



Soil moisture measurements

All it takes for environmental research





Soil moisture measurement

- This presentation shows:
 - Aim and typical research purposes
 - Working principles
 - Limitations of these working principles
 - Main markets
 - Main products with
 - Benefits
 - Remarks
 - Applications
 - Important related products
 - A sheet on how you can get even more information !



Soil moisture measurement

- Aim of the products:
 - Measure (or indicate) soil moisture situation in soil

Soil moisture measurement

■ Typical research purposes

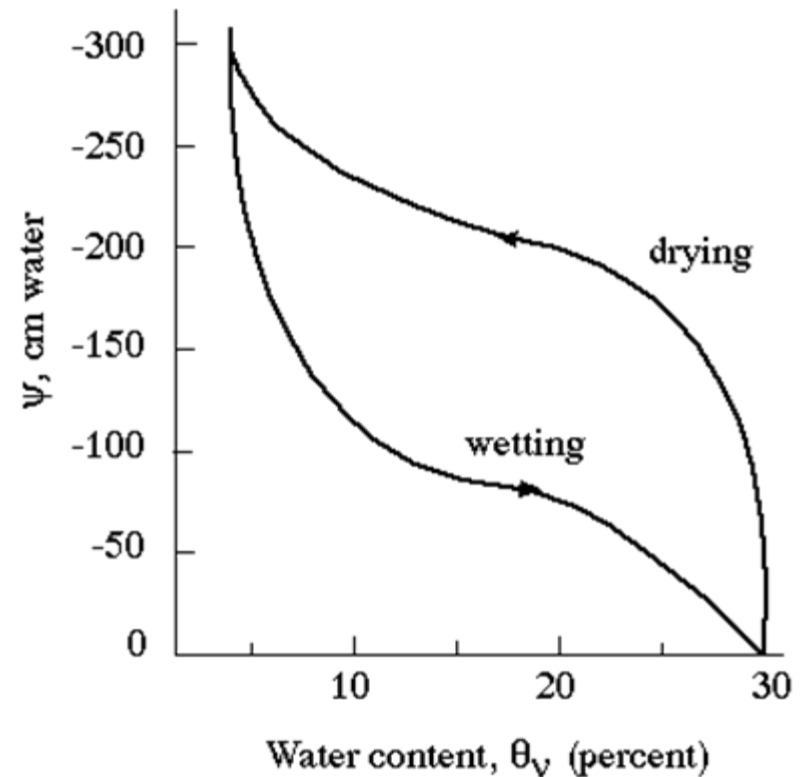
- Determine need for irrigation
- Determine growing conditions for trees, turf and plants anywhere
 - Very old and very young trees (to prevent them from dying)
 - Sport fields
 - Study of nature



Soil moisture measurement

■ Typical research purposes

- Determine behaviour of water in soil during wetting or drying



Soil moisture measurement

■ Typical research purposes

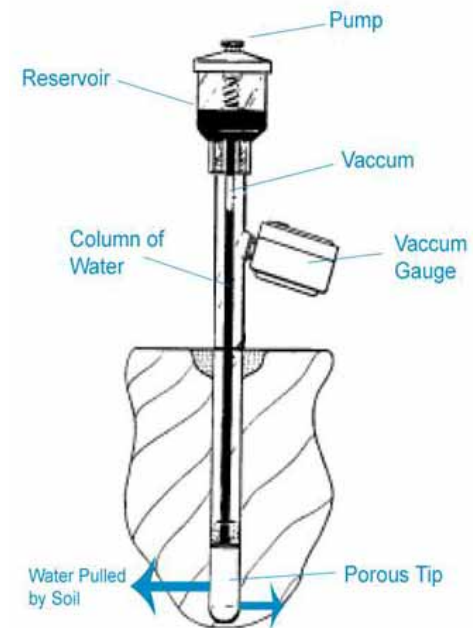
- Determine soil moisture percentage for geotechnical and civil engineering purposes



Soil moisture measurement

■ Working principles, two main principles

- Principle 1. Measure soil suction = force needed for roots to extract water out of soil pores
 - The higher the soil suction is, the higher plant growing stress.
 - Most interesting for agriculture, arboriculture, horticulture, sport fields
 - Soil suction expressed as (negative) pressure





Soil moisture measurement

- Principle 2. Measures purely the quantity of water per volume of soil
 - Most interesting for engineers, soil scientists etc.
 - Expressed as a percentage: 40% means 400 litres of water per 1000 kg of (dry) soil

