Investigating New Methods for Evaluating Soil Characteristics by Geophysics, Drones (UAV), Remote Sensing Data, and Machine Learning

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Geological Engineering

- ❑ **Introduction**
- ❑ **Motivation**
- ❑ **Project questions**
- ❑ **Method and Theory**
- ❑ **Data acquisition and processing**
- ❑ **Conclusion**

Soil characteristics:

- Soil permeability
- Soil texture
- Volumetric Water Content (VWC)
- Electrical Conductivity (EC)

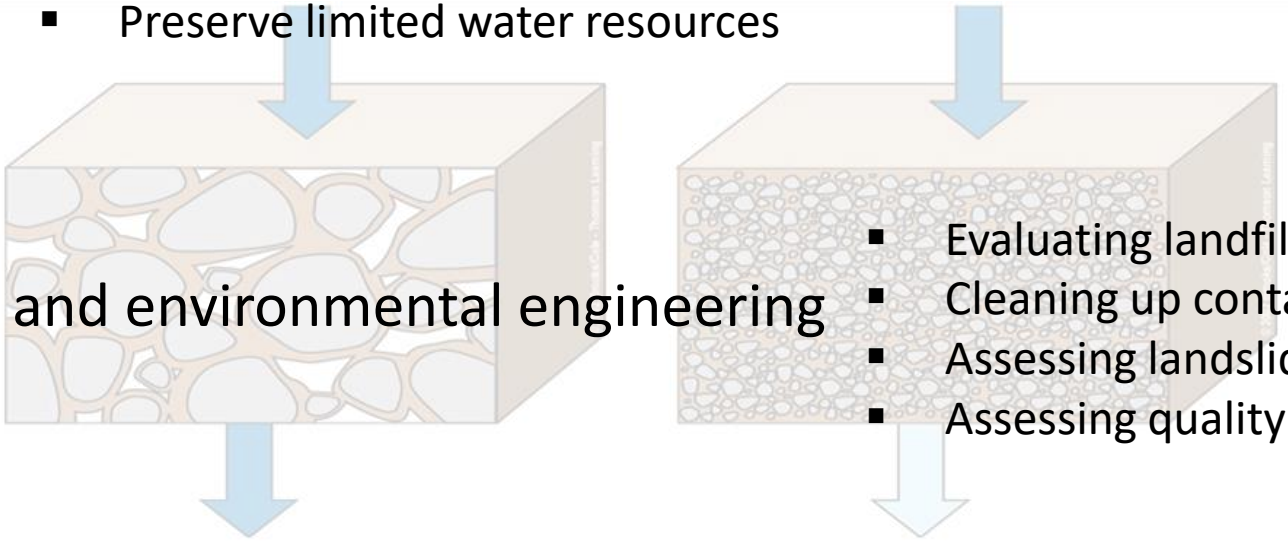
Evaluating the soil characteristics is important, yet difficult.
Soil parameters are spatially and temporally heterogeneous.

The results are useful for:

- Agriculture
- Water resource management
- Construction assessment
- Geotechnical and environmental engineering
- Climate change studies

Soil permeability: The ability of soil to allow water to pass through it.

- In agriculture
  - Prevent contamination of surface water
  - Preserve limited water resources



- In geotechnical and environmental engineering
  - Evaluating landfills and remediation strategies
  - Cleaning up contaminated groundwater
  - Assessing landslide potential
  - Assessing quality of construction
- In climate change models
  - How much precipitation will run off or infiltrate?
  - How much evaporation will occur?
  - Increase the ability to forecast the effects of climate change more accurately.

❑ Soil texture: Composition of particle size

Agriculture
- Choosing the right soil texture for different crops
- Using the best management practices for different soil textures

Construction
- Different soil textures are needed for different applications (sand is needed for water filters, clay for soil liners, etc.)

