# Soil Moisture Sensors for efficient irrigation water management

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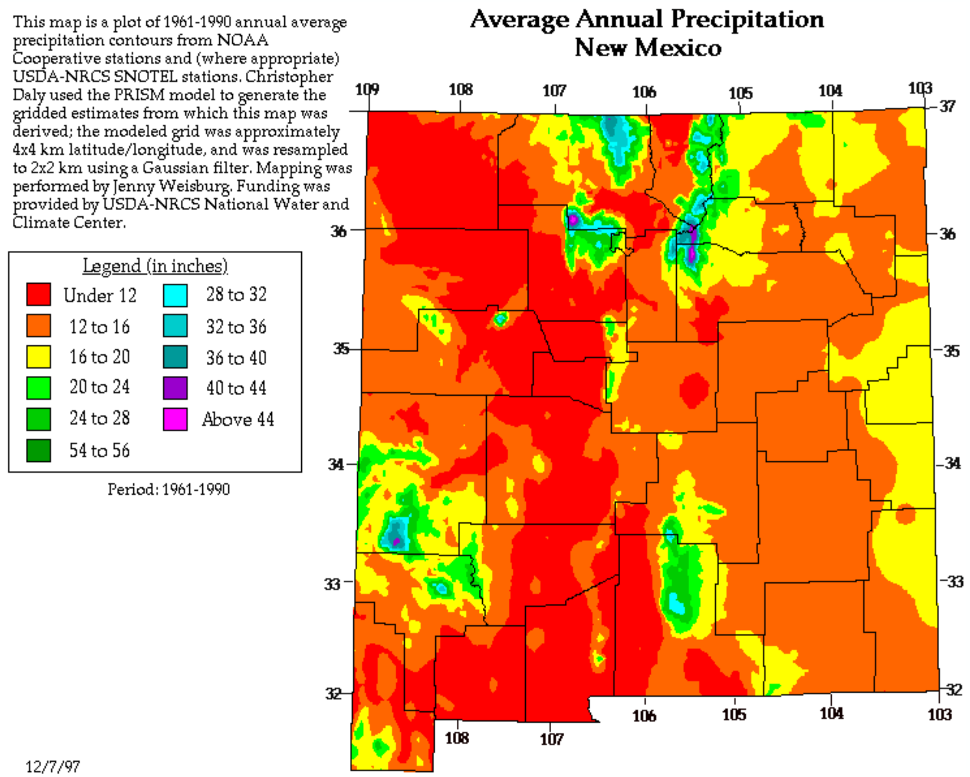
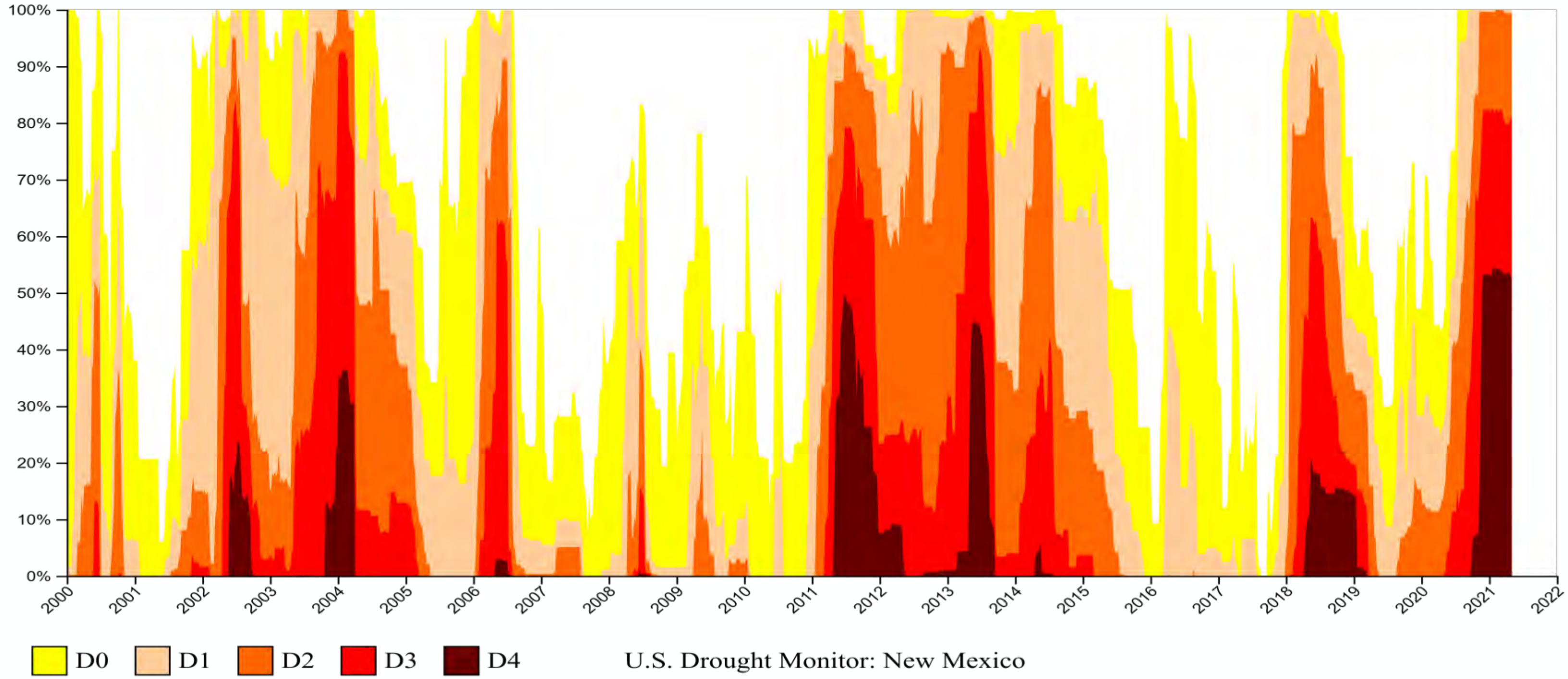
# Introduction