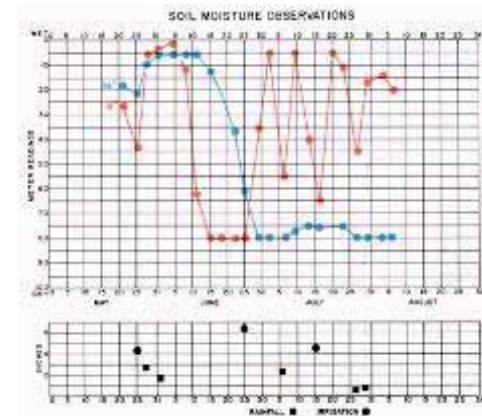
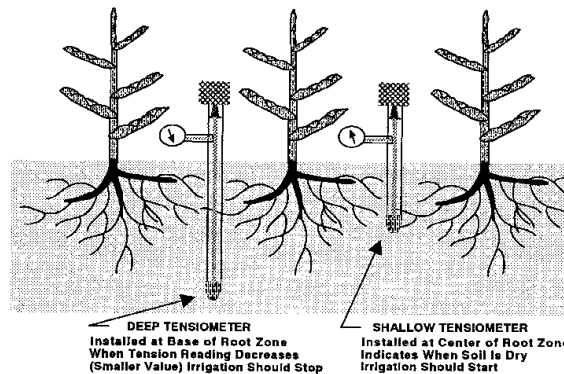
Soil moisture measurement

■ Working principles

- Principle 1: Measuring soil suction

1. Can be done purely physical with a tensiometer

- Limited range (only intensive well irrigated cultures)
- Some tensiometers can also measure oversaturation
 - » Study of stability of dikes / land slides



Soil moisture measurement

2. Or with porous blocks that wet and dry like the surrounding soil
 - In the block there is an open capacitor
 - The isolation characteristics of this capacitor can be measured
 - The “suction” value is derived and displayed
 - Higher measuring range





Soil moisture measurement

■ Working principles

- Principle 2: Measures purely the quantity of water per kg of soil
 1. Can be done gravimetrically in the lab on disturbed samples:
 - Sample with auger → weigh → dry → weigh. Lost weight is moisture% by weight
 2. Gravimetrically on undisturbed samples:
 - Sample with ring → weigh → dry → weigh. Lost weight is volumetric moisture%

Soil moisture measurement

3. Various electrical equipment

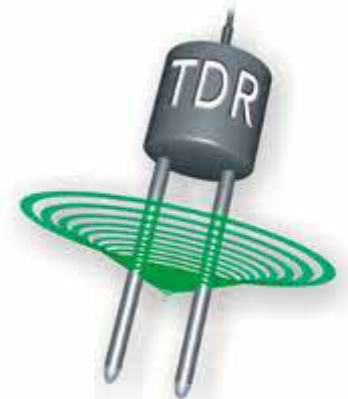
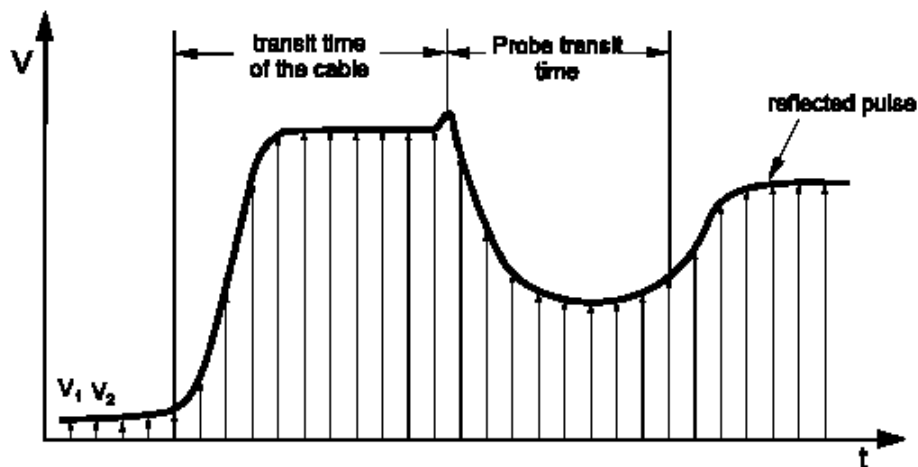
- TDR: Most accurate and expensive is Time Domain Reflectrometry (TDR)
- Examples
 - Trase
 - Trime
- FD: Less accurate and less expensive
Frequency Domain
- Examples
 - » HH2 meter
 - » Moisture Conductivity Temperature (MCT) sensor



