New Technology: Gadgets and Gizmos

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COURSE OBJECTIVE

- To understand the soil, plant, and environmental measurement tools available to sports turf managers and how they are best used in diagnosing and solving management problems to maximize turf playability.

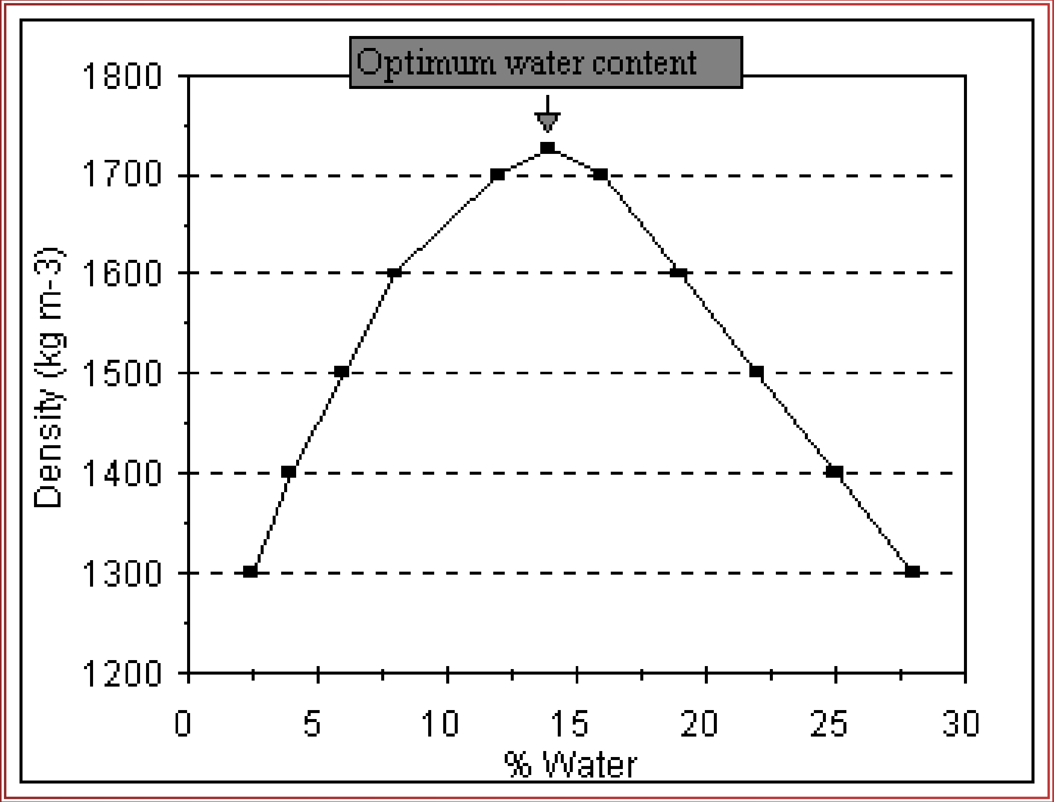
COURSE OUTLINE

- Soil Moisture Measurement
- Light Measurement
- Data Mapping
- Soil Strength
  - Penetrometer
  - Hardness
- Water Infiltration
- Sand Texture
- Salinity
- Stress Detection
- Temperature
- Weather Monitoring
- App's

SOIL MEASUREMENT TECHNOLOGY

Conditions Favoring Compaction

- Fine-textured soil
- Traffic
- Moist soil
- Excessive sodium



Soil Moisture Terms

- Water Content – the amount of water present in the soil, either on a mass (gravimetric) or volume (volumetric) basis
  - ***Measured by probe***
- Water Potential – the amount of suction force required to move water from soil into turf roots
  - ***Indicator of turf drought stress***

Water Content

- The relative proportion of water within a unit of soil, expressed as either:

- ***gravimetric*** (g H_2O / g dry soil) , ***volumetric*** (cm^3 H_2O / cm^3 soil)

Bulk density

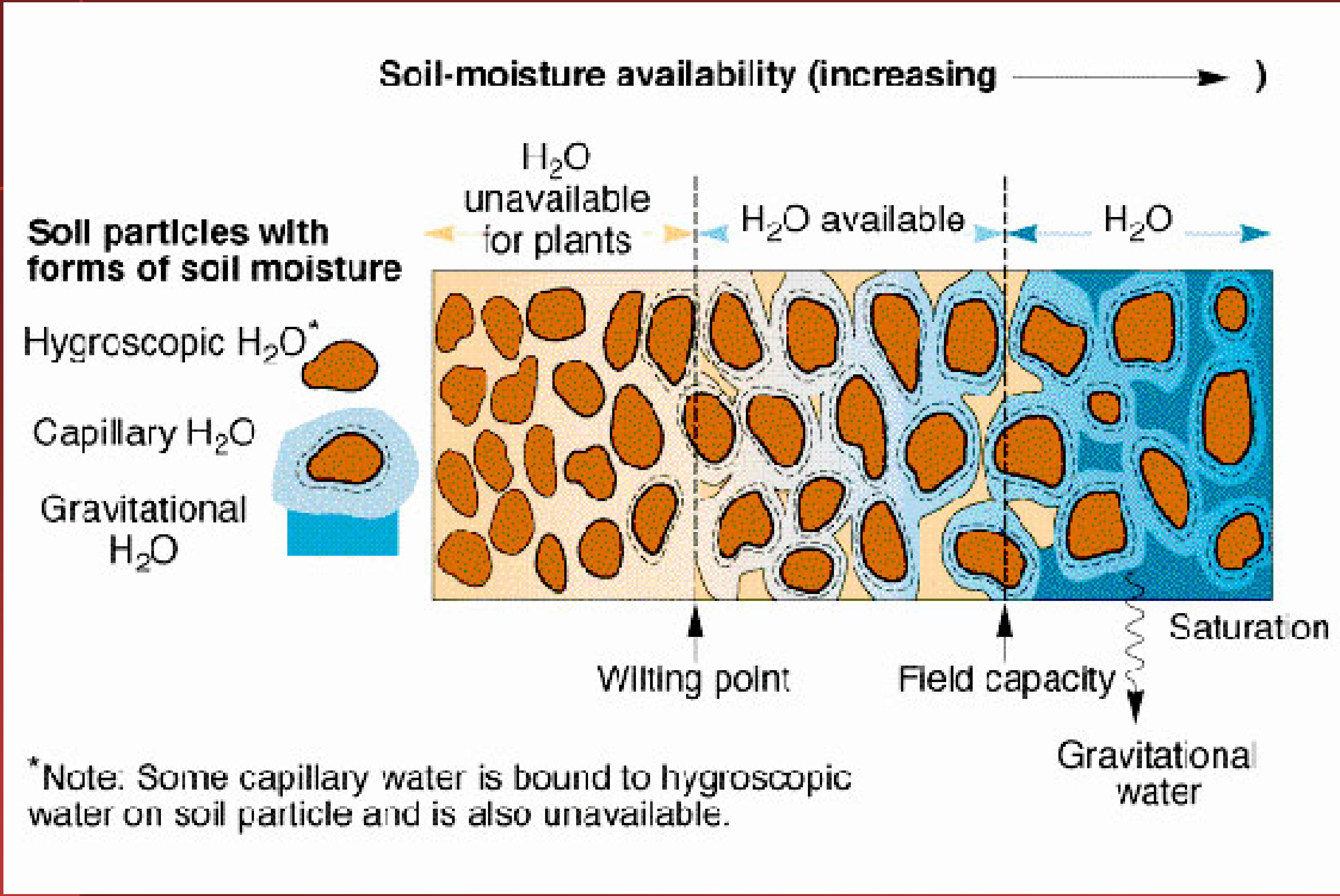
$$\frac{g\ H_2O}{g\ dry\ soil} \times \frac{g\ dry\ soil}{cm^3\ dry\ soil} = \frac{g\ H_2O}{cm^3\ dry\ soil} = \frac{cm^3\ H_2O}{cm^3\ dry\ soil}$$

Gravimetric moisture x bulk density = volumetric soil moisture
(1 g of water = 1 cm^3 of water)

Water Potential

- Amount of work needed to move water from a reference pool to another point. *Amount of suction (negative pressure) necessary to remove additional water from soil.*

  - *Ψ_t under various conditions*
  - *Saturation = 0 kPa*
  - *Field capacity = -30 kPa (loam)*
    < -10 kPa (sand)
  - *Wilting point = -1500 kPa*



Soil-moisture availability (increasing →)
Soil particles with forms of soil moisture
Hygroscopic H_2O*
Capillary H_2O
Gravitational H_2O
H_2O unavailable for plants
H_2O available
H_2O
Wilting point
Field capacity
Saturation
Gravitational water
*Note: Some capillary water is bound to hygroscopic water on soil particle and is also unavailable.

Water Potential Units

- For soils, units of pressure are typically used. SI pressure unit = Pascal (Pa)

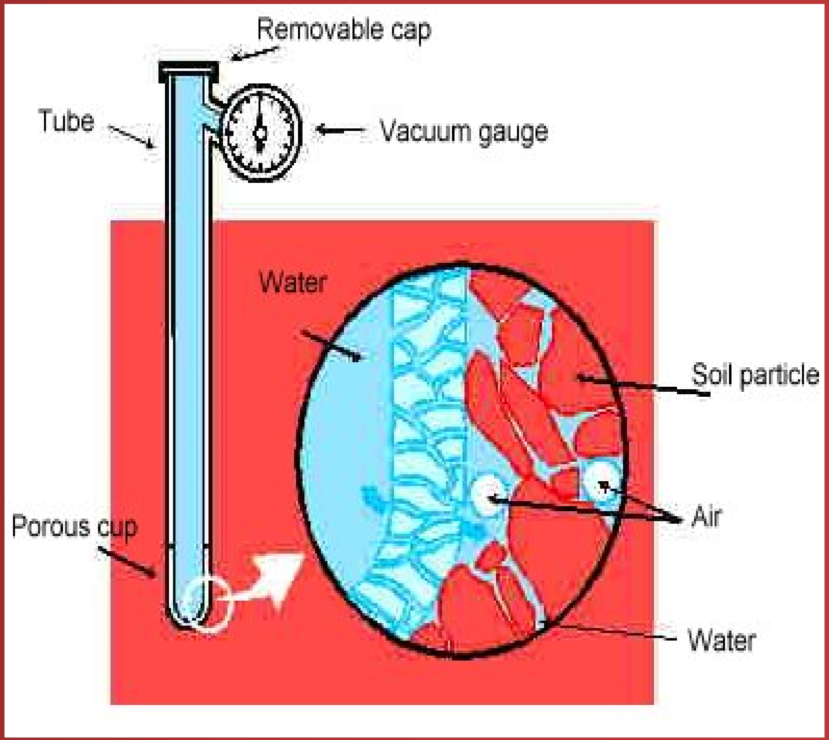
- 1 kPa = 1000 Pa
- 1 MPa = 1000 kPa

- 1500 kPa = 218 PSI

psi	KPa	BAR	Atm
1	6.8948	0.06895	0.06805
10	68.948	0.6895	0.6805
20	137.896	1.379	1.361
30	206.844	2.0685	2.0415
40	275.792	2.758	2.722
50	344.74	3.4475	3.4025
60	413.688	4.137	4.083
70	482.636	4.8265	4.7635
80	551.584	5.516	5.444
90	620.532	6.2055	6.1245
100	689.48	6.895	6.805
psi	KPa	BAR	Atm
125	861.85	8.61875	8.50625
150	1034.22	10.3425	10.2075
175	1206.59	12.06625	11.90875
200	1378.96	13.79	13.61
225	1551.33	15.51375	15.31125

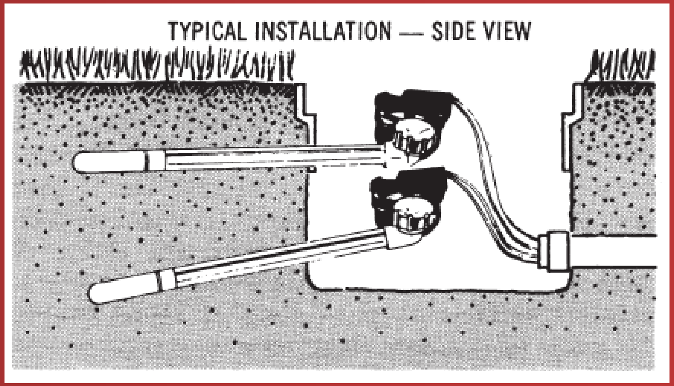
Water Potential Measurement - tensiometers

- Air-tight water-filled tube, which equilibrates w/ soil water
- Vacuum created when water exits tube through ceramic cup
- Water potential read on vacuum gauge