- Climate change
- Reducing available fresh water for crop production
- Produce more food with less water
- Precision agriculture



# Drought in New Mexico from 2000–Present

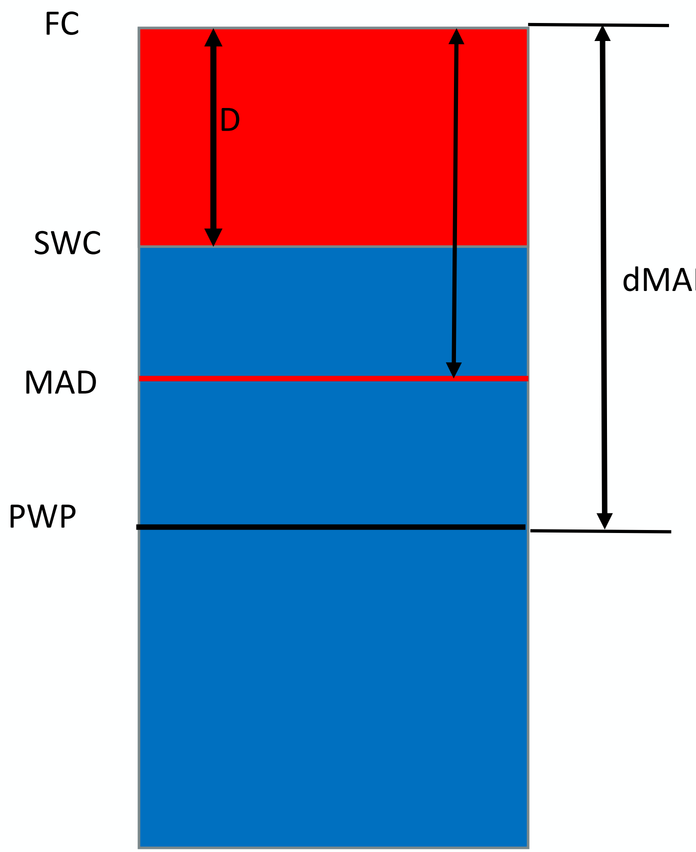



https://www.drought.gov/states/new-mexico

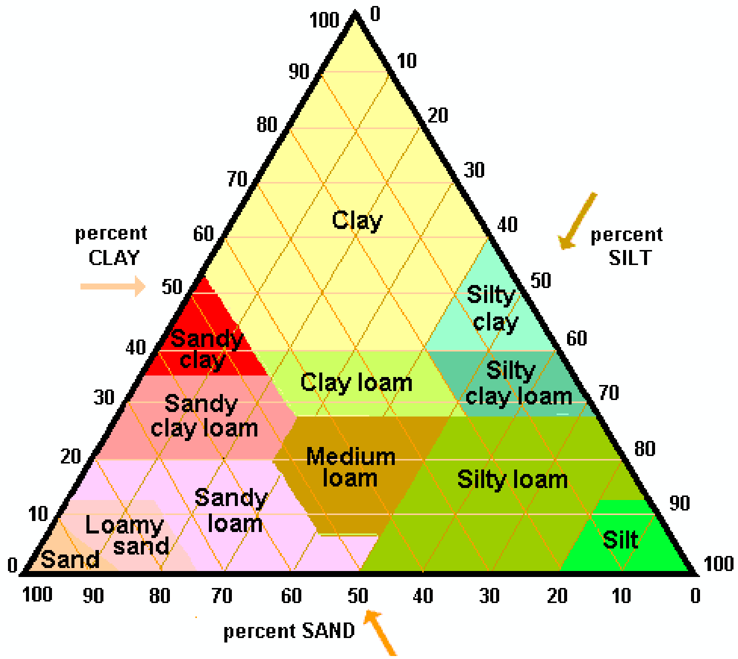
The most intense period of drought occurred the week of January 19, 2021, where D4 affected 54.27% of New Mexico land.

# Items needed for soil based water management

- Soil Texture
- Rooting Depth
- MAD % based on crop
- Tension to inches conversion
- System output (in/hr)
  - Where :
  - FC: Field Capacity
  - SWC: Soil Water Content
  - AWC: Available Water Content
  - PWP : Permanent Wilting Point
  - D= soil water deficit
  - MAD= Manageable water depletion
  - dMAD: depth of water to MAD



# Soil moisture characteristics of different soil types




| General Soil Water Classes for Agricultural Soils (Water Content, Volume Basis) | | | | | | |
|---|---|---|---|---|---|---|
| | Field Capacity | | Permanent Wilting Point | | Available Water | |
| Texture Class | Average (%) | Range (%) | Average (%) | Range (%) | Average (%) | Range (%) |
| **Coarse** | | | | | | |
| Sand | 12 | 7 - 17 | 4 | 2 - 7 | 8 | 5 - 11 |
| Loamy sand | 14 | 11 - 19 | 6 | 3 - 10 | 8 | 6 - 12 |
| **Moderately coarse** | | | | | | |
| Sandy loam | 23 | 18 - 28 | 10 | 6 - 16 | 13 | 11 - 15 |
| **Medium** | | | | | | |
| Loam | 26 | 20 - 30 | 12 | 7 - 16 | 15 | 11 - 18 |
| Silt loam | 30 | 22 - 36 | 15 | 9 - 21 | 15 | 11 - 19 |
| Silt | 32 | 29 - 35 | 15 | 12 - 18 | 17 | 12 - 20 |
| **Moderately fine** | | | | | | |
| Silty clay loam | 34 | 30 - 37 | 19 | 17 - 24 | 15 | 12 - 18 |
| **Fine** | | | | | | |
| Silty clay | 36 | 29 - 42 | 21 | 14 - 29 | 15 | 11 - 19 |
| Clay | 36 | 32 - 39 | 21 | 19 - 24 | 15 | 10 - 20 |

**Source:** Marvin E. Jensen and Richard G. Allen (Editors). 2015. Evaporation, Evapotranspiration, and Irrigation Water Requirements. ASCE Manuals and Reports on Engineering Practice No. 70 (Second Edition).

# Soil moisture measurement methods

**What is the method used this workshop participants?**

# Hand feel method for quantitative assessment of soil water status

- https://sanangelo.t
  mu.edu/extension/
  gronomy/agronomy
  publications/how-
  to-estimate-soil-
  moisture-by-feel/

