
Hey Buddy, guess what?
I got me an irrigation system.
Now what?
I don't know Junior.
Just turn it on.

Irrigation Engineering and Management

- Planning
- Selection
- Design
- Installation

→ Greater focus

- Management
- Evaluation
- Economics

→ Lesser focus

Proper water management and frequent system evaluation are critical to success or failure of an irrigation system regardless of its robustness.

Economics - Irrigation must pay for itself and more.

Irrigation Water Management:

Determining and controlling the rate, amount and timing of irrigation water application in planned and efficient manner.

Most important aspect of the broader irrigation water management is the <u>scheduling of irrigation.</u>

NATURAL RESOURCES CONSERVATION SERVICE
CONSERVATION PRACTICE STANDARD

IRRIGATION WATER MANAGEMENT

(Ac.)

CODE 449

DEFINITION

The process of determining and controlling the volume, frequency and application rate of irrigation water in a planned, efficient manner.

PURPOSE

This practice may be applied as part of a resource management system to achieve one or more of the following purposes:

- Manage soil moisture to promote desired crop response.
- Optimize use of available water supplies.
- Minimize irrigation induced soil erosion.
- Decrease non-point source pollution of surface and groundwater resources.
- Manage salts in the crop root zone.
- Manage air, soil, or plant micro-climate.
- Proper and safe chemigation or fertigation.
- Improve air quality by managing soil moisture to reduce particulate matter movement.
- Reduce energy use.

CONDITIONS WHERE PRACTICE APPLIES

This practice is applicable to all irrigated lands.

An irrigation system adapted for site conditions (soil, slope, crop grown, climate, water quantity and quality, air quality, etc.) must be available and capable of efficiently applying water to meet the intended purpose(s).

CRITERIA

<u>General Criteria Applicable to All Purposes</u>

Irrigation water shall be applied in accordance with federal, state, and local rules, laws, and regulations. Water shall not be applied in excess of the needs to meet the intended purpose.

Measurement and determination of flow rate is a critical component of irrigation water management and shall be a part of all irrigation water management purposes.

The irrigator or decision-maker must possess the knowledge, skills, and capabilities of management coupled with a properly designed, efficient and functioning irrigation system to reasonably achieve the purposes of irrigation water management.

An “Irrigation Water Management Plan” shall be developed to assist the irrigator or decision-maker in the proper management and application of irrigation water.

Irrigator Skills and Capabilities. Proper irrigation scheduling, in both timing and amount, control of runoff, minimizing deep percolation, and the uniform application of water are of primary concern. The irrigator or decision-maker shall possess or obtain the knowledge and capability to accomplish the purposes which include:

A. General

1. How to determine when irrigation water should be applied, based on the rate of water used by crops and on the stages of plant growth and/or soil moisture monitoring.
2. How to determine the amount of water required for each irrigation, including any leaching needs.
3. How to recognize and control erosion caused by irrigation.
4. How to measure or determine the uniformity of application of an irrigation.

Soil Moisture-based Irrigation Scheduling
Theory and Practice

Objective:

Present a refresher on the science and practice of irrigation scheduling.

Outline:

- Irrigation scheduling methods:
  - Crop-based
  - Climate-based (or ET-based), and
  - Soil-based

  All irrigation scheduling methods in use today are soil-based.

- Soil moisture sensor types, technology, and data access

Past (2011) Webinar on Soil Moisture-based Irrigation

USDA Natural Resources Conservation Service

Water Management Engineering Webinar

Hosted by the West National Technology Support Center in Portland, OR

Irrigation Management Using Soil Moisture Sensors

Brian Lennon
The Irrometer Company

Brian Lennon's presentation will cover the various ways of measuring and monitoring soil tension values and how to use the data to make better irrigation scheduling decisions. Brian will also include updated information such as remote data access (telemetry systems).

Thursday, September 8, 2011

11:00 a.m. – 12:00 Pacific
2:00 p.m. – 3:00 p.m. Eastern

Join the Audio 877.691.8904
Passcode: 844 6369

Click Here to Join the Webinar
Leader: Peter Robinson

Visit the Science & Technology Training Library!

Irrigation Scheduling

Irrigation scheduling is planning to determine how much water to apply and when to:

1. Meet crop water needs to prevent crop yield/quality loss due to water stress;

2. Maximize water use efficiency resulting in beneficial use and conservation of water resources; and

3. Minimize runoff and leaching of water and agro-chemicals to protect water quality.

Proper scheduling of irrigation water is a crucial decision for a farm manager.

Irrigation is a daily management activity.

Irrigation Scheduling

- **When** to irrigate?

  Timing - Turn the system ON

- **How Much** to irrigate?

  Amount - Turn the system OFF

- **Where** to irrigate?

  Site-specific irrigation

Precision Irrigation: Apply the right amount,
at the right time, and
at the right place.

Irrigation Scheduling

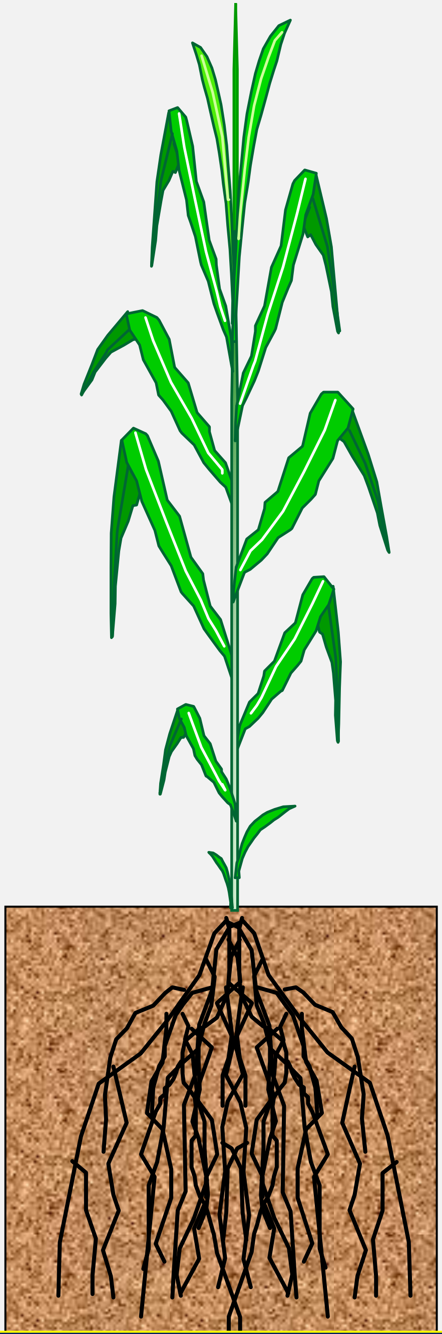
- **Timing?**

  Irrigate when crop comes under water stress large enough to reduce expected yield and/or quality.

  Question: What is large enough?

- **Amount?**

  Refill storage to meet crop water needs while limiting runoff and leaching.



Irrigation Timing

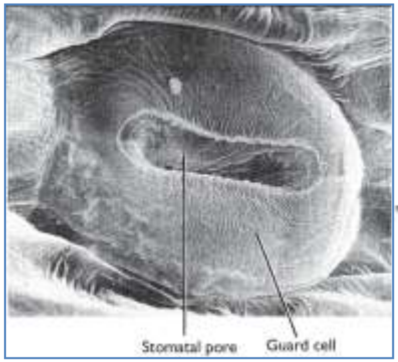
Ideally, we should ask the crop if it is under water stress & thus in need of water.

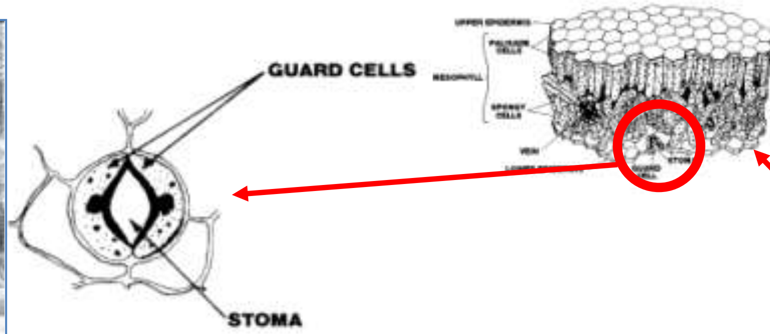
«Crop-based scheduling»

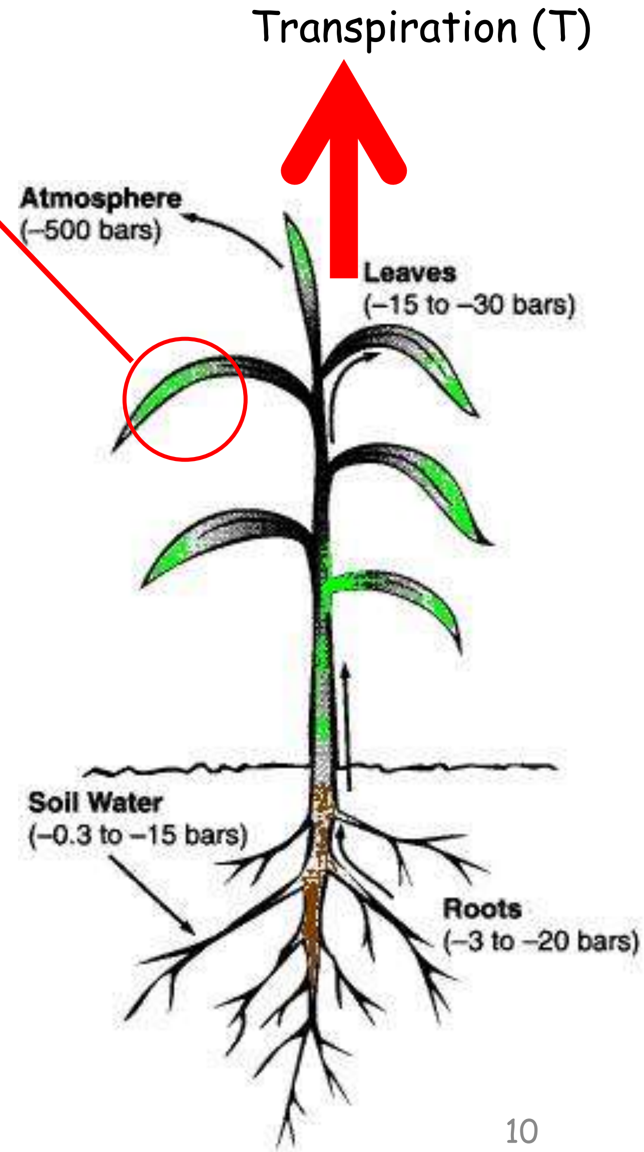
Irrigation based on visual signs of stress is, unfortunately, quite common.

Visual signs: Leaf rolling, darkening, wilting.

Transpiration & the role of stomata





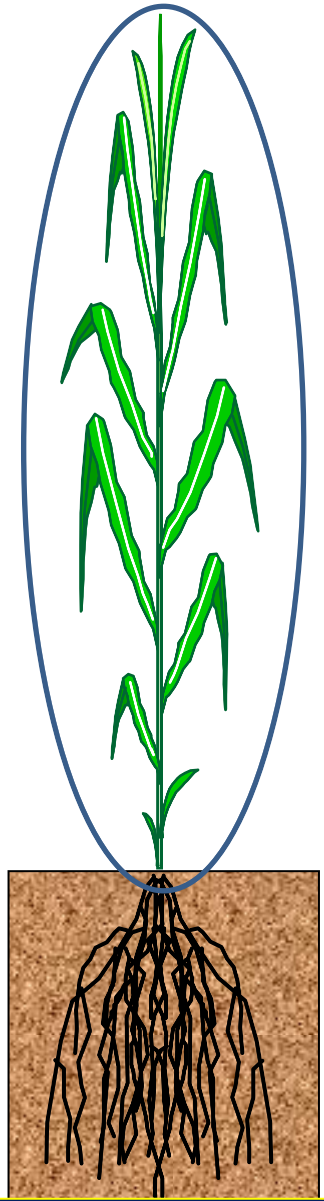


As soil moisture becomes limiting, stomata start to close. This causes:

- Reduced transpiration
- Reduced photosynthesis
- Reduced biomass production
- Elevated temperature (plant fever)

These can be measured, but methods are more suited for research than practice.

Irrigation Timing & Amount



Crop-based scheduling

Asking the plant if it needs water. (Experimental)

Hey, it's Junior again. This is weird, but I am down here to see if you are under stress and how much water you may need.

Soil-based scheduling

Asking the soil if plant needs water and how much.

What is the basis for this?

Soil Moisture and Crop Water Stress

Generally, when about 50 percent of the available moisture is depleted from the soil, crop starts to experience stress.

