McGill

McGill Institute for Global Food Security

Institut pour la sécurité alimentaire mondiale de McGill

Felix Jaria

Soil Moisture measurement

PRESENTATION OUTLINE

- Introduction
- Direct soil moisture measurements
  - Feel
  - Gravimetric
  - Volumetric
  - Advantages and Disadvantages
- Indirect soil moisture measurements
  - Dielectric sensors
  - Tensionomic
  - Advantages and disadvantages
- Summary

INTRODUCTION

- Soil water content can be measure directly or indirectly

- With direct methods a physical soil sample is required and oven dried to measure the water content.

- The indirect methods estimate soil moisture by a calibrated relationship with some other soil measurable variable

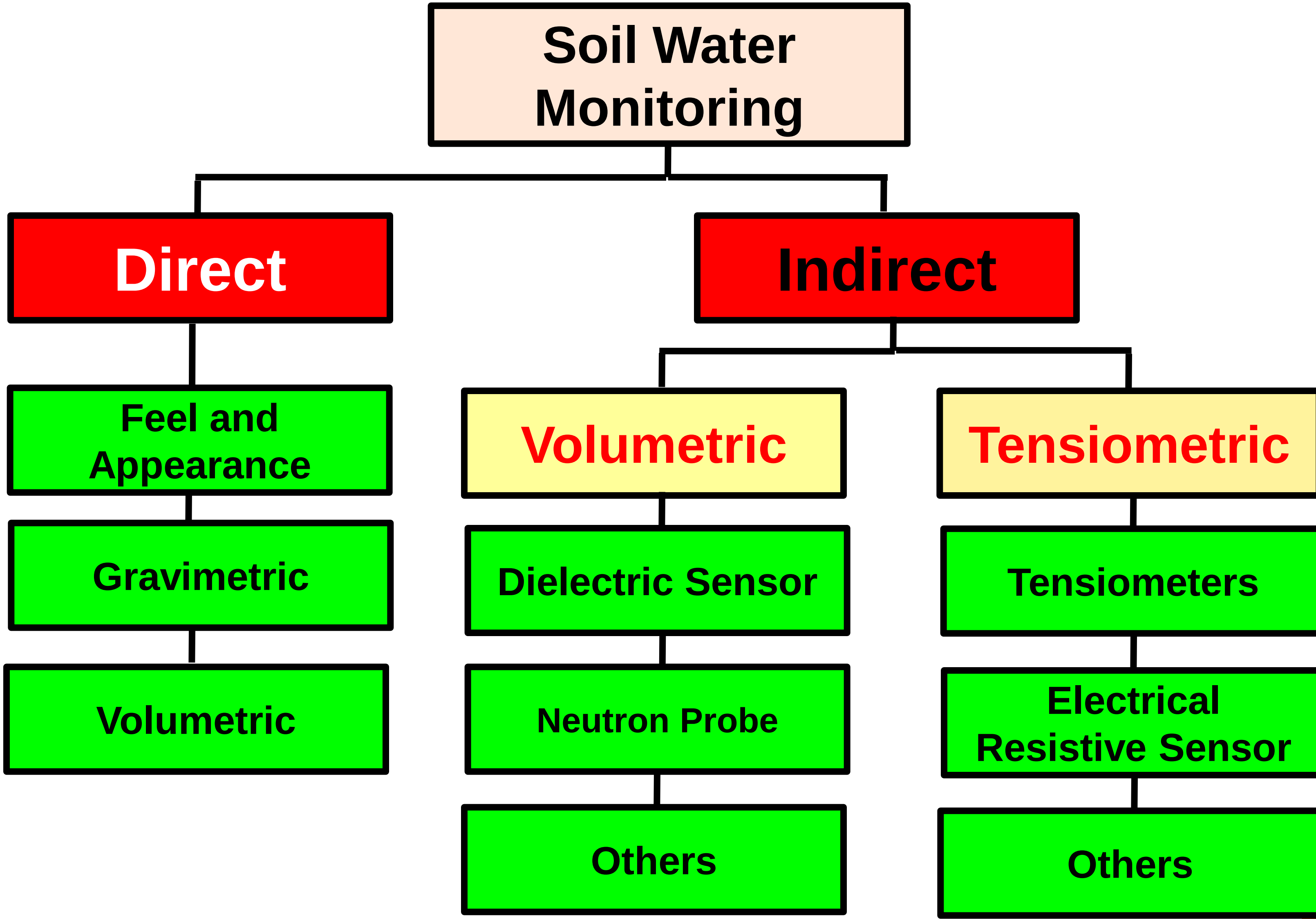
INTRODUCTION

- The suitability of each method depends on several issues like cost, accuracy, response time, installation, management and durability

- Since the late 1970s, a wide range of competing technologies for sensing soil water have been utilized, however most have been found deficient in some way

- Its important that one understand the limitations of each method and work within the confides of each method.

Summary -Soil Moisture Measurement



SOIL MOISTURE ESTIMATION BY FEEL METHOD

Description for Sandy loam Soil	
Moisture Content	Description
0–25%	**Ball of soil is weak and grains break away quickly**
25–50%	**Soil ball is weak, but finger marks show**
50–75%	**Moist ball, dark color, light soil stain on fingers**
75–100%	**Moist soil ball, medium soil stain on fingers**




Soil water monitoring-Direct

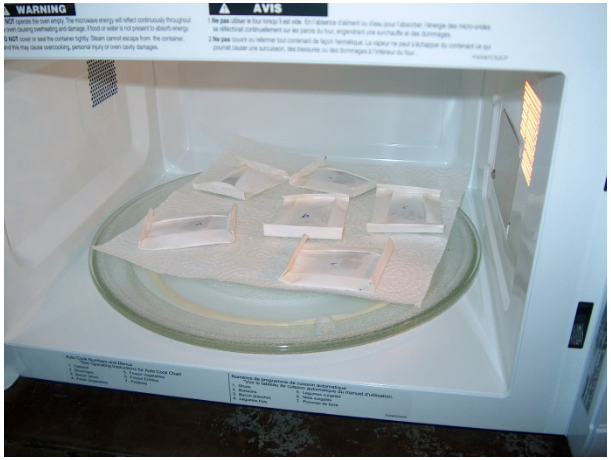
Feel and appearance 1/3

- Probably still the moist common method used.
- Advantages:
  - low cost; Multiple locations; minimum training, not destructive
- Disadvantages:
  - Experience required; Not highly accurate, too subjective,

Soil water monitoring-Direct

Gravimetric 2/3

- Measures mass water content (θ_m)
- Sample is oven dried for 24 hrs. at 105°C
- Microwave (6 minutes)