# Direct measurement of soil water content

- Labor intensive
- Time consuming
- Non continuous measurements

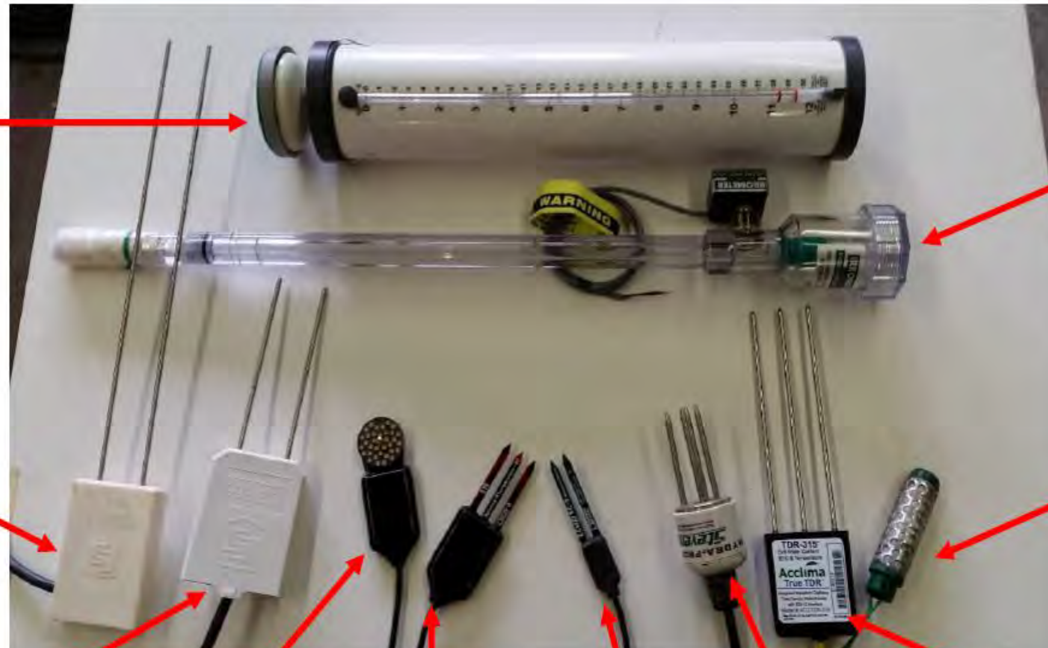
- Remove known/unknown mass (volume) of soil
- Dry at 221oF until constant weight
- $\Theta\,\mathrm{m} = \frac{(Mw - Mmd)}{Md}$
- $\Theta\mathrm{v} = \Theta\,\mathrm{m} * \text{bulk density}$