If soil drying continue, crop starts to wilt and will ultimately die.

This understanding is the basis for nearly all irrigation scheduling strategies in use today.

It ain't bad to *Get MAD*!

"Get MAD"

to muster all one's physical and mental resources in order to do something difficult…

Management Allowable Depletion (MAD)

- MAD is the level to which the irrigator will allow the soil moisture to be depleted before irrigating
- MAD is viewed as irrigation "set point"
- MAD is crop-dependent
  - Field crops: 50% MAD level
  - Vegetables: 30 – 40% MAD level
- MAD depends on crop stage of growth

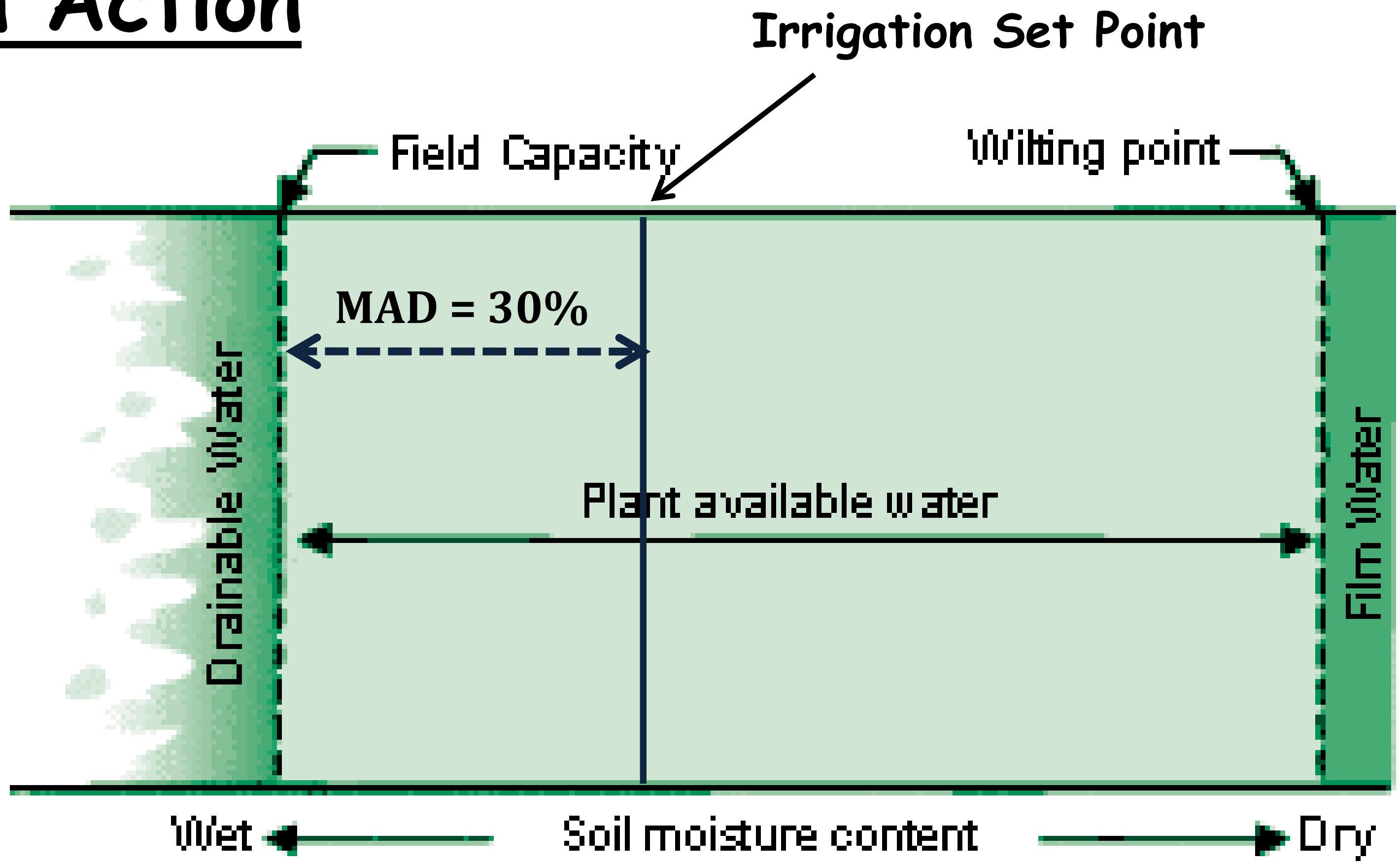
  Flowering is more water sensitive than the vegetative stage.
- KEY: MAD sets irrigation <u>timing</u> and <u>amount</u>

MAD - Function of the crop and stage of growth

Crop	Crop growth stage: Establishment	Vegetative	Flowering yield formation	Ripening maturity
Alfalfa hay	50	50	50	50
Alfalfa seed	50	60	50	80
Beans, green	40	40	40	40
Beans, dry	40	40	40	40
Citrus	50	50	50	50
Corn, grain	50	50	50	50
Corn, seed	50	50	50	50
Corn, sweet	50	40	40	40
Cotton	50	50	50	50
Cranberries	40	50	40	40
Garlic	30	30	30	30
Grains, small	50	50	40 3/	60
Grapes	40	40	40	50
Grass pasture/hay	40	50	50	50
Grass seed	50	50	50	50
Lettuce	40	50	40	20
Milo	50	50	50	50
Mint	40	40	40	50
Nursery stock	50	50	50	50
Onions	40	30	30	30
Orchard, fruit	50	50	50	50
Peas	50	50	50	50
Peanuts	40	50	50	50
Potatoes	35	35	35	50 4/
Safflower	50	50	50	50
Sorghum, grain	50	50	50	50
Spinach	25	25	25	25
Sugar beets	50	50	50	50
Sunflower	50	50	50	50
Tobacco	40	40	40	50
Vegetables				
1 to 2 ft root depth	35	30	30	35
3 to 4 ft root depth	35	40	40	40

For medium to fine textured soils:

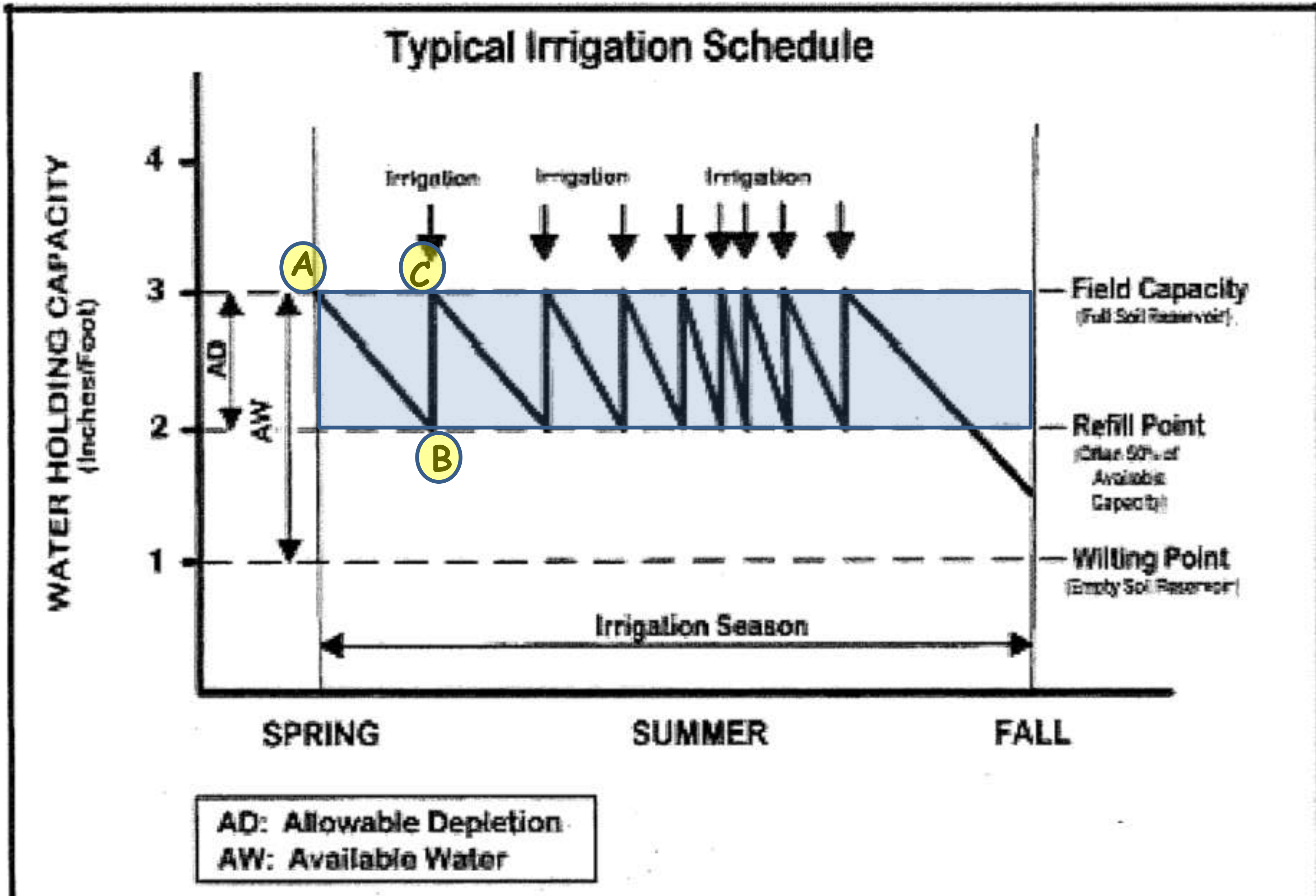
MAD in Action



Irrigation Scheduling using MAD:

Timing: Irrigate each time soil moisture reaches the MAD level.

Amount: Apply sufficient water to bring profile to Field Capacity.


Typical Irrigation Schedule
WATER HOLDING CAPACITY
(Inches/Foot)
4
3
2
1
Irrigation
Irrigation
Irrigation
A
C
B
AD
AW
Field Capacity
(Full Soil Reservoir)
Refill Point
Wilting Point
Irrigation Season
SPRING
SUMMER
FALL
AD: Allowable Depletion
AW: Available Water

Field Capacity, Wilting Point, and MAD

Soil Texture	Field Capacity (%)	Wilting Point (%)	Moisture content at 50% MAD
Coarse Sand	10	5	7.5
Sand	15	7	11
Loamy Sand	18	7	12.5
Sandy Loam	20	8	14
Loam	25	10	17.5
Silt Loam	30	12	21
Silt Clay Loam	38	22	30
Clay Loam	40	25	32.5
Silt Clay	40	27	33.5
Clay	40	28	34

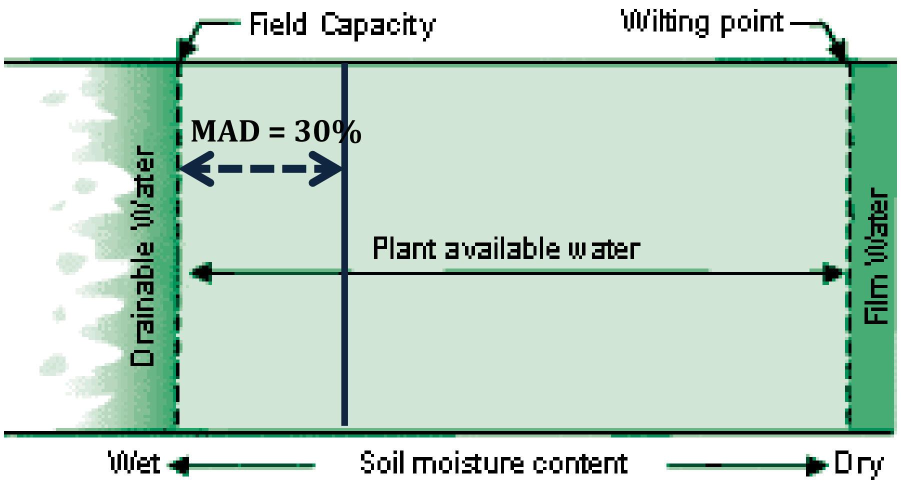
Example: Loam Soil – What would you do if soil moisture content is:

22%? Nothing

18%? Irrigate

13%? I messed up!