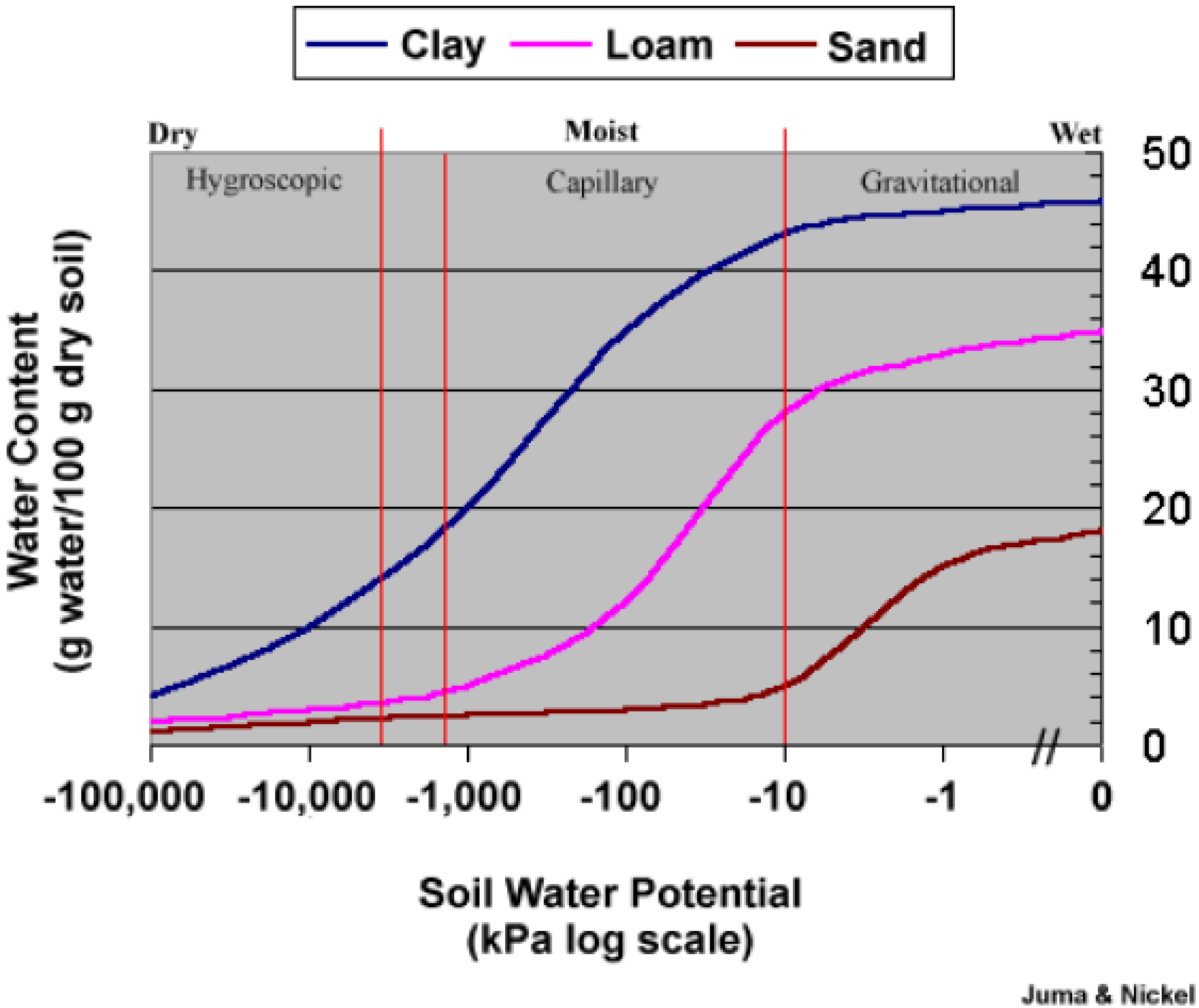


Water Potential Measurement - tensiometers

- Vary in lengths from 6 to 48”
- May be used to automate irrigation scheduling
- Frequent servicing required
- Must be installed in representative location

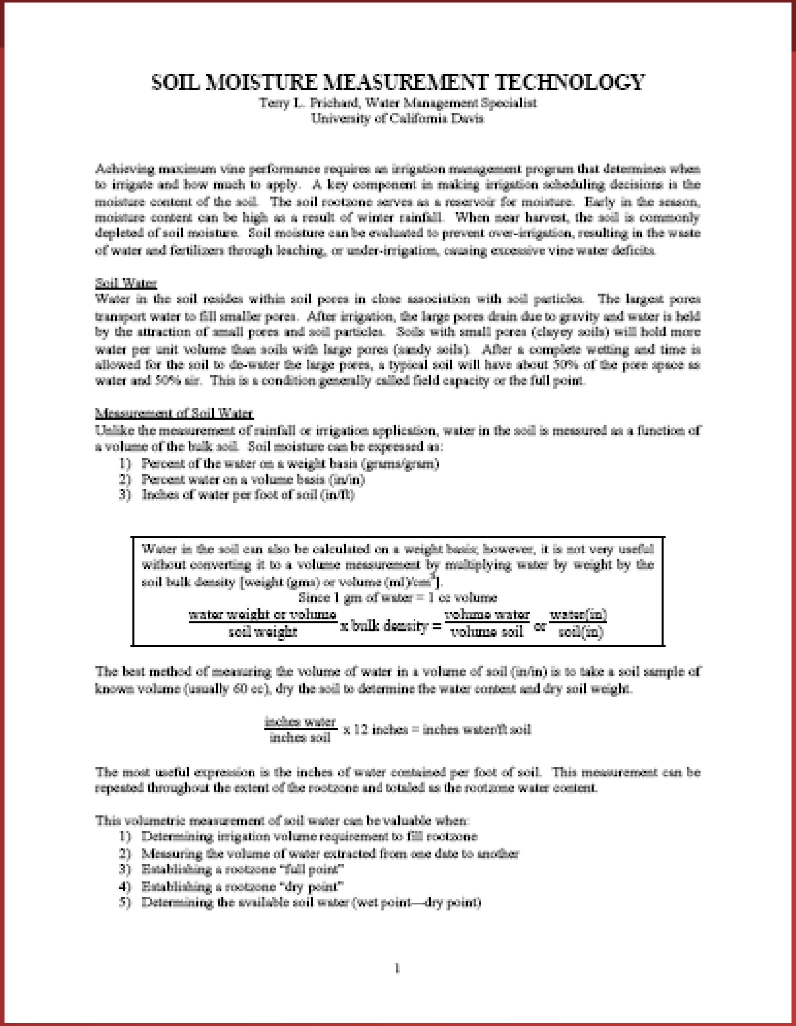


Soil Water Potential Curves:



Soil Water Content - measurement devices

- Porous blocks (electrical resistance)
- Time domain reflectometry (TDR)
- Frequency domain reflectometry (FDR)



SOIL MOISTURE MEASUREMENT TECHNOLOGY

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Achieving maximum vine performance requires an irrigation management program that determines when to irrigate and how much to apply. A key component in making irrigation scheduling decisions is the moisture content of the soil. The soil rootzone serves as a reservoir for moisture. Early in the season, moisture content can be high as a result of winter rainfall. When near harvest, the soil is commonly depleted of soil moisture. Soil moisture can be evaluated to prevent over-irrigation, resulting in the waste of water and fertilizers through leaching, or under-irrigation, causing excessive vine water deficits.

Soil Water

Water in the soil resides within soil pores in close association with soil particles. The largest pores transport water to fill smaller pores. After irrigation, the large pores drain due to gravity and water is held by the attraction of small pores and soil particles. Soils with small pores (clayey soils) will hold more water per unit volume than soils with large pores (sandy soils). After a complete wetting and time is allowed for the soil to de-water the large pores, a typical soil will have about 50% of the pore space as water and 50% air. This is a condition generally called field capacity or the full point.

Measurement of Soil Water

Unlike the measurement of rainfall or irrigation application, water in the soil is measured as a function of a volume of the bulk soil. Soil moisture can be expressed as:

1) Percent of the water on a weight basis (grams/gram)
2) Percent water on a volume basis (in/in)
3) Inches of water per foot of soil (in/ft)

Water in the soil can also be calculated on a weight basis; however, it is not very useful without converting it to a volume measurement by multiplying water by weight by the soil bulk density [weight (gms) or volume (ml)/cm^3].

Since 1 gm of water = 1 cc volume

$$\frac{\text{water weight or volume}}{\text{soil weight}} \times \text{bulk density} = \frac{\text{volume water}}{\text{volume soil}} \text{ or } \frac{\text{water(in)}}{\text{soil(in)}}$$

The best method of measuring the volume of water in a volume of soil (in/in) is to take a soil sample of known volume (usually 60 cc), dry the soil to determine the water content and dry soil weight.

$$\frac{\text{inches water}}{\text{inches soil}} \times 12 \text{ inches} = \text{inches water/ft soil}$$

The most useful expression is the inches of water contained per foot of soil. This measurement can be repeated throughout the extent of the rootzone and totaled as the rootzone water content.

This volumetric measurement of soil water can be valuable when:

1) Determining irrigation volume requirement to fill rootzone
2) Measuring the volume of water extracted from one date to another
3) Establishing a rootzone "full point"
4) Establishing a rootzone "dry point"
5) Determining the available soil water (wet point—dry point)

1

http://ceeldorado.ucdavis.edu/files/45069.pdf

Porous Blocks-how they work

- Made of gypsum, ceramic, nylon, or fiberglass
- Blocks reach water potential equilibrium w/ surrounding soil
- Electrodes w/in block: more water equals less electrical resistance

Porous Blocks
- devices

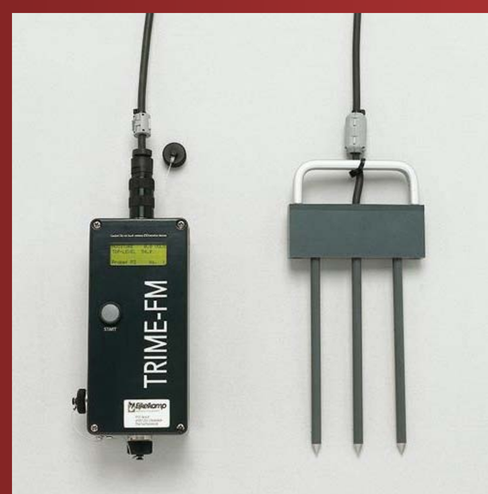
- Watermark Sensor ($300)
- Soil Moisture Meter ($100)
- Several others

Porous Blocks - limitations

- Reading affected by salinity (fertilizer applications)
- Relatively poor measurement sensitivity
- Gypsum will break down over time (esp. in alkaline soils)
- Gypsum blocks not sensitive enough for sandy soils

Soil Moisture Probes (TDR / FDR) - what they measure

- Measures: volumetric soil moisture content
- Units: % (cm^3 water / cm^3 soil)



Soil Moisture TDR Probes -how they work

- Dielectric constant principle
  - Capacity of soil to transmit high frequency electromagnetic waves (600 MHz – 1.2 GHz)
  - Related to volumetric water content
    - Dry soil < 5, Water = 80
- Also, many probes separately measure EC and temperature

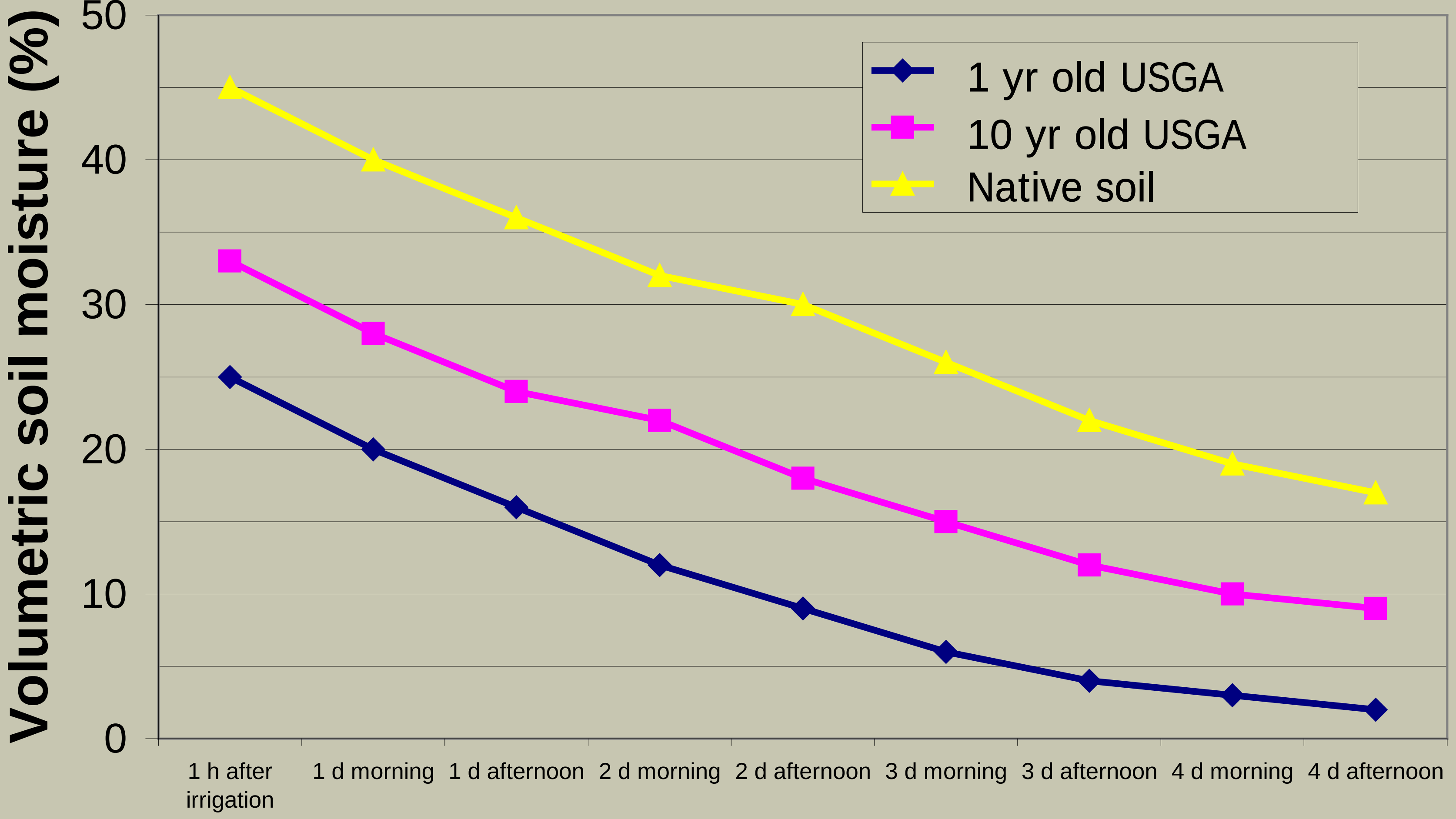
Soil Moisture FDR Probes -how they work

- Similar technology as TDR
  - Use lower frequency radio waves (~ 150 MHz) to measure capacitance of soil
  - Related to volumetric water content

