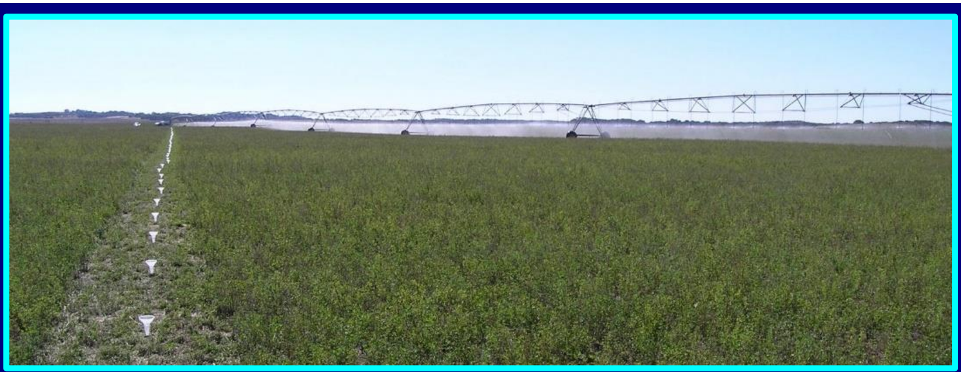

Efficient Irrigation Scheduling for Forage Crops

Workshop on Efficient Water Management for Forage Crops

Tulelake, CA – March 14th, 2024

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OBJECTIVES

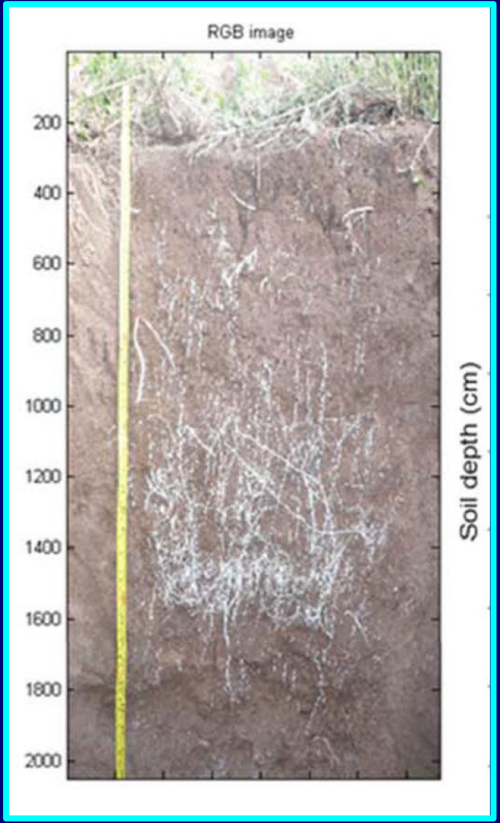
1) Review the main challenges of irrigating Alfalfa

2) Irrigation Scheduling Principles

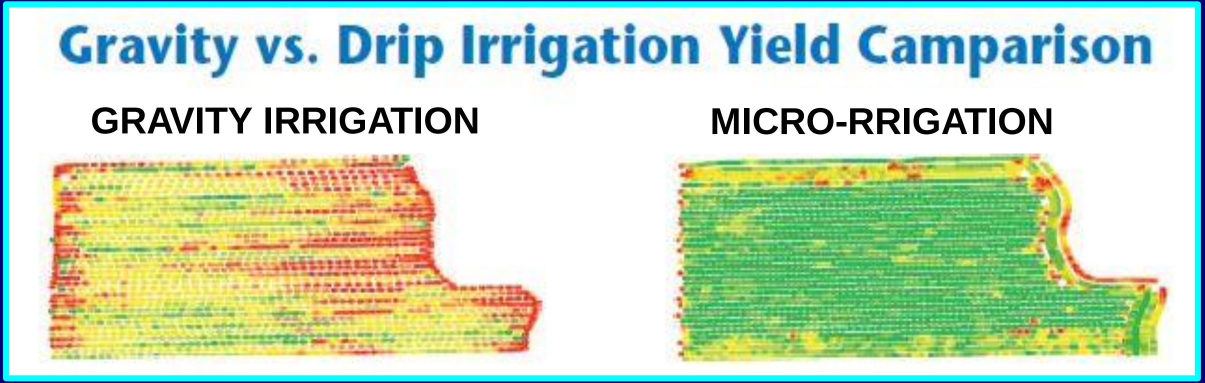
3) Moving from Principles to Field Practice

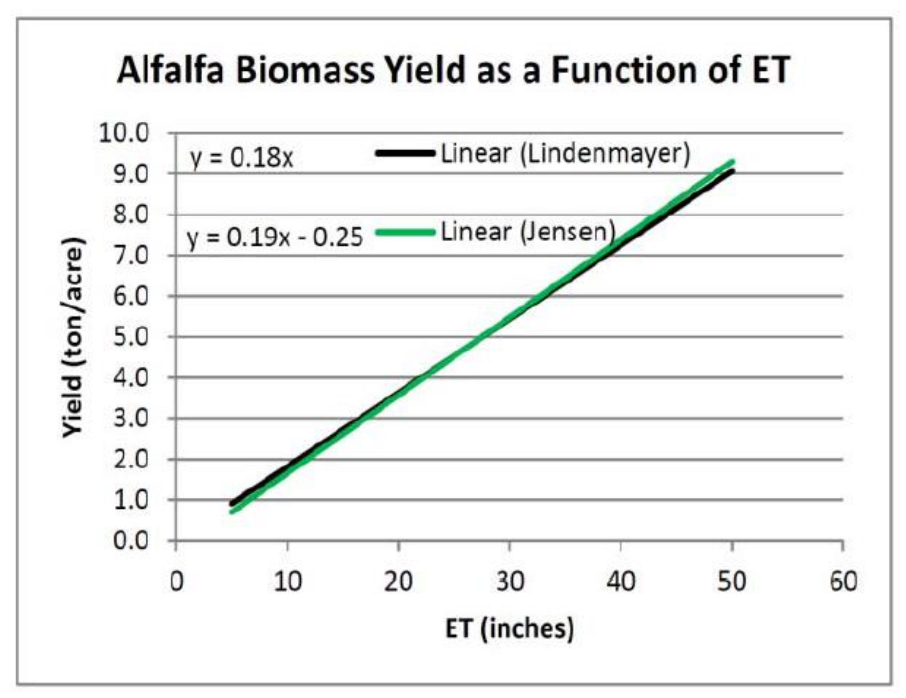
4) Tools that Help in the Field

SOME BASIC FACTS



Alfalfa is a deep-rooted broadcast perennial crop that typically requires most or all of the soil profile to be uniformly wetted.





Good Irrigation Management is Critical to Alfalfa Yield

Seasonal Alfalfa Yield is directly related to Seasonal ET (~1:1)

Max Yield occurs at Max ET (which depends on the climatic conditions)

IRRIGATION MANAGEMENT IN ALFALFA IS CHALLENGING!

- ✓ET-based scheduling is complicated by the periodic cutting & re-growth cycles
- ✓Irrigations must be cut back a few days prior to cutting, and during hay curing onto the ground
- ✓**At least 6- to 20-day periods during which fields cannot be irrigated**
- ✓**Irrigation decisions are driven and constrained by the harvest schedule**

Inadequate irrigation is the main factor limiting Alfalfa yield

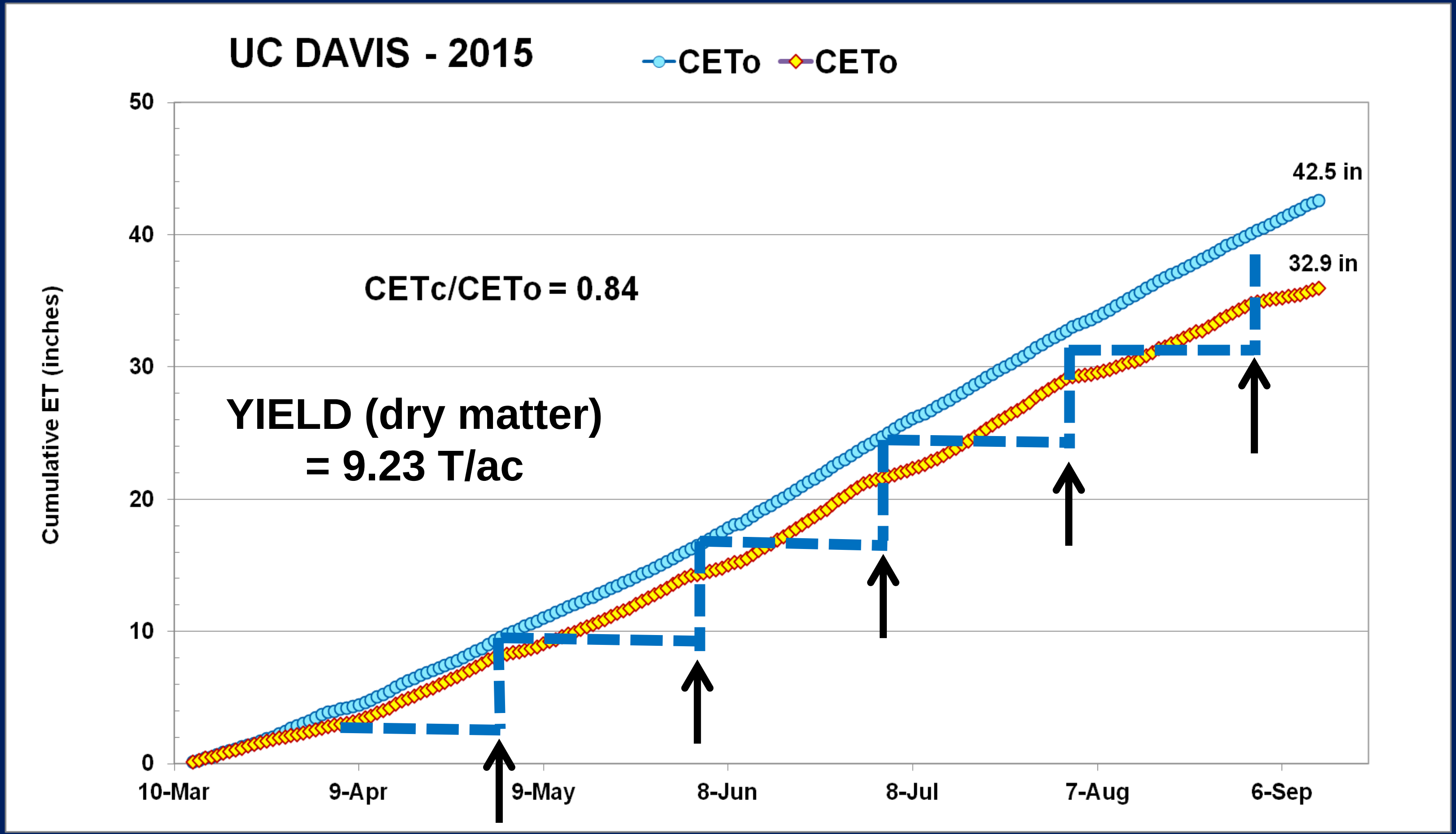
Alfalfa often incur water stress around cuttings and when the new growth starts

MOST SENSITIVE STAGE !!

Irrigation management is always tricky and a bit complicated

Farm organizational constraints usually make possible only 1 to 2 irrigations during the 28-30-day crop cycles

- ✓ With 1 irrigation/cycle growers might end up under-irrigating
- ✓ With 2 irrigations/cycle growers might instead apply too much water



General Irrigation Scheduling Principles

When should we irrigate? ⟷ **How much water to apply?**

Before yield is impacted by insufficient soil moisture

How much soil moisture can be depleted before yield is impacted?