To schedule irrigation:

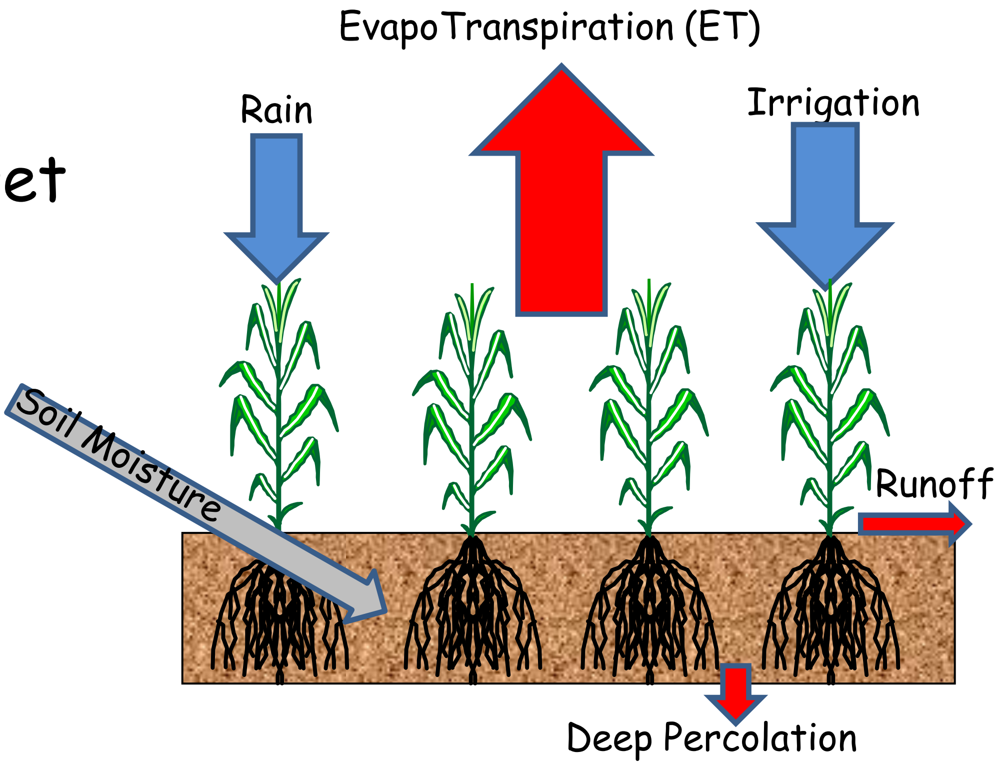


Need knowledge of Soil Moisture Content → Estimate soil moisture

→ Measure soil moisture

Estimating Soil Moisture Content

Solve Soil Moisture Budget for the Root Zone:



Change in soil moisture (today – last time) = Input – Output

Input = Irrigation + Rain
Output = ET + Runoff + Deep percolation

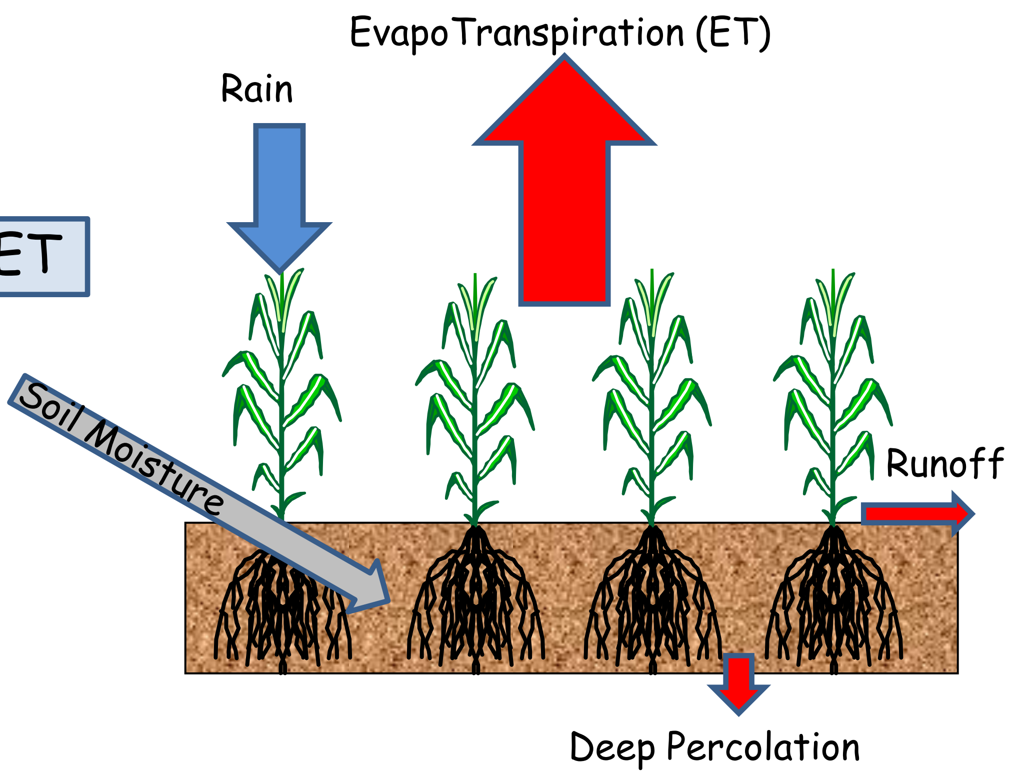
Soil Moisture Budget since last irrigation:

$$SM_{today} = (SM_{last\ time} + Rain) - (ET + Runoff + Deep\ percolation)$$

To solve for soil moisture today, need:

ET:	Estimate
Rain:	Measure
Runoff:	= 0
Deep per:	= 0

$$SM_{today} = (SM_{last\ time} + Rain) - ET$$



ET- or Climate-based Scheduling

On daily or more basis, calculate soil moisture in root zone:

$$SM_{today} = (SM_{last\ time} + Rain) - ET$$

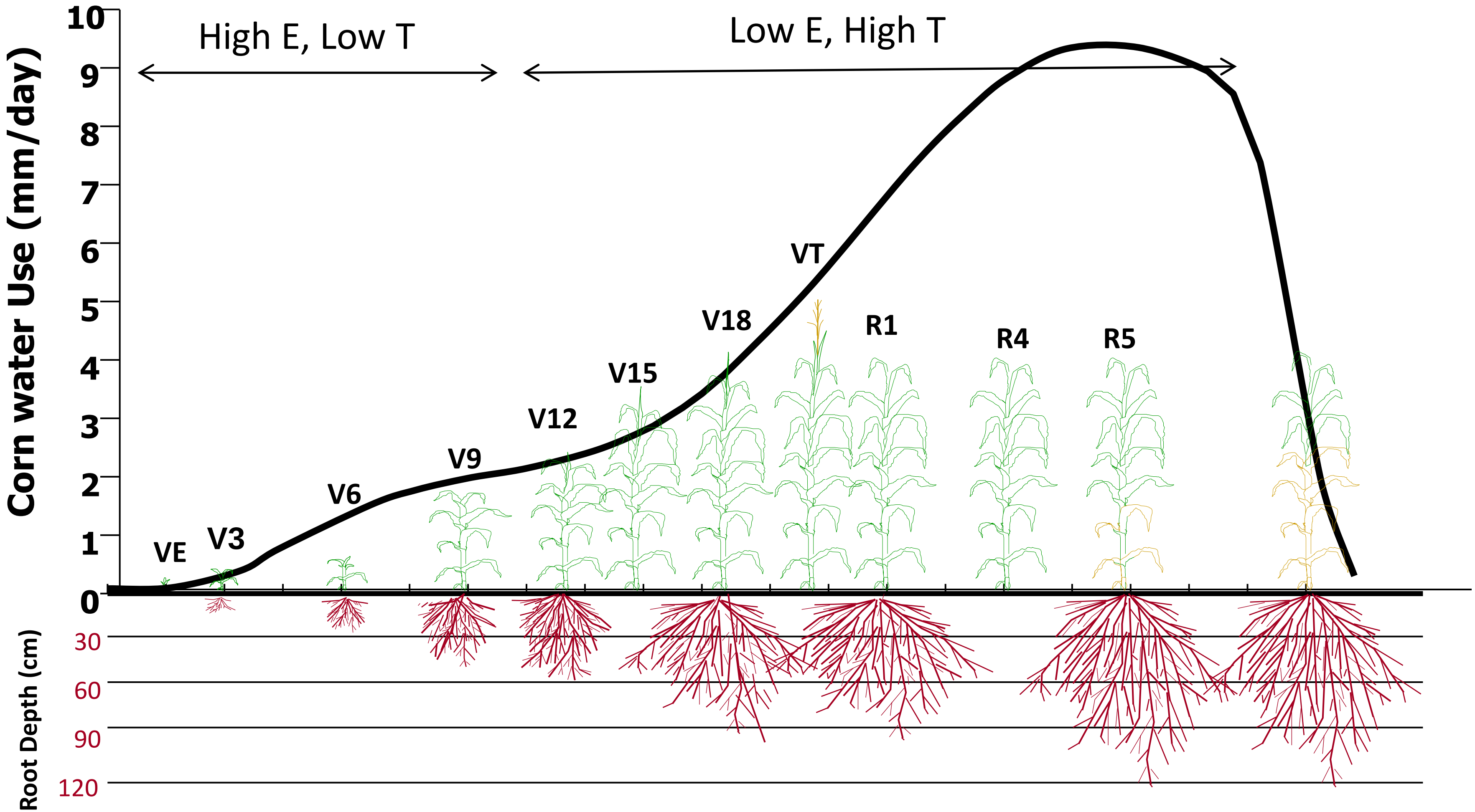
Compare soil moisture with MAD to make an irrigation decision.

This is classic Checkbook method.

Because we estimate ET using climate data, this method is also referred to as ET-based or climate-based irrigation scheduling even though the objective is to estimate soil moisture.

Challenge: How to measure or estimate the variables, especially ET?

Typical Corn Evapotranspiration (ET)
(Crop water use, Consumptive use)

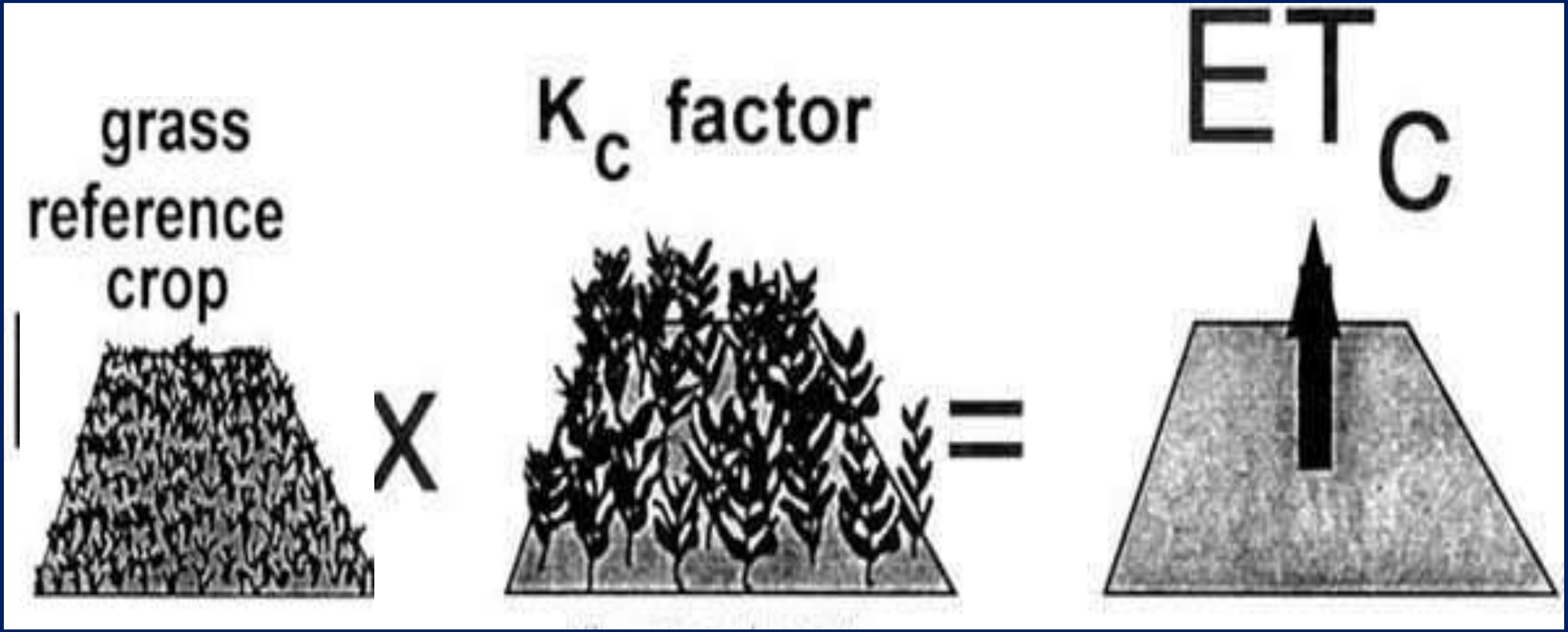


Note: Root depth, root zone, and water use change over time

Estimating Crop ET (ETc)

Actual Crop ET = crop coefficient x Reference ET

$$ET_c = K_c \times ET_0$$



The reference evapotranspiration (ET_0) can be estimated using one of many equations depending on weather data availability.