Engineering
- Estimates soil strength (landslide hazards, foundation design)
- Affects land subsidence
- Selection and modification of building and roads

Climate change
- Affects water holding capacity as another variable for climate change models

❑ Electrical Conductivity (EC): influenced by

- Soil texture (which determines water holding capacity, permeability, etc.)
- Soil salinity, which is used to map salt accumulation in soils
- Soil water content

❑ Soil Volumetric Water Content (VWC): The volume of water per unit volume of soil

- VWC influences the timing and amount of irrigation (applying the minimal amount of irrigation water at the optimal time)
- Satisfy crop needs while conserving water resources
- Reducing the negative environmental impacts of agriculture
- Influences compaction of modified soils

• Conventional methods:

- Collecting soil samples or measurements in one location
- Destructive or disturbing method
- Long time to collect/process these measurements
- Ignore the Heterogeneity of Soil
- Sample you collect at one point doesn't necessarily represent the site well

• Novel methods:

Combining effective methods (Geophysics, multispectral and thermal UAV data, correlate the results using machine learning)

- Non-destructive
- High-resolution measurements
- Many thousands of measurements
- UAVs collect very dense data sets

✓ **Use multispectral and thermal UAV data With Geophysical data sets and Machine learning to map soil properties over large areas with the high resolution**

What do we need? → **What are available methods?** → **How to model the data?** → **Results!**

❑ **Soil Characteristics:**
Soil permeability
Soil texture
EC
Soil VWC

❑ **Geophysics**
Electromagnetic Method
Ground Penetrating Radar (GPR)

❑ **UAVs (drones)**
Multispectral UAV data
Thermal UAV data

❑ **Machine Learning**
Map soil properties over large areas with the high resolution

✓

- Could **machine learning** correlate UAV-based multi-spectral data with VWC, permeability, and EC measurements acquired with geophysical methods?
- How do the difference in crop types and management practices impact VWC, permeability, and EC?
- Does permeability change during the wet and dry season and over the first few years after construction? How does this affect crop vigour?

Geophysical methods:

- ❑ Providing measurements across the traverses
- ❑ Geophysical methods are most accurate
- ❑ Data processing can be time consuming
- ❑ Require more expertise
- ❑ Better than conventional techniques (location based)
- ❑ Instruments are expensive

Unmanned aerial vehicles (UAVs):

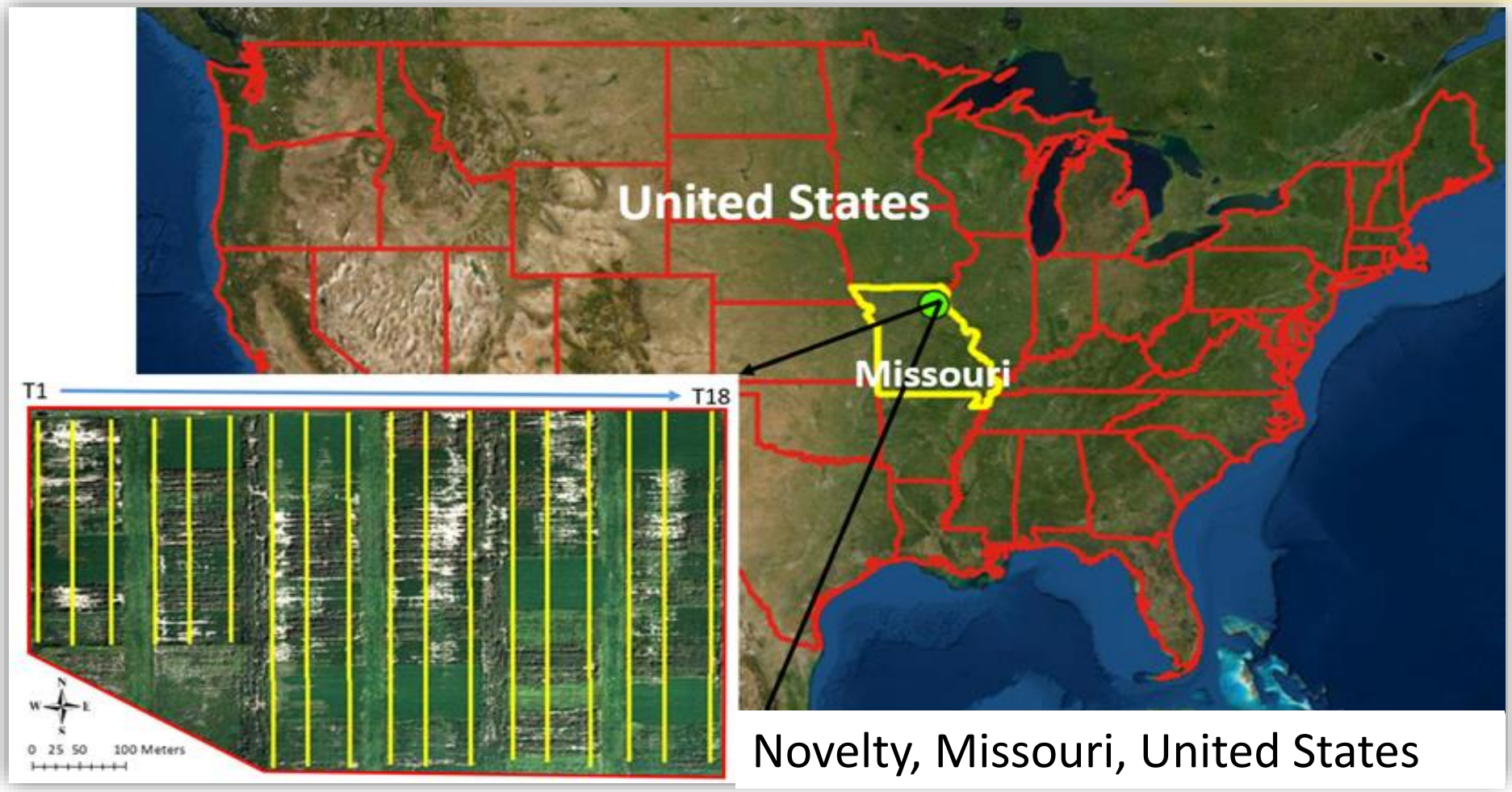
- ❑ Collect data in the entire field
- ❑ Less expensive compared to geophysical methods
- ❑ More quickly
- ❑ High resolution
- ❑ Evaluate crop health
- ❑ Repeatable