How to calibrate your moisture probe:

1. Irrigate the turf thoroughly- take reading 1 hour later
2. Take readings twice daily and note visual moisture stress symptoms
3. Continue until turf shows drought stress symptoms and determine irrigation threshold
4. Calibrate for each soil type

Moisture probe calibration



Soil Moisture Probes - available devices

- Spectrum Fieldscout
- Campbell Sci. Hydrosense
- Dynamax Thetaprobe
- Decagon ECH_2O probes
- IMKO Trime
- Stevens Hydra Probe
- Cost ($500 - > $2000)

Soil Moisture Probes -how to use

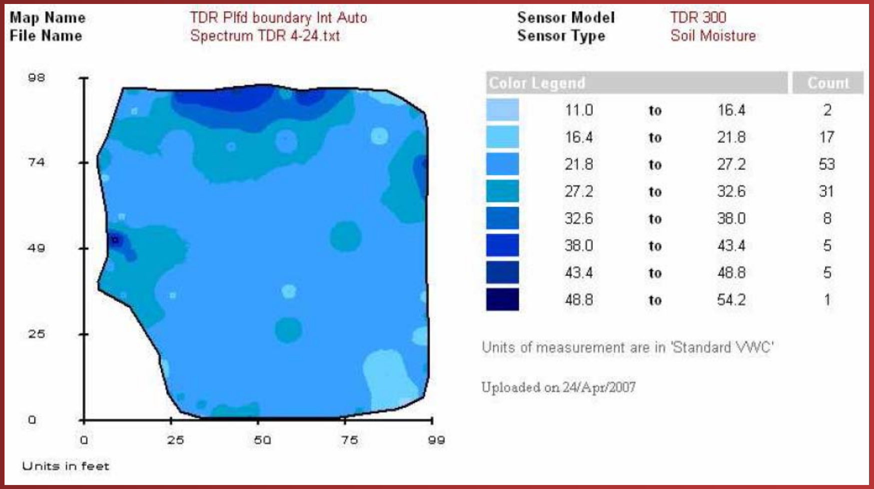
- Irrigation scheduling
- Check irrigation uniformity
- Monitoring skinned areas
- Find drainage problems
- Evaluate wetting agent efficacy

Soil Moisture Probes - Limitations

- Relatively expensive
- Rods difficult to insert into dry native soils (especially > 3”)
- Rods wear out over time and require replacement

Soil Moisture Probes - other applications

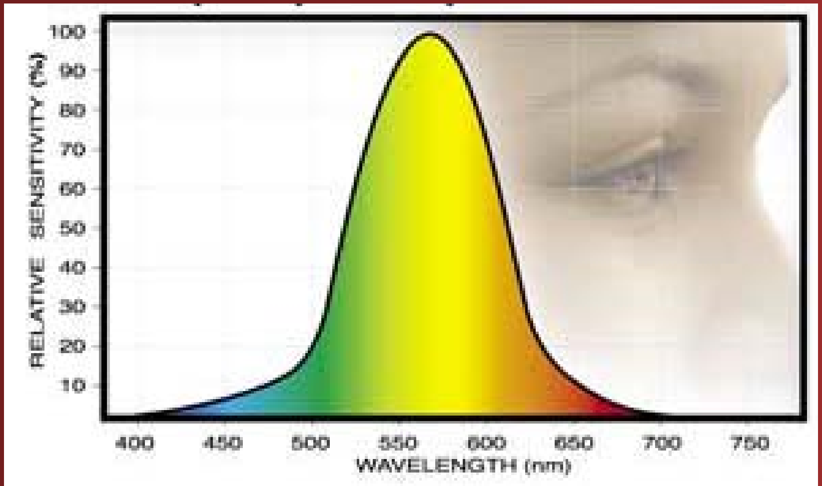
- Wireless sensors
- Automated irrigation scheduling
- Moisture maps



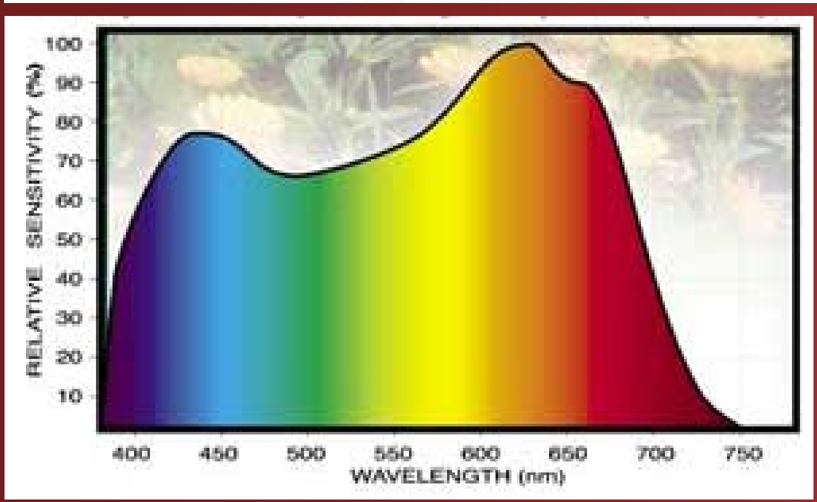
Light measurement

Light measurement

Light meters vs. PAR meters



- The human eye is more sensitive to yellow light
- Standard light meters measure total irradiation and report as total lumens and lux (foot-candles)

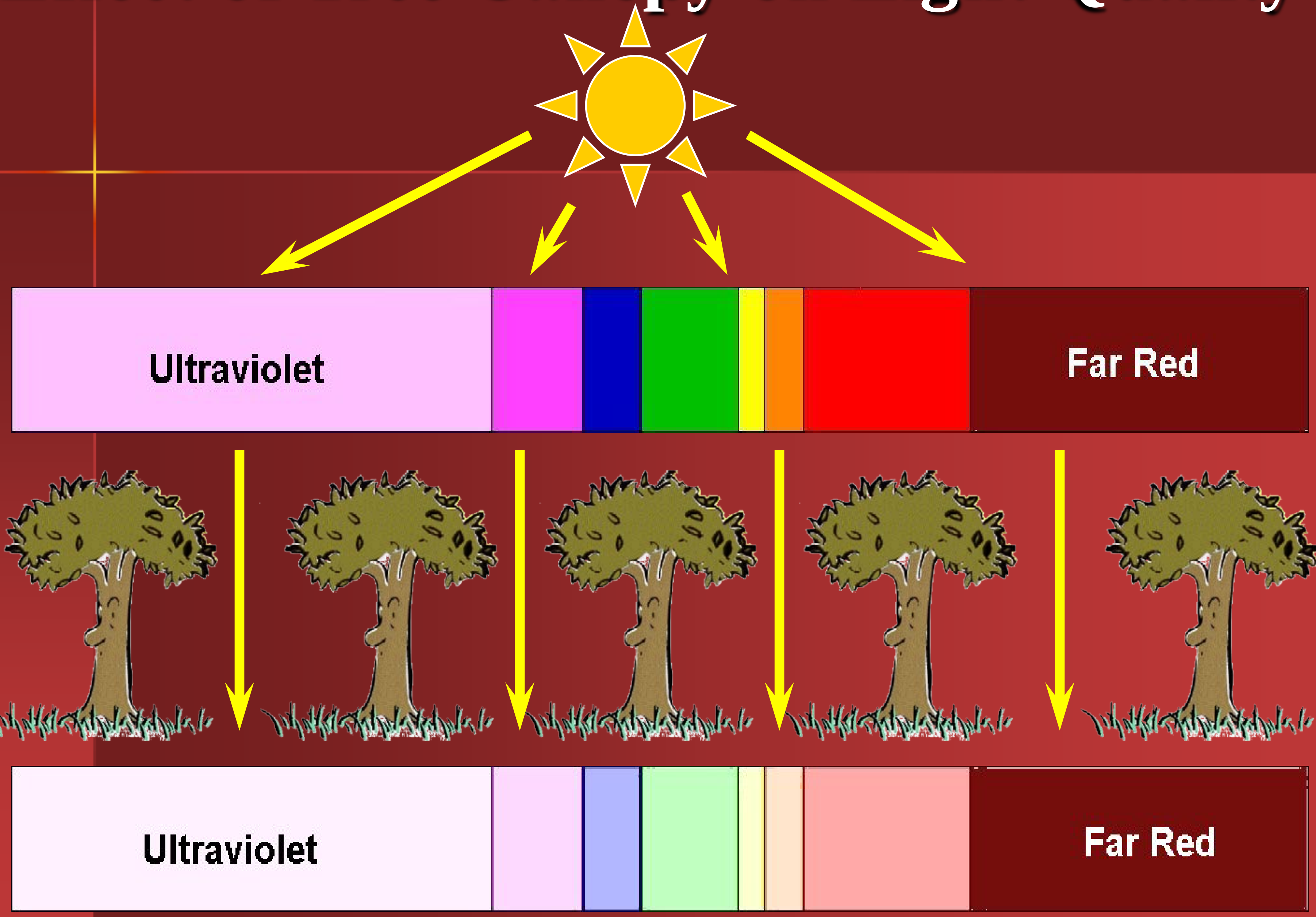


- Plants respond more to blue and red light
- PAR meters focus on the wavelengths important for plant physiology and growth

Total irradiation using a foot-candle or lux meter

- Useful to measure light at turf canopy
- May give erroneous values relative to plant productivity
- Typically, about 50% of total irradiance is PAR irradiance

Effect of Tree Canopy on Light Quality

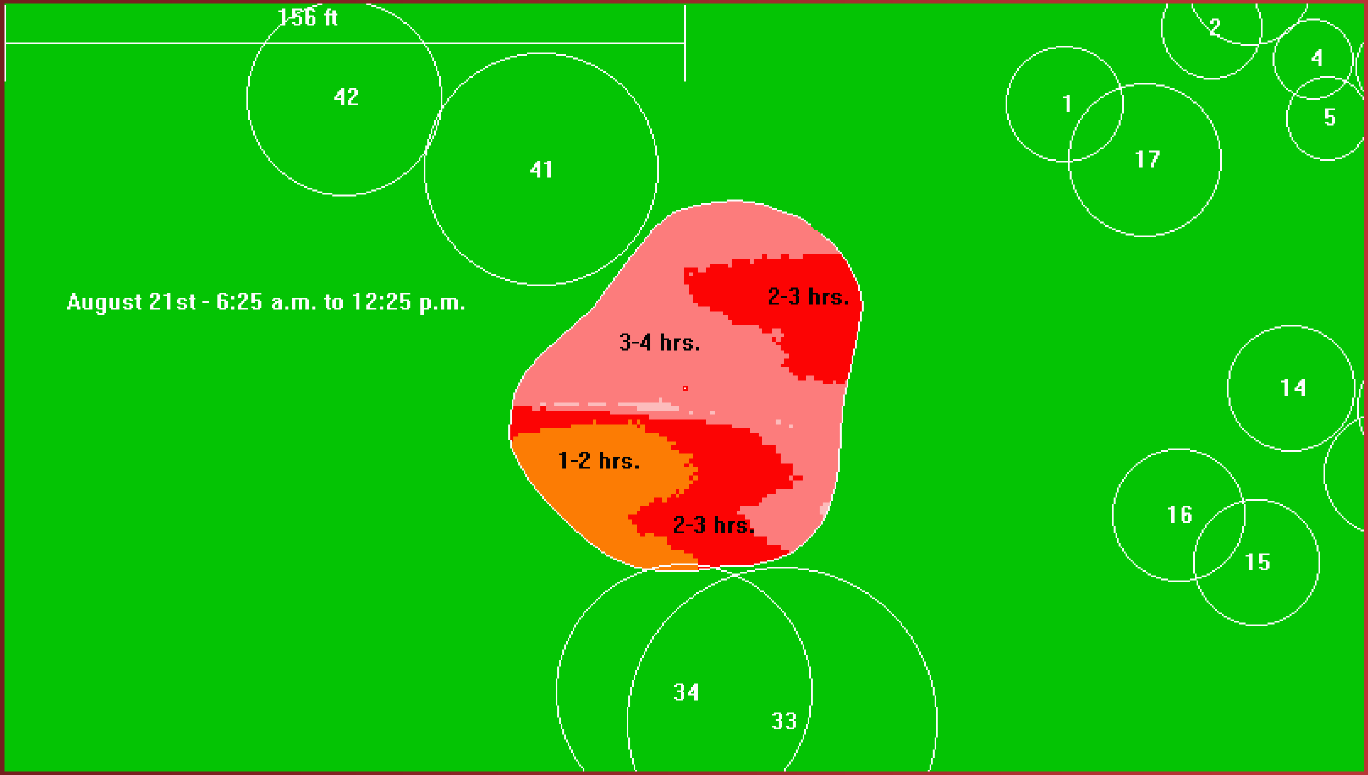


Irradiation measurement using a PAR sensor

- More cost-effective today (~$200)
- Measures light in the 400-700 nm range and reports in µmol / m^2 / sec
- Will give a true reading of the effects of shade on plant productivity

Using light measurements

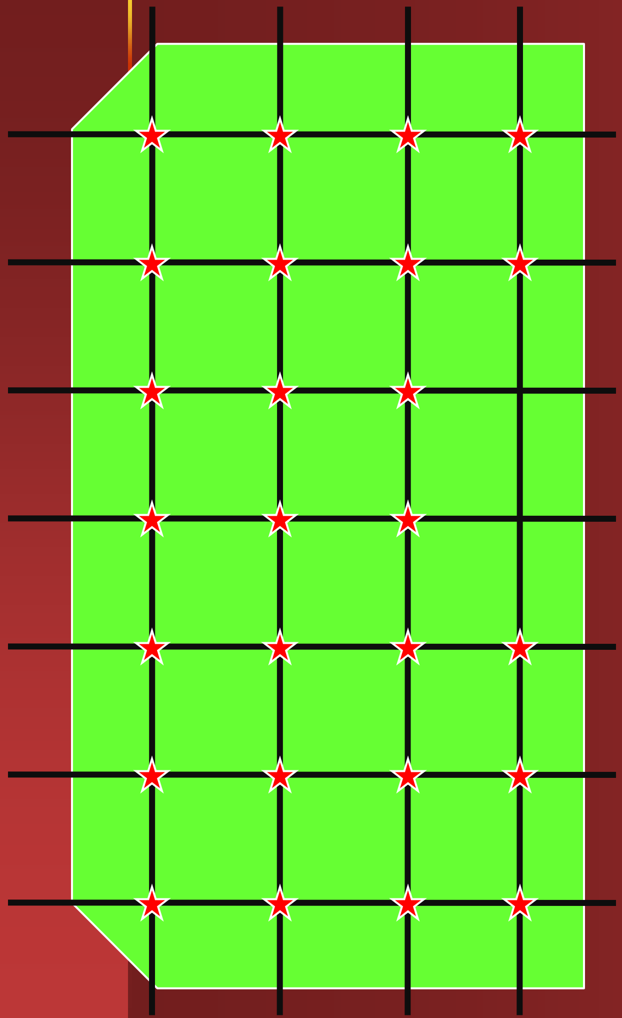
- Document shade effects on grasses



Courtesy of ArborCom Technologies

What if you can’t afford ArborCom… can you do this yourself?