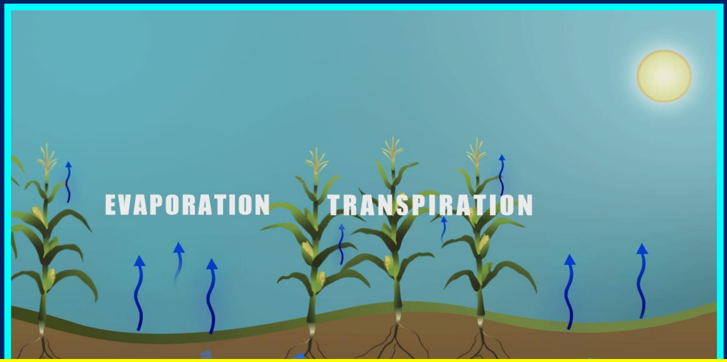
~ < 50 % of Available S.M

WE NEED TO MONITOR SOIL MOISTURE ACCURATELY

Refill the amount of water (inches) depleted between two irrigations

It requires estimation of Crop Water Use (ETc) between irrigations

Historical ETc; or ETc = ETo x Kc



WE NEED TO KEEP TRACK OF CROP ET ACCURATELY

Principles: Calculate Irrigation Timing and Amount

1) Determine the Allowable Soil Moisture that can be depleted before yield is impacted (table of available soil moisture x root depth of alfalfa x ~ 50%)

2) Calculate the daily crop ET between irrigations, either from historic average alfalfa ET values, or from ETc = ETo x Kc

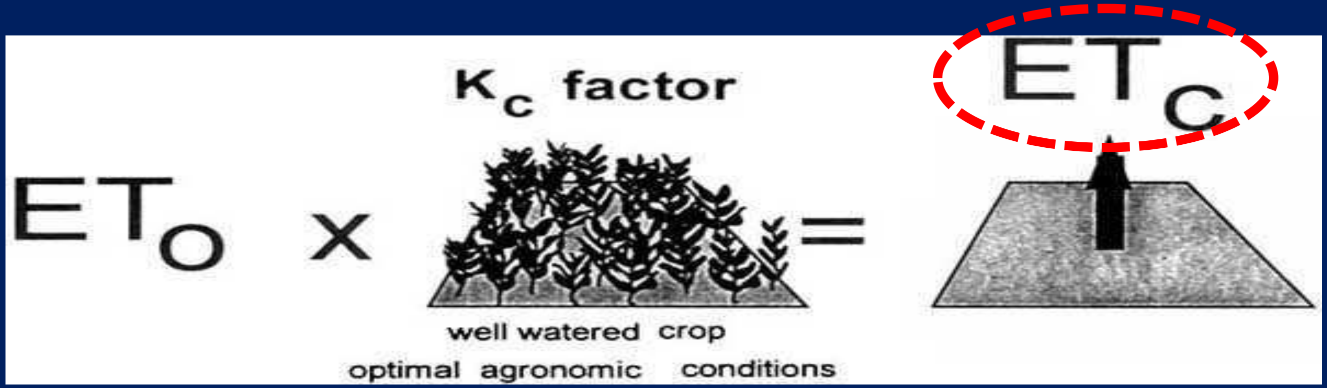
3) Determine the irrigation interval by dividing the Allowable Soil Moisture Depletion by the daily crop ET

Recommended values of **Soil Moisture Content** at which irrigation should occur (50% of TAW depleted)

SOIL TYPE	AVAILABLE WATER (IN./FT)	ALLOWABLE DEPLETION (IN./FT)	AVAILABLE WATER IN 4FT ROOT ZONE (IN.)	ALLOWABLE DEPLETION IN 4FT ROOT ZONE (IN.)
COARSE SAND	0.5	0.25	2.0	1.0
LOAMY SAND	1.0	0.50	4.0	2.0
SAND LOAM	1.5	0.75	6.0	3.0
FINE SANDY LOAM	2.0	1.00	8.0	4.0
CLAY LOAM	2.2	1.10	8.8	4.4
CLAY	2.3	1.15	9.2	4.6
ORGANIC CLAY LOAMS	4.0	2.00	16.0	8.0

Recommended values of **Soil Moisture Tension** at which irrigation should occur (50% of TAW)

Soil Type	Soil Moisture Tension (centibars)
Sand or loamy sand	40-50
Sandy loam	50-70
Loam	60-90
Clay loam or clay	90-120



Amount of water lost by alfalfa for ET

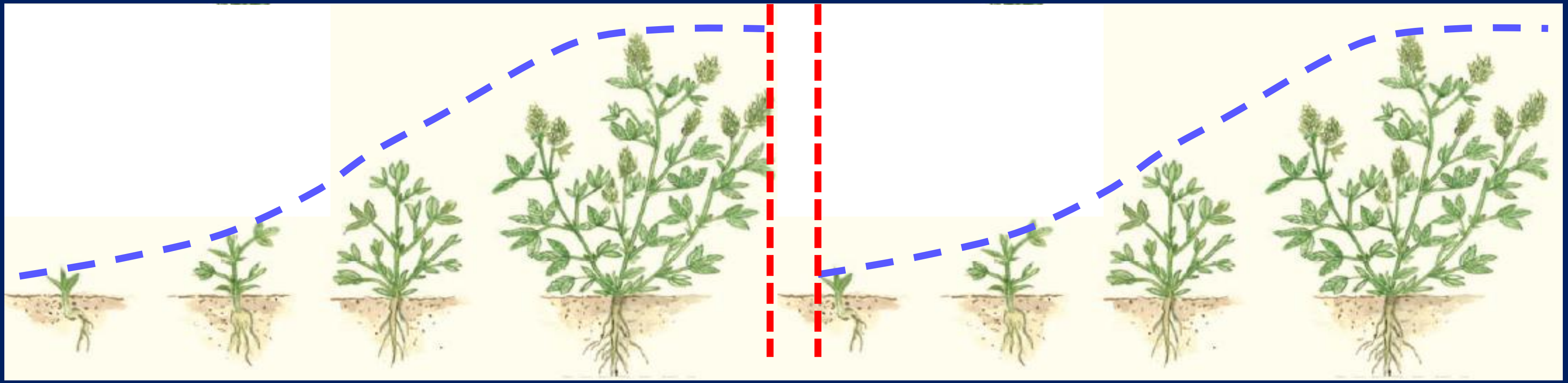
Seasonal Crop Coefficient:

K_c = 0.86 – 0.90 (averaged over the entire crop season)

Within-cycle Crop Coefficient:

$K_c \approx$ 0.35 - 0.40 after cutting until irrigation starts

$K_c \approx$ 1.00 - 1.05 from 2-3 days after irrigation till the next cutting



SCHEDULING EXAMPLE FOR PEAK MONTH (JULY)

Location: Mc Arthur, CA
Soil: Clay Loam
Root depth: 5 ft
Period: July (1-31)

Available soil moisture: 1.7 in./ft. x 5 ft. = 8.5 in.

Total Allowable Depletion = 50% of 8.5 in. = 4.3 in.

Crop ET (Mc Arthur): 0.25 in./day (July)

Irrigation timing: at soil moisture depletion < or @ 4.3 in.

Irrigation interval: 4.3 in./0.25 in./day = 17 days

Soil Texture	Water Holding Capacity (in/ft)	Total available soil moisture storage for 5-ft depth (in)	50% of Available Soil Moisture (in)
Sand	0.7	3.5	1.8
Loamy sand	1.1	5.5	2.8
Sandy loam	1.4	7.0	3.5
Loam	1.8	9.0	4.5
Silt loam	1.8	9.0	4.5
Sandy clay loam	1.3	6.5	3.3
Sandy clay	1.6	8.0	4.0
Clay loam	1.7	8.5	4.3
Silty clay loam	1.9	9.5	4.8
Silty clay	2.5	12.5	6.3
Clay	2.2	11.0	5.5

FROM PRINCIPLES TO FIELD PRACTICE

Once we have done our scheduling calculations, we need to adjust those numbers to the field-specific conditions

FIELD CONSIDERATIONS

1. **Constraints of the irrigation systems and available labor on the farm**

2. **Soil Infiltration: is it sufficient to refill water used by Crop ET?**

   Often, soils limit the possibility to recharge the root zone (surface sealing, or cracking soils)

3. **Is the irrigation frequency compatible with the harvest schedule?**

   Often irrigation scheduling is constrained by the harvest schedule

   - ✓ Harvests occur every 28-30 days
   - ✓ The 1st irrigation takes place after the bales are removed from the field
   - ✓ The last irrigation prior to cutting must allow sufficient time for soil drying before the harvesting equipment can enter the field.

FIELD CONSIDERATIONS Cont'd

In the field practice, a normal cutting cycle of 28-30 days leaves a window available for irrigation only of about 16 days.

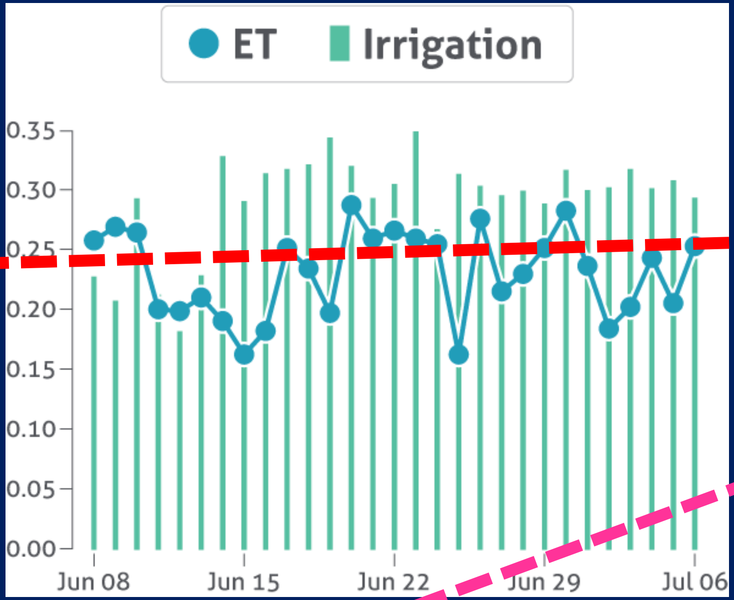
With conventional flood and sprinkler systems, within 16 days available growers can only irrigate once or twice.

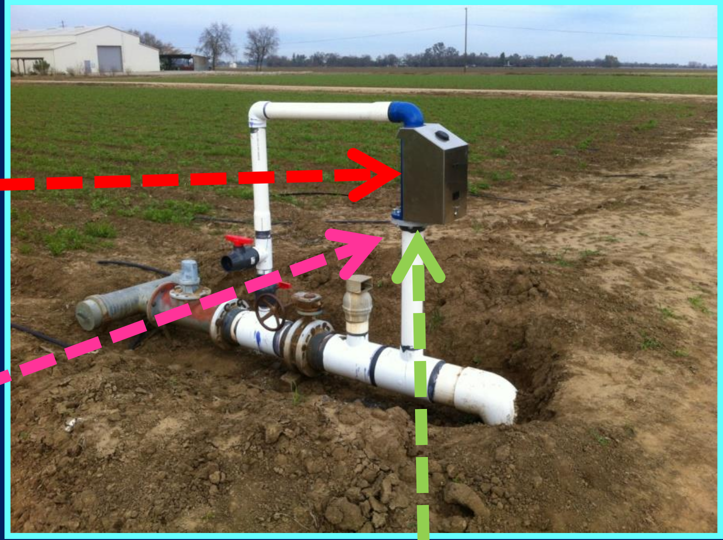
- ✓ 1 irrigation may result in excessive moisture depletion, and therefore yield may be impacted
- ✓ With 2 irrigations, water must be applied before the allowable depletion occurs and in small amounts.

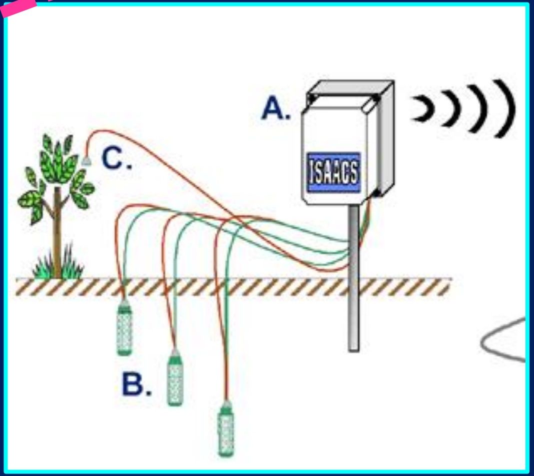
Growers often cannot irrigate based on ET or the allowable soil moisture depletion.