Measuring EC, VWC, and Permeability

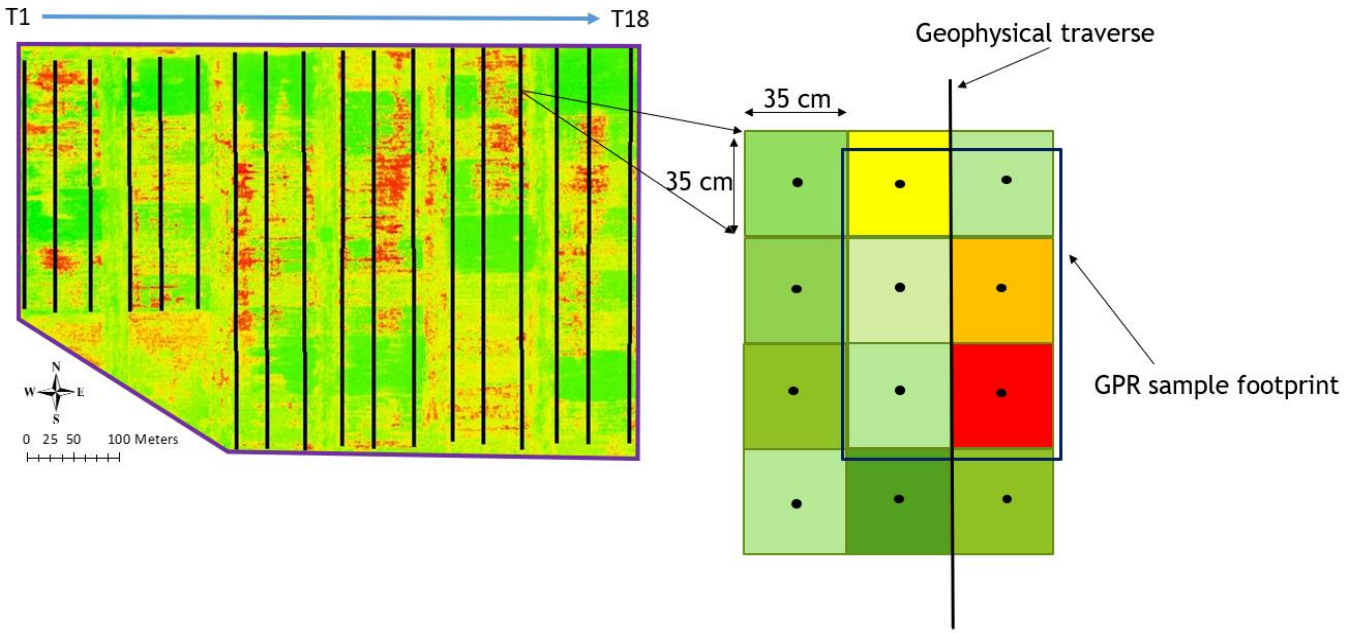
- Geophysical methods:
- Electromagnetic
  - Measure(EC) with EM38
- Ground Penetrating Radar (GPR)
  - Evaluate VWC and Permeability with GPR