# Soil Moisture Sensors & ETgage

**Legend:**
SWP: Soil Water Potential
SWC: Soil Water Content
Temp: Soil Temperature
EC: Bulk Electrical Conductivity




ETgage (Atmometer)
Reference ET

Irrometer Tensiometer
SWP

Campbell Scientific CS616
SWC

Irrometer Watermark
SWP

Campbell Scientific CS655
SWC, Temp, & EC

MPS-2 or MPS-6
SWP & Temp

5TE
SWC, Temp, & EC

EC-5
SWC

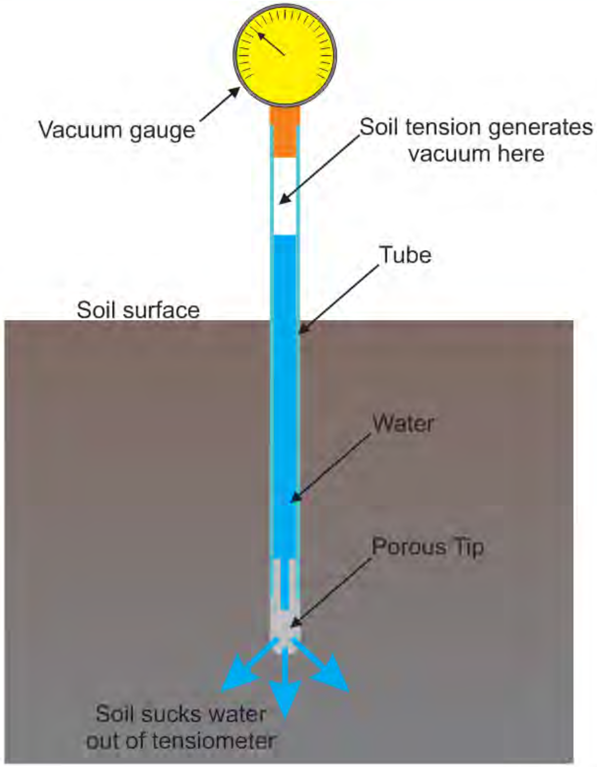
---------- Decagon Devices ----------

Stevens Hydra Probe II
SWC, Temp, & EC

Acclima True TDR
SWC, Temp, & EC

Source: Rudnick , 2016

# Tensiometers



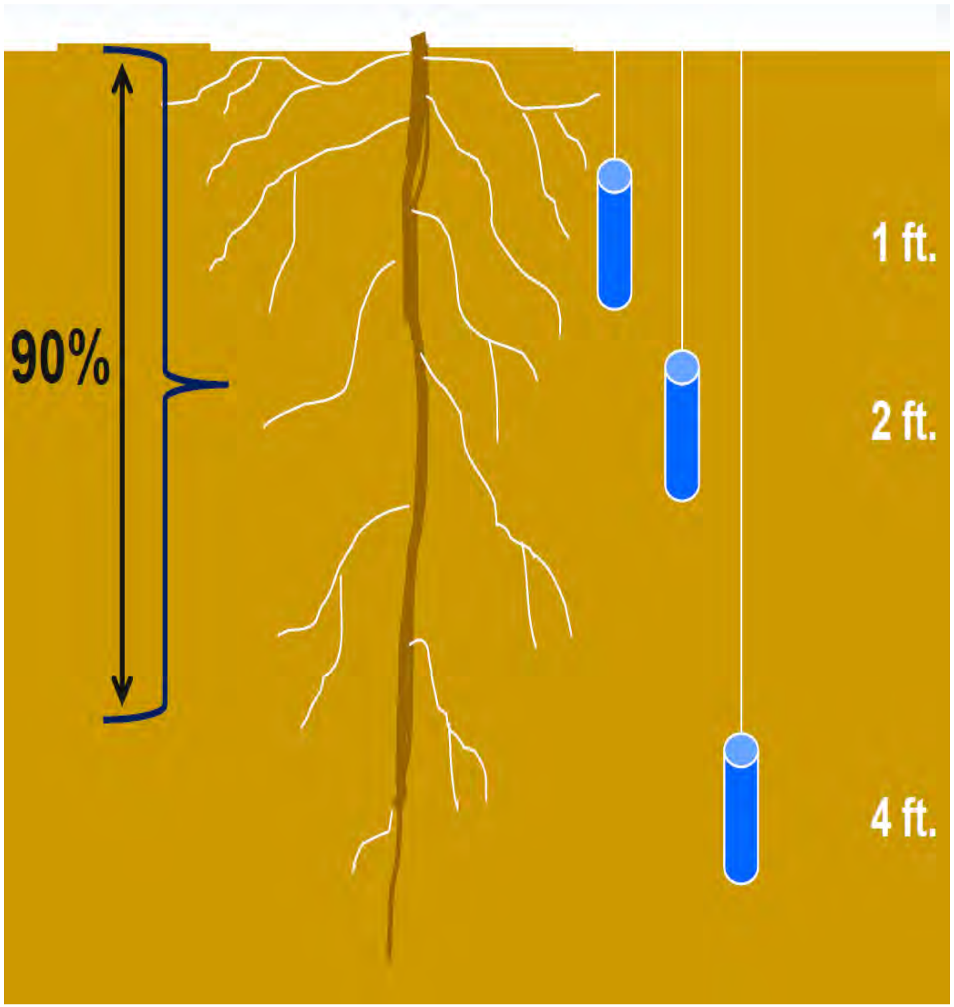

- A water filled tube with a hollow ceramic tipis placed in the soil at a desired depth.
- The sensor will equilibrate with the soil, by pulling water out of the tube while the soil dries and pulling water into the tube as the soil wets.
- The process creates tension within the access tube, measured using a vacuum gauge or pressure transducer.

