807.16, 847.71, 857.85, 867.99, 878.13, 888.26

## Summary and Conclusions

- There are a set of bands ( $> 736$  nm) that are statistically different when comparing no stress and low stress grape readings
- This also true when comparing no stress to high stress with bands 553.73 and 563.87 also showing up as significant

- The bands do not appear to be able to delineate between mild stress and moderate stress (at least based on how water stress is understood in grape plants)
- Future research should focus on examining actual physiology of the grape plants or the grapes themselves and how those characteristics may be seen in hyperspectral bands

- Preliminary examination has shown that while the bands themselves may not be very good predictors of water stress, there may be some non-linear relationships between the bands that are more predictive

# Any Questions?



## Research Sponsors

- CSU Agricultural Research Initiative Grant
- Corning
- Raintree Foundation





Thank you!

Future Questions:  
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