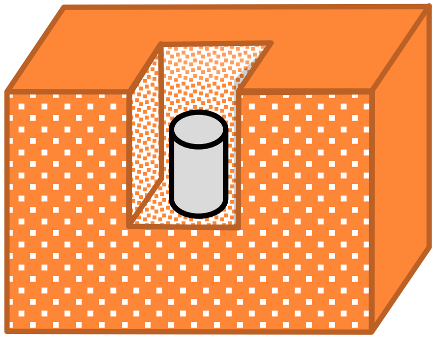


$$\theta_g = \frac{mass\ of\ water}{mass\ of\ oven\ dry\ soil}$$

SOIL WATER MONITORING-DIRECT

<u>Volumetric 3/3</u>

- Gives the water content as volume of water in a volume of undisturbed soil (soil core) expressed as m^3m^{-3}.
- It is not always practical to obtain soil sample of know volume
- Gravimetric water content can be converted to Volumetric water content



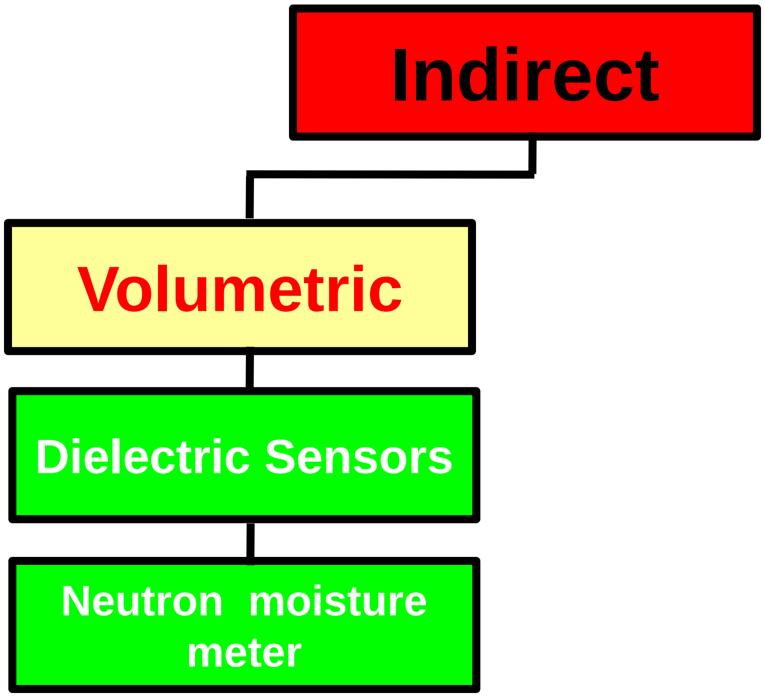
$$\theta_v = \frac{(mass\ of\ water)/\ \rho_w}{(mass\ of\ oven\ dry\ soil)/\ \rho_B} \approx \theta_g * \rho_B$$

Soil water monitoring-Direct

<u>Gravimetric and Volumetric</u>

Advantages	Disadvantage
Accurate	Labor
Multiple locations	Time delay
Not dependent on salinity or soil type	Destructive
inexpensive	Cannot be automated
Easy to calculated	Require bulk density
Use to calibrate indirect methods	

Indirect Soil Moisture monitoring - Volumetric



Indirect Soil Moisture monitoring

- Estimates of soil water content base on measurement of soil properties

- or measurement of a property of some object placed in the soil that are assumed to be correlated with water content
- Volumetric include - dielectric, neutron and heat dissipate sensor
- Tensiometric include - tensiometers, porous media and wetting front sensors

INDIRECT - VOLUMETRIC

DIELECTRIC VOLUMETRIC SENSORS

- The two main methods which have emerged over the past 30 years are TDR and capacitance sensors

- They measure the soil water content by measuring the soil bulk permittivity or dielectric constant

- Every material has a dielectric constant (k), water is 81, soil is 2-5 and air is 1

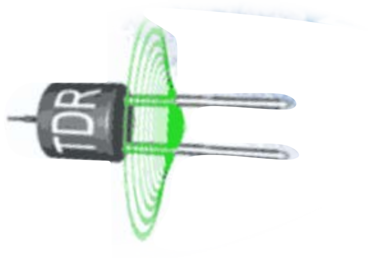
Indirect - Volumetric

DIELECTRIC VOLUMETRIC SENSORS

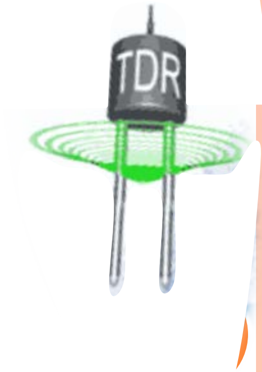
- The dielectric constant is a measure of the capacity of a nonconductive material to transmit electromagnet waves or pulses.
- Small changes in in the quantity of free water in the soil have large effects on the electromagnetic properties of the soil water media.
- Since the dielectric constant of liquid water is much larger than that of the other soil constituents (air, soil), the total permittivity of the soil is mainly governed by the presence of liquid water.

Indirect –Volumetric 1/3

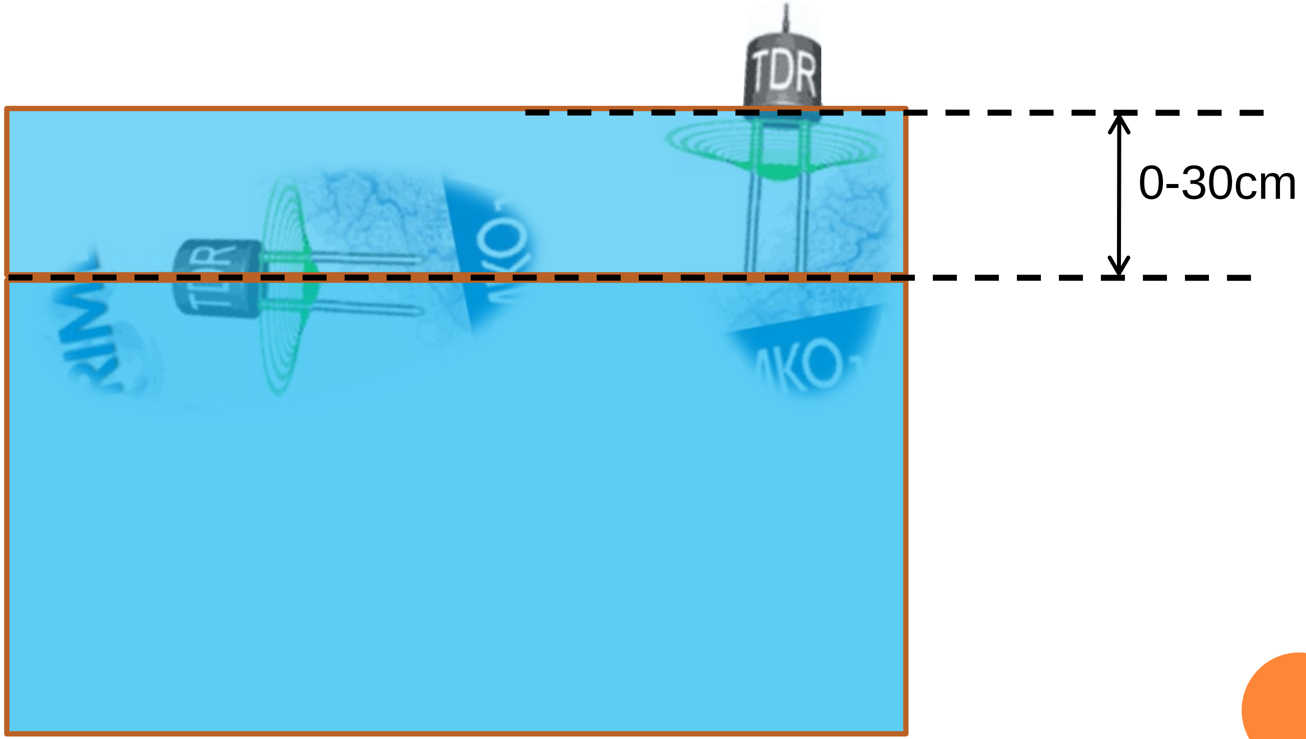
Time Domain Reflectometer (TDR)