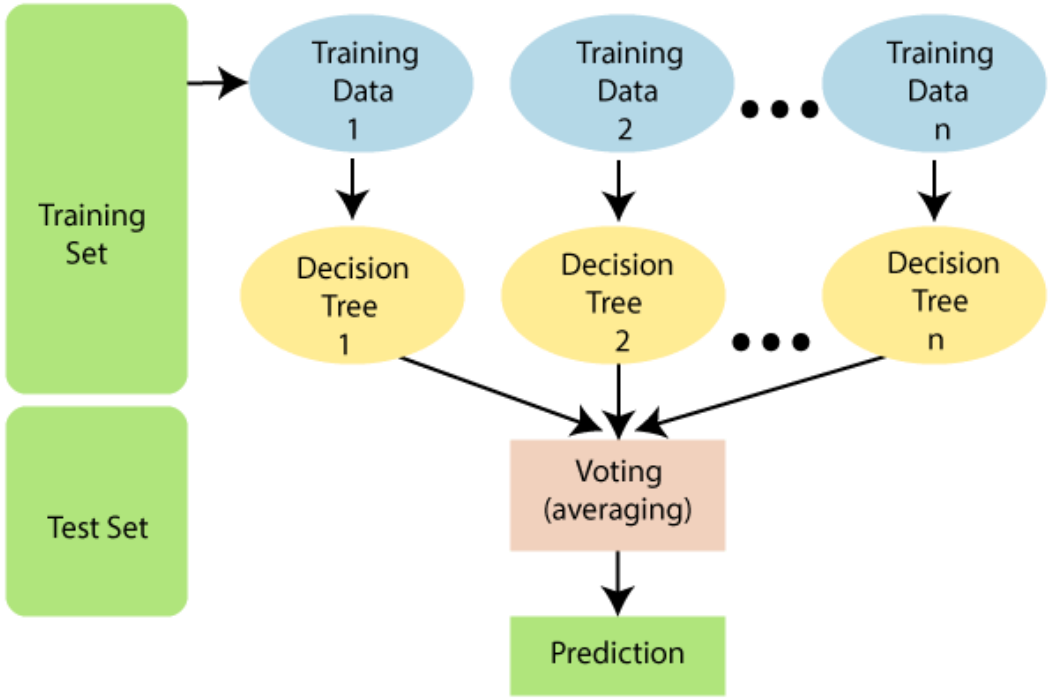
Predicting EC, VWC, and Permeability

- UAVs
- Multispectral data with DJI Inspire 1 V2.0 UAV
- Sentera Double 4K Lock & Go Sensor
- Programming by **Machine Learning**