# Electrical resistance sensors:

Watermark Sensor

Gypsum blocks

Data loggers



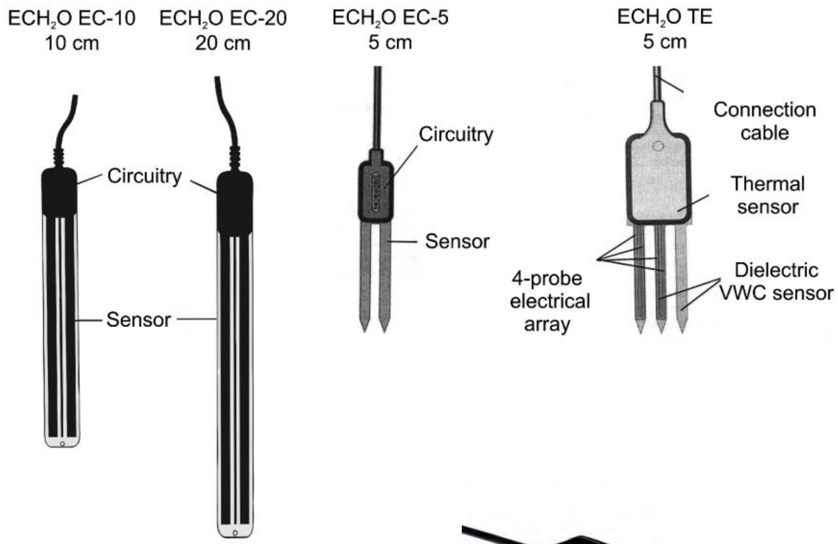
# Watermark in peanut and corn


# TDR 100 soil moisture meter



Very easy and simple to use
Measure the volumetric water content
Good for small garden

# Decagon



$ECH_2O$ EC-10
10 cm
$ECH_2O$ EC-20
20 cm
$ECH_2O$ EC-5
5 cm
$ECH_2O$ TE
5 cm
Circuitry
Sensor
Circuitry
Sensor
Connection cable
Thermal sensor
4-probe electrical array
Dielectric VWC sensor


ECHO EC-5
Moisture Sensor


Em50

# The TDR-315L, TDR-310S, SDI-12 soil moisture sensors



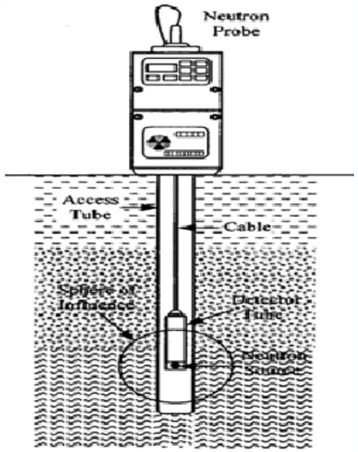



- **Volumetric Water**
- **Bulk EC**
- **Temperature**

# Campbell Scientific CS655, CS650, cs616 water content reflectometer


- Measure the volumetric water content from 0% to saturation
- Precision: 0.05%

# Neutron Probe: 4301/02 SOIL MOISTURE GAUGE




# Troxler Sentry 200 AP


- Install probe access tube in the crop row
- Take rearing twice a week

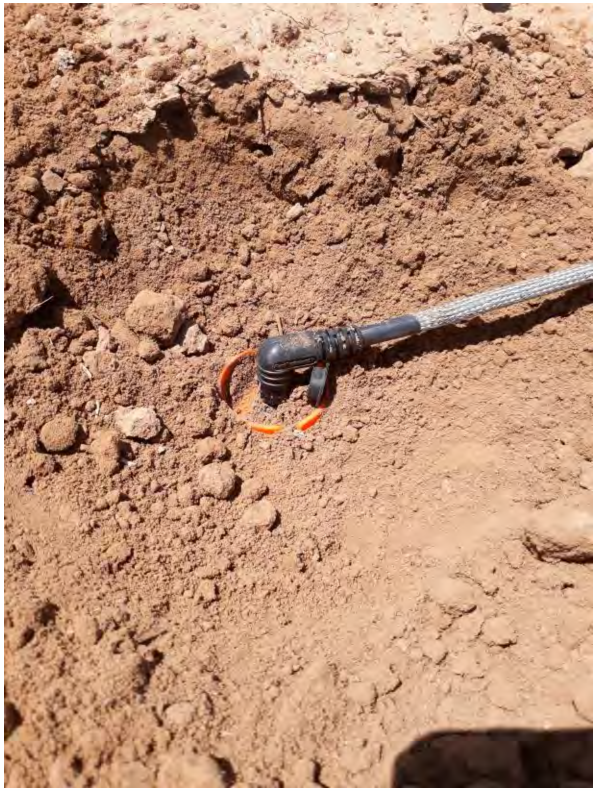
# PR2 Soil Moisture Profiling Monitor


- Install probe access tube in the crop row
- Take rearing twice a week or as often depending of the main power availability

# John Deere Field connect

- Monitors moisture levels and feeds data to web-based interface
- Support timely irrigation decisions helping to reduce over watering and nutrient leaching
- Alerts you when moisture levels are reaching full or refill points