Taking multiple light measurements over a day



Raw Data

	1	2	3	4	5	6	7	8	9	10
1	1925	1940	1950	1945	1940	1940	1940	1940	1945	1945
2	1950	1940	1950	1945	1940	1945	1945	1940	1945	1945
3	1940	1940	1950	1945	1945	1945	1945	1940	1945	1945
4	1920	1850	1800	1820	1700	1600	1850	1920	1940	1950
5	1800	1700	1600	1600	1200	1400	1800	1900	1935	1940
6	1500	1200	1100	1000	900	1200	1500	1800	1940	1930
7	800	750	650	700	700	750	800	1200	1800	1850
8	560	680	450	350	450	680	560	850	1300	1600
9	580	500	200	200	300	500	580	600	800	1000
10	400	350	250	150	200	350	400	500	700	1000

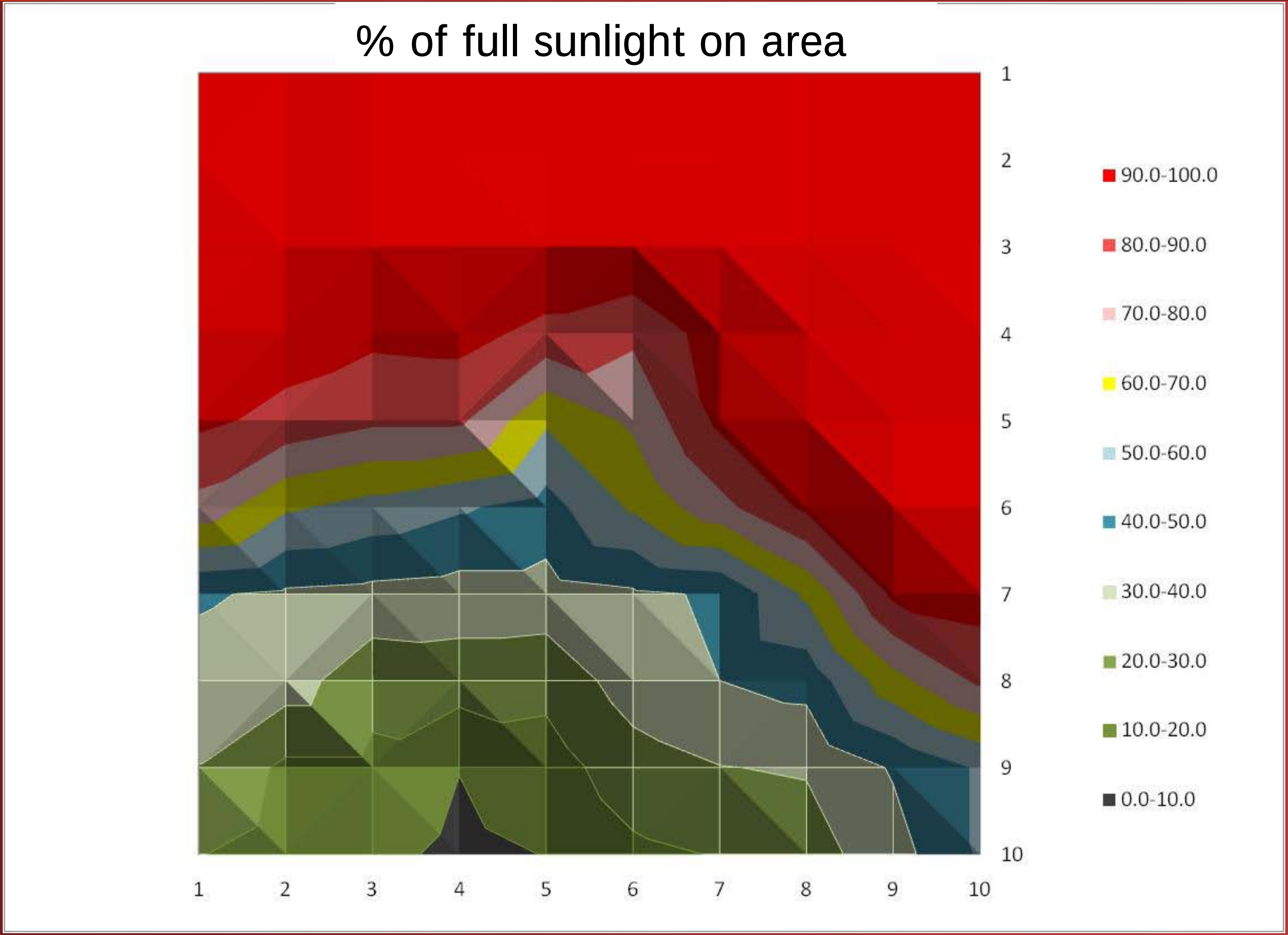
Max Sunlight

1950

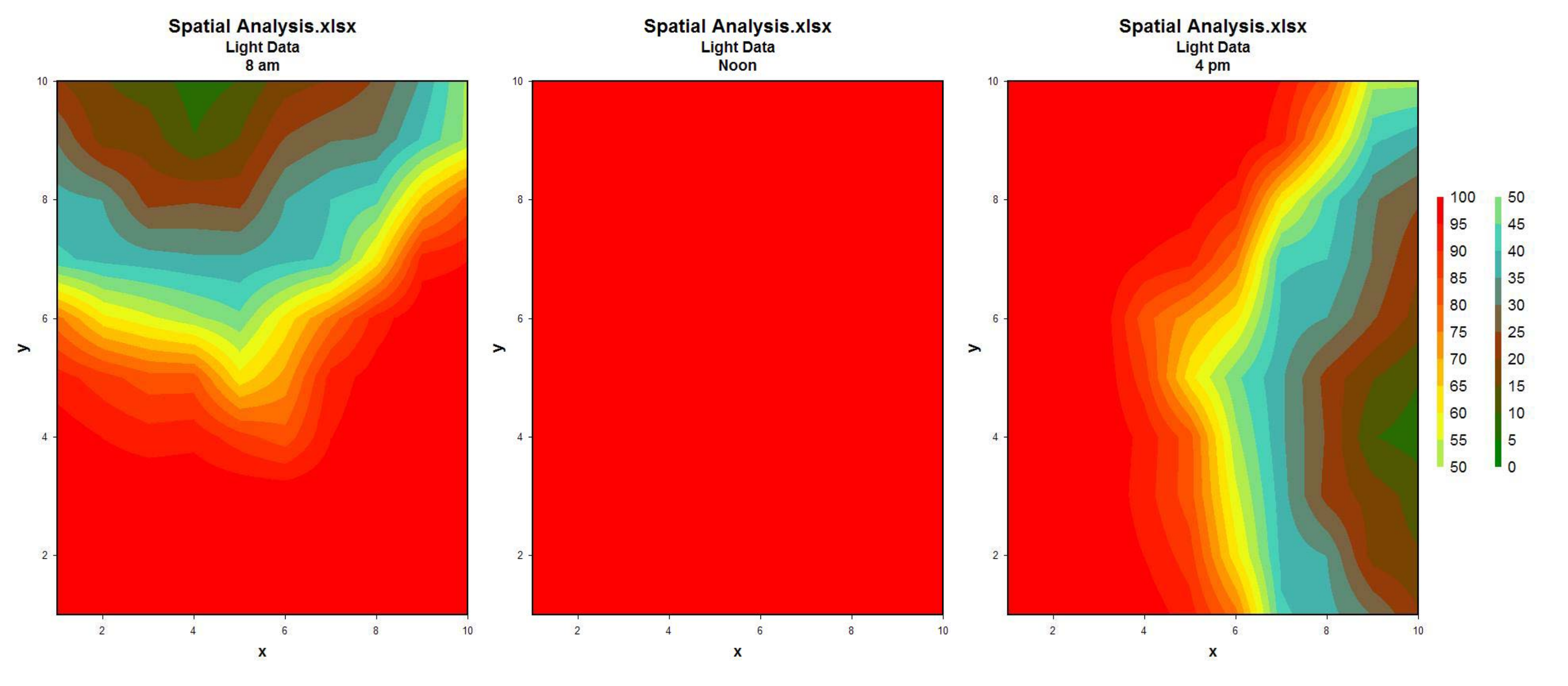
Calculated Shade (% of full sun)

	1	2	3	4	5	6	7	8	9	10
1	98.7	99.5	100.0	99.7	99.5	99.5	99.5	99.5	99.7	99.7
2	100.0	99.5	100.0	99.7	99.5	99.7	99.7	99.5	99.7	99.7
3	99.5	99.5	100.0	99.7	99.7	99.7	99.7	99.5	99.7	99.7
4	98.5	94.9	92.3	93.3	87.2	82.1	94.9	98.5	99.5	100.0
5	92.3	87.2	82.1	82.1	61.5	71.8	92.3	97.4	99.2	99.5
6	76.9	61.5	56.4	51.3	46.2	61.5	76.9	92.3	99.5	99.0
7	41.0	38.5	33.3	35.9	35.9	38.5	41.0	61.5	92.3	94.9
8	28.7	34.9	23.1	17.9	23.1	34.9	28.7	43.6	66.7	82.1
9	29.7	25.6	10.3	10.3	15.4	25.6	29.7	30.8	41.0	51.3
10	20.5	17.9	12.8	7.7	10.3	17.9	20.5	25.6	35.9	51.3

Creating a spatial map with Excel



By collecting data at multiple points during the day, a more complete picture of shade problems can be presented



Mapping Your Data

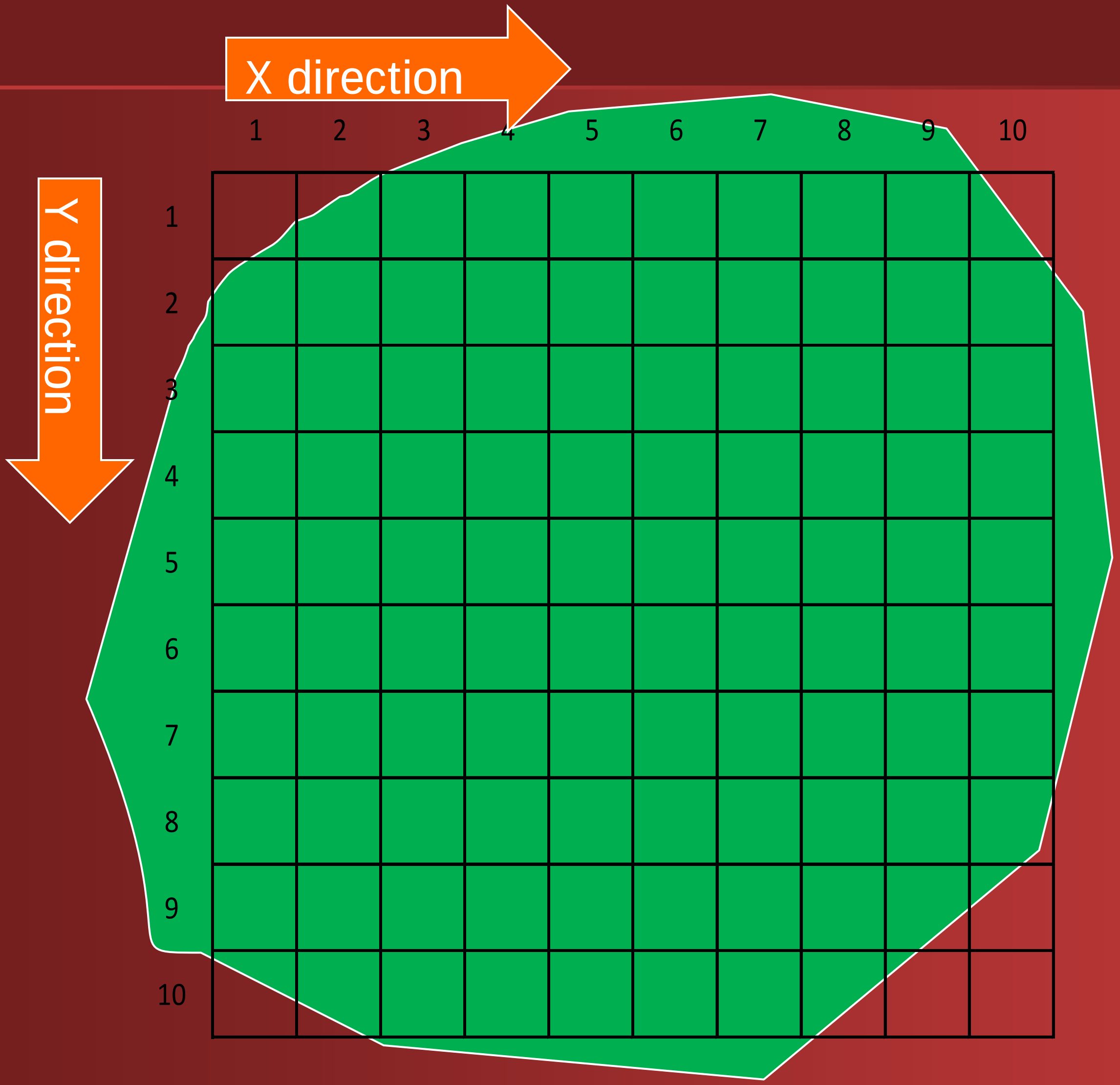
- Graphical presentation of your data across a sizeable surface
- Excellent way to demonstrate management challenges or effects of management to clientele
- Requires graphing software and spatial coordinates (X,Y) or GPS for each data point