Soil moisture measurement

■ Working principles TDR and FD

- TDR: A short electric pulse is send into an isolated probe.
 - If the surrounding material is air or dry soil (almost same ϵ) the shape of the reflected pulse will be different from when the soil is wet.
 - Analysing the pulse gives the volumetric soil moisture %



Soil moisture measurement

■ Working principles TDR and FD

- FD: Less accurate and less expensive: Frequency Domain
 - The soil is regarded as a capacitor here.
 - The dielectric constant ϵ (permittivity) of this “capacitor” varies with water content.
 - Electric contacts are used to measure the ϵ of this capacitor
 - Examples
 - » HH2 meter
 - » Moisture Conductivity Temperature MCT sensor



Soil moisture measurement

- Working principles TDR and FD (conductivity)
 - Conductivity of (bulk) soil can be indirectly measured with TDR (analysis of reflected pulse)
 - TRIME and Trase
 - Can be measured directly with FD:
 - Electric contacts are used to measure the specific conductivity (resistance) of the bulk soil
 - Examples
 - HH2 meter with WET sensor
 - Moisture Conductivity Temperature MCT sensor



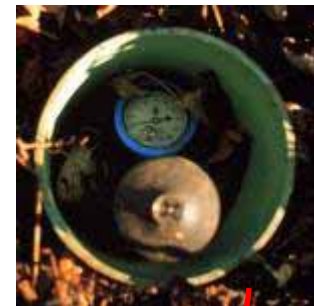
- » Of course air gaps and humidity level influence the reading
- » When measuring in a bucket or pot the pot must be sufficiently large and non-metallic



Soil moisture measurement

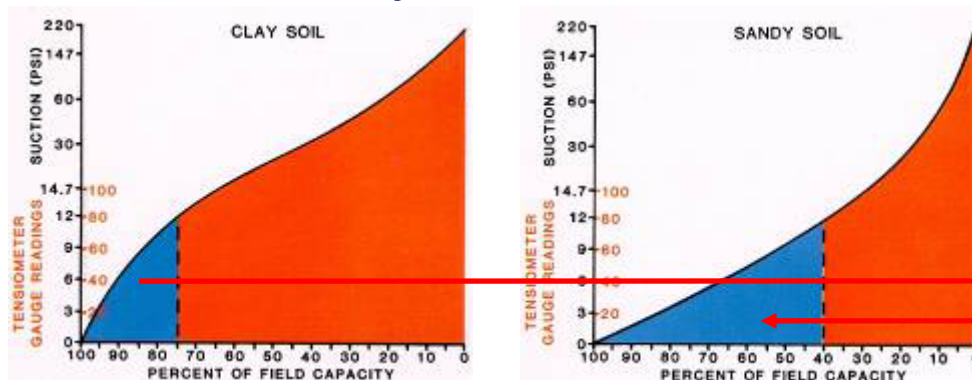
■ Limitations of principle

- Tensiometers will dry out when soil is drier than 100 cBar or 100 kPa →
 - Refilling can be done in the field.
 - Tensiometers may freeze
 - Must be left in the field (damage)
 - Have a limited range
 - Only useful for intensive cultures



A well protected tensiometer

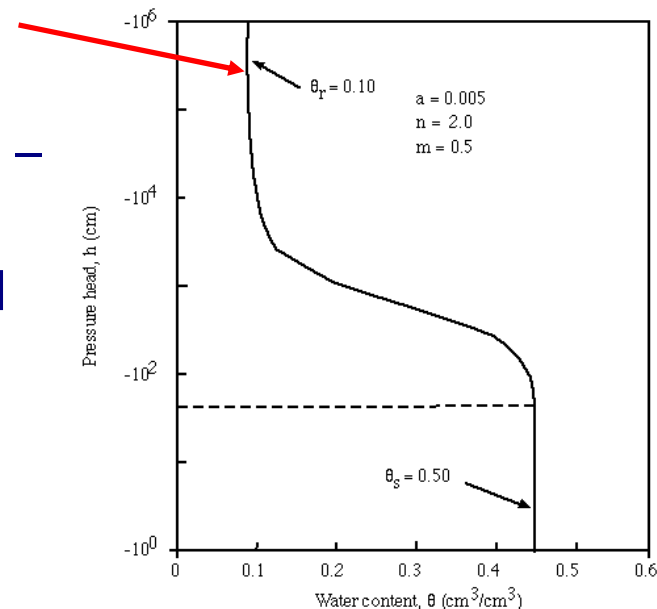
Measuring range of tensiometer



Soil moisture measurement

■ Limitations of principle

- TDR and FD meters do NOT directly inform on plant-root stress: First a pF curve needs to be made of that soil !
 - pF curve = Relation between soil moisture content and soil suction values (varying from 0 – 1600 kPa !!)
 - pF curve = also mentioned water retention curve
 - However TDR/FD meters are very wanted for irrigation advice.