FAO-56 Method is:
The Penman Monteith Model

Reference Grass ET (ET_o)
Penman-Monteith Equation

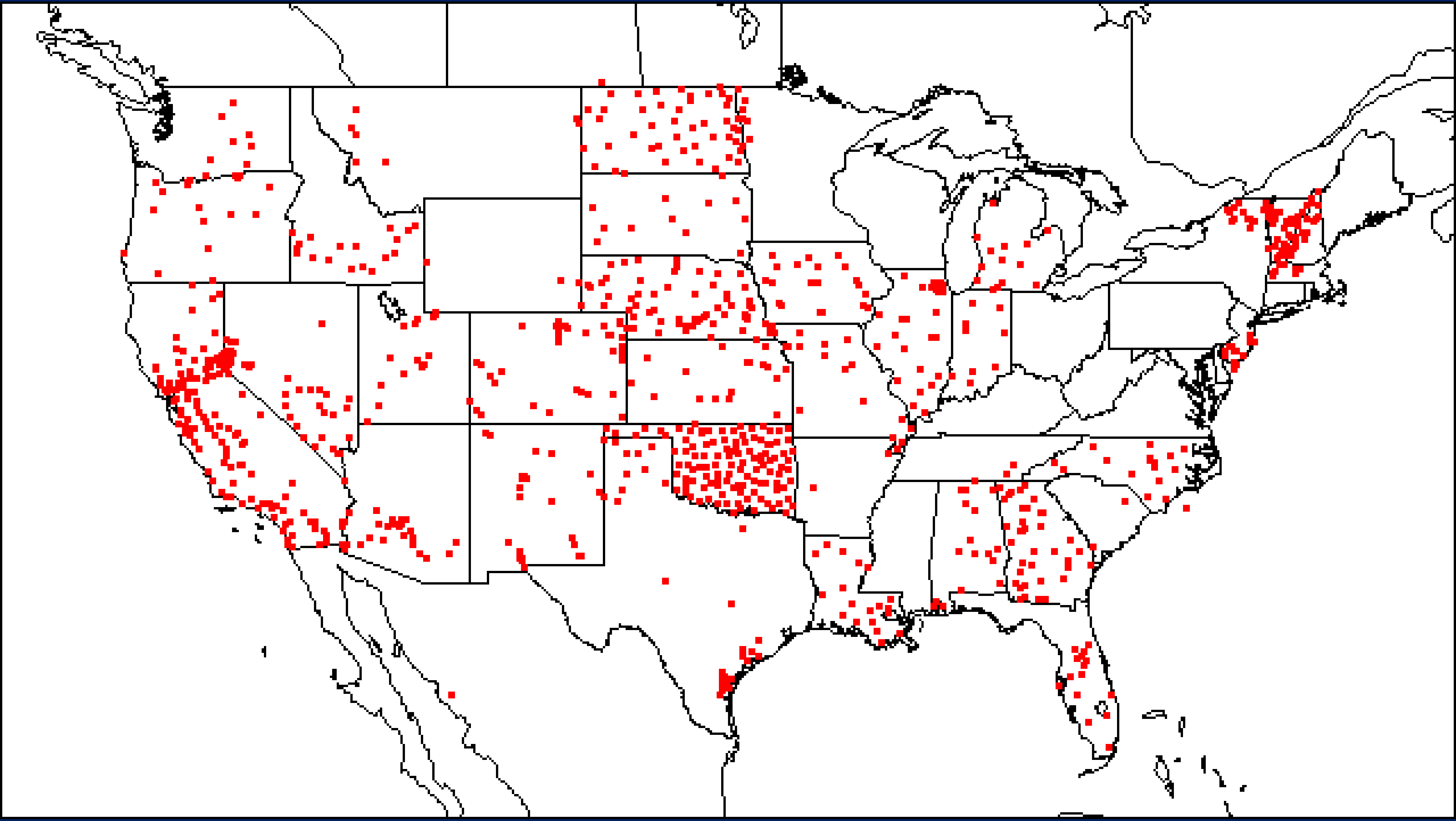
$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \dfrac{900}{T + 273} u(e_s - e_a)}{\Delta + \gamma(1 + 0.34u)}$$

Need climate data (air temperature and humidity, solar radiation, and wind) to calculate ET_o.

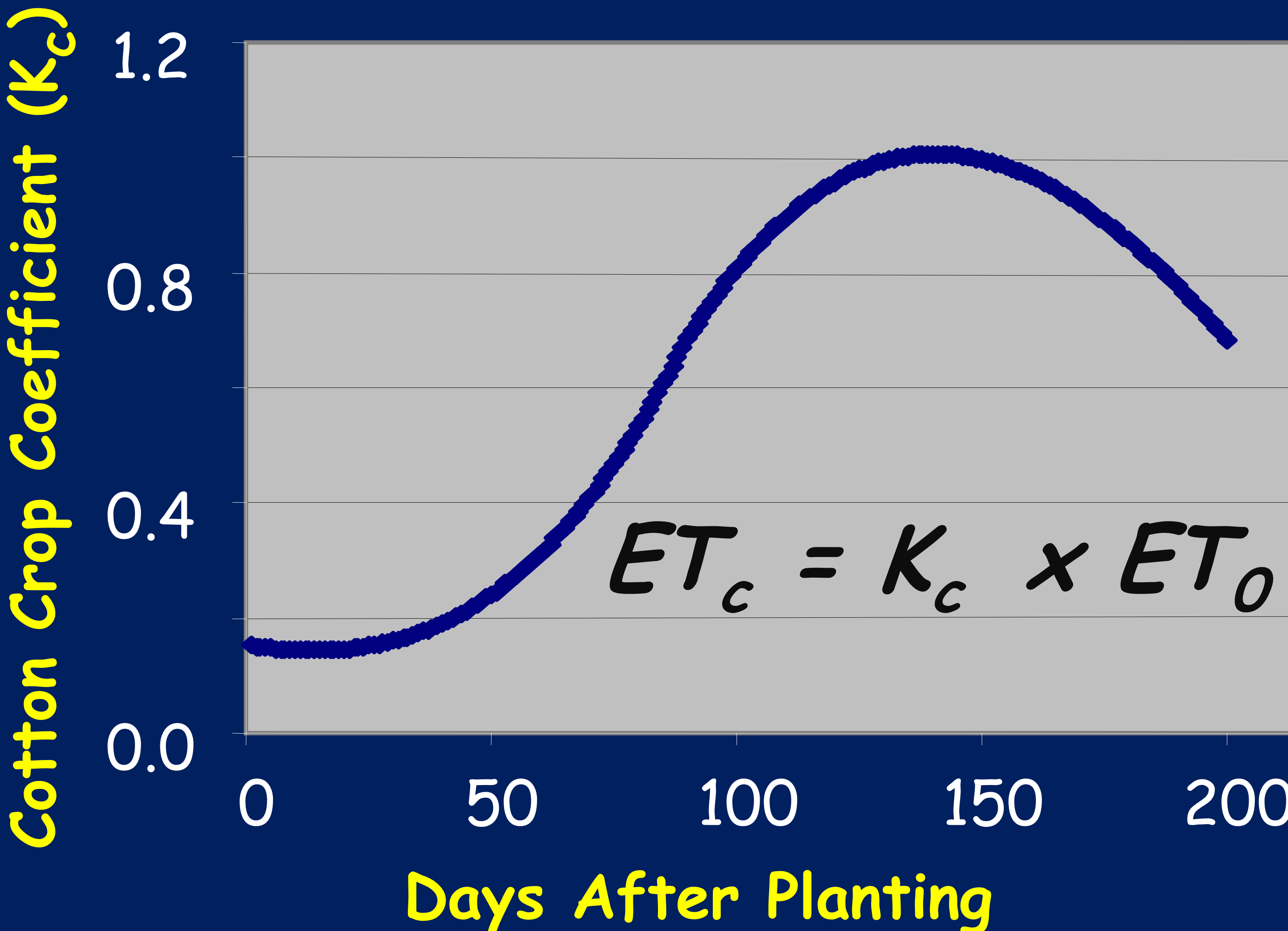
States with a network of agricultural meteorology stations provide daily data adequate to solve the above equation.

In several states, ETo is computed and made available online.

US Networks of Agricultural Meteorological Stations

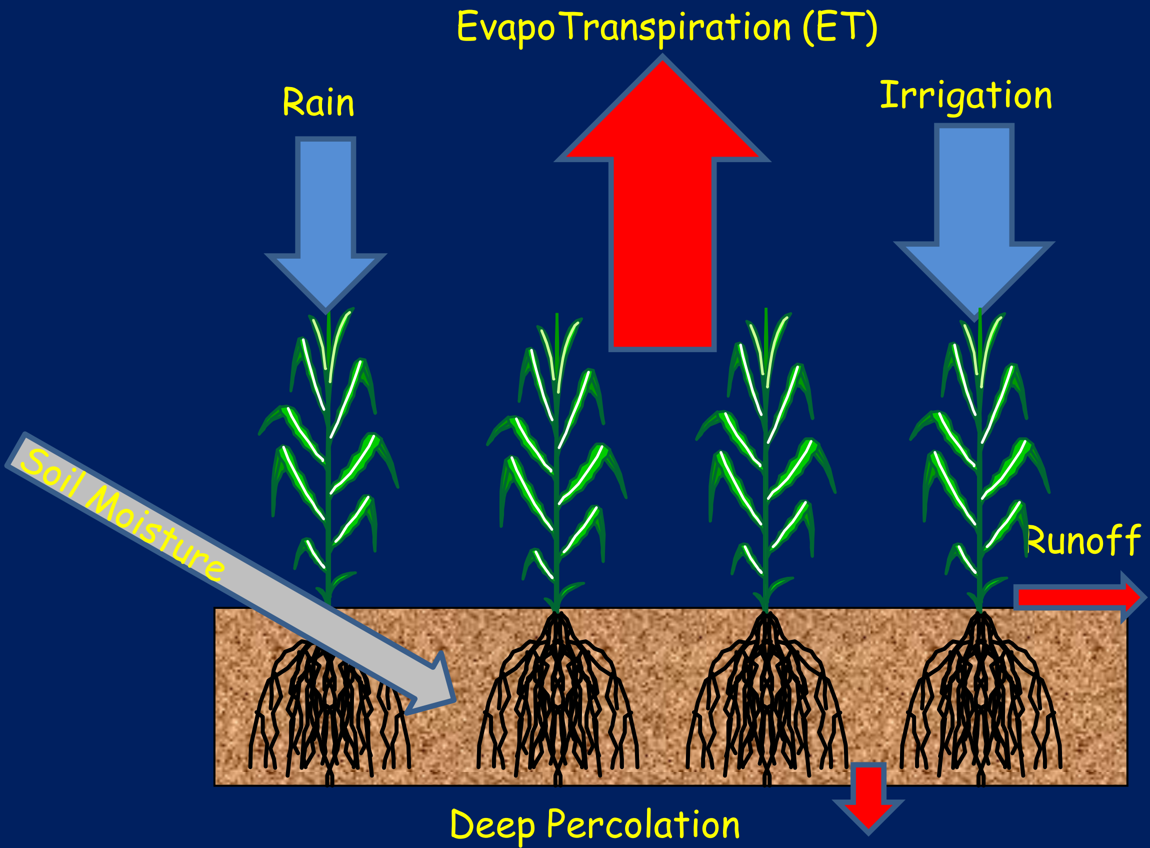


Crop Coefficient (K_c)???



Estimating *versus* Measuring Soil Moisture

At the end of the day, the outcome of all these is a change in soil moisture.



ET-based scheduling: Estimate all parameters and then solve for soil moisture

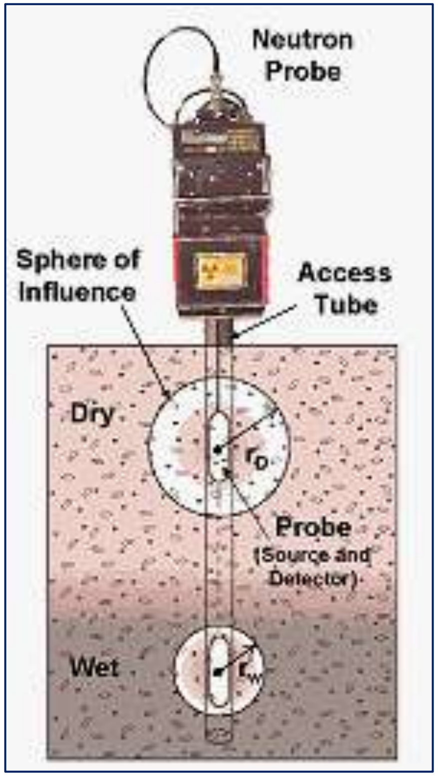
Soil Moisture-based: Forget about all and just measure soil moisture

Soil Moisture Measurements

- Feel and appearance
- Gravimetric
- Neutron scattering
- Tensiometers & Electrical resistance blocks
- New electronic sensors (TDR, TDT, FDR and Capacitance based probes based on soil dielectric properties)

Soil moisture measurement technologies

Soil Moisture Content or Soil Moisture Tension



Soil Moisture Measurement

- Most sensors are reasonably accurate for field use
- #1 problem with poor reading is installation
- Other important factors are:
  - Sensor type and selection
  - Monitoring site(s) selection and depths
  - Sensor and access tube installation
  - Soil profile placement (orientation)
  - Data recording and retrieval (manual, edge of field, online)
  - Calibration and maintenance
  - Cost
  - See CPS 434

NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

SOIL MOISTURE MEASUREMENT (NO.)