Mapping Software

- Many products from Excel to specialized software (dPlot, Surfer, and many others) that interpolates values between data points

- Some meter data can be downloaded into specialized mapping software (SpecMaps)

Collecting Data on a Grid

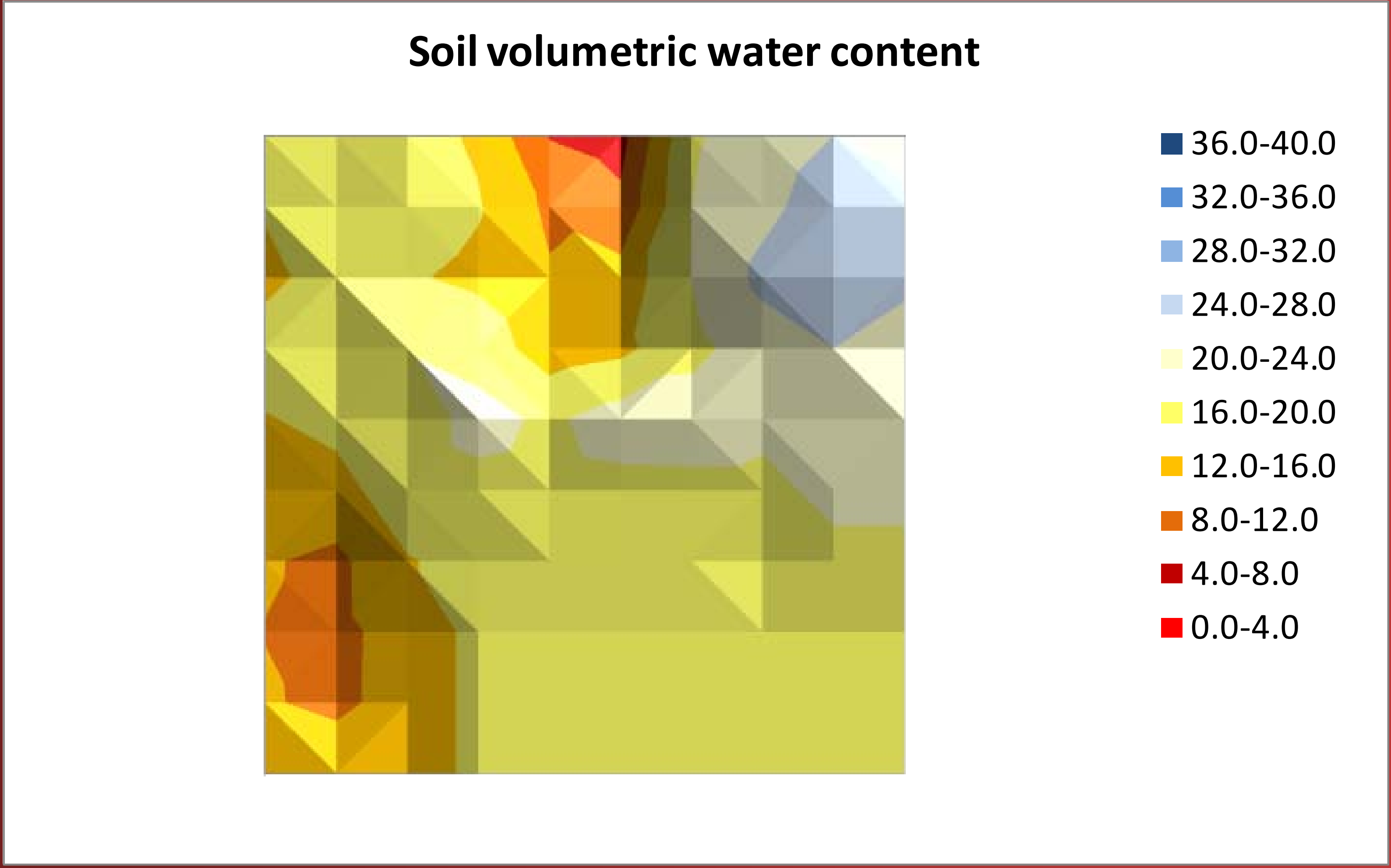


Excel Mapping Template

Raw Soil Moisture Data

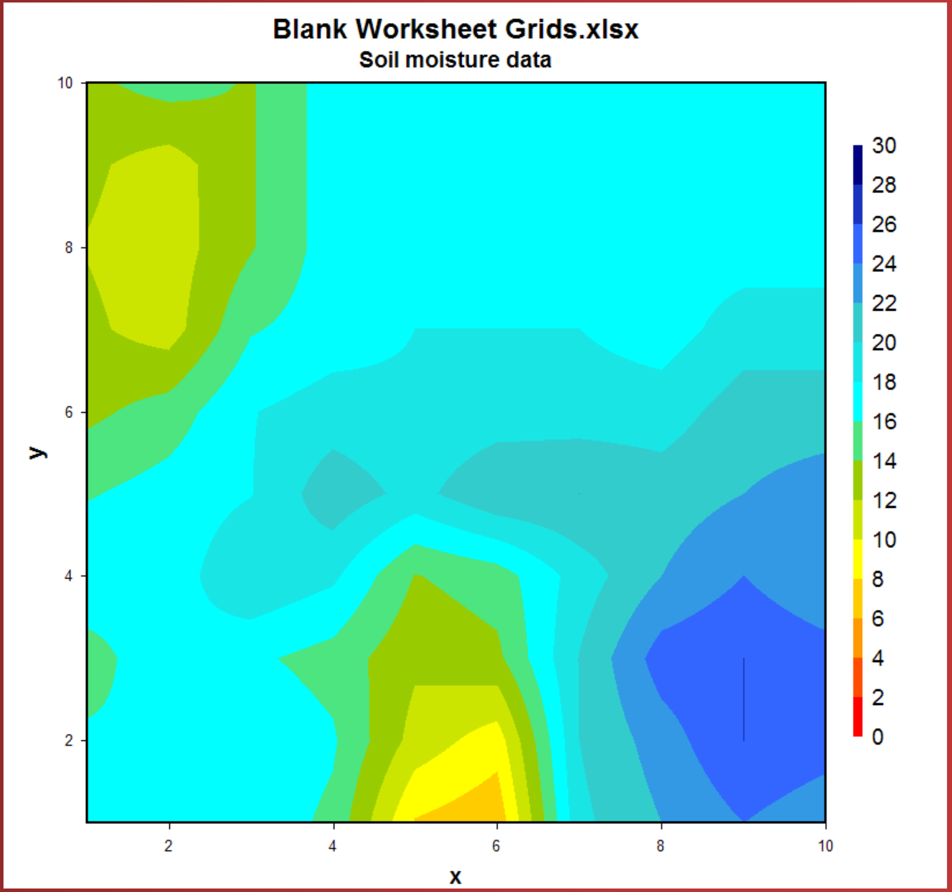
	1	2	3	4	5	6	7	8	9	10
1	17.4	16.4	17.4	15.5	7.8	6.5	19.5	22.0	24.0	22.5
2	16.4	16.4	17.8	16.3	11.2	8.9	20.0	23.0	26.0	25.0
3	14.9	17.9	16.4	15.2	12.4	13.5	20.1	25.0	26.0	25.0
4	17.9	16.9	19.8	18.4	13.9	15.0	18.9	22.0	24.0	22.0
5	15.8	16.9	17.9	21.3	19.3	21.8	22.0	21.0	22.0	23.0
6	13.5	14.9	17.9	18.9	18.4	18.9	19.0	19.0	21.0	21.0
7	12.4	11.0	15.8	17.0	18.0	18.0	18.0	17.0	19.0	19.0
8	11.9	10.9	13.8	17.0	17.0	17.0	17.0	17.0	17.0	17.0
9	12.4	11.0	13.8	17.0	17.0	17.0	17.0	17.0	17.0	17.0
10	13.5	14.9	13.8	17.0	17.0	17.0	17.0	17.0	17.0	17.0

Excel Mapping Template



DPlot Moisture Map

- Add-in feature to work with Excel
- Free version available (DPlot Jr)
- Full version: $70
- www.dplot.com

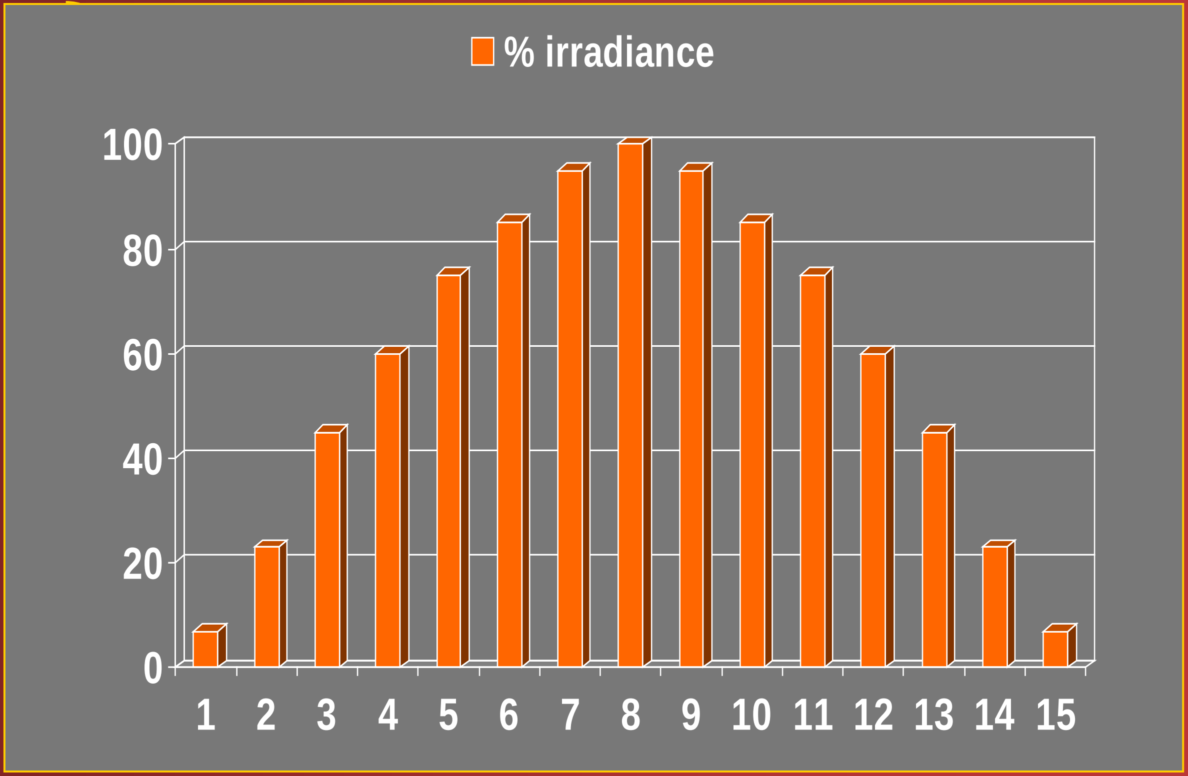


Something new…
daily light integration

How much energy is provided per day to an area in full sun in a 15-h day?

2000 μmol / m² / sec PAR measured at the solar zenith.