Soil moisture measurement

- Main markets (see PKD for more details !)
 - Tensiometric + TDR/FD
 - Agricultural consultants / crop growers / irrigation seed suppliers / plant breeding / sport stadiums / golf courses
 - Civil engineering / landfill and waste disposal sites
 - Road constructors (determination of moisture content of building material)
 - Education





Soil moisture measurement

Main products

Soil moisture measurement

■ 11.41.11 e+ SOIL MCT sensor

- Measures (FD) and logs moisture conductivity and temperature
- Benefits
 - Follows soil moisture% behaviour and stores in memory
 - Records conductivity and temperature also !
 - Large memory, data can be send with modem
 - In-situ field uploading (or read-out) possible
 - Different lengths available for profile research
 - Perfect for trend analyses
 - Standard 5 point calibration in logger
 - User 2 point calibration
- Remarks
 - Air gaps around probe tips reduce accuracy
 - Lab soil specific data will increase accuracy
 - You can correct data in excel
 - Soil specific 5 point calibration in factory on request



Soil moisture measurement

■ 11.41.11 e+ SOIL MCT sensor

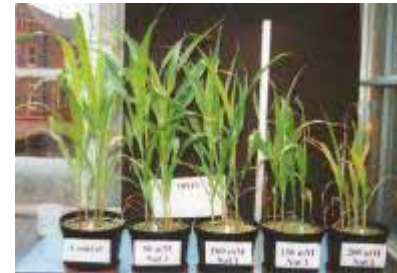
- Main applications

- See PKD for more detailed information

- Applied and scientific soil and lab research
- Irrigation studies and field measurements
- Agriculture / Horticulture (open air) monitoring and research
- Public gardens / Open space planning monitoring and research
- Forestry monitoring, studies on seedlings
- Horticulture (greenhouse) monitoring
- Soil moisture profile studies
- Measurements of oversaturated soils (geotechnics)



Monitoring water-logging or drought problems



Monitoring salinity problems

Soil moisture measurement

■ 14.26 Thetaprobe soil moisture measuring system

- FD system for immediate volumetric moisture percentage
- Benefits
 - Acceptable accuracy for a reasonable price
 - Powerful read-out device with manual data-storage
 - Two standard calibrations: Mineral and organic soil
 - Irrigation advice possible after pF curve determination
 - Can also be used with profile probes and WET sensor
 - Probe can be extended for deeper layers
- Remarks
 - Probe will be damaged in very stony soil



Soil moisture measurement

■ 14.26 Thetaprobe soil moisture measuring system

- Main applications (see PKD for more detailed information)
 - Irrigation studies and field measurements
 - Equipment fit for small scale farming
 - Agriculture / Horticulture (open air) monitoring and research
 - Applied and scientific lab and field research
 - Turf / Sport fields monitoring and research
 - Public gardens / Open space planning monitoring and research
 - Forestry monitoring, studies on seedlings (nurseries)
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Profile probes



Soil moisture measurement

- 14.22 Soil moisture measuring system with gypsum blocks
 - Measures soil moisture suction indirectly in a gypsum block fitted with an “open” capacitor
 - Benefits
 - Cheap meter, very cheap sensors
 - Fair for schools or indicative measurements
 - Very large (“full”) measuring range
 - Remarks
 - Reacts quick on wetting; slow on drying
 - Gypsum blocks do not last long (one season)
 - Salt sensitive





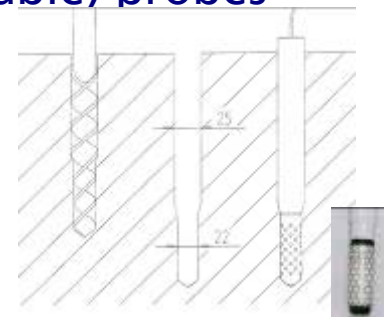
Soil moisture measurement

- 14.22 Soil moisture measuring system with gypsum blocks
 - Main applications (see PKD for more detailed information)
 - Indicative applied and scientific lab and field research
 - Indicative field “measurements”
 - Soil moisture profile studies
 - Equipment fit for small scale farming
 - Good for schools