- Electrical pulse is generated
- Propagates an electromagnetic wave



Installation of WCR



INDIRECT –VOLUMETRIC 1/3

TIME DOMAIN REFLECTOMETER (TDR)

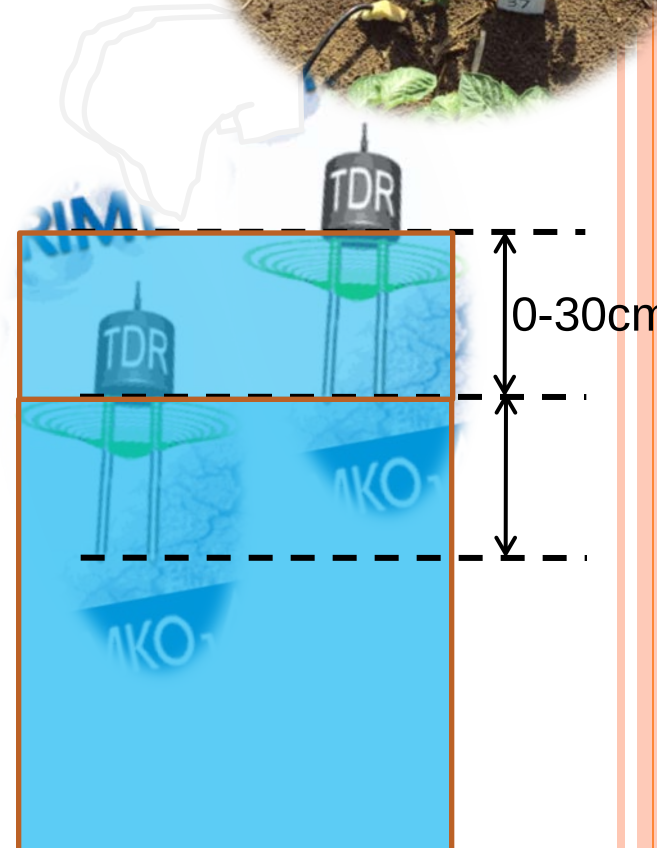
- Electrical pulse is generated
- Propagates an electromagnetic wave down the steel probe buried in the soil.
- The signal reaches the end of the probe and is reflected back to the TDR control unit

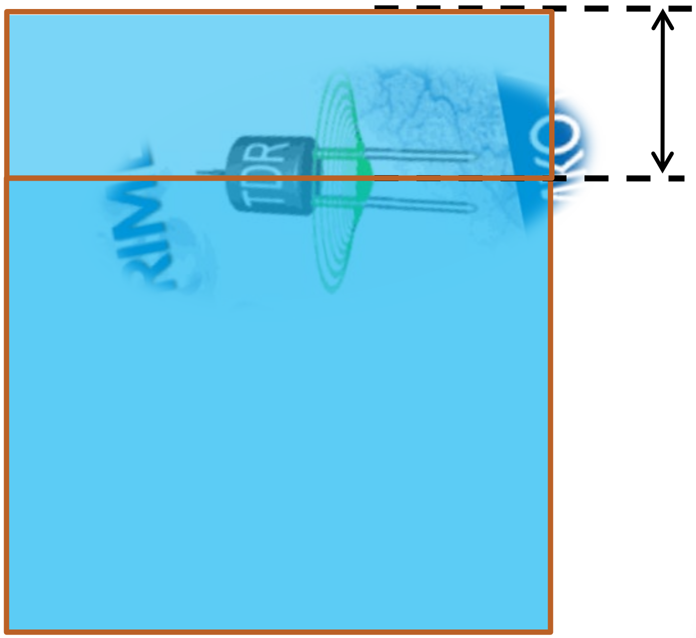
WCR Cont.

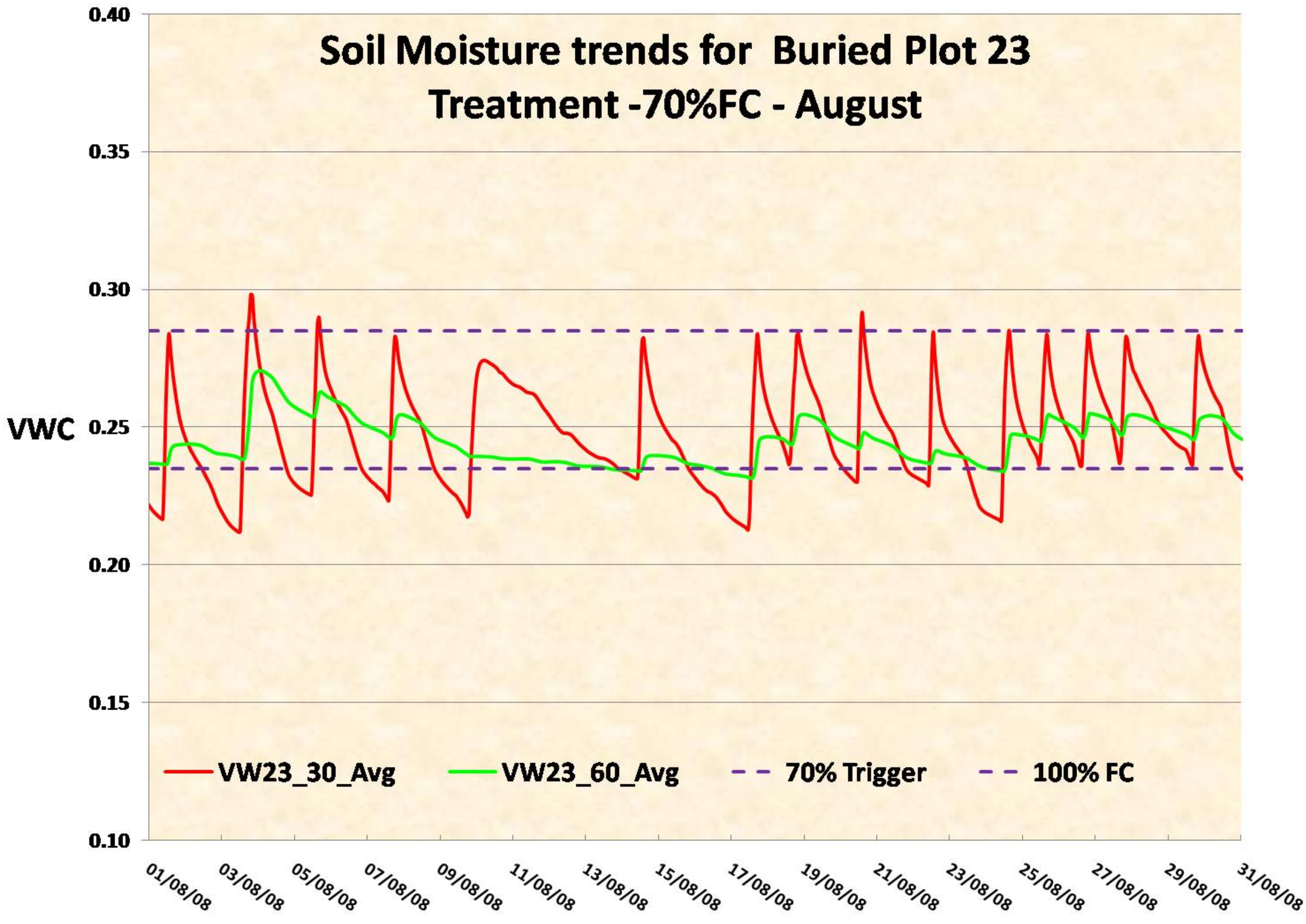
- The travel time – function of the dielectric property of the water in the soil.