CODE 434

DEFINITION

The evaluation of *in situ* soil moisture status using sensors in the soil profile.

PURPOSE

This practice may be applied as part of a resource management system to provide necessary data for:

- Optimization of water use efficiency by minimizing the over and under application of irrigation water.
- Minimizing degradation of surface and ground waters by nutrients and pesticides that results from improper quantity or timing of irrigation applications or from applications of agricultural waste products.
- Reduction of non-renewable energy consumption caused by excessive frequency and quantity of pumping.

Refer to NEH, Part 652, Irrigation Guide, Chapter 9, Irrigation Water Management for soil moisture measurement methods.

This standard does not apply to soil moisture estimation by feel and appearance, soil penetration probing, or by gravimetric methods (weighing, drying and re-weighing of soil samples).

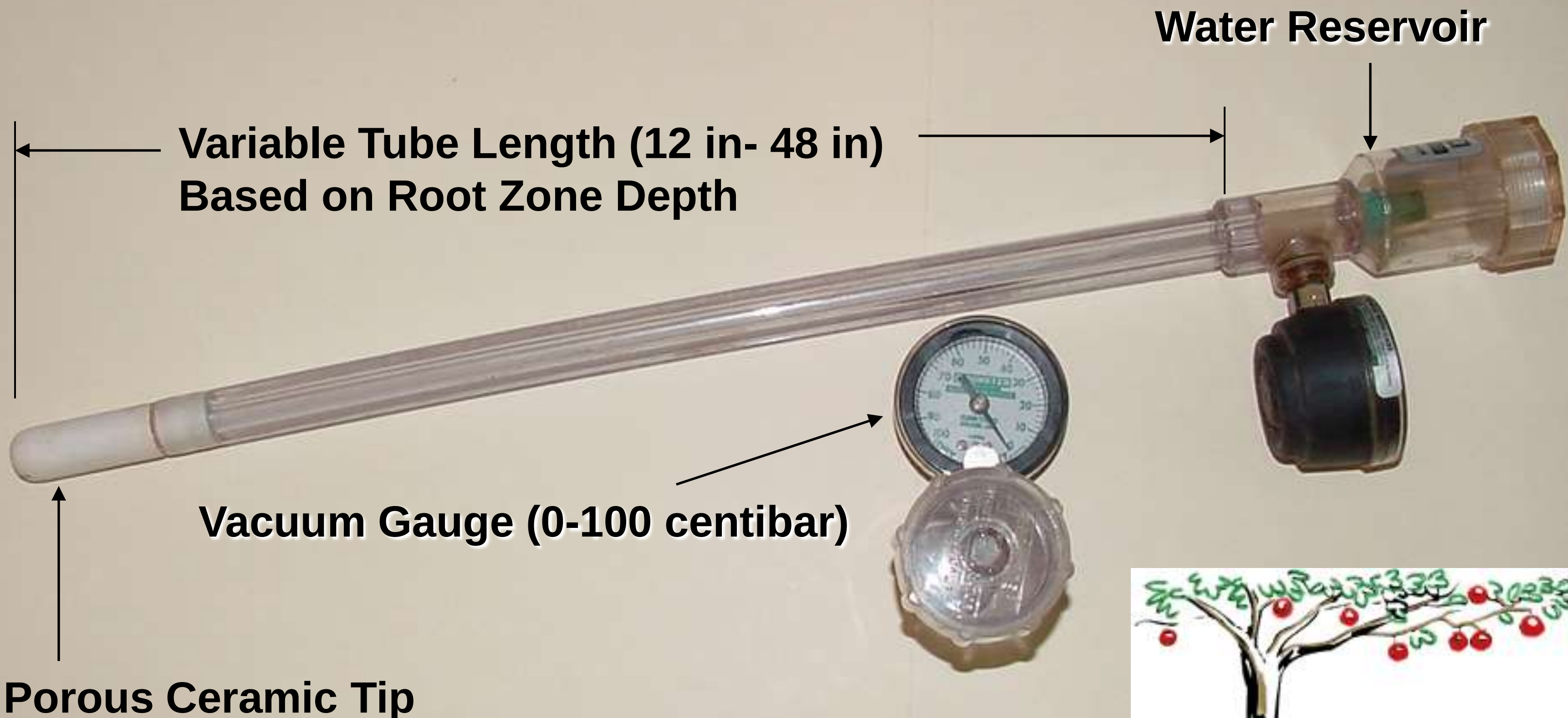
CRITERIA

General Criteria Applicable to all Purposes

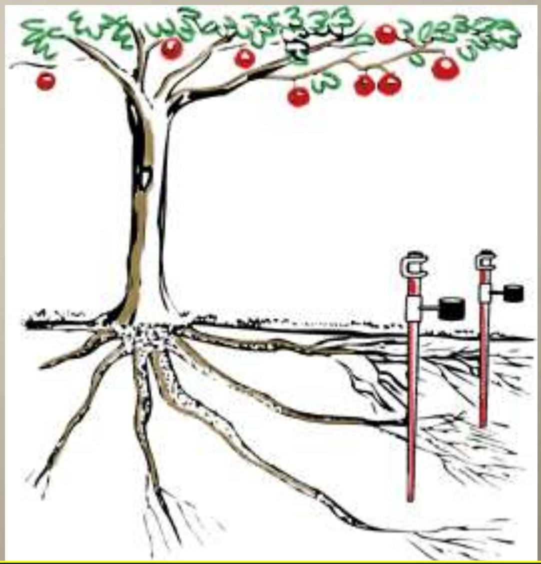
The soil moisture monitoring system shall be designed and implemented on an individual field basis to meet site conditions and functional requirements as part of an approved and overall engineering plan for irrigation or similar purposes that involve application of water to soil or for field hydrology and soil water budget analysis.

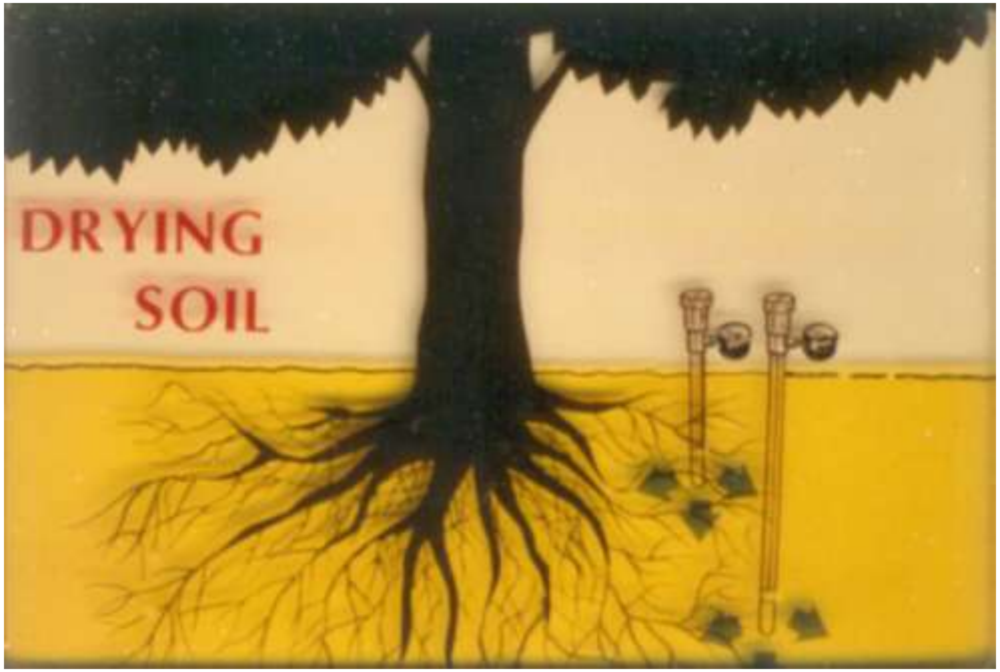
In irrigated land, implement a plan meeting the

Tensiometer



- Measure soil moisture potential (tension)
- Practical operating range is about 0 to 0.75 bar of tension (this can be a limitation on medium- and fine-textured soils)




DRYING
SOIL


60 50 40
70 30
80 20
90 10
100 0
DRY
12"
30 cm


IRRIGATION


60 50 40
70 IRROMETER 30
MOISTURE INDICATOR
80 20
IRROMETER CO.
RIVERSIDE, CALIF.
90 10
100 0
DRY
24"
60 cm

Electrical resistance blocks

- **Measure soil moisture potential (tension)**
- **Tend to work better at higher tensions (lower moisture contents)**

WATERMARK Sensors

- Low cost granular matrix
- Works in most soils
- Indirect method
- Salinity buffering
- No freezing
- Manual or Automatic
- No maintenance
- Stable proven calibration.