Soil moisture measurement

■ 14.27 Soil moisture measuring system Watermark

- Measures soil moisture suction indirectly in a durable not salt sensitive block fitted with an “open” capacitor
- Benefits
 - Cheap but serious measuring instrument
 - Results directly expressed in soil suction
 - Range allows measuring at trees and dry crops
 - Therefore ideal for irrigation advice
 - No field maintenance of probes
 - Stable long lasting salinity insensitive (affordable) probes
 - Easy read-out with simple cheap instrument
 - Temperature can be corrected
- Remarks
 - Probes need good contact with soil →



Soil moisture measurement

■ 14.27 Soil moisture measuring system Watermark

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 - Equipment fit for small scale farming
 - Forestry monitoring, studies on seedlings (nurseries)
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 - Soil moisture profile studies



Drought
stress

Soil moisture measurement

■ 14.04.nn Tensiometers

- Soil tries to suck water from a porous element on a closed reservoir. The suction is measured.
- Benefits
 - Direct read out of plant water stress
 - Simple purely physical operating principle
 - Set perfect for schools and horticulturists
 - Exchangeable porous ceramic cups
 - Simple installation



Moisture profile
research

Soil moisture measurement

■ 14.04.nn Tensiometers

- Remarks

- Need for infield refilling after drying of soil (very easy with jet-fill types)
- Not for extensive cultures (too dry)
- Not frost resistant



Installing a
tensiometer





Soil moisture measurement

■ 14.04.nn Tensiometers

- Main applications (see PKD for more details)
 - Direct (plant root) suction measurement
 - Equipment fit for small scale farming
 - Irrigation studies and field measurements Applied and scientific lab and field research
 - Turf / Sport fields monitoring and research
 - Forestry: studies on seedlings (nurseries)
 - Horticulture (open air) monitoring and research
 - Soil moisture profile studies

Soil moisture measurement

- 14.04.08/09/10/11 Tensiors electronic pressure transducers
 - Tensiors are tensiometers with electronic pressure sensors on the porous cup or on the pipe.
 - Benefits
 - Many models available
 - Perfect for scientific research
 - Can also read positive pressures (land slide research)
 - Can be used for automatic irrigation management
 - Models with pressure sensor on top cannot freeze
 - Model T8 can be refilled without removing from soil



Soil moisture measurement

- 14.04.08/09/10/11 Tensiometers electronic pressure transducers
 - Main applications (see PKD for more detailed information)
 - Applied and scientific lab and field research
 - Measurements of oversaturated soils (geotechnics)
 - Direct (plant root) suction measurement
 - Soil moisture profile studies
 - Irrigation studies and field measurements
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 - Forestry: Studies on seedlings (nurseries)
 - Agriculture / Horticulture (open air) monitoring and research
 - Horticulture (greenhouse) monitoring



Oversaturated soils

Soil moisture measurement

- 14.62 and 14.63 TDR measuring devices: TRIME TDR, TRASE TDR
 - TDR: A short electric pulse is send into an isolated probe.
 - If the surrounding material is air or dry soil (almost same ϵ) the shape of the reflected pulse will be different from when the soil is wet. This gives the volumetric soil moisture %



Mini Trase kit



Soil moisture measurement

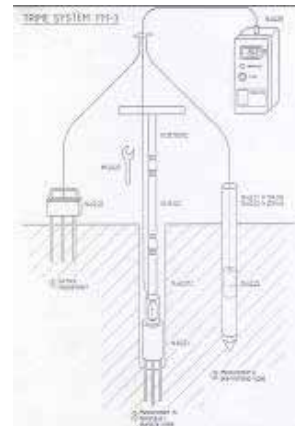
■ 14.62 and 14.63 TDR measuring devices: TRIME TDR, TRASE TDR

- Benefits
 - Most accurate field device to measure volumetric %
 - TRASE and TRIME with many different probes
 - Measurement also possible in buried tube (TRIME)
 - Immediate read-out or logging (ask for details)
- Remarks
 - Soil specific calibrations are possible but preferably extreme soil data can be corrected later in excel



Soil moisture measurement

- 14.62 and 14.63 TDR measuring devices: TRIME TDR, TRASE TDR
 - Main applications (see PKD for more detailed information)
 - Applied and scientific lab and field research
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Soil moisture measurement