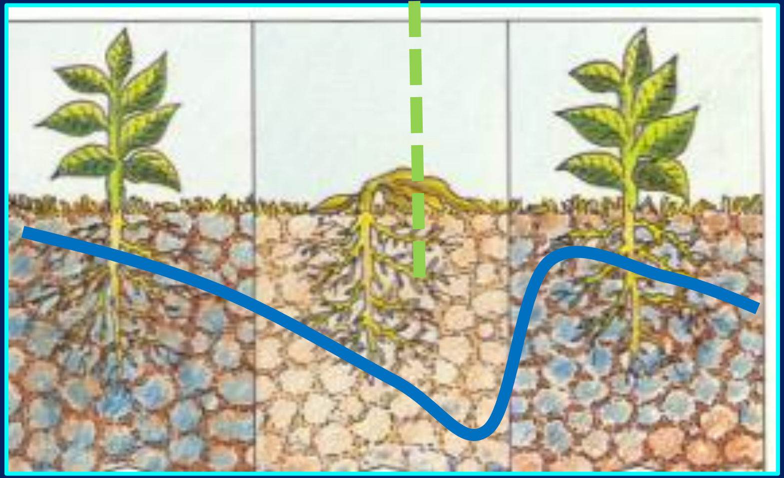
They must use judgement and optimal irrigation timing and amount must be determined from field experience.

THINGS THAT HELP IN THE FIELD WITH IRRIGATION SCHEDULING

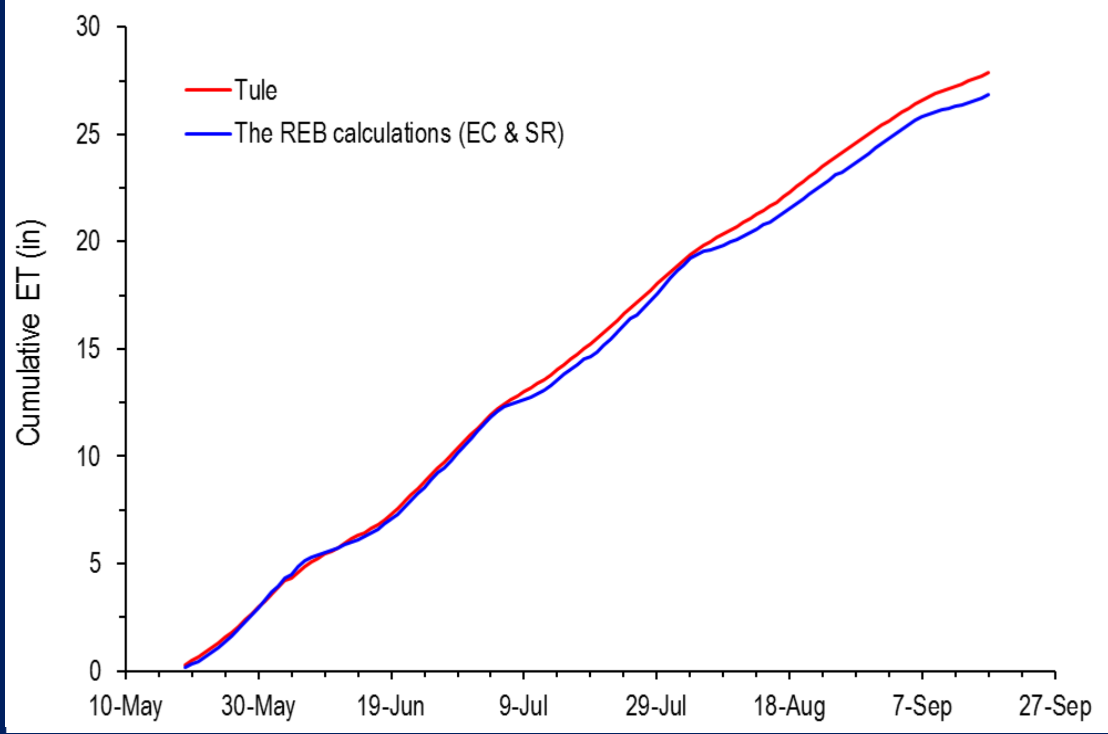









tule


Tule
The REB calculations (EC & SR)
Cumulative ET (in)
0
5
10
15
20
25
30
10-May
30-May
19-Jun
9-Jul
29-Jul
18-Aug
7-Sep
27-Sep

SUMMARY

ET-based irrigation scheduling in alfalfa is complicate due to cuttings and re-growth periods.

✓ Requires to keep track of crop ET and do some basic calculations

✓ Knowing soil texture, soil infiltration, and soil water holding capacity

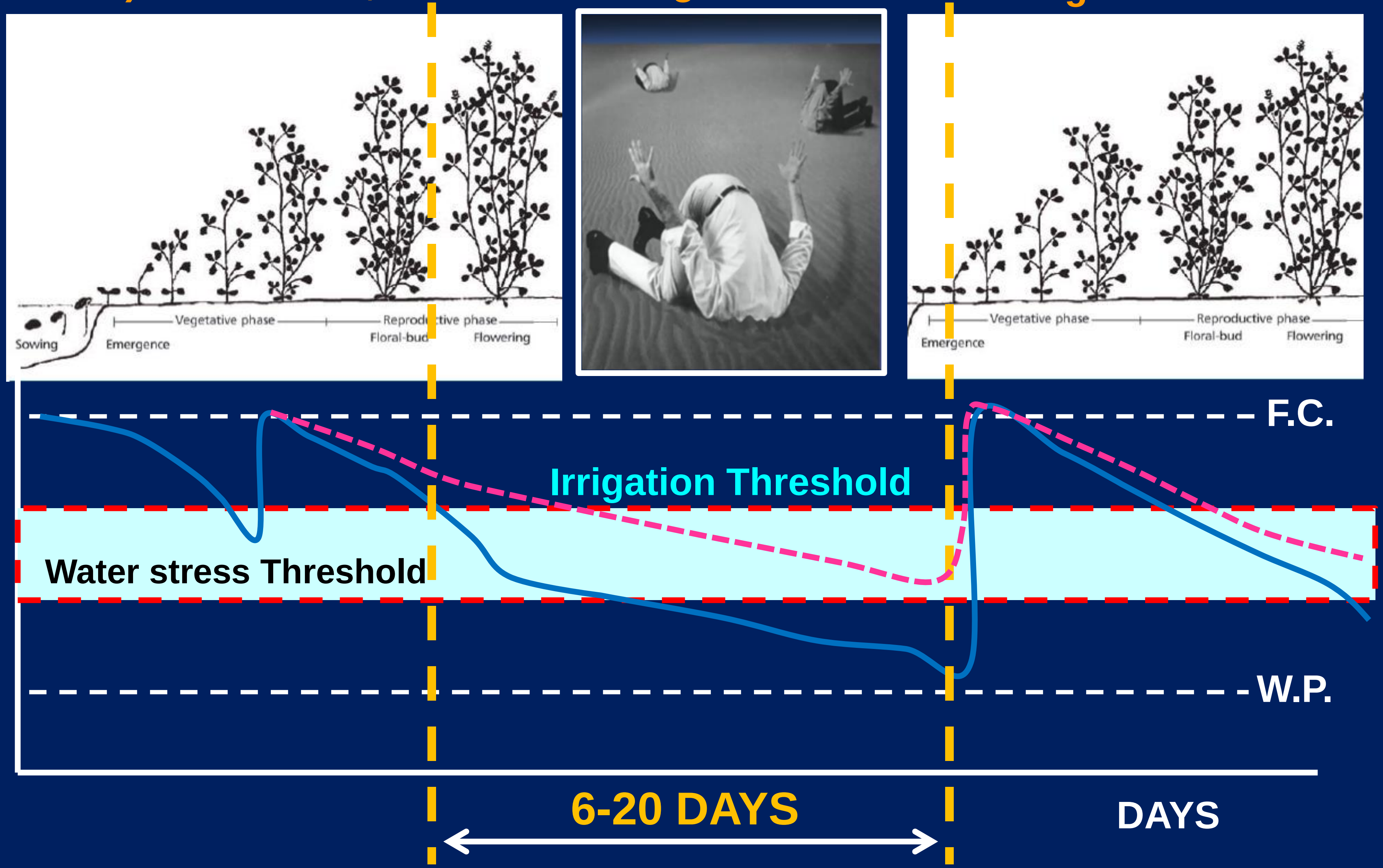
✓ Create deep soil water reserve to avoid water deficit around harvest

✓ Eventually monitoring soil moisture and ET is of great help

WHAT HAPPENS DOWN THERE IN THE SOIL?

Water stress in the root zone (deficit or excess)? How much, and for how long?

Is there any deep soil water storage available?



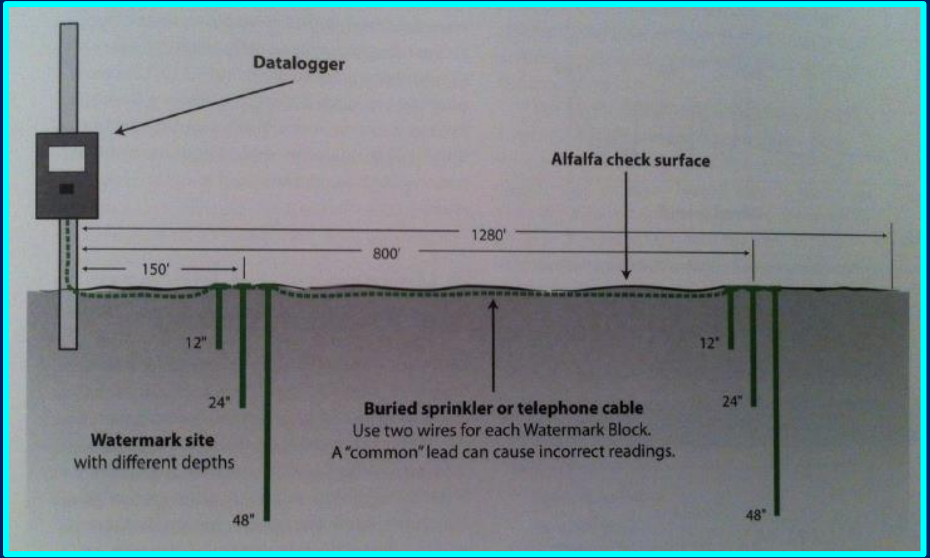
SOIL MOISTURE-BASED IRRIGATION SCHEDULING

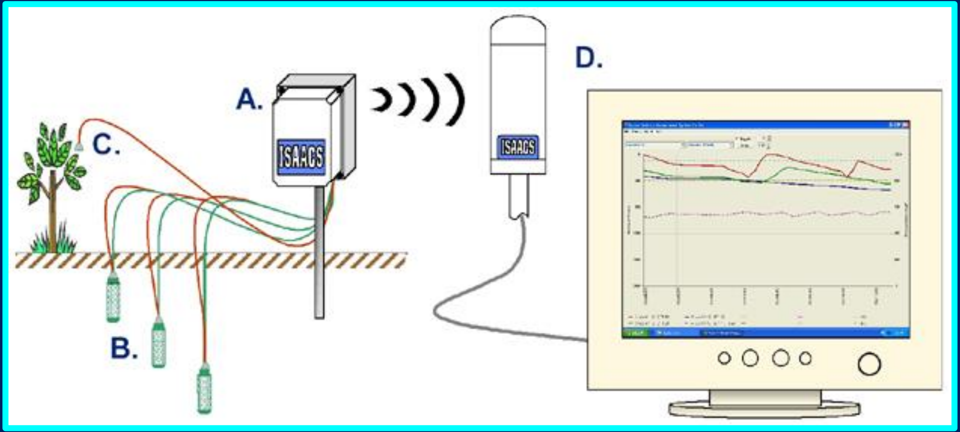
1. Observe soil moisture frequently
2. Start irrigation at target level of soil moisture (allowable depletion, allowable matric potential or tension)
3. Stop irrigation when soil moisture reaches target levels
4. If soil allows, apply some extra water to create a buffer for avoiding crop stress on the next cutting-regrowth
5. The next irrigation could also be predicted based on the measured soil moisture depletion rate

ADVANTAGES OF SOIL MOISTURE MONITORING

<u>**keep track of what is happening in the soil root zone with regard to**</u>:

1. How much water infiltrates during an irrigation
2. How much water is depleted (up-taken by plants) between irrigations
3. Maintaining optimal soil water conditions for plants production





S.M.M helps matching irrigation applications with actual crop water use (ET) to target optimal soil water conditions