# AQUASPY



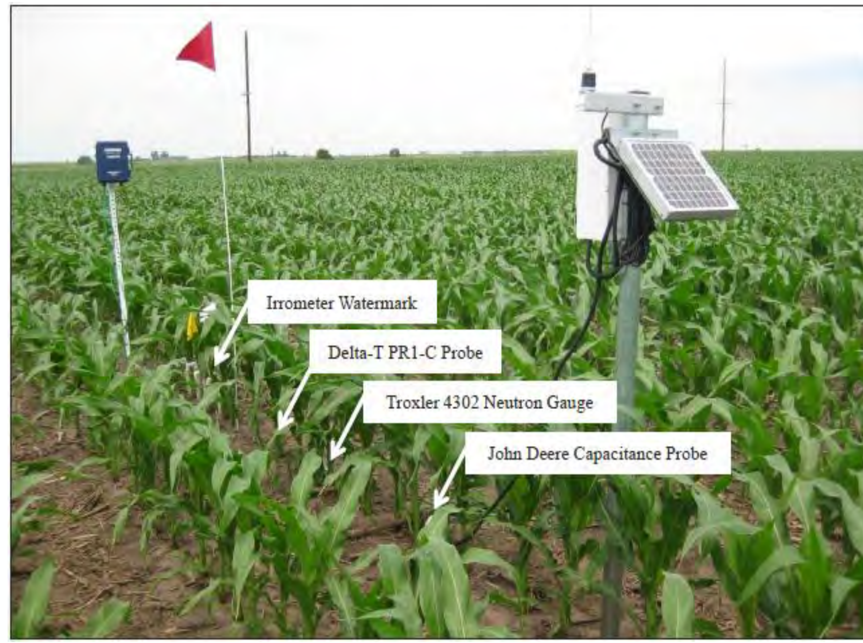
**Provides continuous soil moisture data at different soil depths as function of the field capacity**
**Access on smart phone and PC**

# TriSCAN™ **Sensor (**Sentek Diviner-2000: Sentek Moisture probe)

# Choice of soil moisture sensor: Performance analysis

Lab evaluation

Field evaluation




Source: Rudnick et al., 2016

# Accuracy of soil moisture sensors

**Soil and Climate Related:**

- Range of the measured soil moisture
- Soil and water salinity
- Soil content in different ions
- Soil Temperature
- Soil texture and structure
- Soil Layering in different horizons
- Wetting and Drying Cycles: Hysteresis