User calibration and checking of instruments



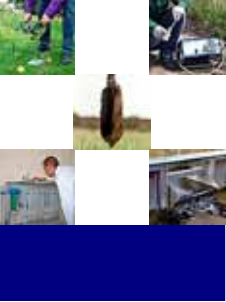
Soil moisture measurement

User-calibration and checking of the instruments

1. Suction instruments

■ Tensiometers

- Manometer should read zero (0 +/- 5 cBar) suction when ceramic completely dry or with ceramic element removed
- Remove ceramic element and connect an accurate manometer and a vacuum pump with the tensiometer. Pump vacuum and check if values are equal (+/-5 cBar)
- Checking integrity of ceramic element and other leaks: First completely saturate element with water and wrap in aluminium foil. Then connect vacuum pump with manometer. Full vacuum should be possible without leakage.



Soil moisture measurement

User-calibration and checking of the instruments

Tensiometer general check

■ Tensiometers

- First completely saturate element with water (manual). Then wrap dry tissue. The manometer should run up. Repeat contacting with dry paper until full suction shows (at the end air will pass through the porous cup and the suction is lost !)



Soil moisture measurement

User-calibration and checking of the instruments

Tensiometer field problems

- In coarse material there is insufficient water transfer between coarse soil material and fine pores of ceramic. Make a paste (mud) of fine sand and use this as intermediate material between wet ceramic and soil. Wait a few days before first reading
- Use in soil moisture situations with suction > 100 cBar will cause air leaks in porous material of cup. Air will enter tensiometer. Refill with water when moisture situation has improved
- Remove before winter. Do not allow instrument to freeze.



Soil moisture measurement

User calibration of suction reading instruments

■ Gypsum and Watermark blocks

- Completely dry element should read correct “dry” value
 - Oven dry at 70 degrees C during two days or use new block
- Water saturate element for 1 hour and read completely wet value
- You may establish a relation between real tensiometer readings and blocks readings and establish a relation which you can put in an excel file. Be aware of the hysteresis problem.



Soil moisture measurement

User calibration of the volume% instruments

■ TDR-TRIME

- All instruments are supplied with a standard multipoint calibration curve for mineral soils
 - You may user calibrate this curve in dry and saturated glass beads (1/yr)
 - Do not install another (soil specific curve) in the instrument this will disturb all other feature readings
- Soil specific calibration: Establish an excel file with vol% data obtained from coring rings and from standard readings with the TDR instrument at various moisture levels (\pm saturated, \pm field capacity + a few drier levels) during the season.
- Later use the excel file to interpret all future TDR readings



Soil moisture measurement

User calibration of the volume% instruments

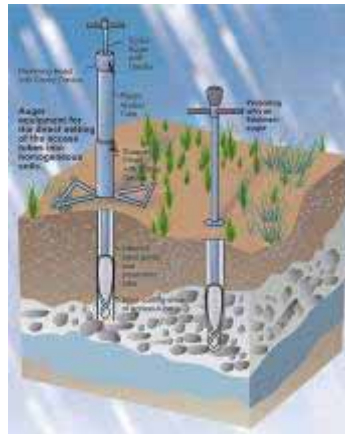
■ FD (Thetaprobe, MCT logger)

- All instruments are supplied with a standard multipoint calibration curve for mineral soils
 - You may user calibrate this curve according to the manual in air and water (e.g. 1/yr)
- Thetaprobe also has a standard calibration curve for organic soils
- With Thetaprobe you may install 3 soil specific curves in the instrument. This will not disturb the two standard curves.
- Other soil specific calibrations: Establish an excel file with vol% data obtained from coring rings and from standard readings with the FD instrument at various moisture levels (\pm saturated, \pm field capacity + a few drier levels) during the season.
- Later use the excel file to interpret all future FD readings

Soil moisture measurement

■ Important related products:

- Augers and gouges to install probes or access tubes
- Vacuum pump to prepare tensiometers
- Soil sample ring kits for undisturbed soil samples (to calibrate soil moisture measurements)
- e-SENSE modems to read-out MCT sensor at home / office
- Rain gauge and other meteo equipment





Soil moisture measurement

■ More information ?

- On pF see presentation pF measurements in the lab (PKD)
- On presentation “Soil moisture measurement suction or volumetric (basics)” in PKD
- Brochures (catalogue and www.eijkelkamp.com)
- Complementary information (not for all products)
- Manuals (almost all products)
- Product Knowledge D-base (PKD-internet)
- Product Training: ETC@eijkelkamp.com
- Additional questions ?! Write info@eijkelkamp.com or ask local distributor!