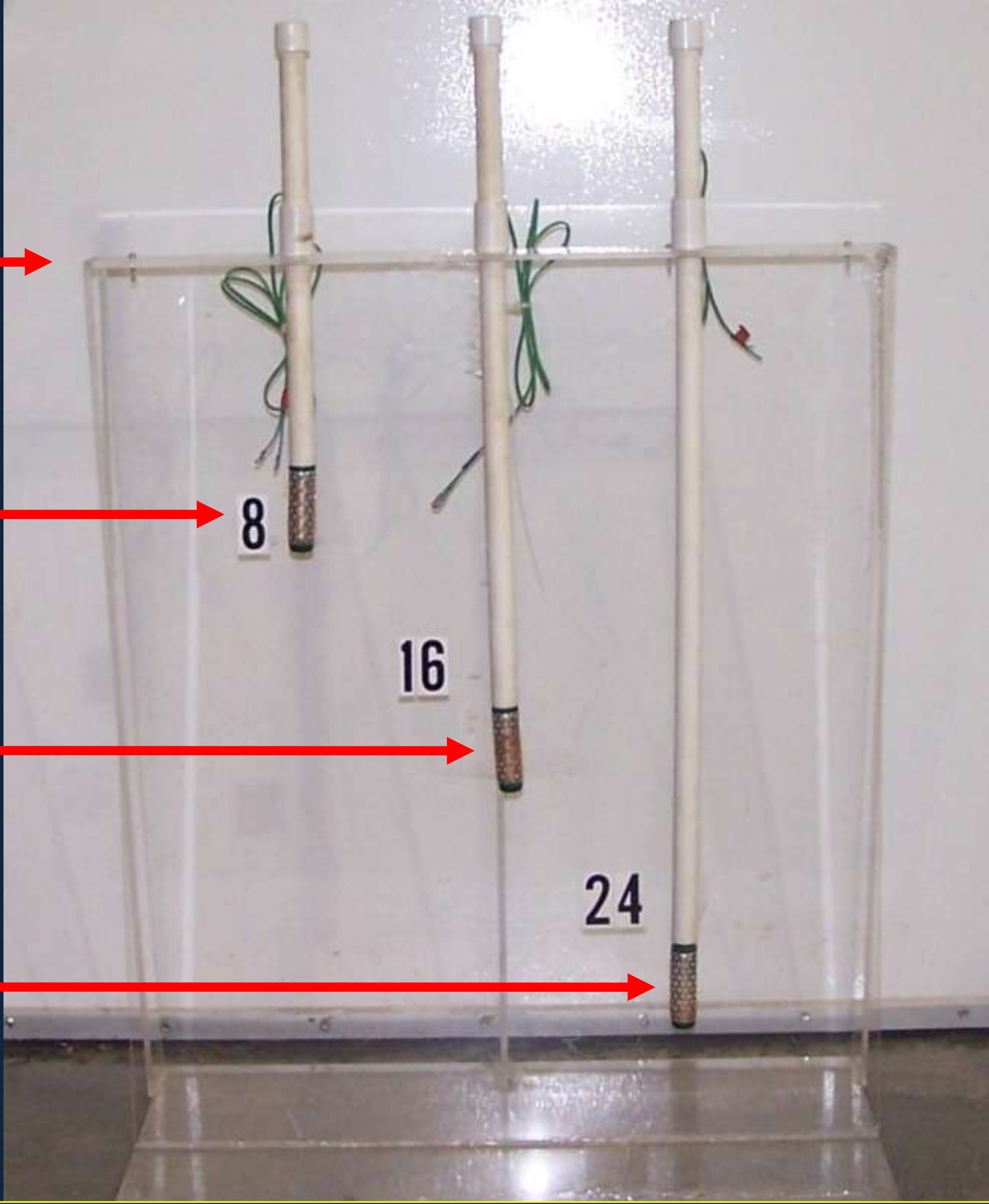
Sensor Profile Placement

Soil Surface

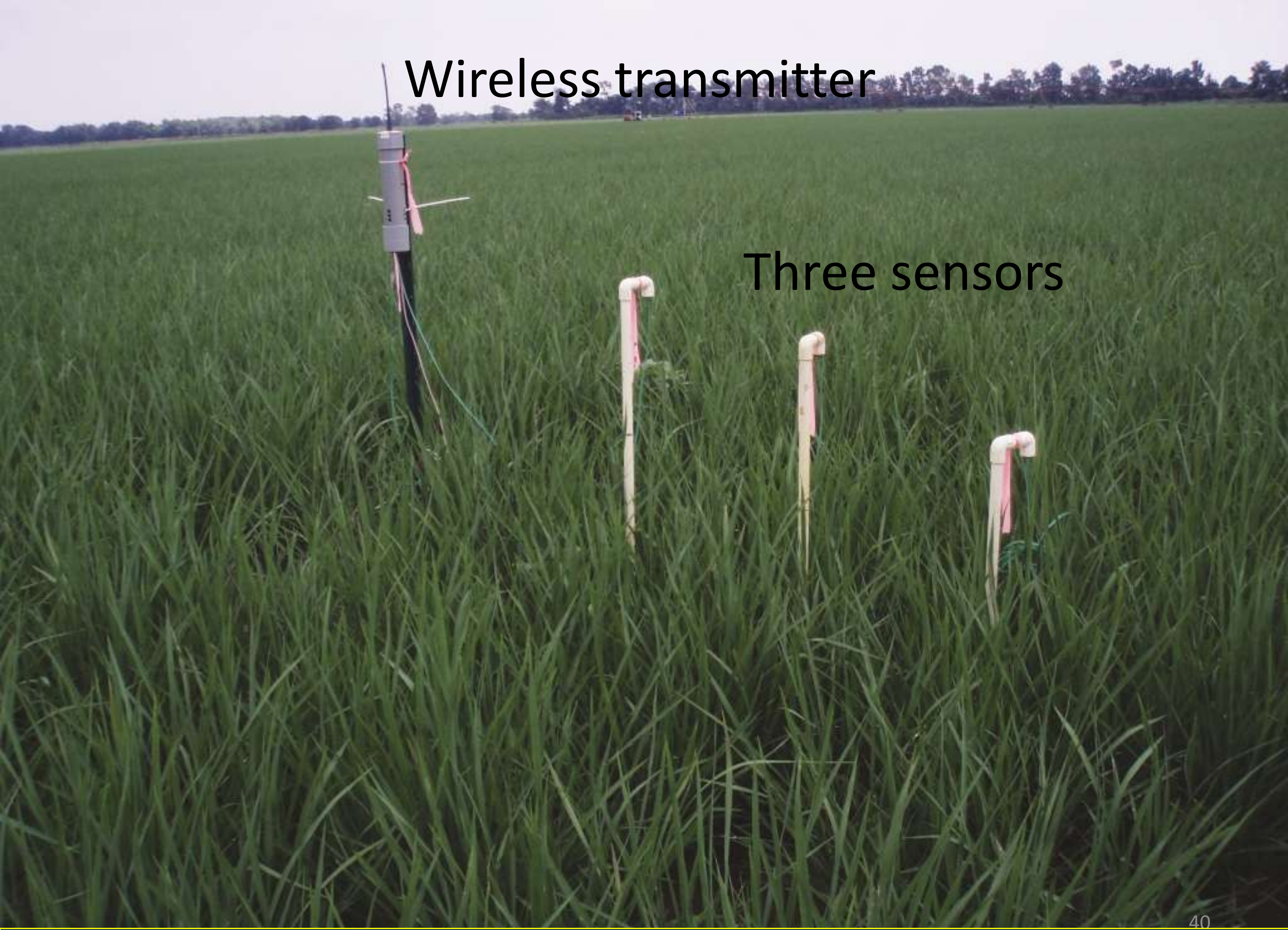
8 in

16 in

24 in



Take readings and make data entry


Wireless transmitter
Three sensors

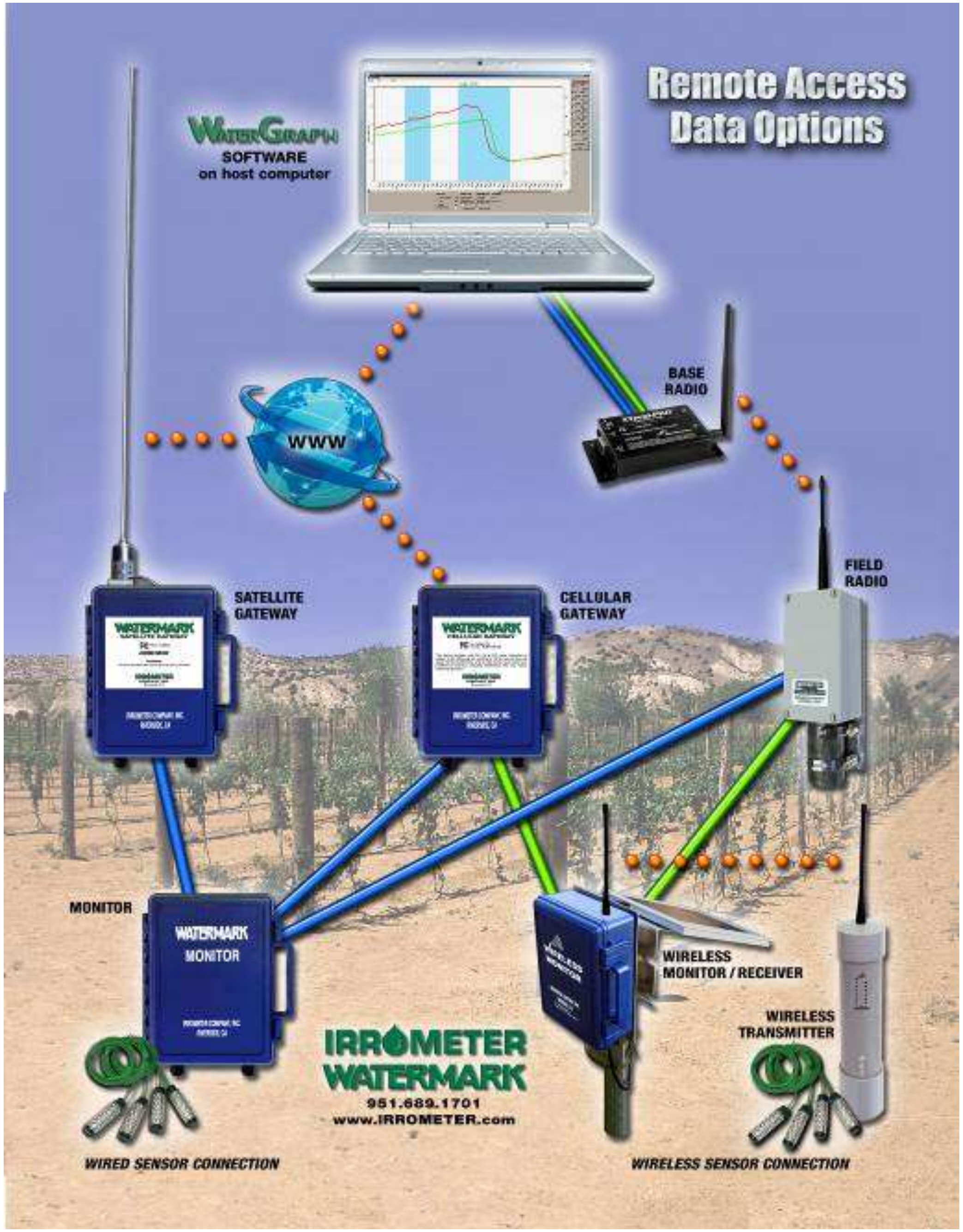
Towards Remote Access & Web-based Presentation

Soil Moisture Sensor

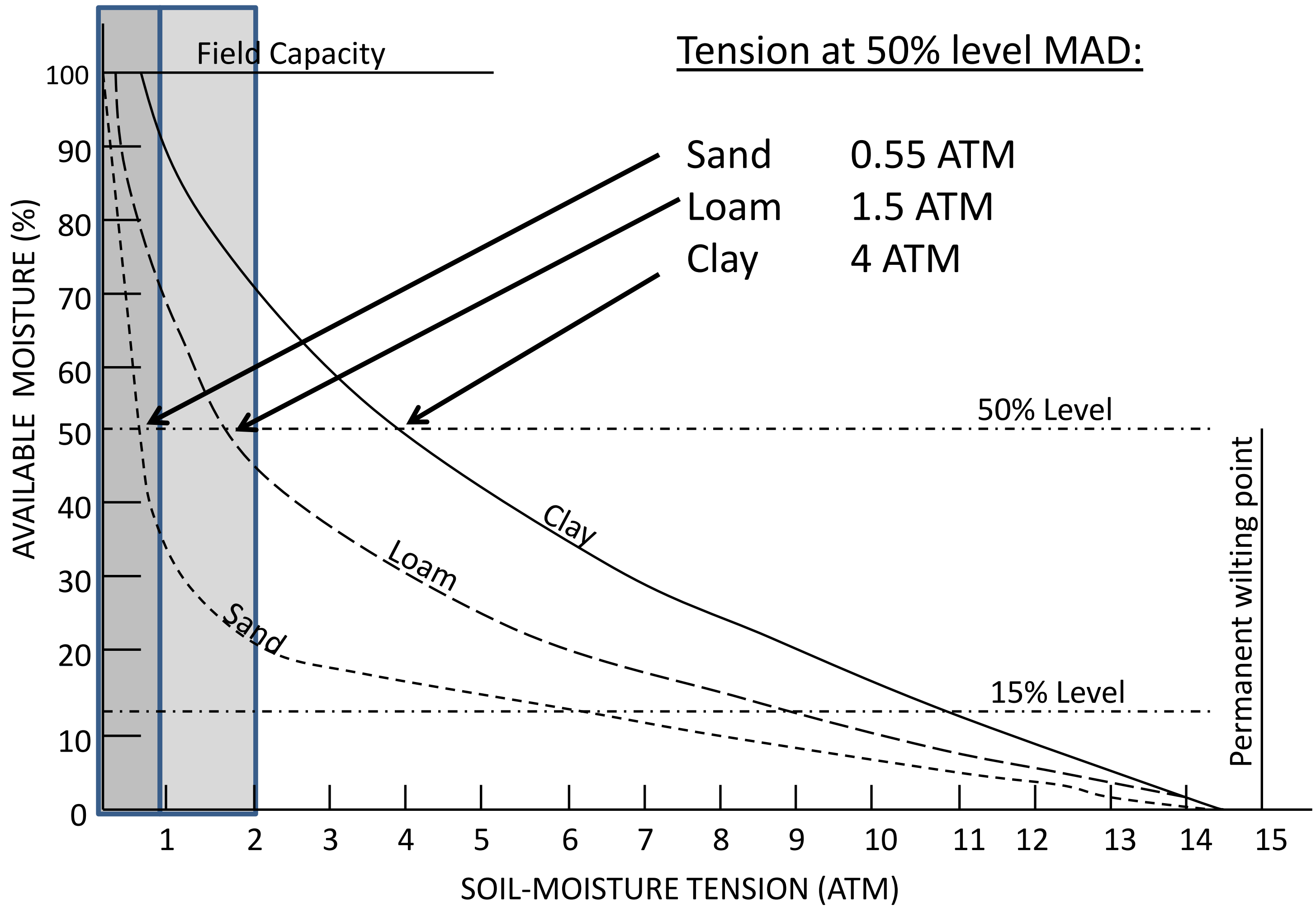
Manual Data Collection using a Handheld Meter

Manual Data Download using a Laptop

Wireless Sensors Module


Remote Access
Data Options
WaterGraph
SOFTWARE
on host computer
WWW
BASE
RADIO
FIELD
RADIO
SATELLITE
GATEWAY
CELLULAR
GATEWAY
MONITOR
WATERMARK
MONITOR
WIRELESS
MONITOR / RECEIVER
WIRELESS
TRANSMITTER
IRROMETER
WATERMARK
951.689.1701
www.IRROMETER.com
WIRED SENSOR CONNECTION
WIRELESS SENSOR CONNECTION