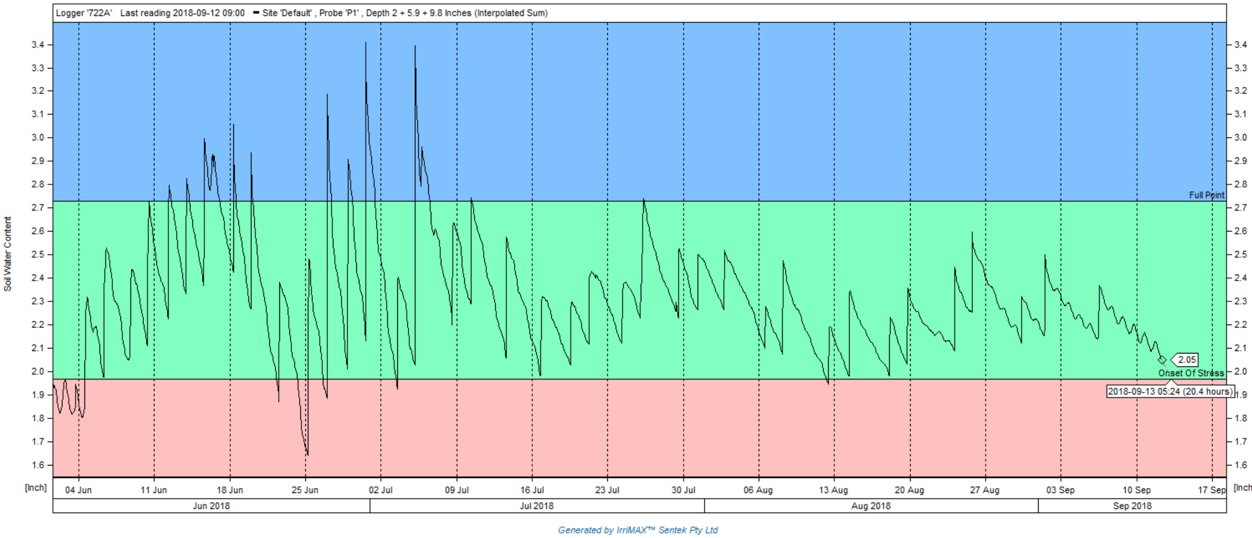
**Sensor Technology:**

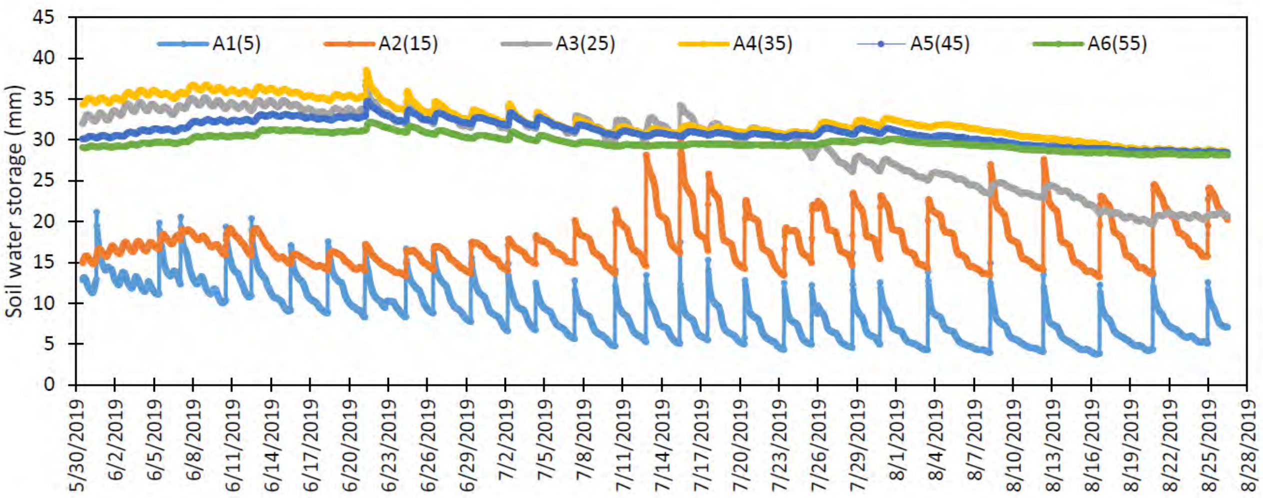
- Sensing Volume (Related to soil)
- Sensor Spacing (Vertical)
- Response Time
- Operational Range and Frequency

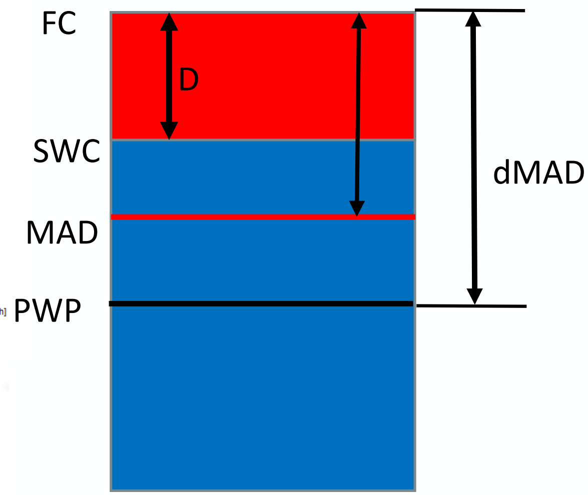
**Sensor site specific calibration:**

- Factory calibration is usually performed under controlled laboratory conditions
- Sensor technologies may respond differently the same
- Spatial and temporal variability of influencing factors, can require separate calibrations
- Soil top layers closer to the surface usually show great fluctuations in soil temperature and water content; which may consequently result in greater error if un-adjusted as compared to lower soil depths

# Soil water and irrigation management




**Keep the soil moisture between field capacity and MAD to avoid water stress and yield reduction.**

# Conclusion

Soil moisture sensor adoption is dependent on:

- How much are the sensors?
- Is there annual subscription fee?
- Do I need some one to install and remove the sensors?
- Do I have to purchase the installation kit?
- Can the sensor or data be accessed remotely?
- Is there local product support and or dealer for assistance?
- Can the seasons be used for multiple growing seasons?
- Are there cost share or Leasing opportunities?

**What is the best soil moisture sensor?**

**It depends !!!!**

# Contact Information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https://scholar.google.com/citations?user=nUldMQkAAAAJ&hl=en

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