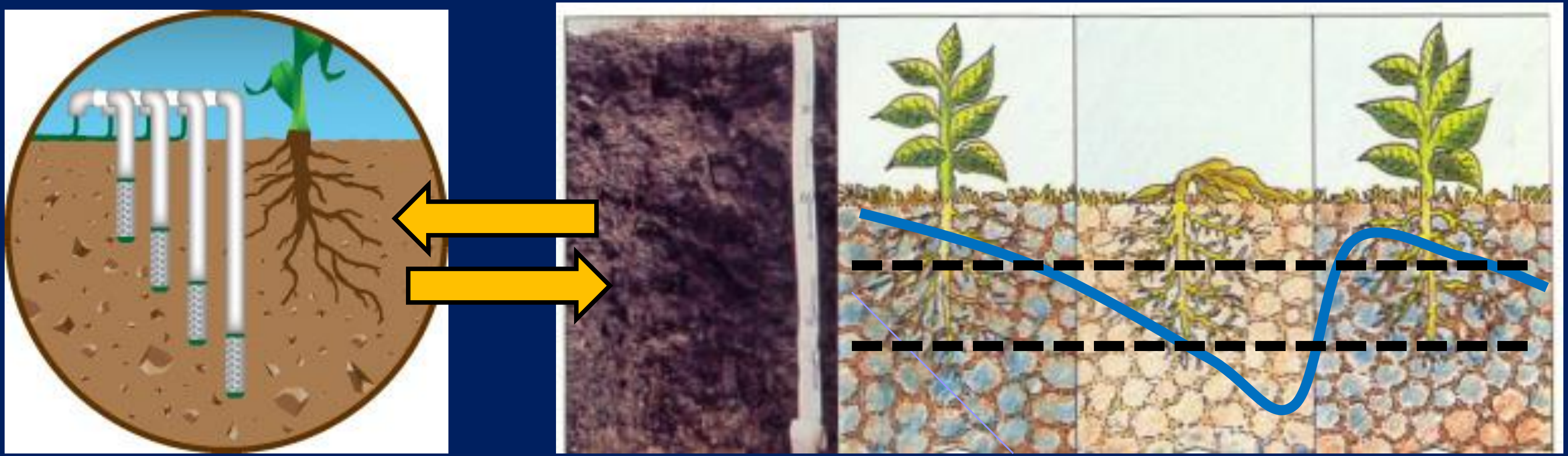
S.M.M. HELPS ANSWERING THE FOLLOWING QUESTIONS

- ✓When to start irrigation (and when to stop it)?

- ✓Has enough water infiltrated the root zone during an irrigation?

- ✓Are we applying enough, insufficient, or excessive water?

- ✓Is there any deep soil water reserve for crop water uptake during periods of no irrigation, or at re-growth?



HOW IS SOIL MOISTURE MEASURED?

SOIL MOISTURE CONTENT (%, in/ft)

How much water is available per unit of soil?

% weight = (weight of water/weight of dry soil) x 100

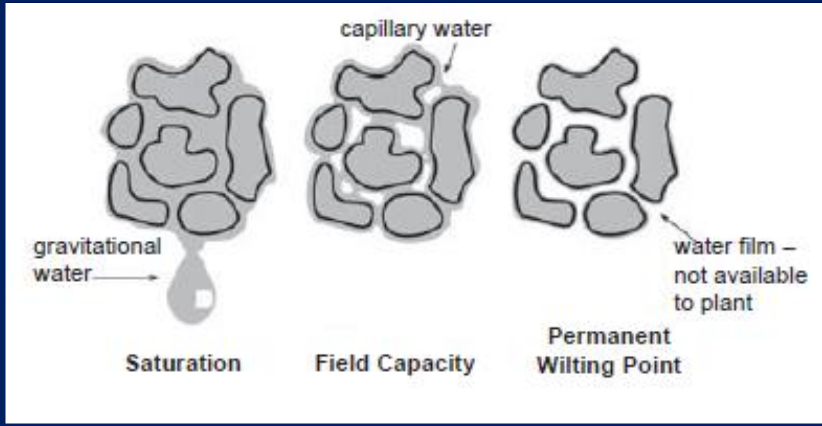
% volume = (volume of water/volume of soil) x 100

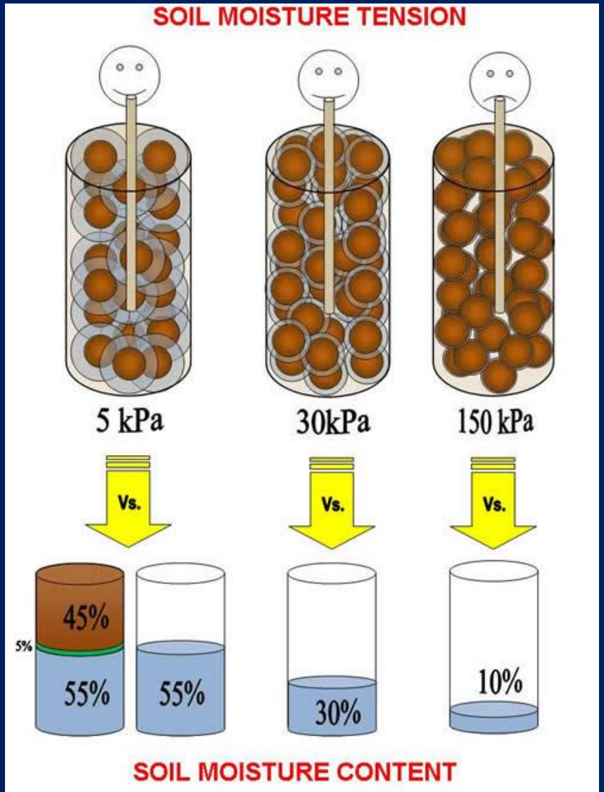
Depth = (inches of water/foot of soil) => MOST COMMON AND PRACTICAL

SOIL MOISTURE TENSION (centibars, kPa)

How strongly water is held by soil particles

The higher the tension, the drier the soil and the more difficult is for plant to extract water

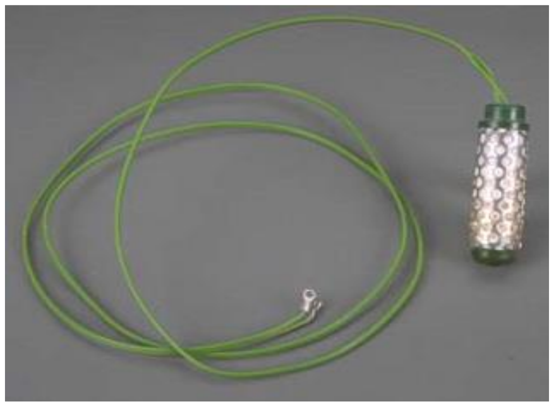




Some sensors measure soil water content and others measure soil water tension

In reality all sensors measure some property/parameter that are related to soil moisture content or soil moisture tension through a specific calibration

SOIL WATER TENSION



GYPSUM BLOCKS (tension)

- ✓Very cheap & Maintenance free
- ✓Can last 1-5 years (soil moisture)
- ✓Sensitive to soil temperature
- ✓Corrosion of electrodes

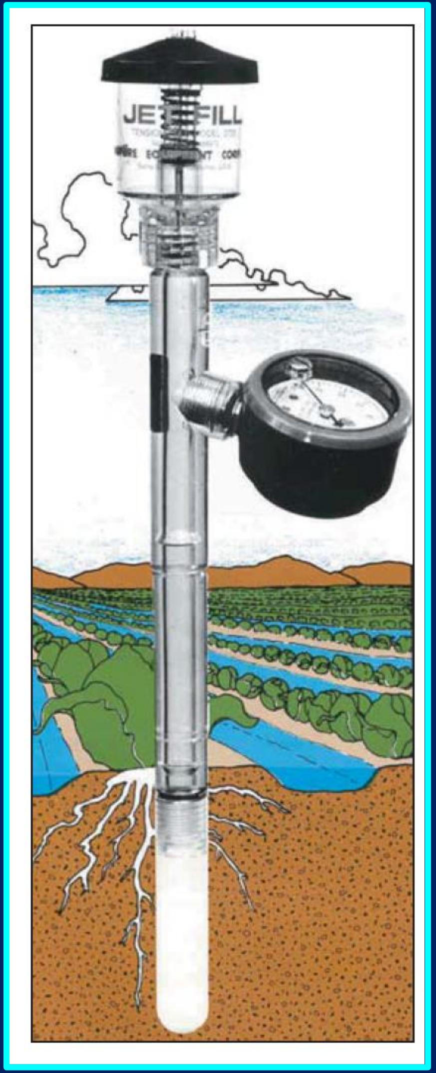
WATERMARKS (tension)

- Read from 0 to 200 centibars
  - Low soil moisture tension indicates moist soil
  - High soil moisture tension indicates dry soil
- Saturated soil after irrigation or rainfall
  - Reading < 5-10

- Don’t need further calculations; easy to interpret
- Robust and reliable in field conditions
- Buffers against salinity
- Can be hooked up with data loggers and telemetry and monitor in continuous mode

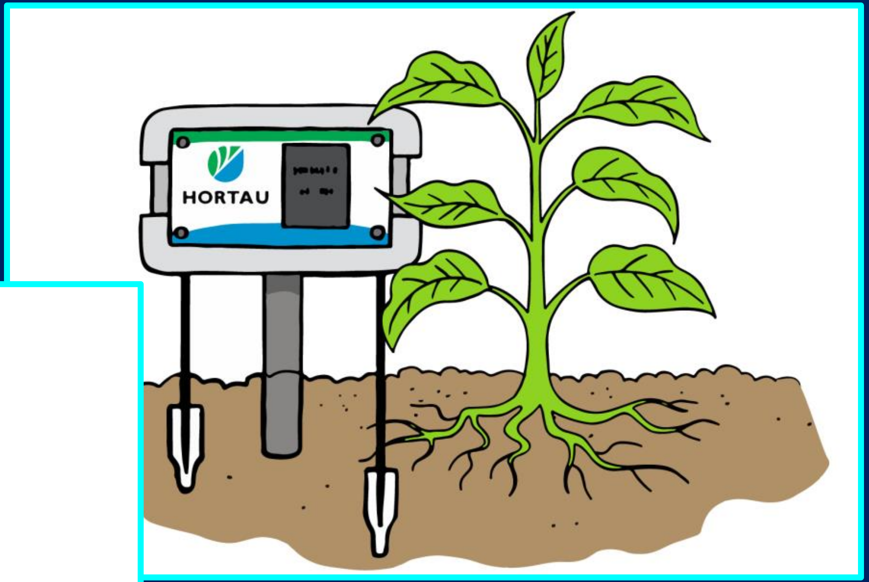
SOIL WATER TENSION

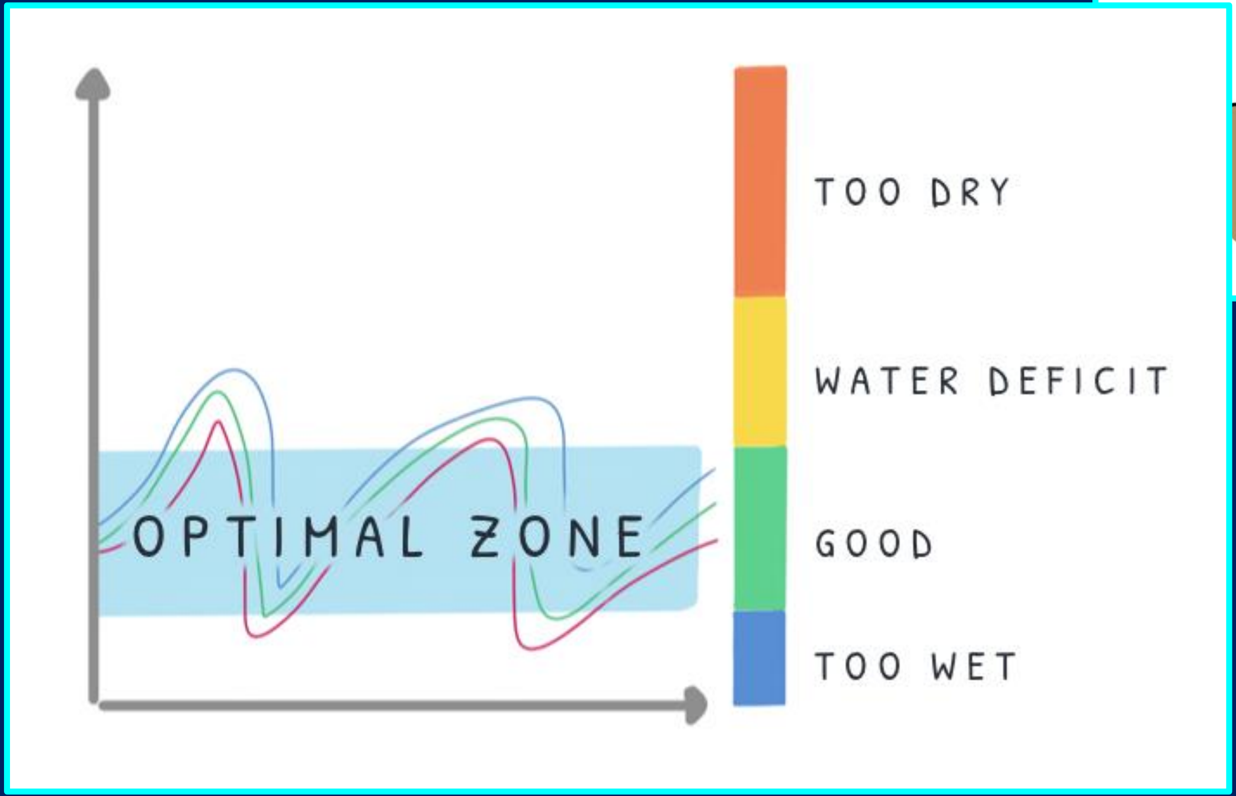
TENSIOMETERS (tension)