- 2 hr @ 7%
- 2 hr @ 23%
- 2 hr @ 45%
- 2 hr @ 60%
- 2 hr @ 75%
- 2 hr @ 85%
- 2 hr @ 95%
- 1 hr @ 100%

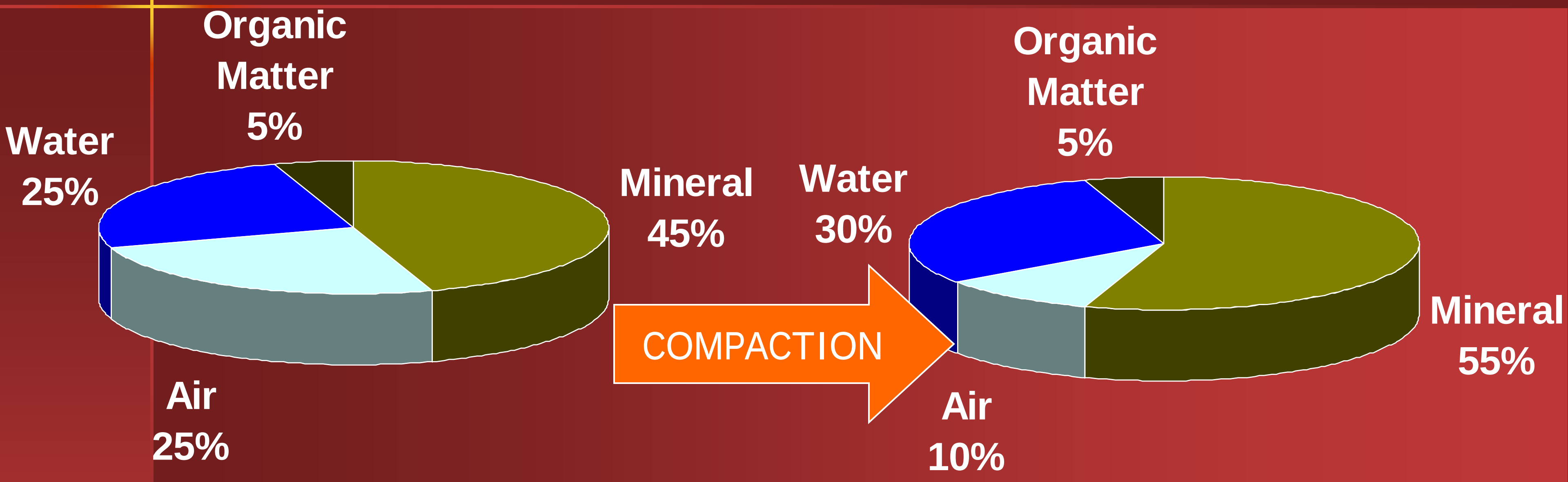


Can you calculate the total energy upon the turf per day ?

Visit the spreadsheet…

Something new…
daily light integration

Soil Compaction



- Compaction reduces air-filled pores and total pore space; may increase water-filled pores.
- Compaction influenced by **traffic, soil moisture, and texture**.
- Measured by **bulk density** (units: grams / cm^3)

Soil Strength

- A transient localized soil property which is a combined measure of adhesive and cohesive status. The ability of the soil to resist shearing or deformation.
  - – Affected by soil moisture and bulk density

Soil Compaction & Surface Strength - equipment

- Compaction (bulk density)
  - Soil probe/cup cutter, oven, and balance
  - Divide oven dry weight (g) by soil core volume (cm^3)
  - *A 3 inch long cup cutter sample has a volume of ~ 700 cm^3; so if its oven dry weight was 1050 g, its bulk density would be 1050 / 700 =* ***1.5 g / cm^3***

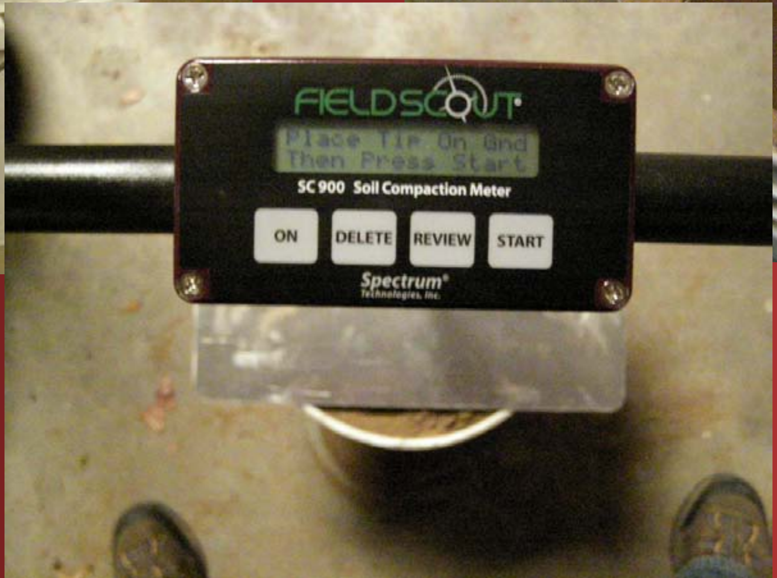
- Soil strength
  - Penetrometer (many models)
  - Accelerometer (Clegg, USGA Tru-Firm)

Penetrometer

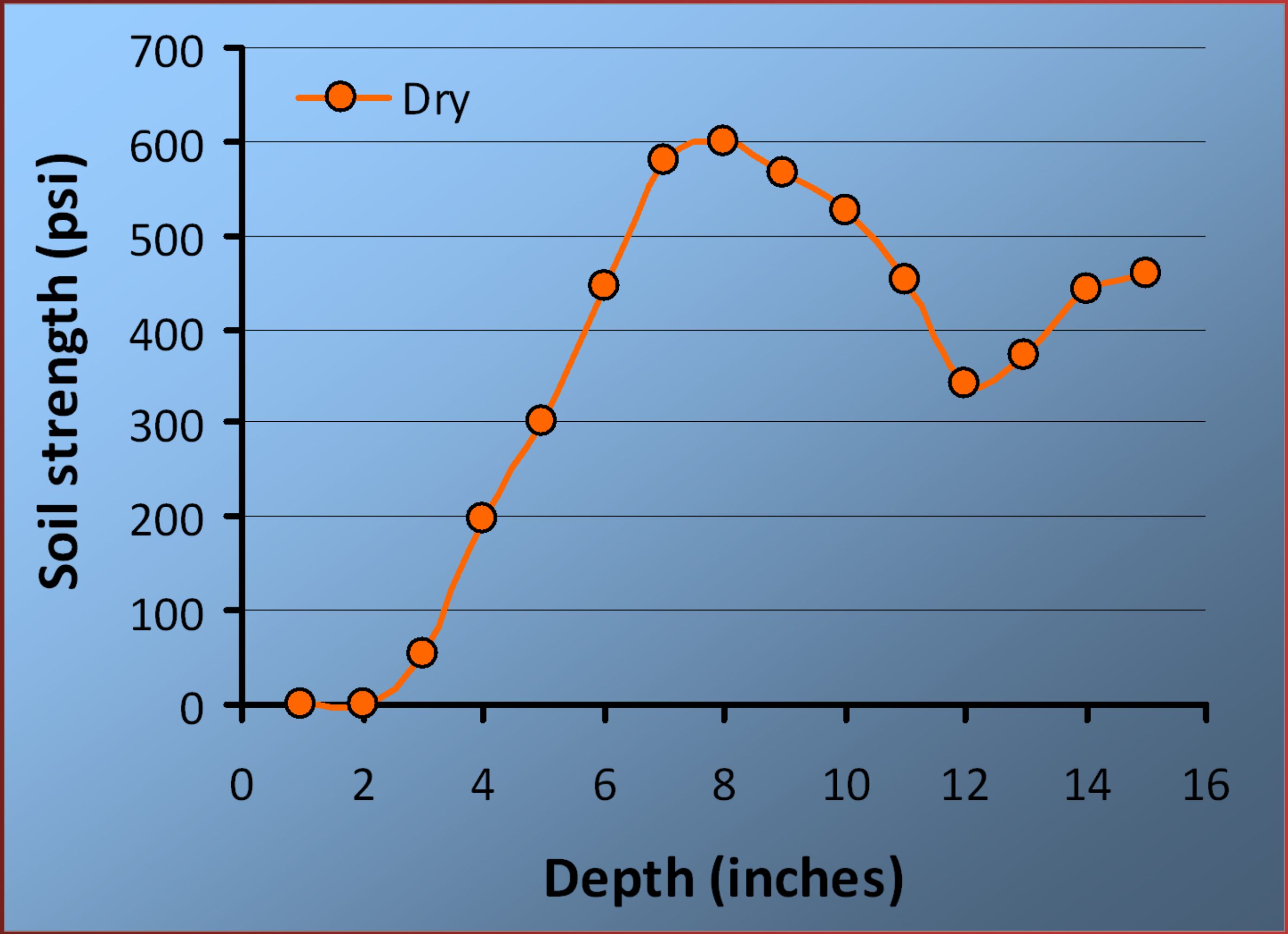
- Measures soil strength
- Affected by soil moisture
- Can measure by depth
- $300 - $1,600


FIELDSCOUT®
0106 PSI 02 IN
N = 1
SC 900 Soil Compaction Meter
ON
DELETE
REVIEW
START
Spectrum®
Technologies, Inc.