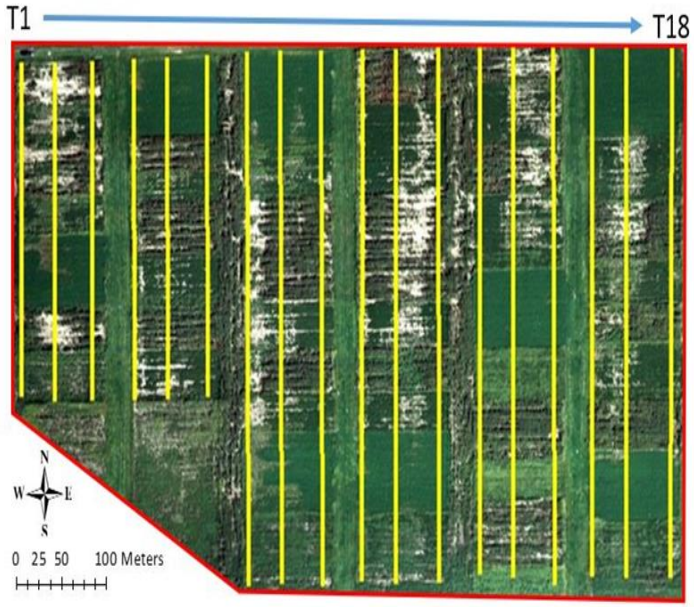
Novelty, Missouri, United States

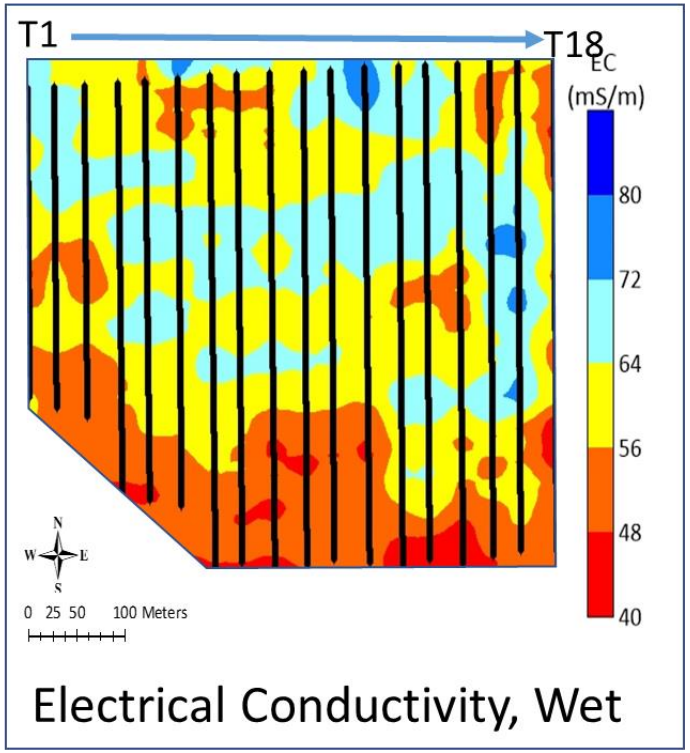




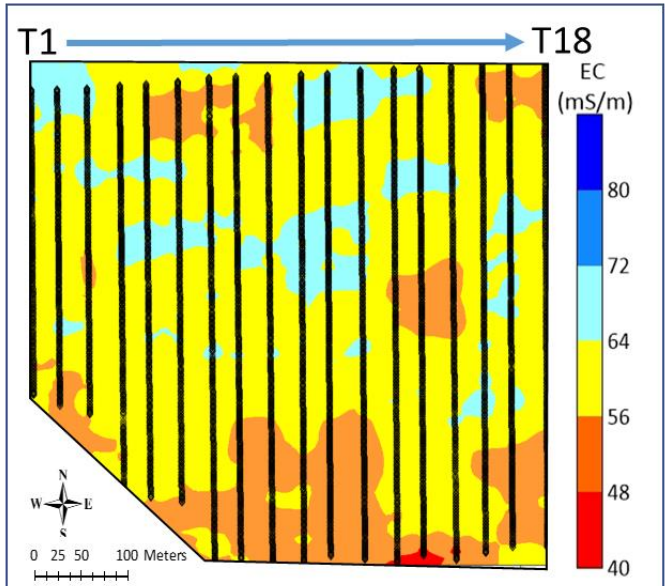
Random Forest method Machine Learning in Python