Positive features

- ✓Measures soil water tension (relevant to water stress)
- ✓Simple and cheap; no cabling required
- ✓Easy to maintain and read
- ✓Data can be used without further calculations





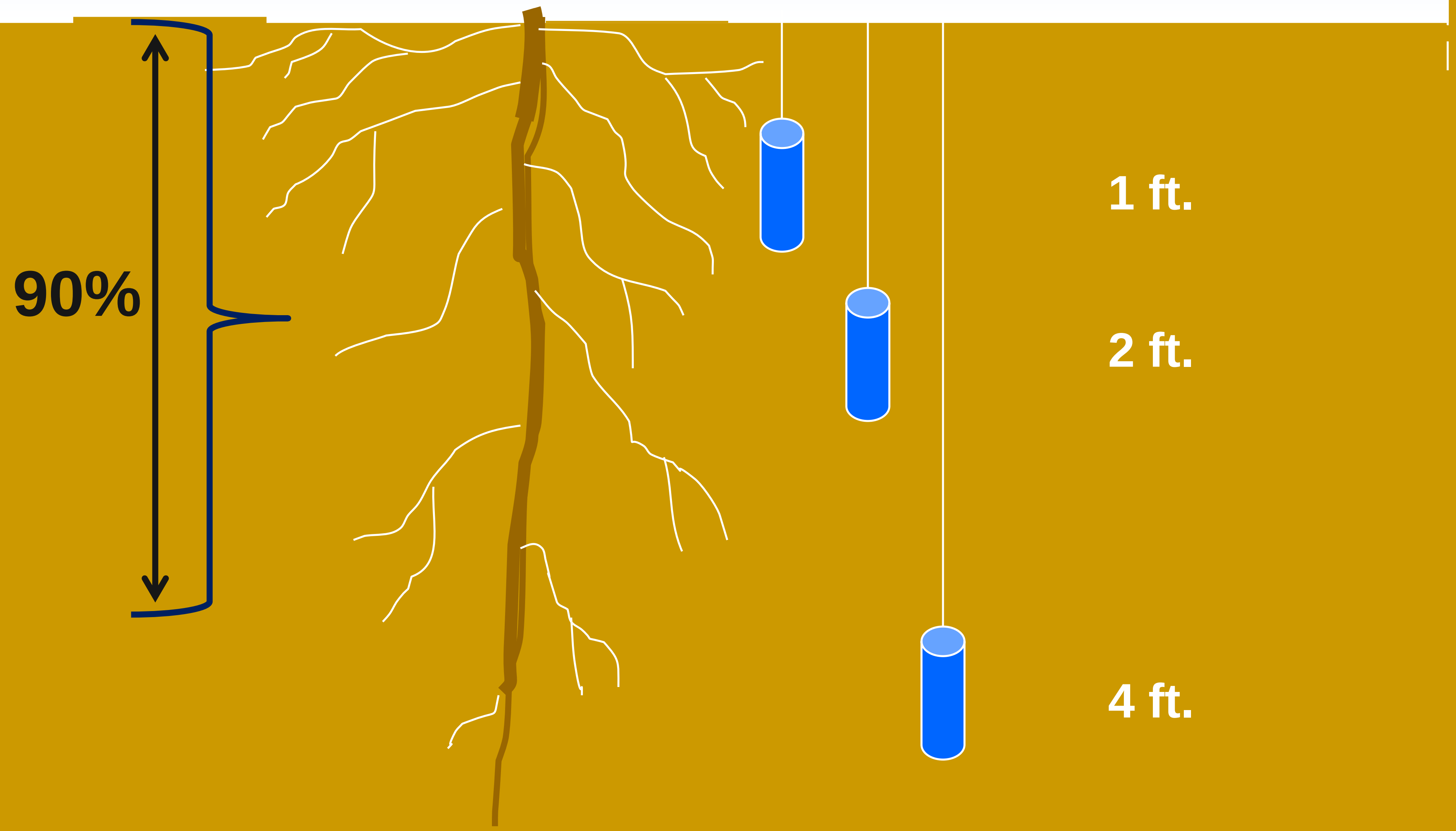
DIELECTRIC (EM) SENSORS (content)

- Measure volumetric soil moisture (vol. water/vol. soil)
  - Sense soil dielectric constant (function of soil moisture)
  - Dry soil = 3-5; air = 1; water = 80
  - Can be Capacitance, TDR and TDT

Limitations

- Need calibration bw. dielectric constant and soil moisture (provided by manufacturer) **and soil-specific calibration**
- Very sensitive to access tube installation (air gaps, cracks)
- Zone of influence very limited (1-4 inches from the sensor)

Recommended installation of S. M. sensors



WETTING FRONT DETECTORS

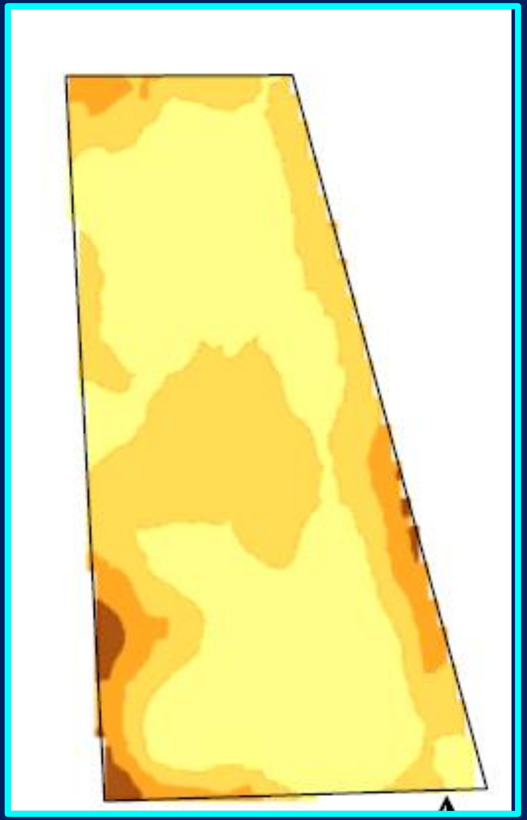
ACTUATED GATE

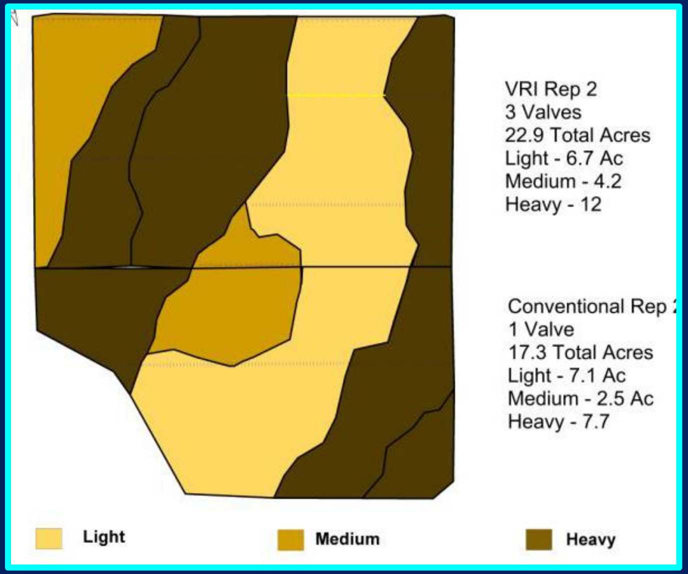
Are soil moisture switches detecting when the wetting front arrives at a certain point along the field

The switch closes the circuit and sends a signal to a gate actuator or valve to close/reduce the flow

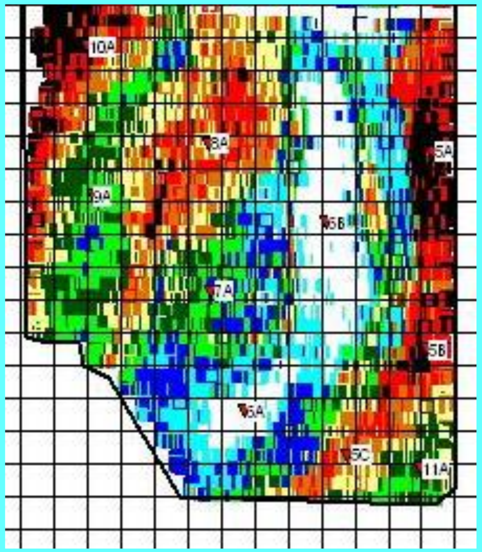
SOME PRACTICAL QUESTIONS

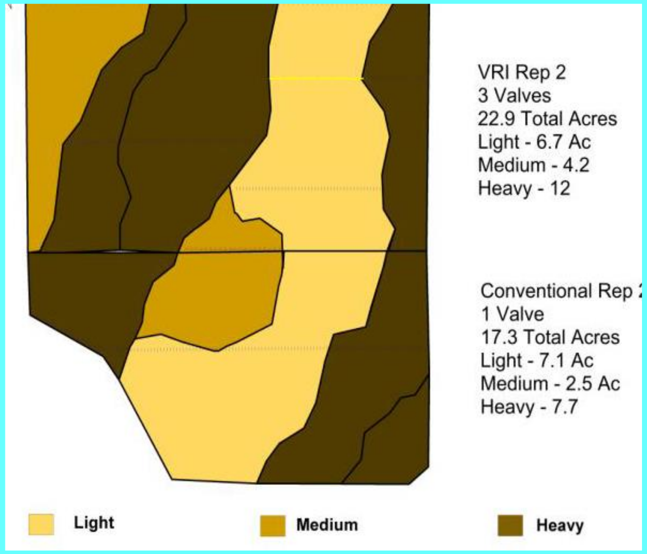
- ✓ How many S. M. stations to install
- ✓ How many sensors per station?
- ✓ Where to install S.M. monitoring station, and when?
- ✓ What type of sensors to install?
- ✓ How frequently shall we check the S. M. data?
- ✓ How to use the information from S. M. moisture monitoring?



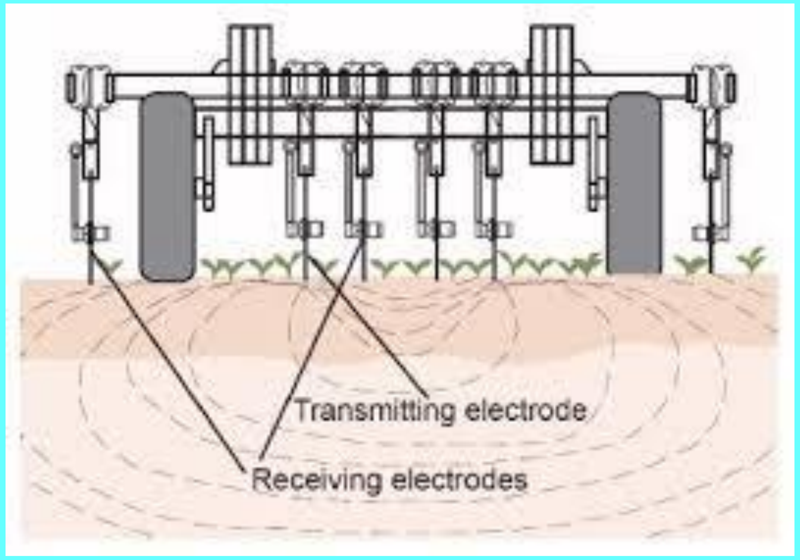


WHERE TO PLACE THE SENSORS & HOW MANY SITES?