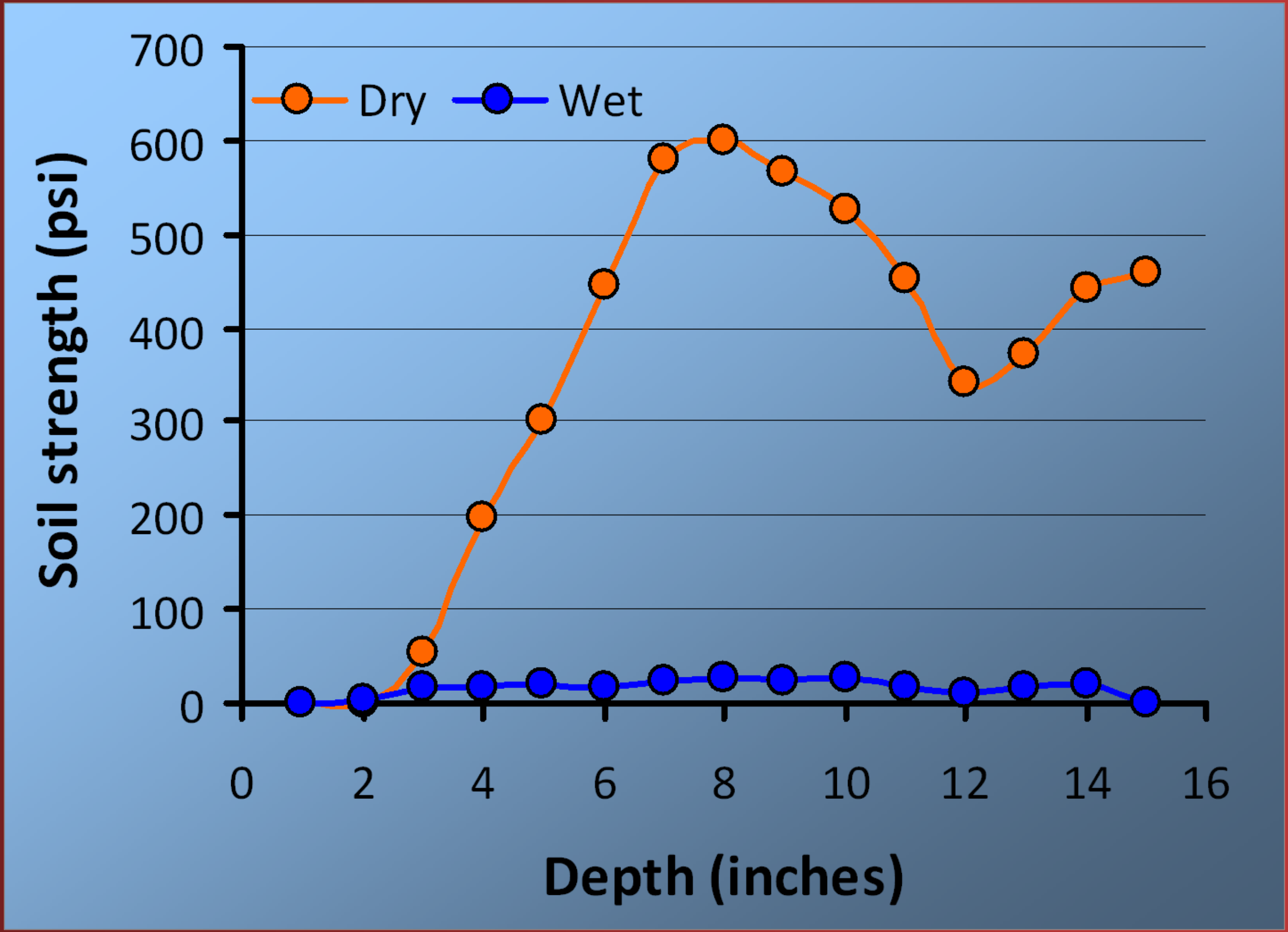
Penetrometer and Soil Moisture



Penetrometer and Soil Moisture



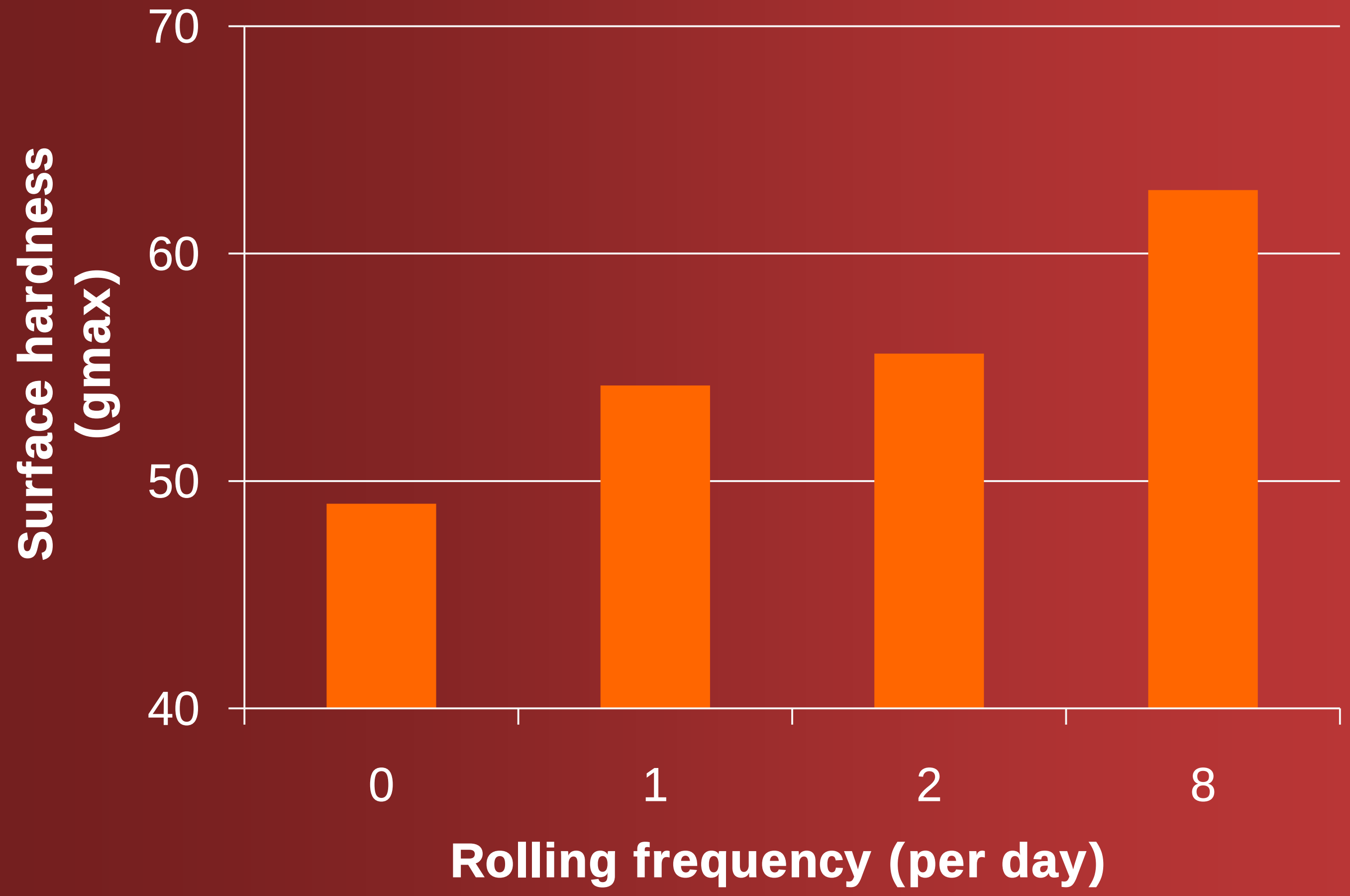
Penetrometer and Soil Moisture



Surface Hardness Measurement Tools

- Clegg Impact Soil Tester
- USGA Tru-Firm

Rolling Frequency Affects Surface Hardness (Clegg)



Clegg Limitations

- Expensive
- Limited knowledge on target values
- Values depend on many factors
  - Moisture, thatch, topdressing, cultivation, etc.

Water Infiltration

- Rate of water movement into the soil (in/hr) or (cm/hr)
- Estimate of compaction & drainage rate
- Measured by Infiltrometer

Infiltrometers

- Highly variable (relative results)
- Variablity improved with:
  - Double rings
  - Larger rings
  - Constant head of water (Mariotte siphon)
  - Multiple measurements*
- Typical infiltration rates:

Soil Type	Infiltration Rate (in/hr)
USGA sand	>6
Native sand	> 1.5
Sandy loam	0.75 - 1.5
Loam	0.5 - 0.75
Clay loam	0.25 - 0.5
Clay	0 - 0.25

Surface Strength Equipment - how to use

- Correlate values to desirable firmness (optimal shot holding characteristics)
- Monitor OM accumulation
- Monitor compaction
- Monitor effectiveness of cultivation
  - Use before vs. after data to demonstrate importance of regular core aerification

Sand Texture Measurement

- Relative proportion of sand sample (by weight) that is:
  - Gravel (> 2.0 mm)
  - Very coarse sand (1.0 – 2.0 mm)
  - Coarse sand (0.5 – 1.0 mm)
  - Medium sand (0.25 – 1.0 mm)
  - Fine sand (0.15 – 0.25 mm)
  - Very fine sand (0.05 – 0.15 mm)
  - Silt and clay (< 0.05 mm)

All Sands Are Not Equal

- USGA rootzone sand is mostly (>60%) medium and coarse sand (0.25 – 1.0 mm)
- Must have little fine or very coarse material

USGA Sand Specifications

Class	Particle Diameter	Recommendation (by weight)	
Fine gravel	2.0 – 3.4 mm	Not more than 10 % ; maximum 3% fine gravel	
Very coarse sand	1.0 – 2.0 mm		
Coarse sand	0.5 – 1.0 mm	Minimum of 60%	
Medium sand	0.25 – 0.5 mm		
Fine sand	0.15 – 0.25 mm	Not more than 20%	
Very fine sand	0.05 – 0.15 mm	Not more than 5%	Not more than 10%
Silt	0.002 – 0.05 mm	Not more than 5%	
Clay	< 0.002 mm	Not more than 3%	

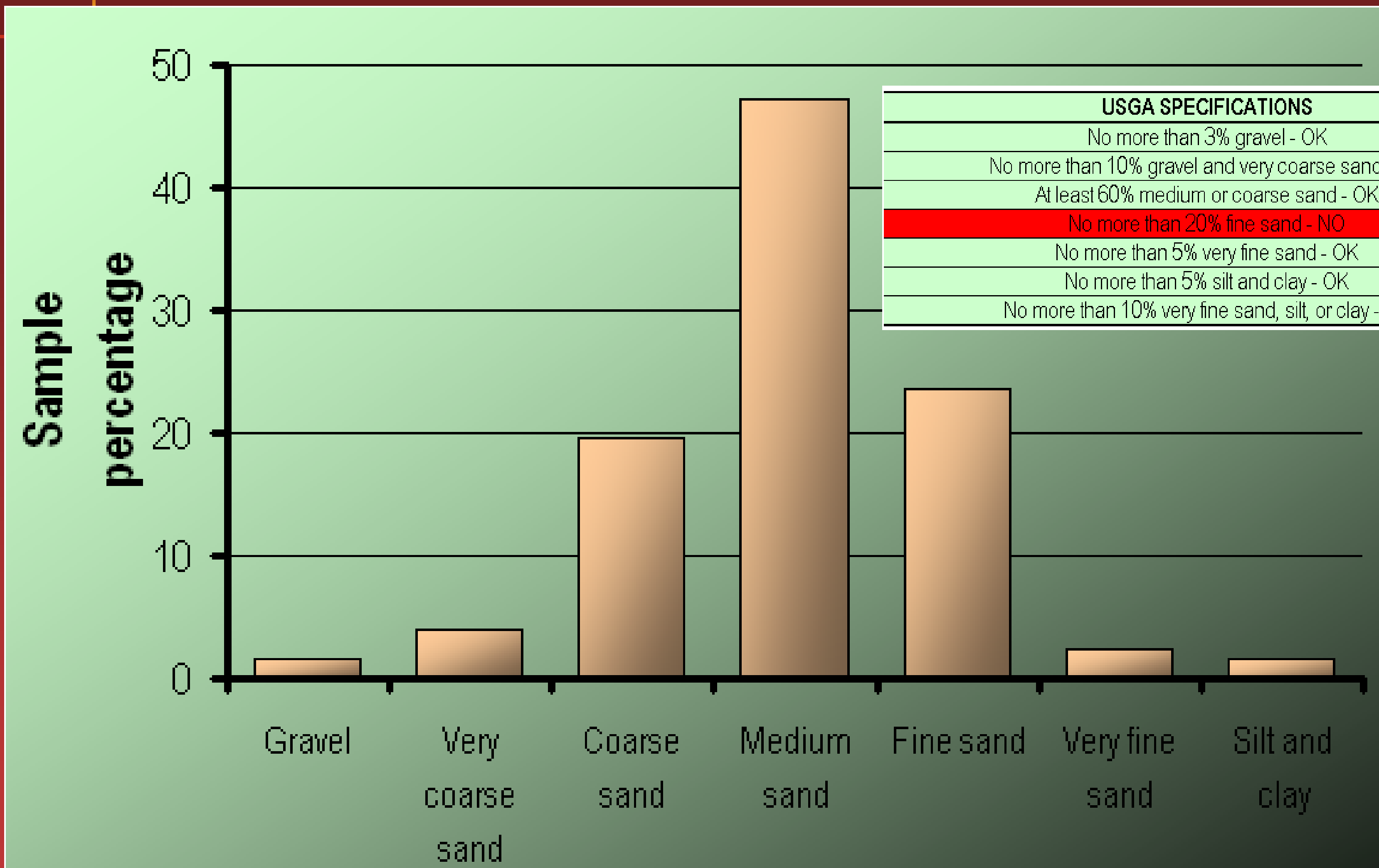
Sand Texture -equipment

- Nest of sieves
  - One sieve per particle size categ
  - Larger diameter sieves
    - More accurate
    - More expensive
    - Require specialized shaker

Sand Sieves - how to use

- Preliminary screen of potential sand and gravel sources
  - Bridging and permeability factors
  - Stability (uniform sands are poor)
- Quality control
  - Topdressing sand should match rootzone sand

Sand Sieve Analysis



USGA SPECIFICATIONS
No more than 3% gravel - OK
No more than 10% gravel and very coarse sand - OK
At least 60% medium or coarse sand - OK
No more than 20% fine sand - NO
No more than 5% very fine sand - OK
No more than 5% silt and clay - OK
No more than 10% very fine sand, silt, or clay - OK

Soil Salinity

- the quantity of mineral salts found in a soil

Cations (+)	Anions (-)
Na^{+1}	Cl^{-1}
Ca^{+2}	SO_4^{-2}
Mg^{+2}	CO_3^{-2}
K^{+1}	HCO_3^{-1}

Increasing soil salinity decreases the soil water potential (becomes more negative), which decreases plant available water.

$$\Psi_t = \Psi_g + \Psi_p + \Psi_o + \ldots$$

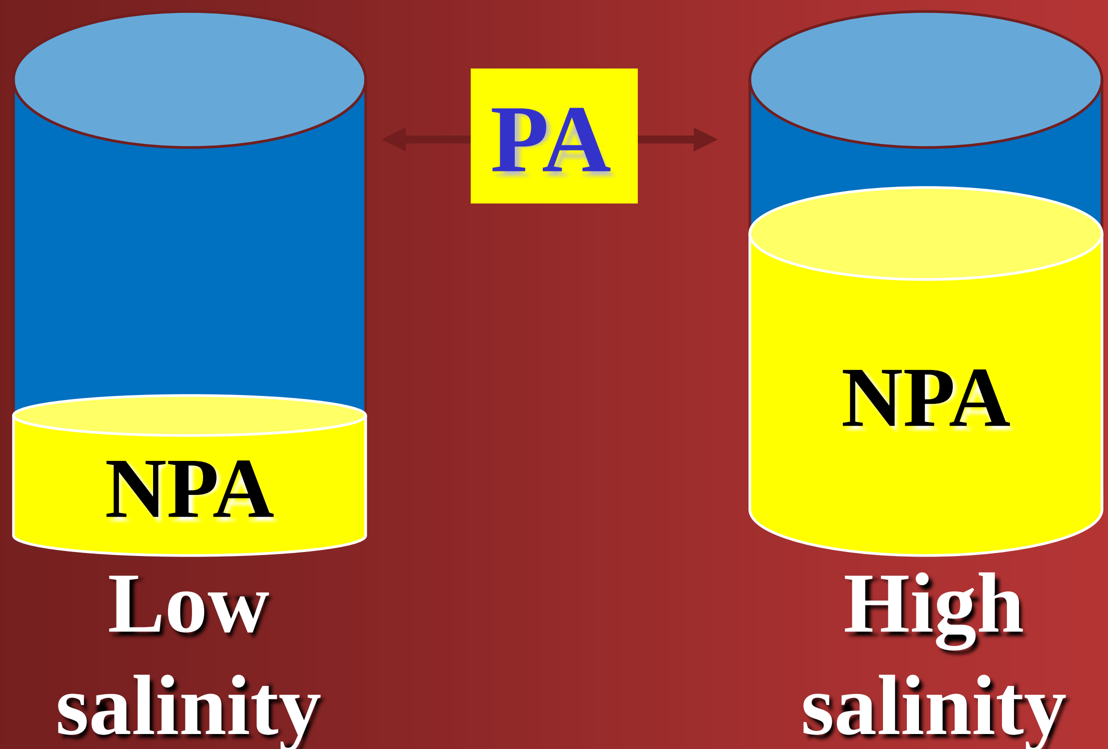
where

Ψ_t = total soil water potential

Ψ_g = gravitational potential

Ψ_p = pressure (matric) potential

Ψ_o = osmotic potential



Soil Salinity Measurement

- Electrical conductivity (EC) of soil/water slurry (1:2) measured in the lab
  - salty water is a good conductor of electrical current
  - units: deciSiemens per meter (dS/m) and millimhos per cm (mmho/cm) most common
  - this is an estimate of the total dissolved salts (TDS) in the solution
    - 1 dS/m ≈ 640 ppm TDS
  - EC below 2-4 dS/m is desirable

EC / TDS Conversions

Conversion factors

To convert from:	To:	Multiply by:
µ S/cm	mS/cm	0.001 (or divide by 1000)
mS/cm	µ S/cm	1000
µ S/cm	dS/m	0.001 (or divide by 1000)
dS/m	µ S/cm	1000
mS/cm	dS/m	1 (i.e. they are the same)
µ S/cm	ppm or mg/L	0.6 (approximately)
mS/cm	ppm or mg/L	600 (approximately)
dS/m	ppm or mg/L	600 (approximately)