- Calibration equation to convert time to VWC.

Installation of TDR



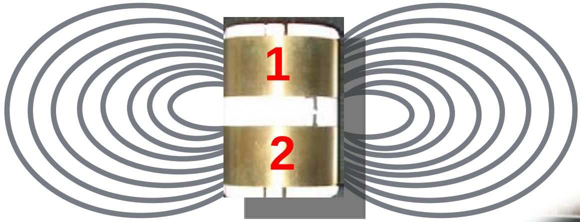


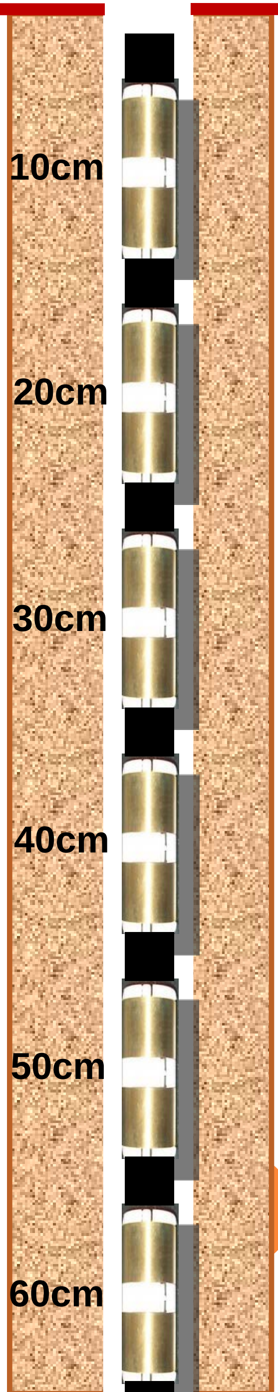


Soil Moisture trends for Buried Plot 23
Treatment -70%FC - August
VWC
0.40
0.35
0.30
0.25
0.20
0.15
0.10
VW23_30_Avg
VW23_60_Avg
70% Trigger
100% FC
01/08/08
03/08/08
05/08/08
07/08/08
09/08/08
11/08/08
13/08/08
15/08/08
17/08/08
19/08/08
21/08/08
23/08/08
25/08/08
27/08/08
29/08/08
31/08/08

INDIRECT –VOLUMETRIC 2/3

FREQUENCY DOMAIN REFLECTOMETER





- Capacitance sensor – paired

- The moist soil forms part of th
  of the capacitor.

- An electromagneti nt down the
  probe

- The frequency of t wave is
  measured – function of the water content .