- **Electrical Conductivity (EC)**



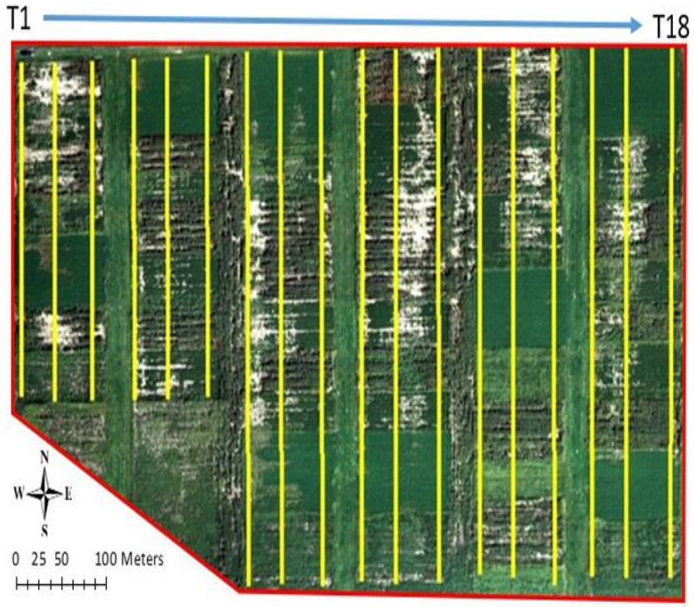


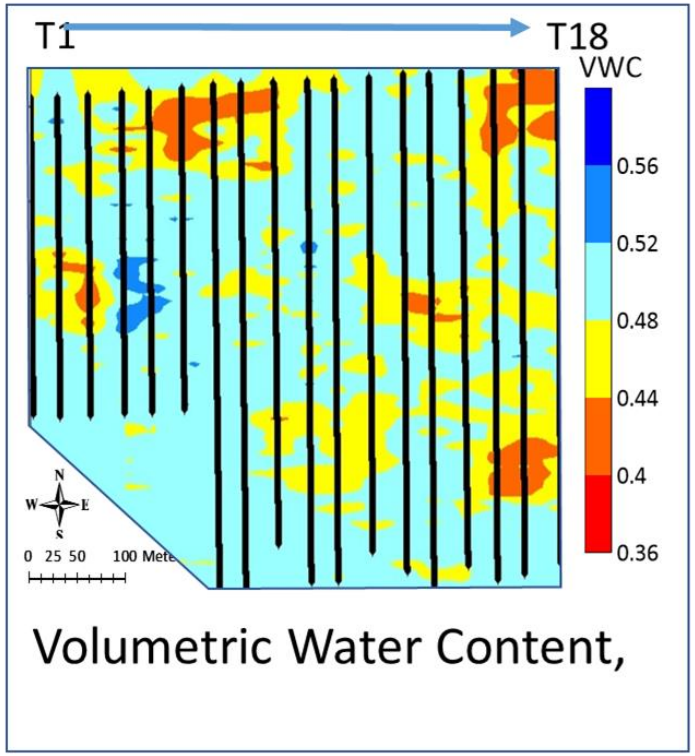
Electrical Conductivity, Wet



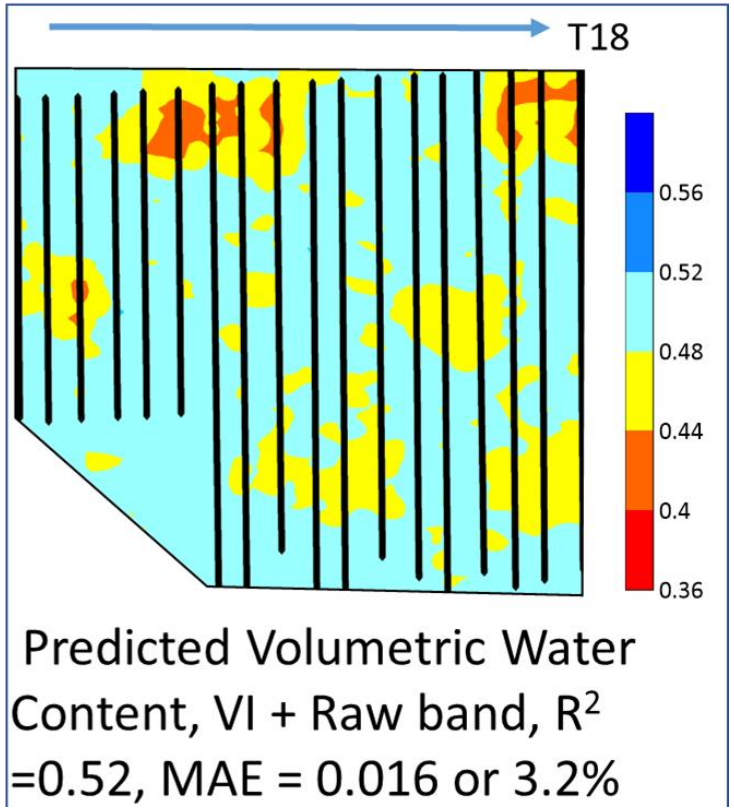
Predicted Electrical Conductivity, Wet, VI + Raw bands, R^2 = 0.49, MAE = 4.2

- **Volumetric Water Content VWC**





Volumetric Water Content,



Predicted Volumetric Water Content, VI + Raw band, R^2 =0.52, MAE = 0.016 or 3.2%

How this could be applied in industry?

1) **Patent algorithms for converting from UAV multispectral and thermal data to soil properties.**
2) **Farmers can send their data in for processing, and we process it for a fee. This is already done for crop vigor, where farmers collect the data, and a processing company sends them maps of crop vigor. We would do the same, except the maps would be soil properties.**
3) **Quality control/assurance for geotechnical construction companies**
4) **Assessment of aquifer recharge potential for municipal water supply**
5) **Assessment of waste-water treatment or waste storage facilities for industrial or agricultural applications**
6) **We could have a Positive Effect on Agriculture, Construction, Environmental Protection issues, Water Resource Management, Climate Change Studies…, it seems ALL!**

Thank You!

Questions?