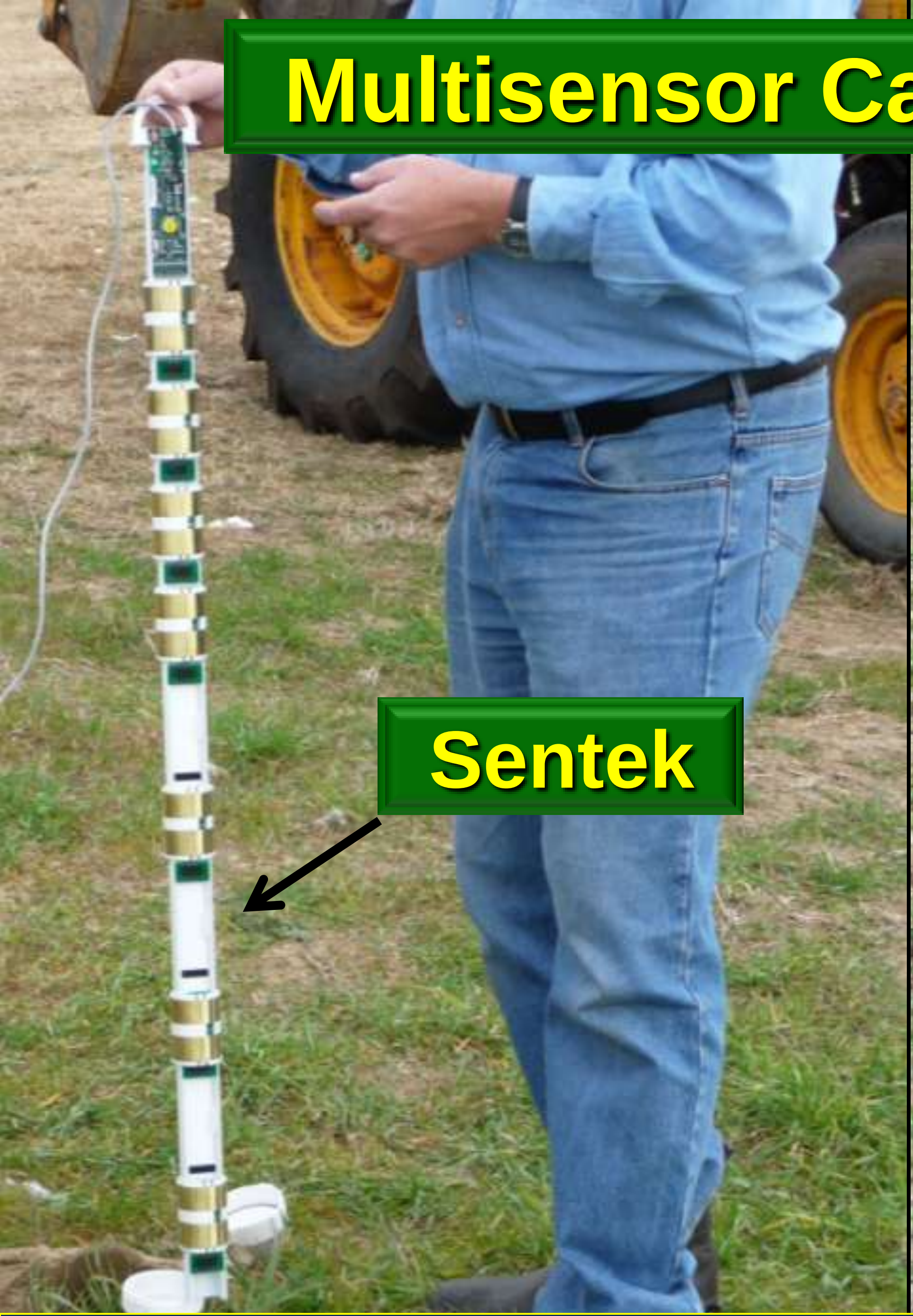
Soil Moisture *versus* Tension Relationship



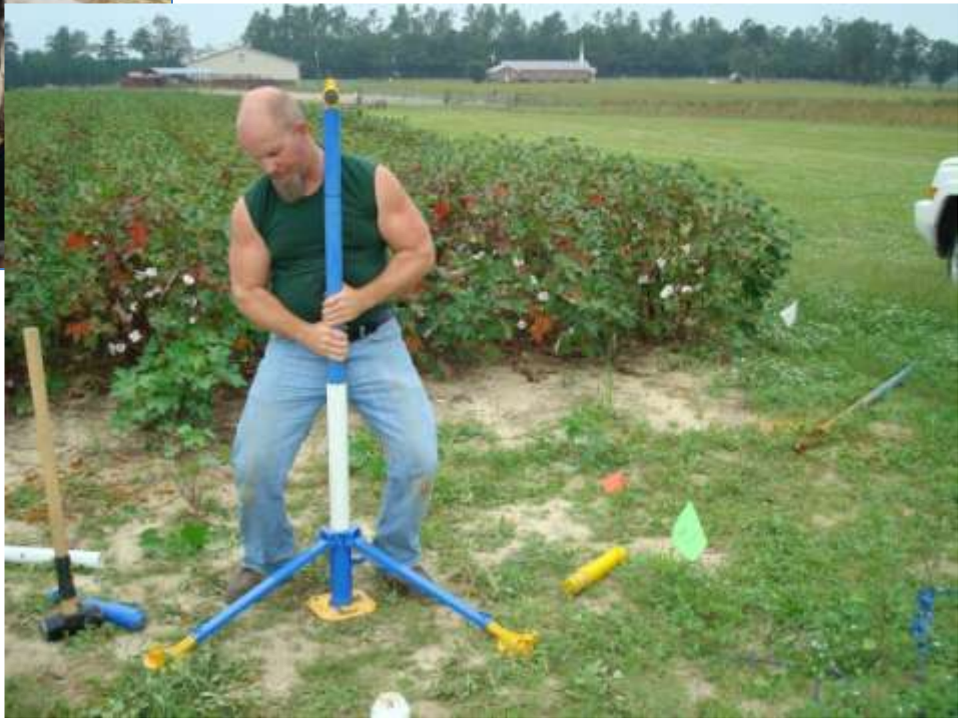
Newer Electronic Sensors
Dielectric constant

- A soil's dielectric constant is dependent on soil moisture
- Time domain reflectometry (TDR)
- Frequency domain reflectometry (FDR)
- No longer a research tool
- Many data retrieval options

Multisensor Capacitance Probes



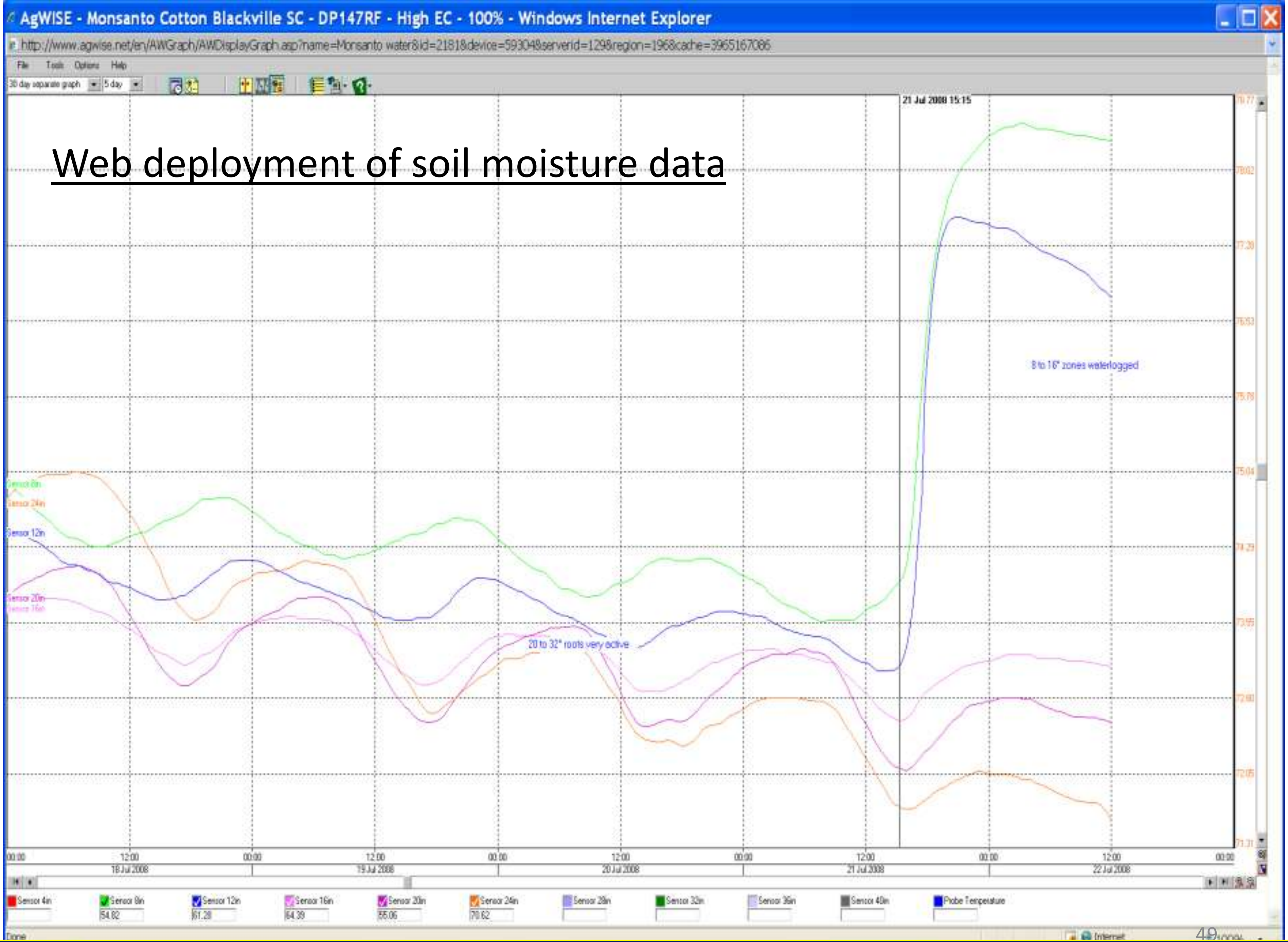
Installation – With and without access tube



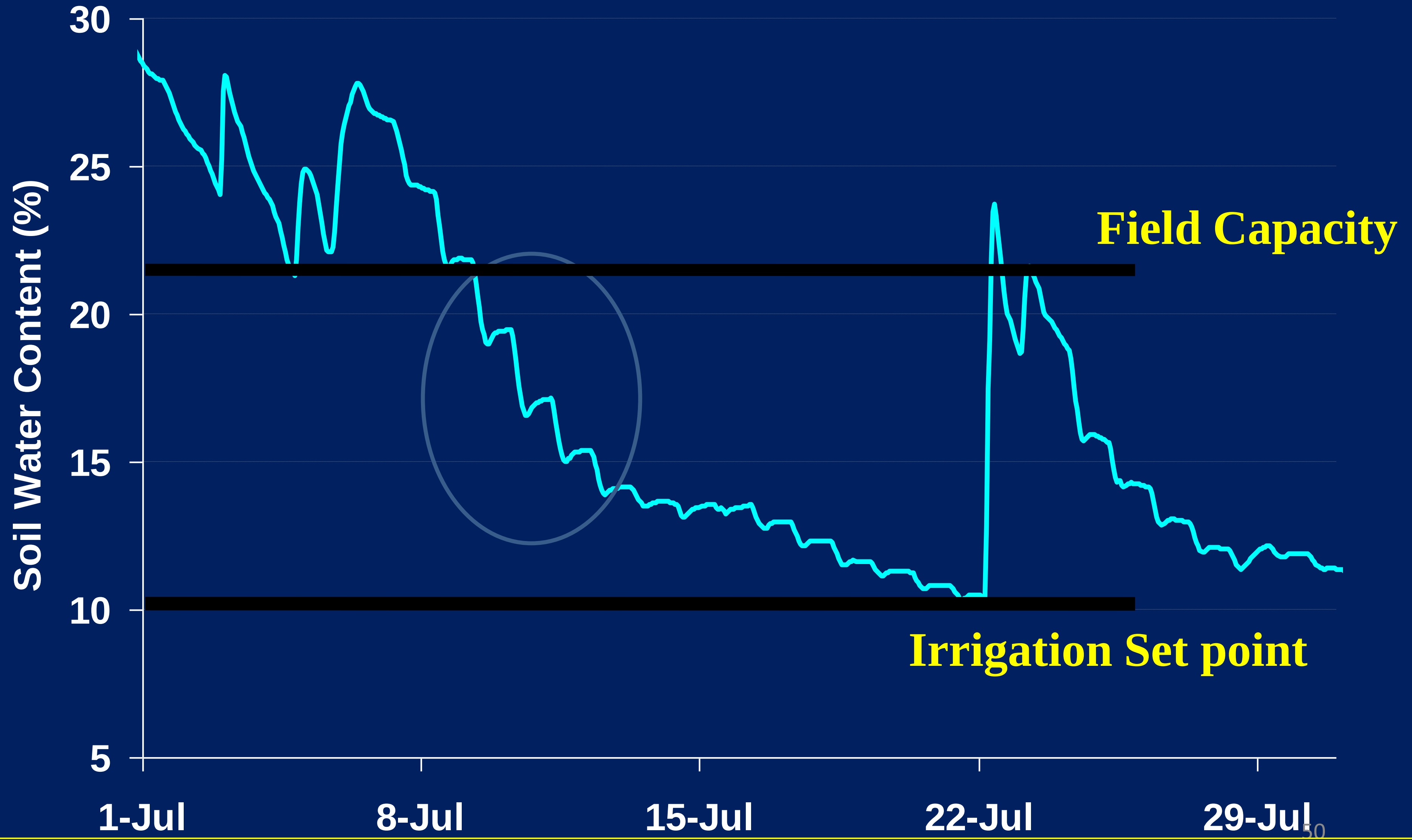
EasyAg Probe (Syntek) – readings at 10, 20, 30, 40, 50 cm depths