Installation of FDR

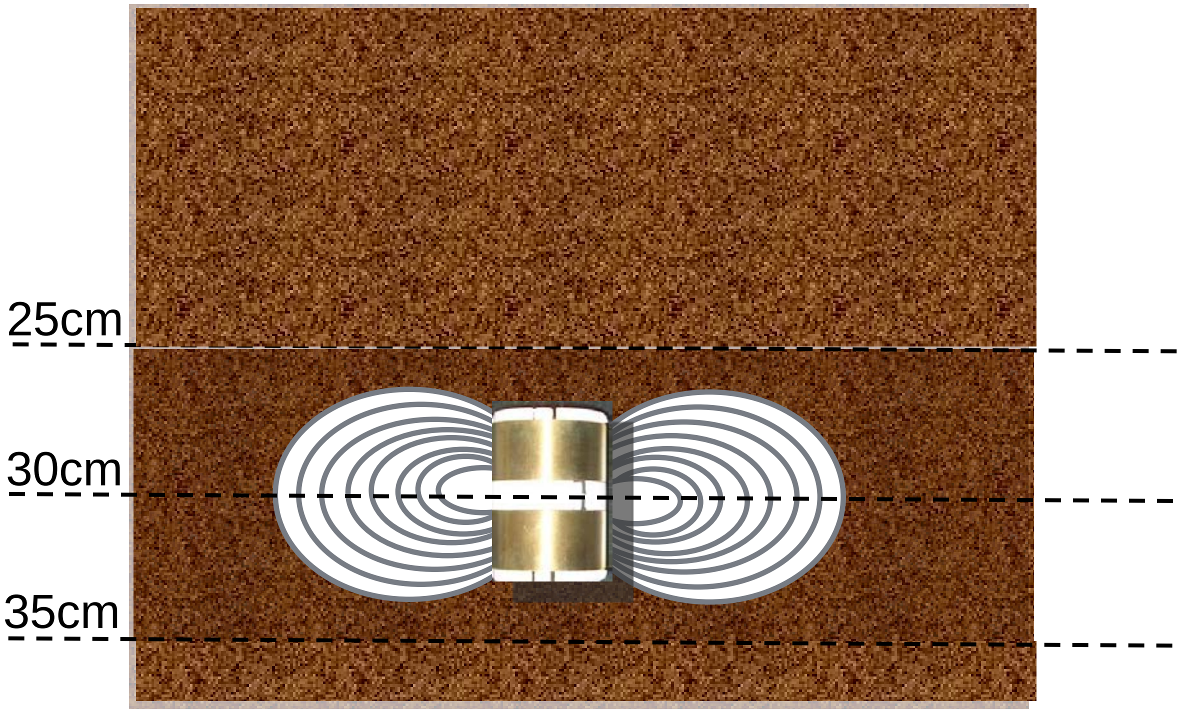




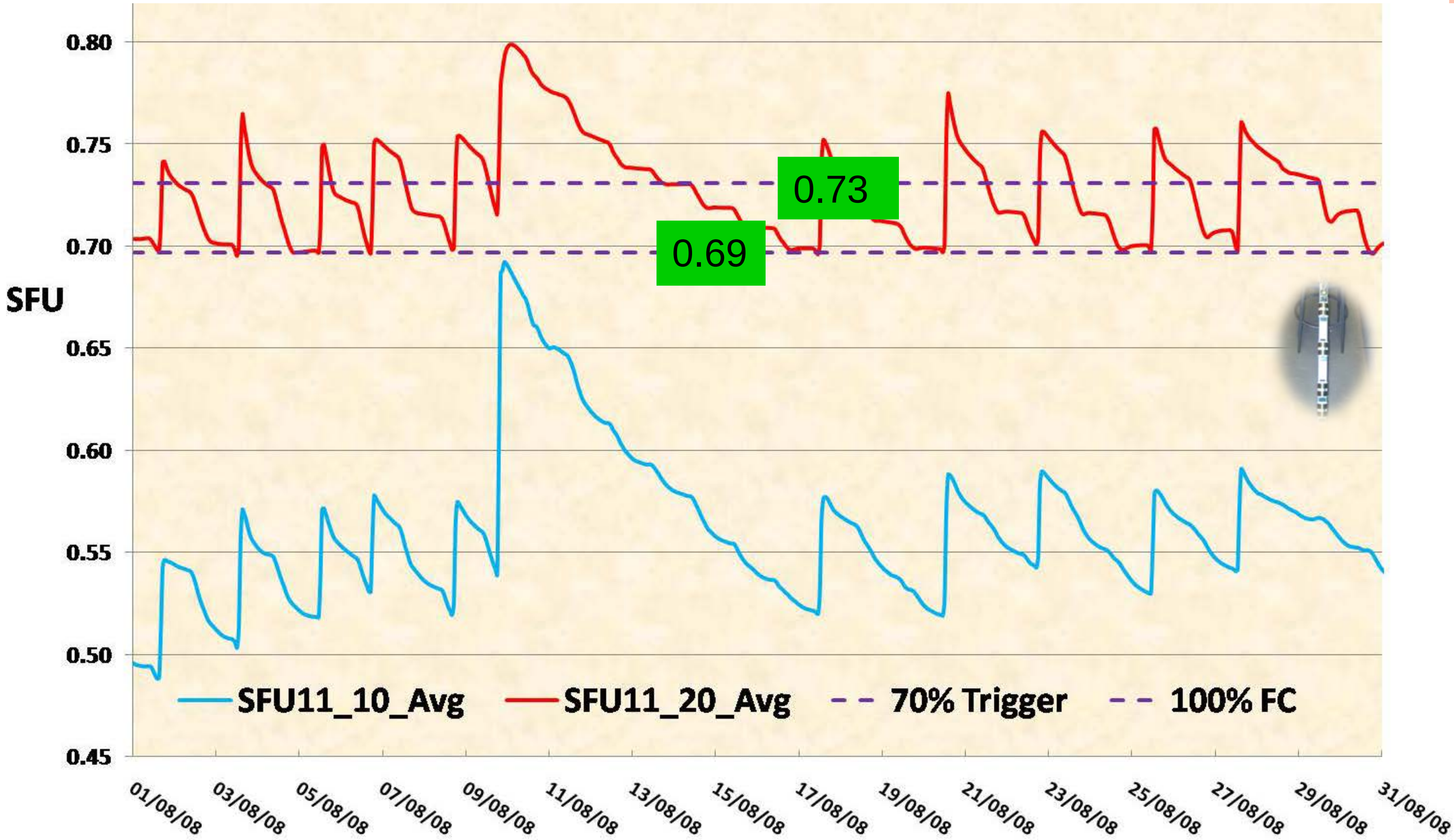





FDR Sensor at 30 cm depth



IRRIGATION SCHEDULING BASED ON SOIL MOISTURE CONTENT USING FDR



SFU- Scale Frequency Units

Dielectric Soil Moisture Monitoring

Advantages

- Attractive because they can be automated
- Safely installed in the field without causing any environmental hazards.
- Quick response time
- Collect continuous data
- Minimal soil disturbance
- Wide variety of probe configuration

Dielectric Soil Moisture Monitoring

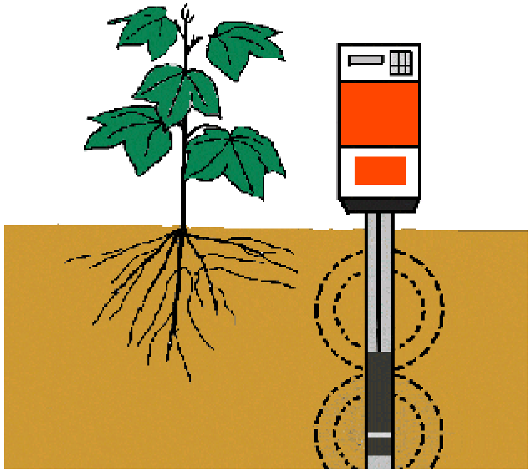
Disadvantages

- Small sphere of influence governed – 10 cm Collect continuous data
- They require calibration in the field for the most precise results
- The sensors are relatively expensive equipment due to complex electronics
- They have potentially limited applicability under highly saline conditions or in highly conductive heavy clay soils.
- The presence of macropores, rocks, roots channels, and large aggregates may influence field TDR measurements

INDIRECT –VOLUMETRIC 2/2

NEUTRON MOISTURE METER (NMM)