Textural classes include gravelly loam, silt loam, and silty-clay loam soils

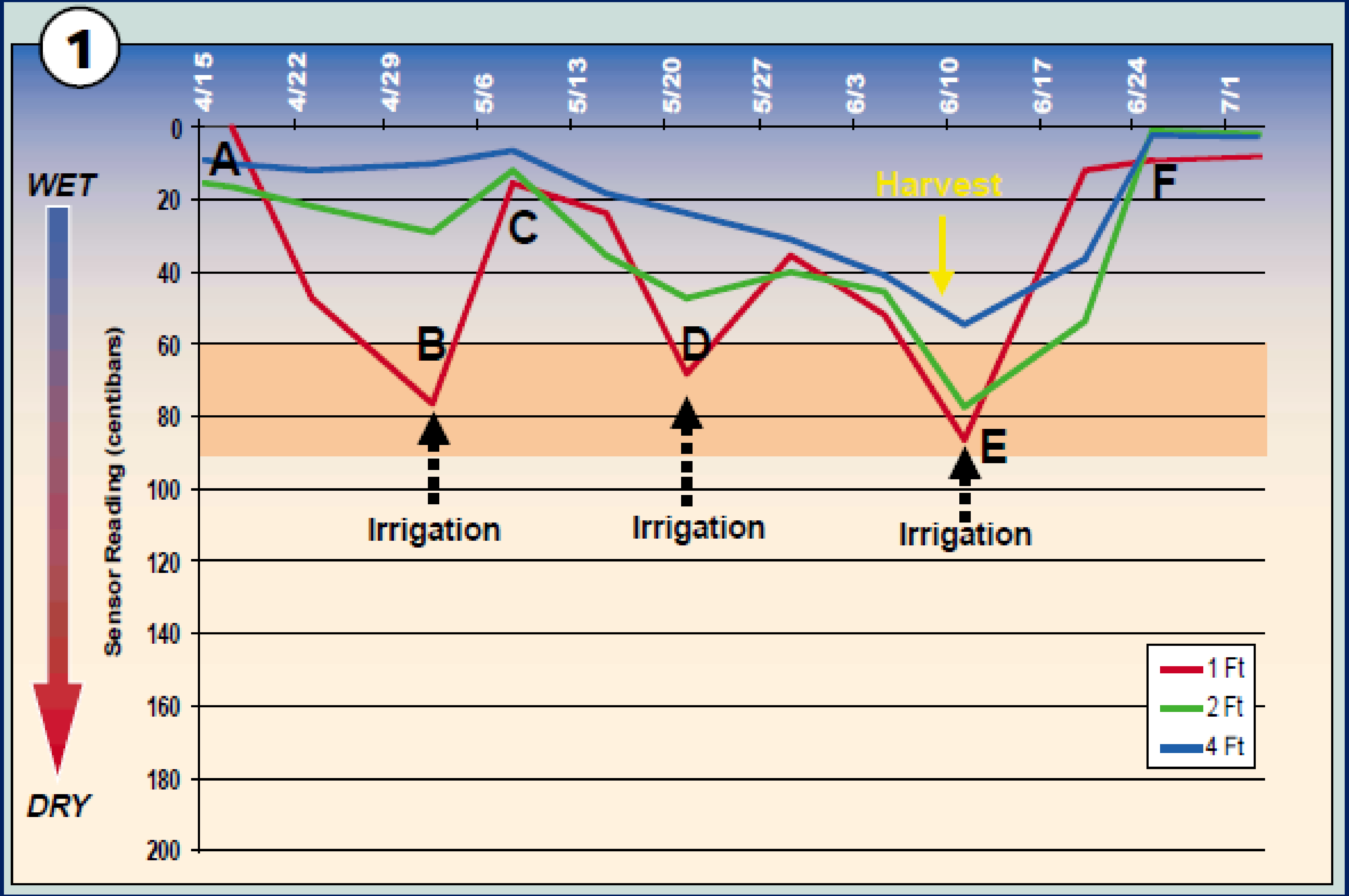


DO WE NEED ANY PRELIMINARY EVALUATION?

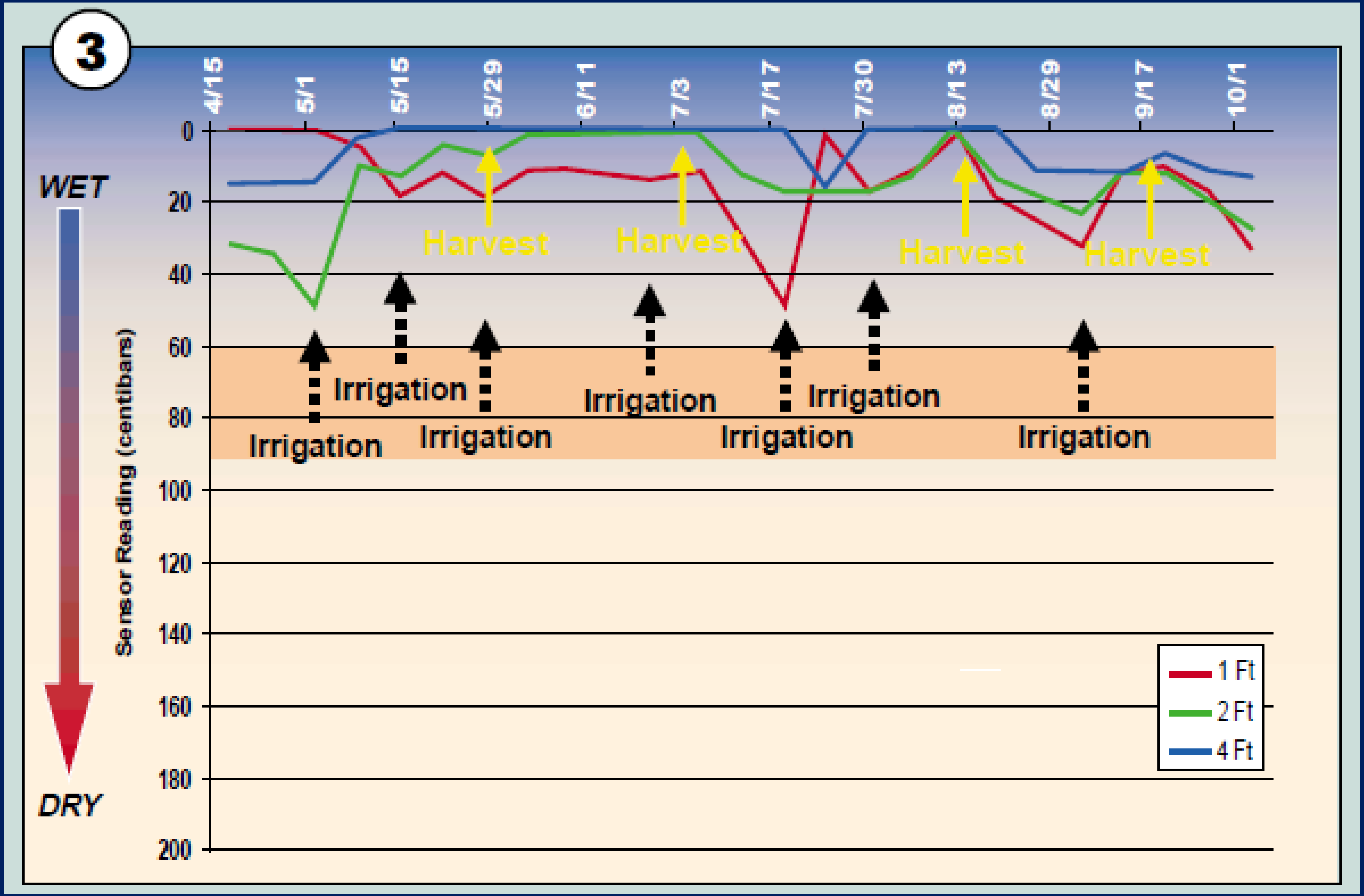
How uniform is our soil within the field?

ZONING + Accurate evaluation of soil differences ($40-60/Ac)

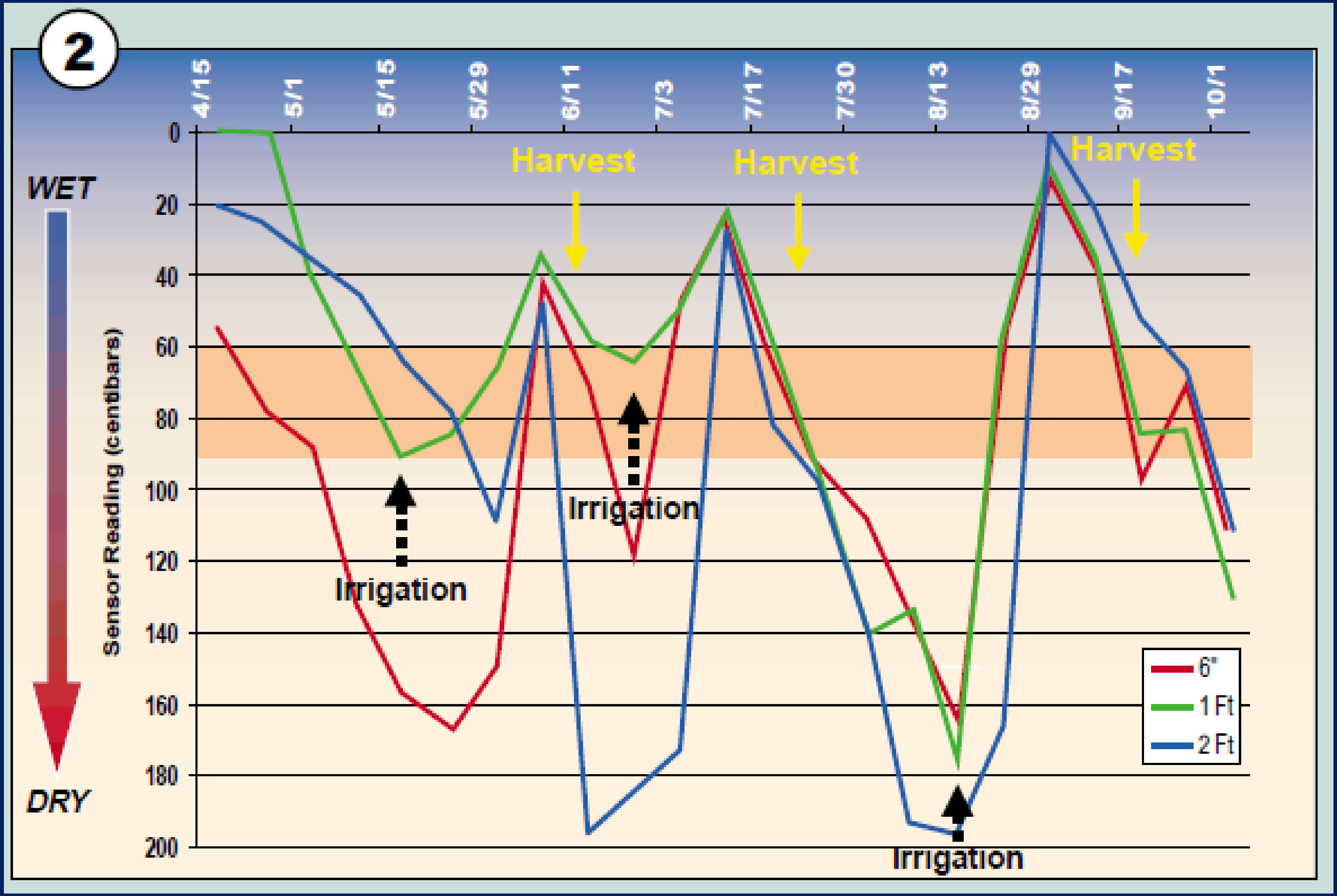
Irrigation Scheduling Example: LOAMY SOIL