Trend: Continuous Monitoring and Web Deployment of Soil Moisture via Cellular or satellite means

Web deployment of soil moisture data



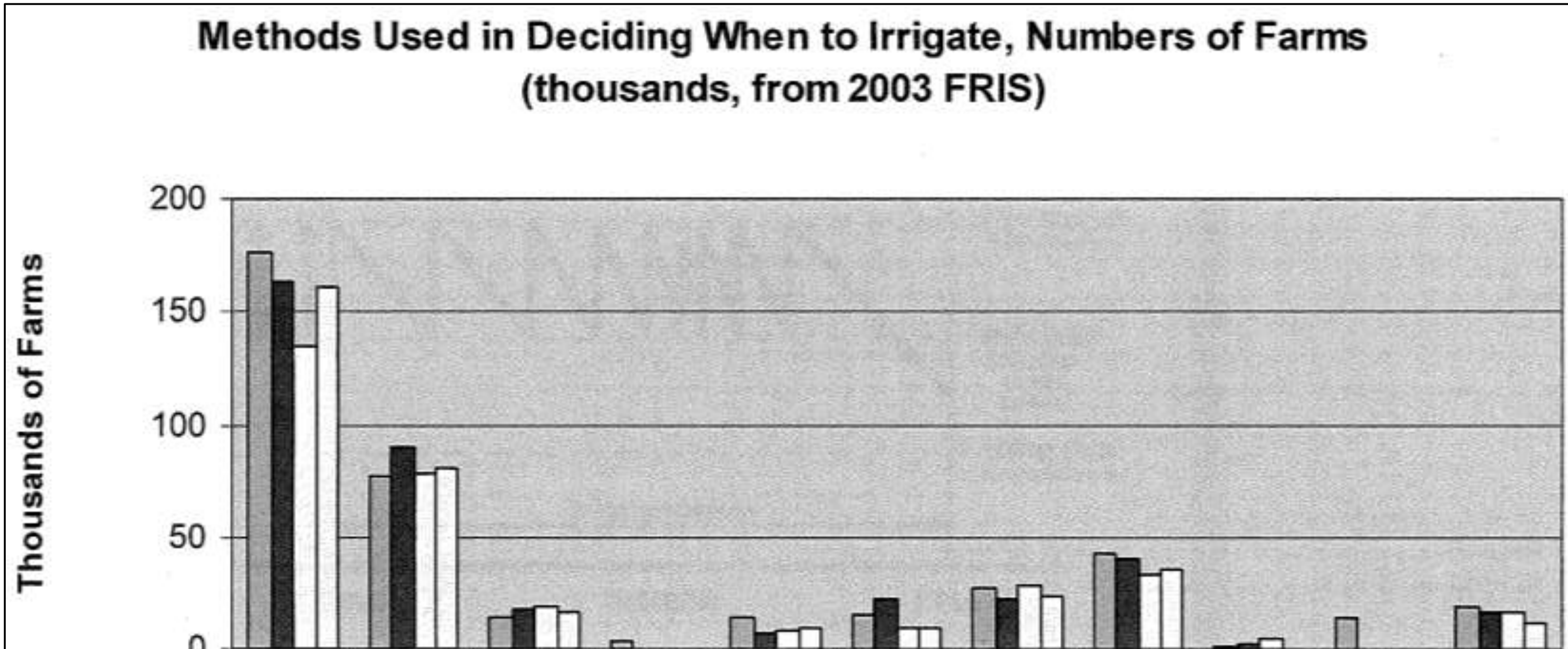
Continuous Soil moisture Content Measurement
(wireless capable & internet deployable)



Sensor-based Agriculture

Future Sensors: Miniature Wireless Capable & Internet Deployable (nanotechnology)

Reality Check! State of Irrigation Scheduling



	Condition of Crop	Feel of Soil	Soil Moisture Sensing	Plant Moisture Sensing	Scheduling Service	ET Data	Scheduled by District	Personal Calendar	Computer simulation models	When neighbors irrigate	Other
2003 Census	176	77	14	3	14	15	27	43	1	14	19
1998 Census	163	90	18		7	22	23	40	2		16
1994 Census	135	78	19		8	9	28	33	5		17
1988 Census	161	81	17		10	10	24	35			12

Survey by Dr. Joe Molnar (Alabama):

81% irrigated their fields based on observation of crop condition.

Only 9% used soil moisture sensing devices.

Take Home Messages

Rely on DIRECT measurement of soil moisture to schedule irrigation than trying to estimate soil moisture as the residual of soil moisture budget.

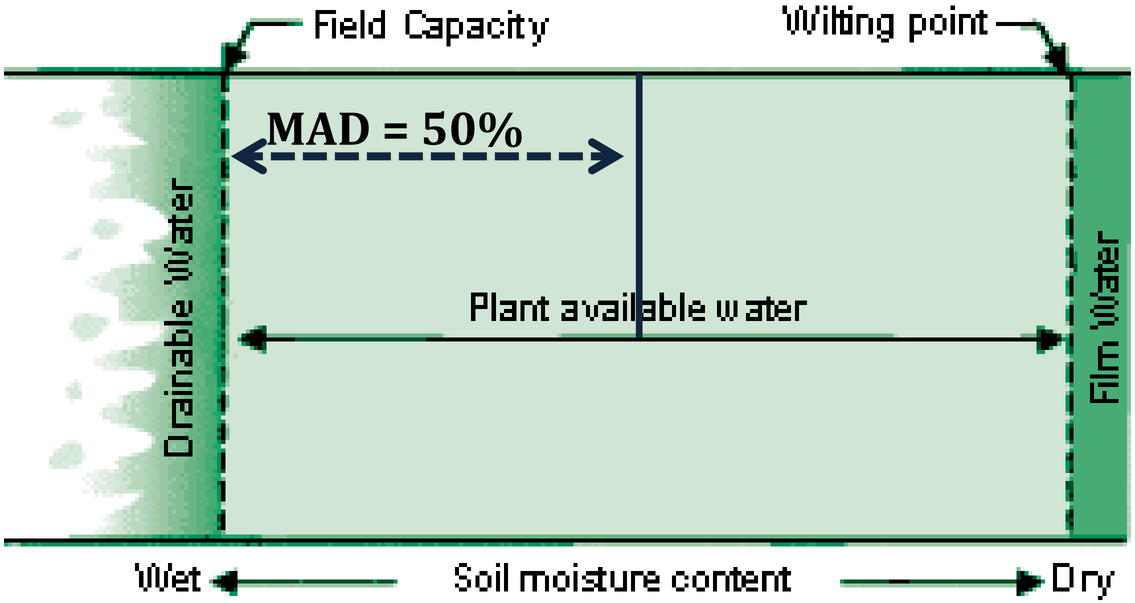
In humid regions and because of significant rainfall, and in high frequency irrigations (like drip), scheduling based on measured soil moisture is a preferred approach.

Embrace the technology, try a sensor.

Stop chasing sensors in the field. GO wireless with online deployment.

Practice tactical (real-time) scheduling for greater management control and flexibility.

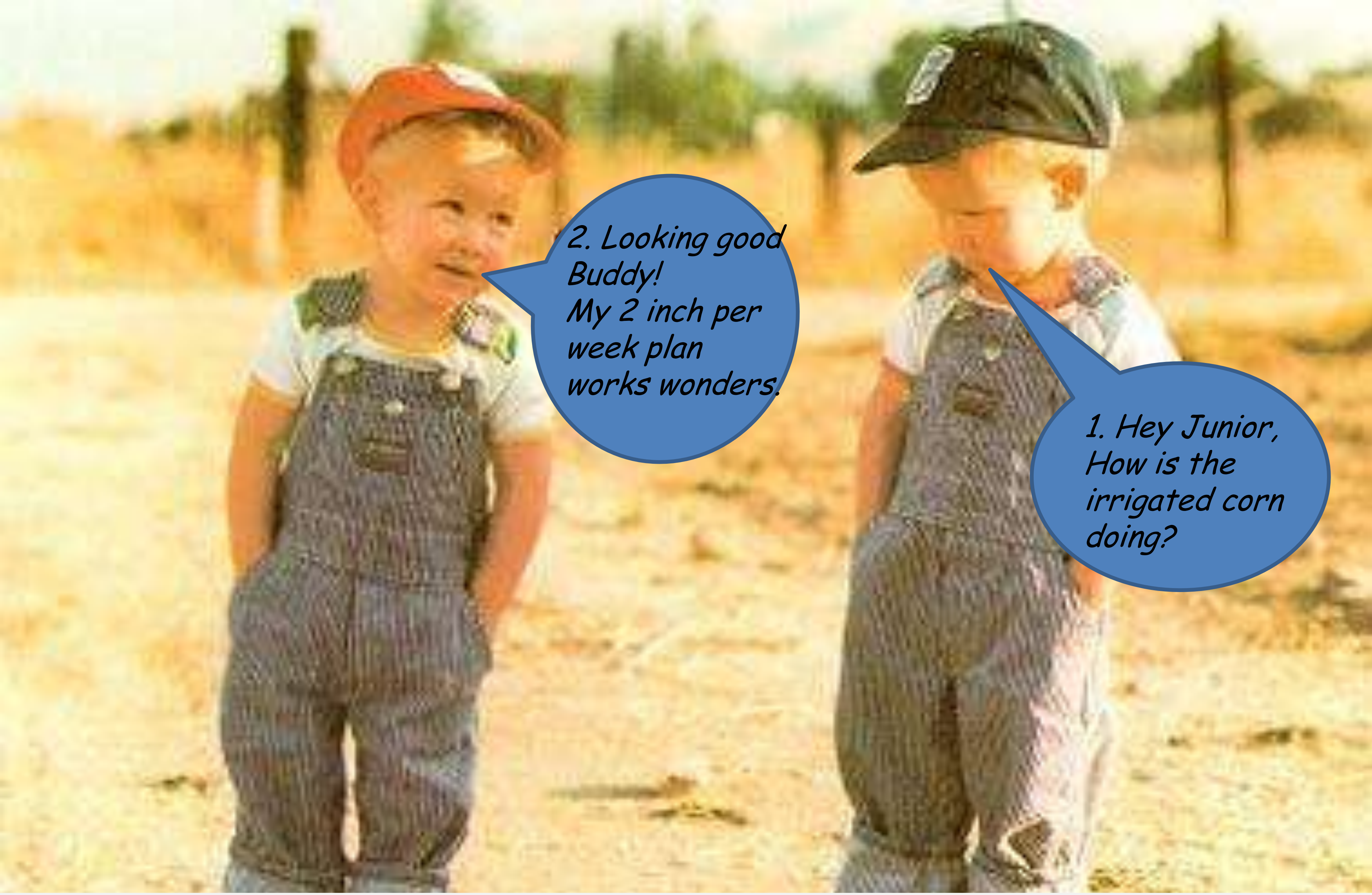
Summary Soil-based Scheduling using MAD



<u>Turn system ON</u> each time soil moisture reaches the MAD level.

<u>Turn system OFF</u> when soil profile is back to Field Capacity.

Many years later…



Scheduling irrigation on frequent intervals and in routine amounts wastes water, energy, and inputs, and costs money.

Precision Irrigation?

Questions? Now or call/email later;

Hamid.farahani@gnb.usda.gov

336-370-3350