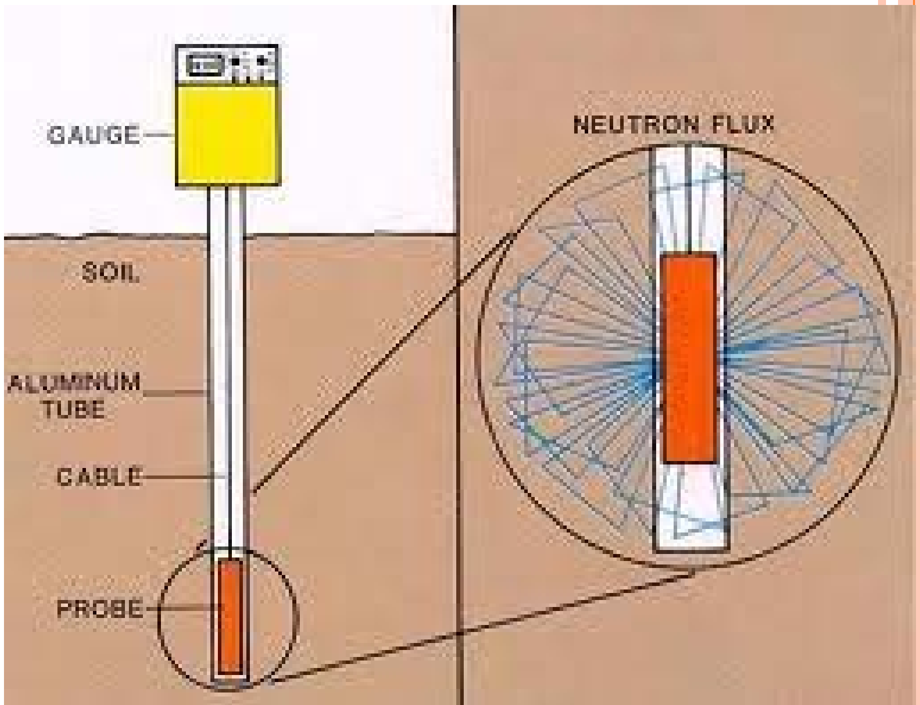
- The neutron moisture meter (NMM) was the first device used to measure SWC in the 1950s
- Consist of a cylindrical probe which is connected by a cable to a case containing the power supply, display, keypad and microprocessor
- The probe is lowered down an access tube in contact with the surrounding soil. The tube is usually thin-walled aluminum and extend to the surface



INDIRECT –VOLUMETRIC 2/2

NEUTRON MOISTURE METER (NMM)

- Uses a radioactive source that emits fast neutrons.
- Hydrogen is present in the soil as a constituent of soil organic matter, soil clay minerals and water.
- The neutrons are slowed and deflected primarily by the H atoms in soil water
- The number of returning slow neutrons is proportional to the soil water content in mineral soils



NEUTRON MOISTURE METER (NMM)

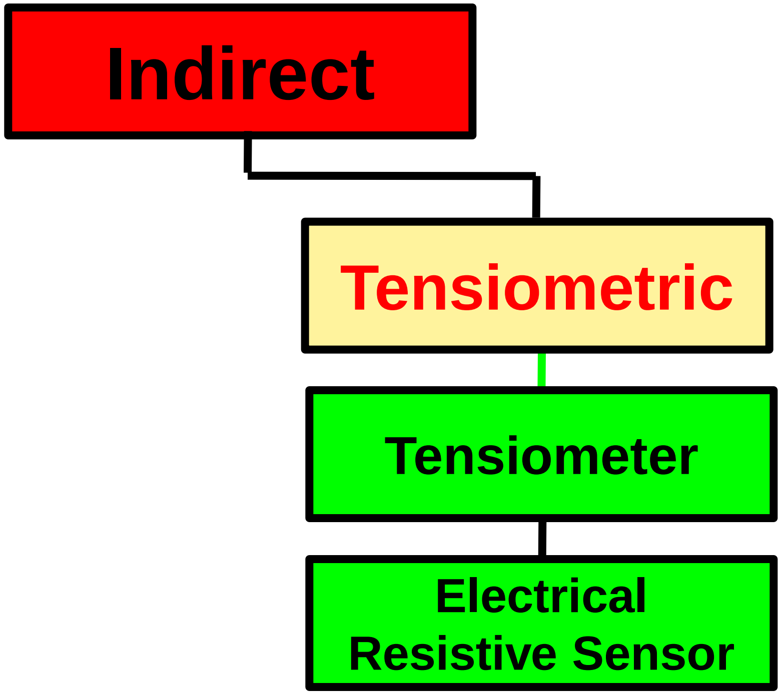
ADVANTAGES

- It has a relatively large sample volume and is very convenient for profiling
- Non-destructive method and water content can be measured in any phase
- Quick response time

NEUTRON MOISTURE METER (NMM)
DISADVANTAGES

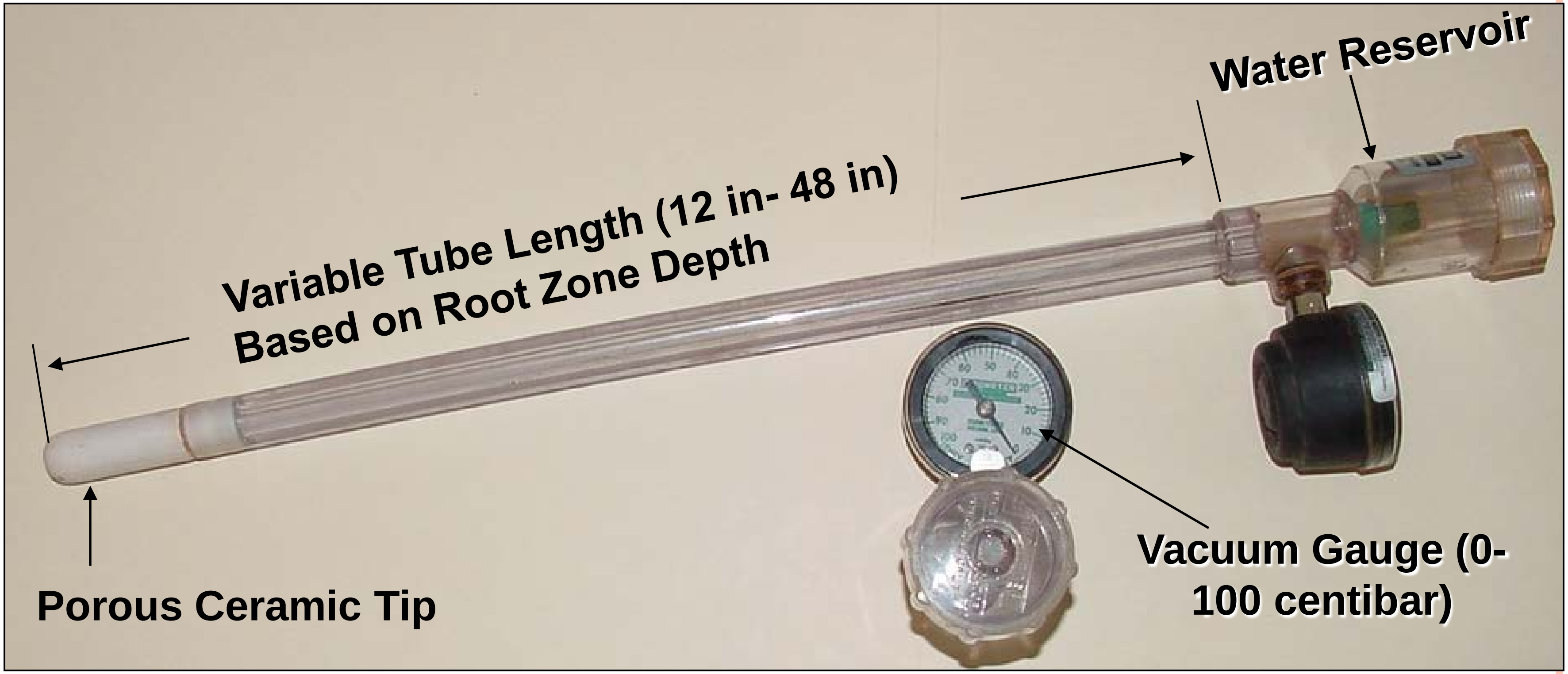
- inaccurate for shallow measurements (<30 cm)
- It a radioactive hazard that requires adhering to rigid guidelines.
- It is costly
- Requires calibration for different soils,
- Necessitates the installation and subsequent removal of access tubes.