Over-Irrigation Example

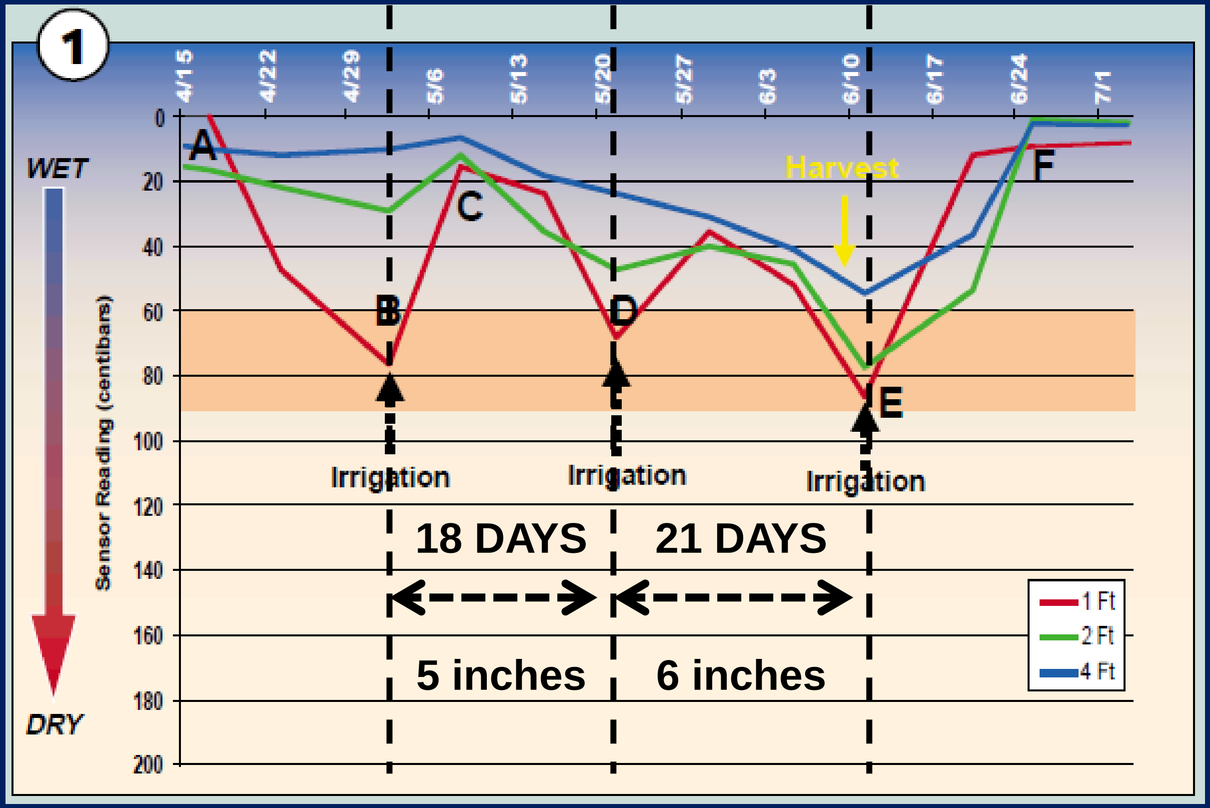


Under-Irrigation Example



BEST IRRIGATION SCHEDULING APPROACH?

Combination of soil moisture monitoring & ETc

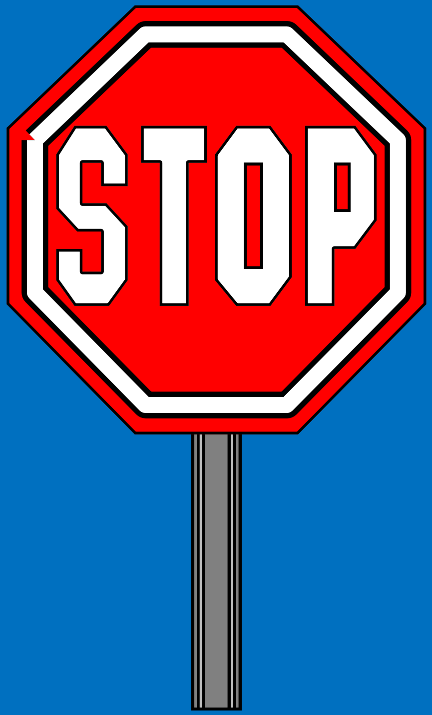


1. Irrigation start timing from Soil Moisture (S.M. Tension or Content)
2. Irrigation amount (inches) from ETc since last irrigation
3. Ground-truthing from Soil Moisture Sensors

CONCLUSIONS

SMM provides real and cost-effective advantages to growers

- ✓Understanding what is going on in the soil profile
- ✓Ground-truth irrigation decisions
- ✓Avoid costly irrigation mistakes
- ✓Create deep soil water reserve to buffer for potential mistakes/outages
- ✓Avoid spending too much in water & energy
- ✓Fine-tune current irrigation practices



THANK YOU !!

QUESTIONS OR COMMENTS?

HOW MUCH WATER DOES ALFALFA USE FOR ET ON AVERAGE IN CA OVER THE CROP SEASON?

SITE	SEASONAL ETc (inches)
Intermountain	33-36
Sacramento Valley	44-46
Central Valley	48-52
Desert Areas	58-66

IRRIGATION WATER TO APPLY TO MEET ET

Irrig. Need = [(ETc – Rain)/Eff$_{APP}$]

System	Eff.$_{APP.}$
Surface Irrigation	**0.60 – 0.65**
Sprinkler	**0.70 - 0.75**
Micro-sprinkler	**0.80 – 0.85**
Drip	**0.85 – 0.90**

Year	Field	ET_{os}	ET_{cs}	K_{cs}	Ending date
		in.	in.		
	A5	32.5	27.9	0.86	11-Sep
2012	A7	32.3	29.7	0.92	10-Sep
	A8	31.5	27.7	0.88	6-Sep
	A1	37.8	32.7	0.87	5-Oct
2013	A2	36.8	34.8	0.95	26-Sep
	A5	29.0	25.5	0.88	5-Sep
	A1	35.3	32.8	0.93	6-Sep
2014	A2	33.5	28.8	0.86	27-Aug
	A5	37.3	31.0	0.83	16-Sep
	Means	**34.0**	**30.1**	**0.89**	**12-Sep**

Seasonal ET_o, ET_c, and K_c (ET_{os}, ET_{cs}, *and* K_{cs}) for the three seasons in Scott
The season start date is 15 March and the season ends on the indicated da

Age Of alfalfa	Seasonal ET (inches)	Reference ET (inches)
3	55.8	73.2
2	66.0	73.3
3	55.6	67.9
2	63.5	73.2
2	59.8	70.0
2	65.8	70.0
2	56.6	57.0
3	59.4	59.3
3	49.4	63.6

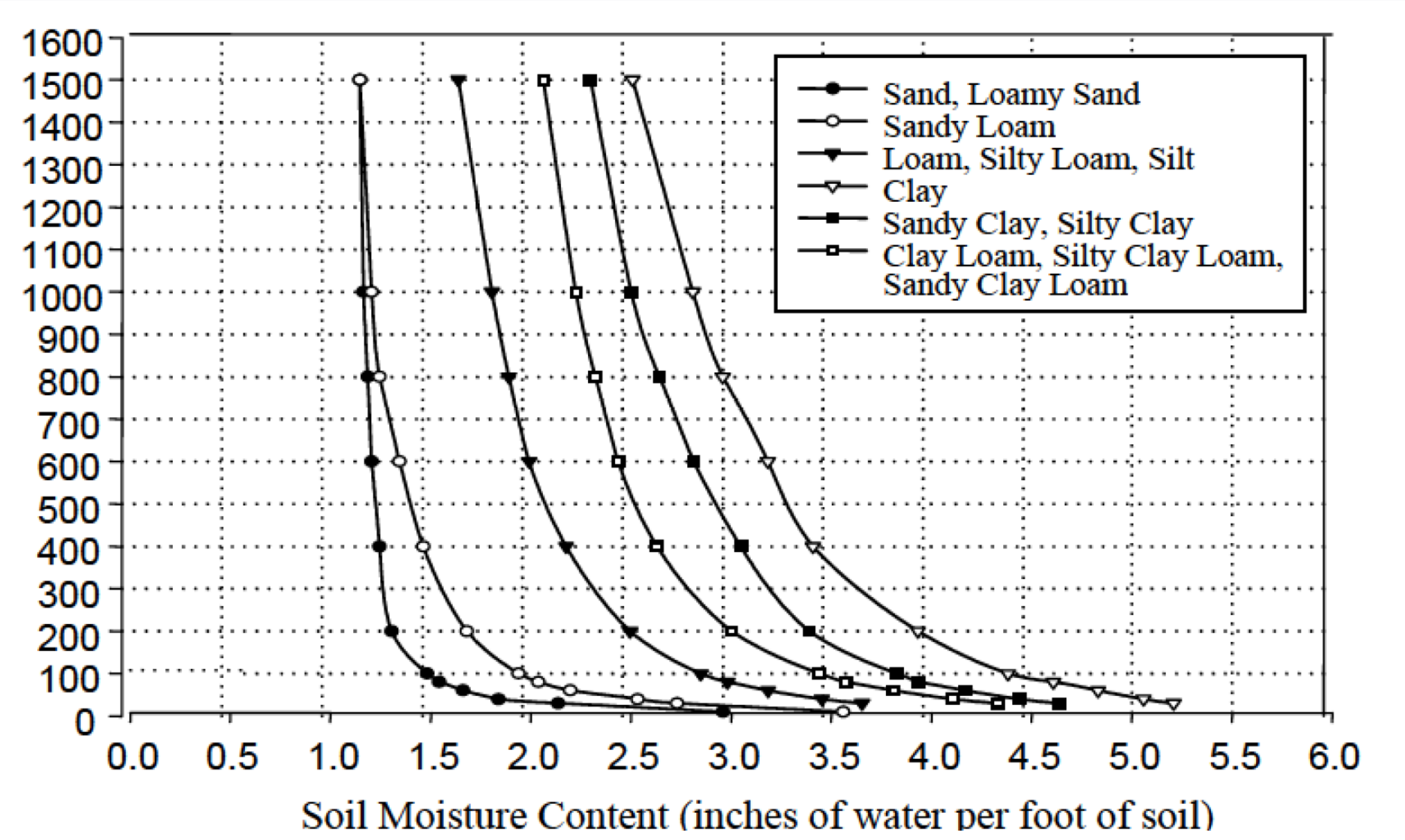
	EW	2010
Scott Valley/Shasta Valley	EN	2007
	EN	2008
	EN	2009
	FI	2009
	SH	2009
	AP	2010
	FI	2010
	FA	2010
Tulelake	TU	2007
	TU	2008

Year	Field	ET_{oc}	ET_{cc}	K_{cc}
		in.	in.	
	A5	45.7	37.3	0.82
2012	A7	45.7	39.5	0.86
	A8	45.7	38.4	0.84
	A1	47.7	40.0	0.84
2013	A2	47.7	43.0	0.90
	A5	47.7	40.2	0.84
	A1	48.6	42.5	0.87
2014	A2	48.6	38.9	0.80
	A5	48.6	39.7	0.82
	Means	**47.3**	**40.0**	**0.84**

Annual cumulative ET_o, ET_c, and K_c (ET_{oc}, ET_{cc}, and K_{cc}) for the three fields in Scott Valley by year. The annual starting and ending dates are 1 January 1 and December 31.

SOIL WATER RETENTION CURVES

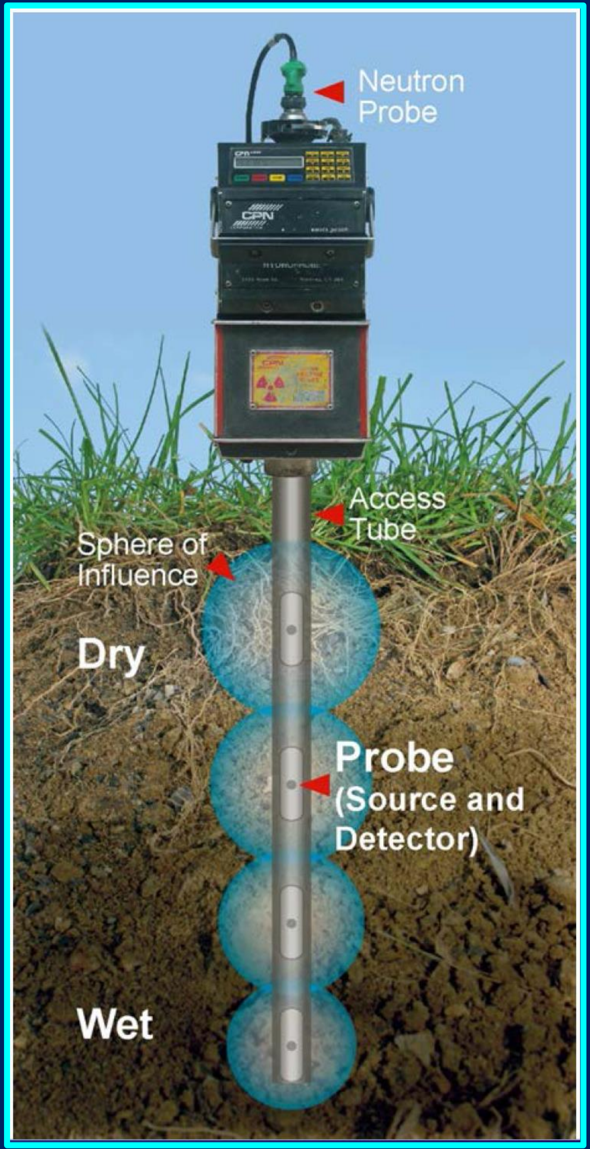
Soil moisture content versus soil moisture tension for different soil textures



Source: Ley et al., 1996

SOIL WATER CONTENT

NEUTRON PROBE (content)



Positive features

✓Robust and accurate measurements

✓Measures large soil volume (15-cm wet, 70-cm dry)

✓Measurements at multiple depths

✓Not affected by air gaps around access tube

Limitations

✓Manual reading & recording take time (2.5 min/tube)

✓Not good at shallow depths (< 6 in.)

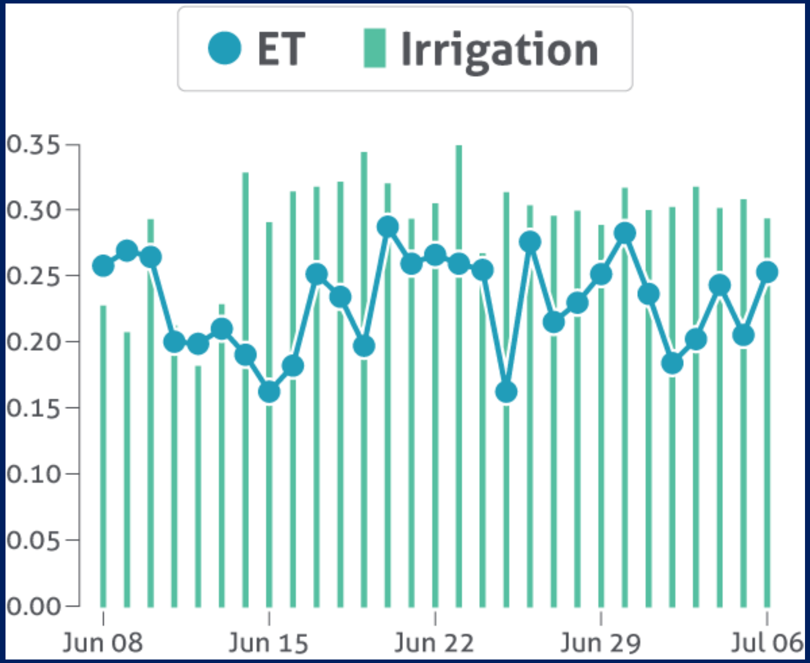
✓Need training & licensing (operation and storage)

✓Radioactive source

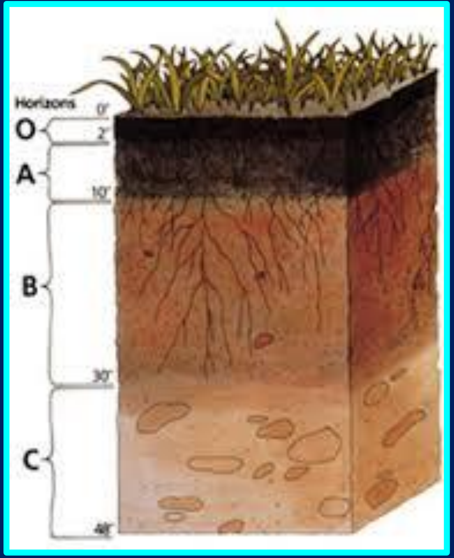
✓Need soil-specific calibration

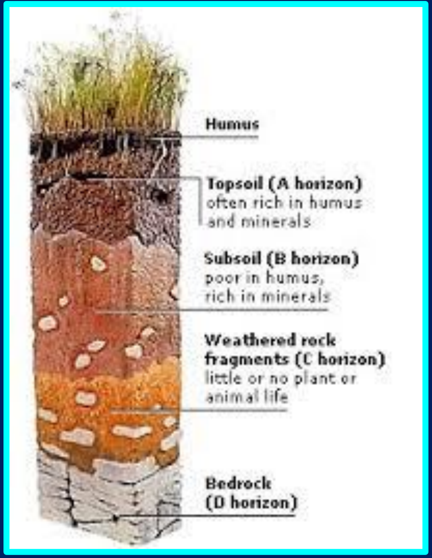
THINGS THAT HELP IN THE FIELD

ET STATION



WHAT OTHER INFORMATION WE NEED TO IRRIGATE ALFALFA?

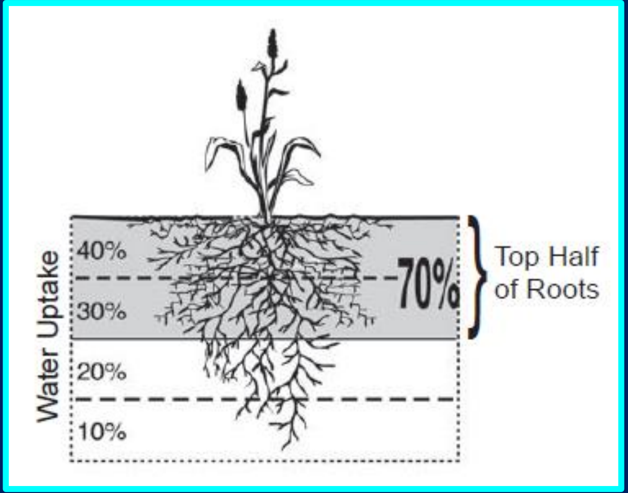




✓Homogeneous soil profile or layered?

✓Any confining/hard layer that constrain roots growth?

✓How deep is soil for roots growth?



What is the root zone depth and the pattern of water uptake by roots

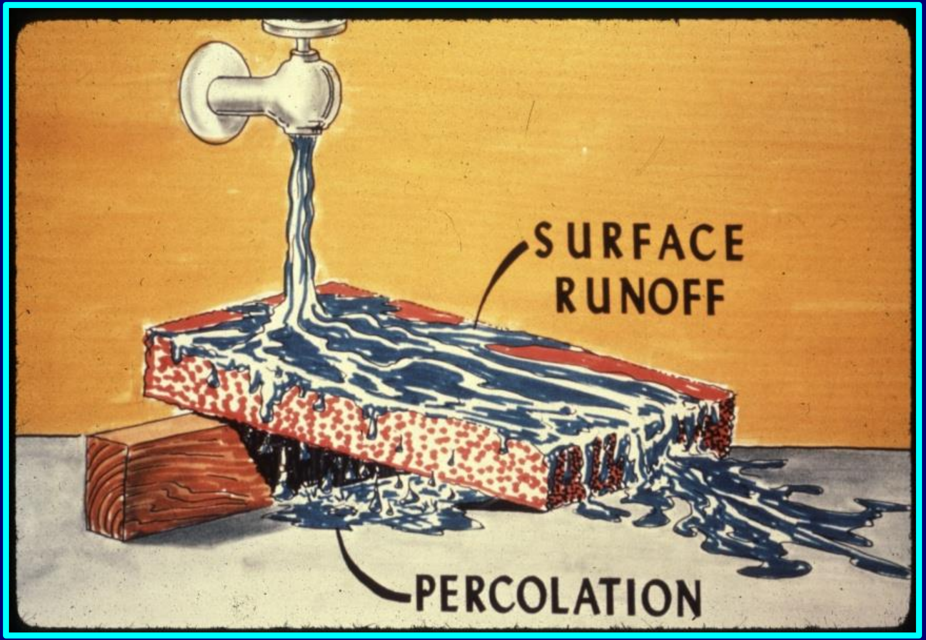
Well watered and <u>No Constraints</u> => RZ is around 4 feet (end of 1st year)

70% uptake from the first 2 feet

90 % uptake from the fist 3 feet

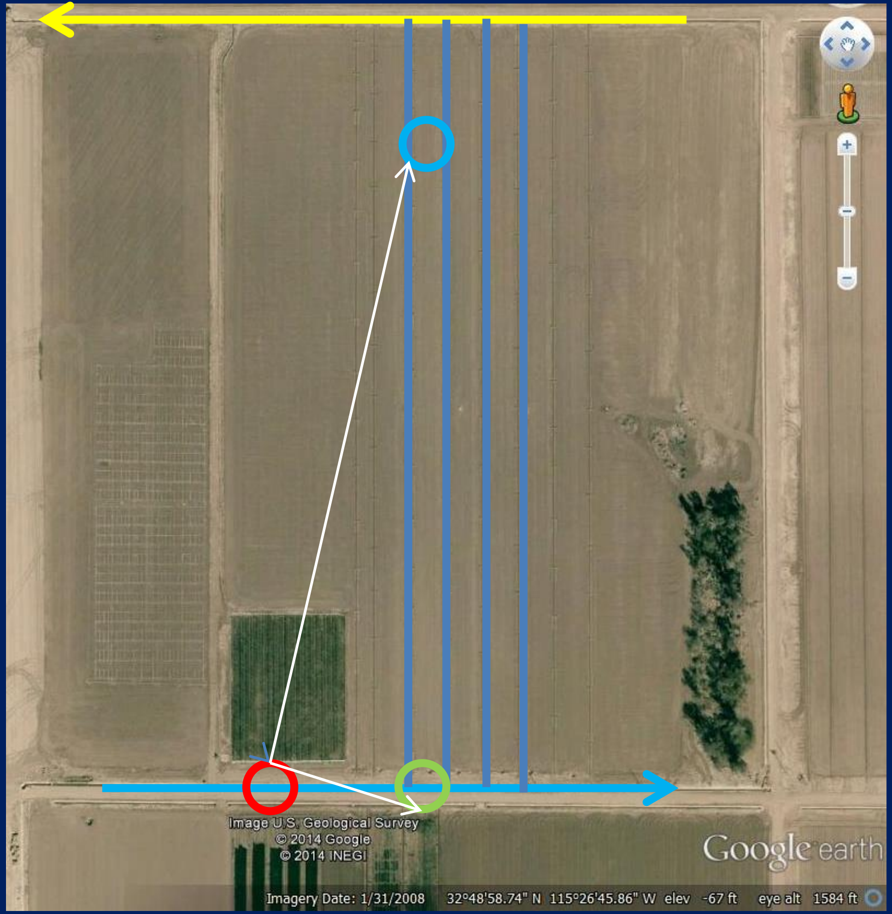
OUR GOAL AS IRRIGATORS IS MAX PROFITABILITY

- ✓ Avoid or minimize water stress (water deficit, water excess)
- ✓ Reduce water and energy cost (groundwater pumping)
- ✓ Reduce leach-outs (nutrients, fertilizers and pesticides)
- ✓ Comply with current environmental regulations



Automation Operating Cycle: Once Canal has Filled → Start Irrigation

- Main Control (MC)
- Field Advance (FA)
- Section 1 Gate (G1)



- MC activates FA
- MC opens G1
- MC computes inc vol
- MC keeps sect vol total
- MC keeps field vol total