Indirect Soil Moisture monitoring - Tensiometric



INDIRECT TENSIONOMIC-1/2

TENSIOMETER



The tensiometer is one of the oldest and most widely used instruments for irrigation scheduling around the world

Tensiometers

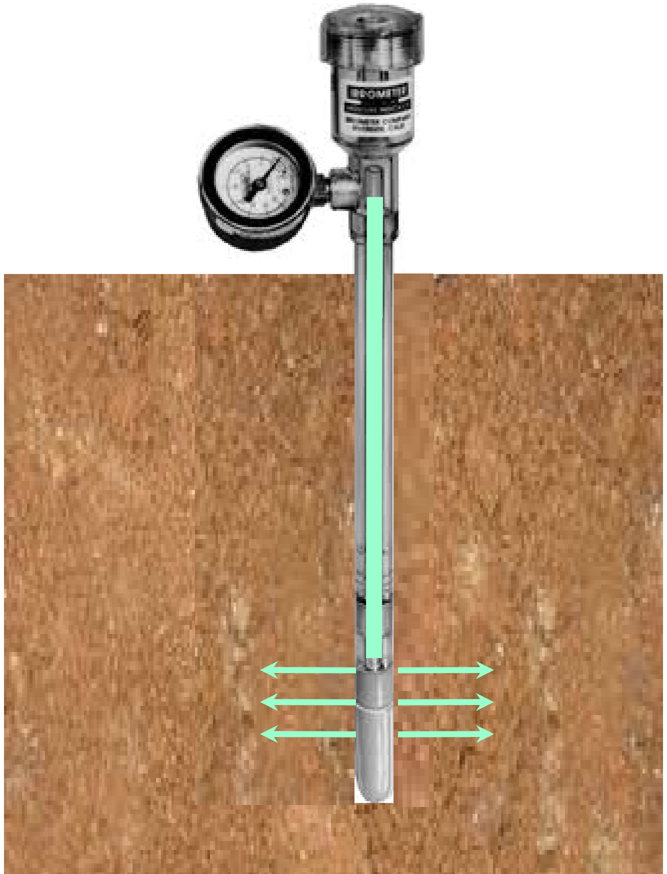
- Tensiometric methods estimate the soil water matric potential.

- Consist of a sealed water-filled plastic tube with a ceramic cup at one end and negative pressure gauge at the other.

- When in contact with the soil through a permeable and saturated porous material, water (inside the tube) comes in to equilibrium with the soil solution.

Tensiometers

- As the soil dries out, water is sucked from the tube, through the cup. This causes a partial vacuum in the tube and increases the pressure reading on the gauge.



TENSIOMETERS

- It is at the same pressure potential as the water held in the soil matrix.
- The soil water matric potential is equivalent to the vacuum or suction created inside the tube.
- Measuring range is between 0.0-0.8 bars.

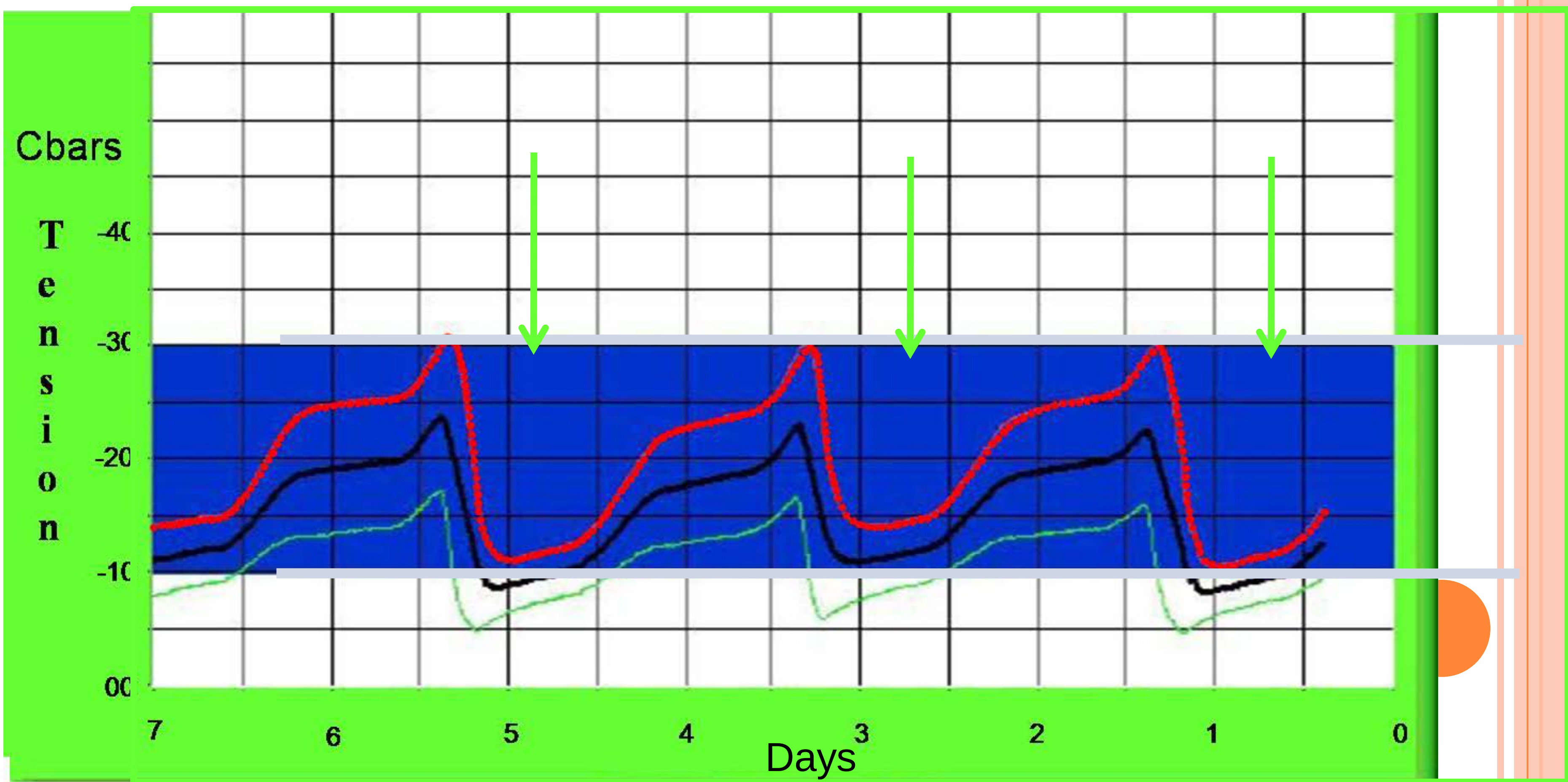
20-27th August 2008

15cm sensor

Average trend at 25cm

45cm sensor

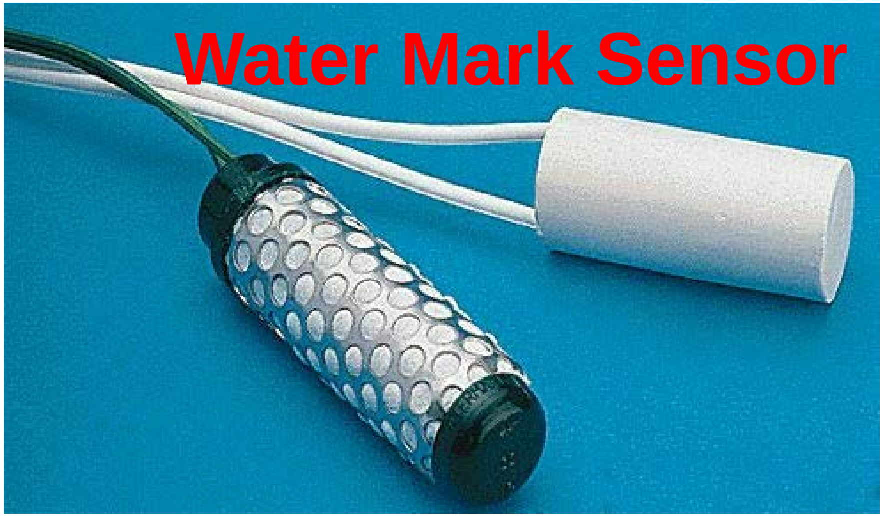
Commencement of irrigation



TENSIOMETER

Advantages	Disadvantages
Direct Reading	Limited soil suction range (<1bar)
Up to 4" (100mm) measurement sphere radius	Relative slow response time
Can be automated	Requires intimate contact with soil around ceramic cup
Electronics and power consumption avoidable	Reinstallation in necessary in swelling or coarse soils
Well suited for high frequency sampling or irrigation scheduling	Require frequent maintenance (refilling) to keep tube full of water.
Minimal skill required for maintenance	
Not affected by soil salinity	
Inexpensive	

INDIRECT TENSIONOMIC-2/2
ELECTRICAL RESISTIVE SENSOR



Gypsum Block

- One of the most common electrical resistance sensors for estimating soil water tension is the gypsum block
- First introduced in 1940

- A gypsum block sensor constitutes an electrochemical cell with a saturated solution of calcium sulphate as electrolyte encasing two concentric electrodes
- The pore sizes are similar to the surrounding soil and exhibits a water retention characteristic similar to the soil

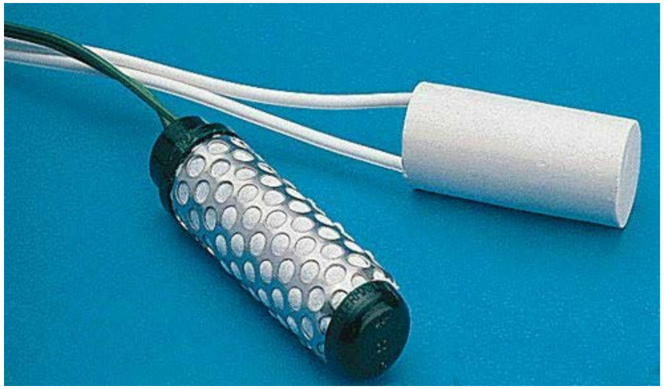
Gypsum Block

- The sensor may be buried at any desired depth in the soil.

- The water in the soil will reach equilibrium with the water in the gypsum block
- A two-wire lead from the sensor is connected to a meter, which is used to read the sensor resistance using an alternating current,
- The electrical resistance is then determined and related to moisture content as a tension (kPa or bars)
- The range of soil water determined by gypsum blocks is generally given as field capacity to the permanent wilting point

Water mark Sensor

- Measures water potential between -10 and 200 kPa
- Can be attached with a data logger



- It consists of two concentric electrodes embedded in a reference granular matrix material
- The granular matrix material is surrounded by a synthetic membrane for protection against deterioration.
- There is an internal gypsum tablet which buffers against salinity levels found in irrigated soil
- Operates on the same principles as other electrical resistance sensors.

Gypsum Block

- The sensor may be buried at any desired depth in the soil.



- The water in the soil will reach equilibrium with the water in the gypsum block
- A two-wire lead from the sensor is connected to a meter, which is used to read the sensor resistance using an alternating current,
- The electrical resistance is then determined and related to moisture content as a tension (kPa or bars)
- The range of soil water determined by gypsum blocks is generally given as field capacity to the permanent wilting point

Electrical Resistive Sensor

Advantages

- Useful indicator of the soil moisture content in respect to root conditions
- Gypsum sensors can be made easily by unskilled labour and can be very low-cost (~US$12 each)
- Can be automated

Disadvantages

- The block dissolves and degrades over time (especially in saline soils) losing its calibration properties
- Block pore size distribution match the soil texture being used
- The readings are temperature dependent (up to 20kPa per 10°C)

ELECTRICAL RESISTIVE SENSOR

Advantages

- Not significantly affected by small stones cavities or plant roots adjacent to the instrument

Disadvantages

- Gypsum blocks do not measure the moisture content at low potential (from 0 to -100 kPa) well
- There is the potential for large errors due to slow equilibrium of blocks
- Calibration is required

#	Attributes	Sensors		
		TDR	FDR	Hortau
		Score	Score	Score
1	Effective Range of measurement.	8	8	8
2	Accuracy	14	14	14
3	Soil Type (for use with range of soils)	11	11	11
4	Reliability	13	13	13
5	Frequency	13	13	13
6	Soil disturbance during installation	8	0	0
7	Data handling	8	8	8
8	Communication (for remote data manipulation)	8	8	12
9	Operation and maintenance	14	4	16
10	Availability and Technical Assistance	4	0	8
	Total	**101**	**79**	**103**

SUMMARY -SOIL MOISTURE MEASUREMENT

Soil Water Monitoring

Direct

Indirect

Feel ar

c

Tensiometric

Tensiometers

Electrical Resistive Sensor

Others

Others

SUMMARY -SOIL MOISTURE MEASUREMENT