1 mmho / cm = 1 dS/m
1 mmho / cm = 1000 µmho / cm

Soil Salinity Measurement
- EC measurement in the field

- Probes only measure the soil solution
- Values decrease as soils dry
- Measure at standard water content
  - – i.e. 30 min. following heavy irrigation
- Values not comparable to lab values



Hand-held microscopes

Hand-held microscopes

Applications

- Pest identification
- Mower quality assessment
- Sand analysis

Illuminated hand-lenses

Stress-detection glasses

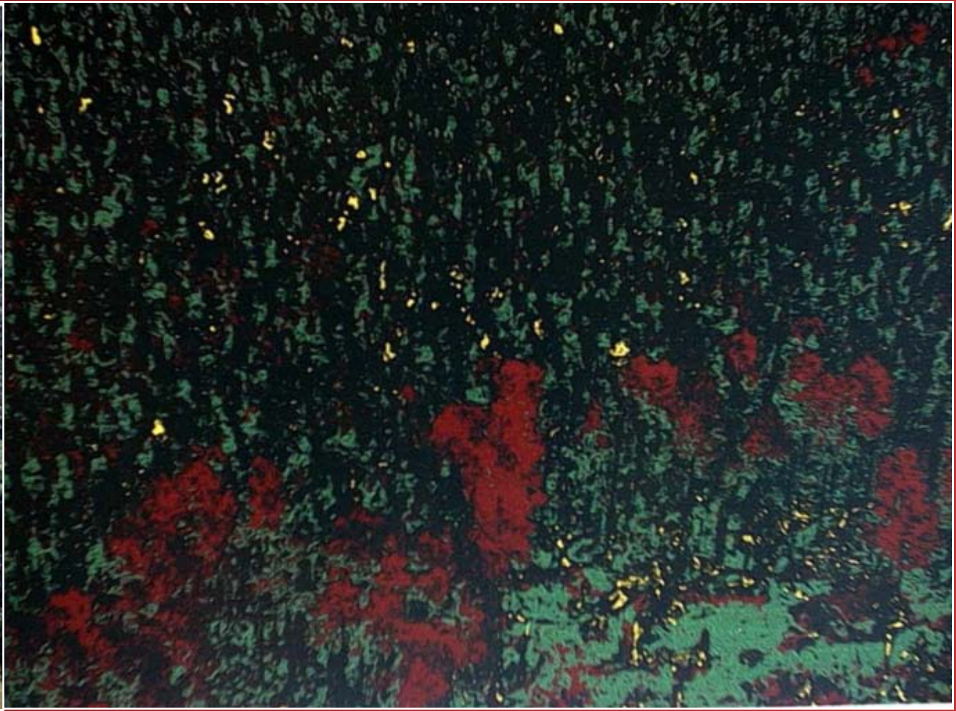
Best used in conjunction with a magnetic, reverse-ionization, copper-tungsten bracelet...

Stress-detection glasses

How they work…

- Block out green wavelengths, making anything with chlorophyll appear gray or black
- Anything with reduced chlorophyll will appear as red or orange against black

How they work…



Normal view of stressed pines

View of stressed pines through glasses

ENVIRONMENTAL MEASUREMENT

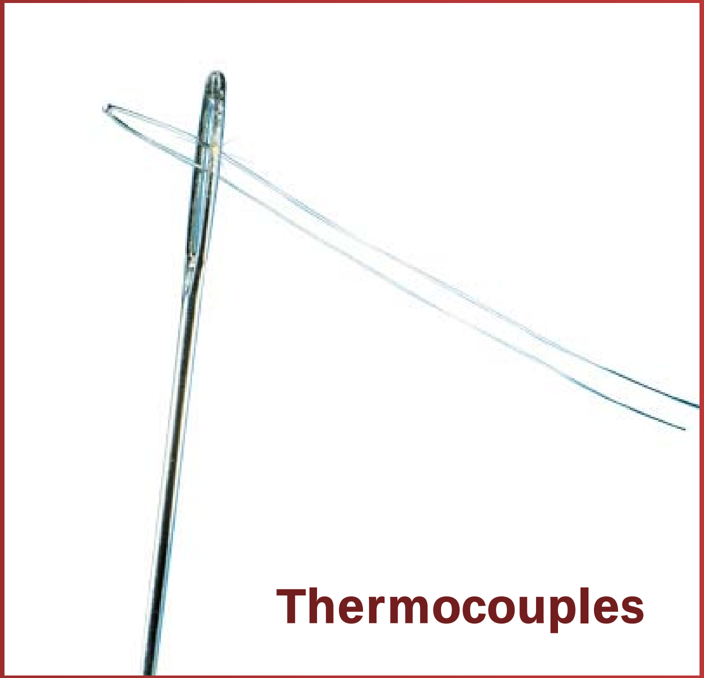
- Temperature
- Light
- Wind

Temperature measurement


Liquid-expansion


Bi-mettalic
250
300
200
150
100
50
500
°F


Infrared
INFRARED THERMOMETER
CAUTION
LASER RADIATION - DO NOT STARE INTO BEAM
OUTPUT < 1mW AT 630 - 670nm
CLASS II LASER PRODUCT


Thermocouples

Fluid-expansion and bi-metallic thermometers

- Advantages:
  - cheap
  - no power required
  - Accurate – especially fluid expansion
- Disadvantages:
  - not easy to transmit or record the data

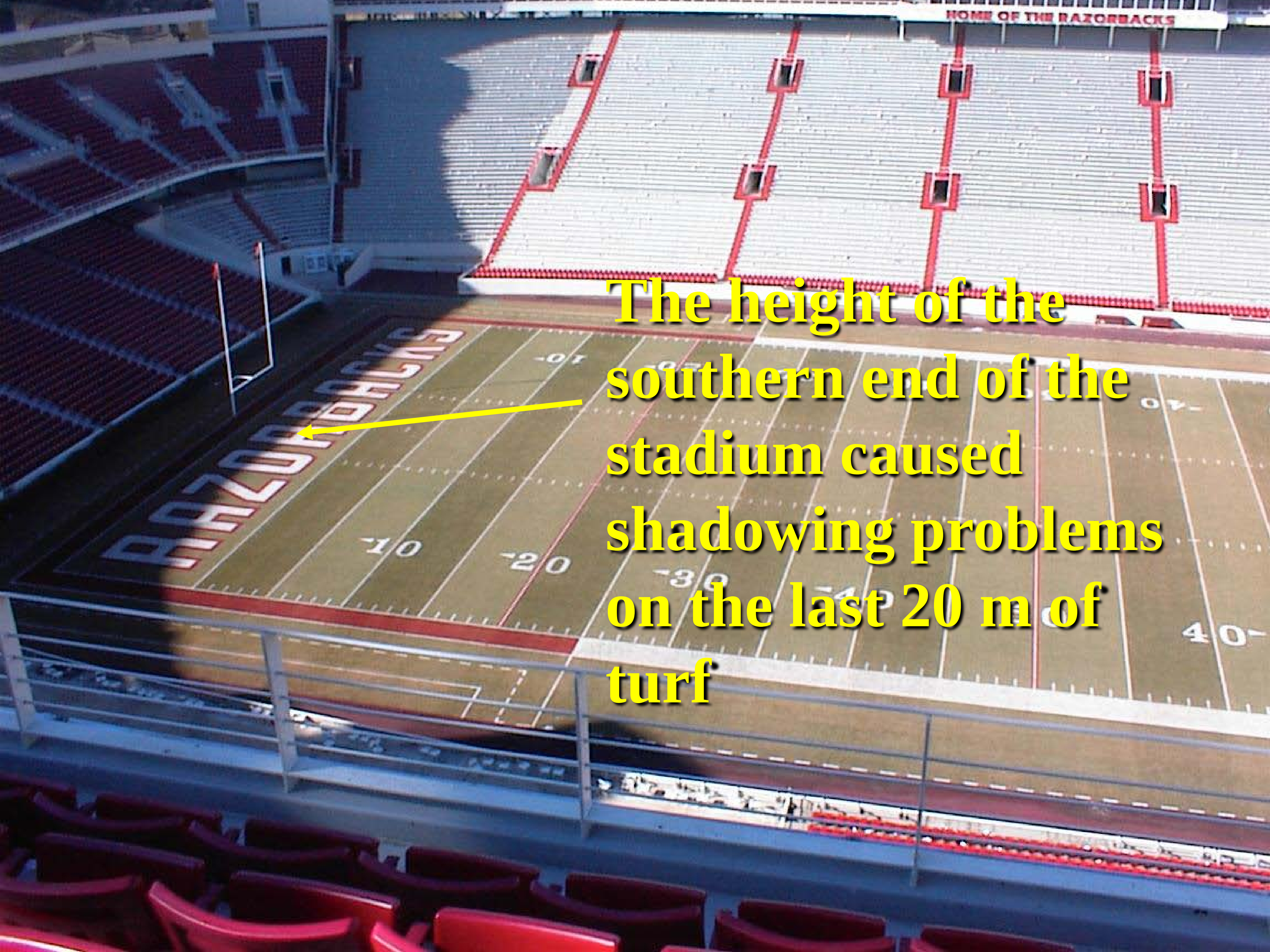
Thermocouples

- Measure the thermoelectric voltage between two metals which are attached at one end
- Advantages:
  - Simple and rugged
  - Data is easy to capture
  - Relatively inexpensive - ~$80
- Disadvantages:
  - Slightly more expensive than other methods

HOBO Temperature loggers

- Measure and record up to 8,000 temperature readings
- Sampling interval will dictate length of data collection
  - Minimum - 0.5 seconds (1.1 hours)
  - Maximum - 9 hours (8.2 years)
  - 1 hour (333 days); 30 min. (166 days)
- programmable start time/date
- retains data even if battery fails
- NOT weatherproof, but can be stored in a water-proof container

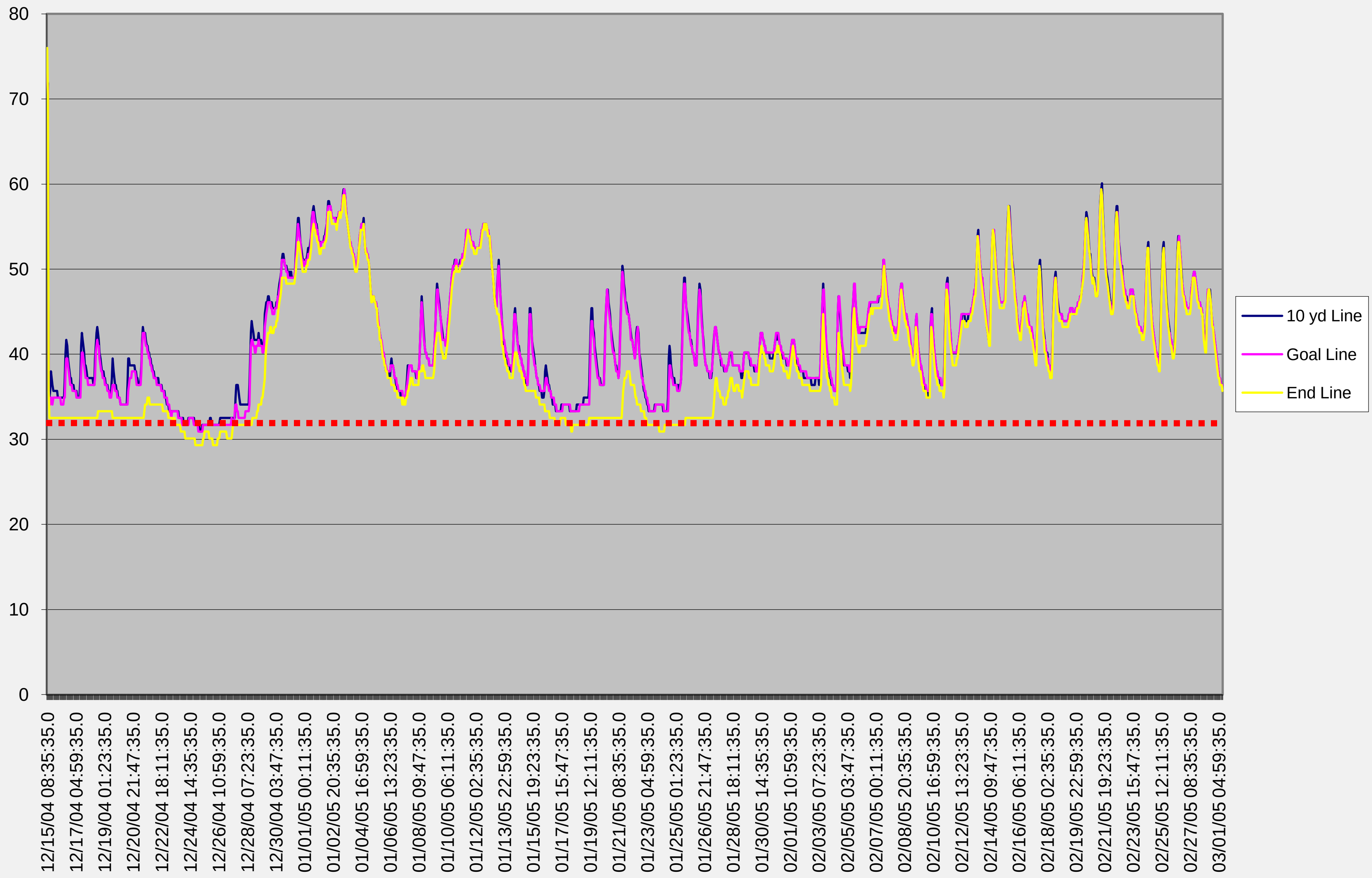
Installing a temperature logger

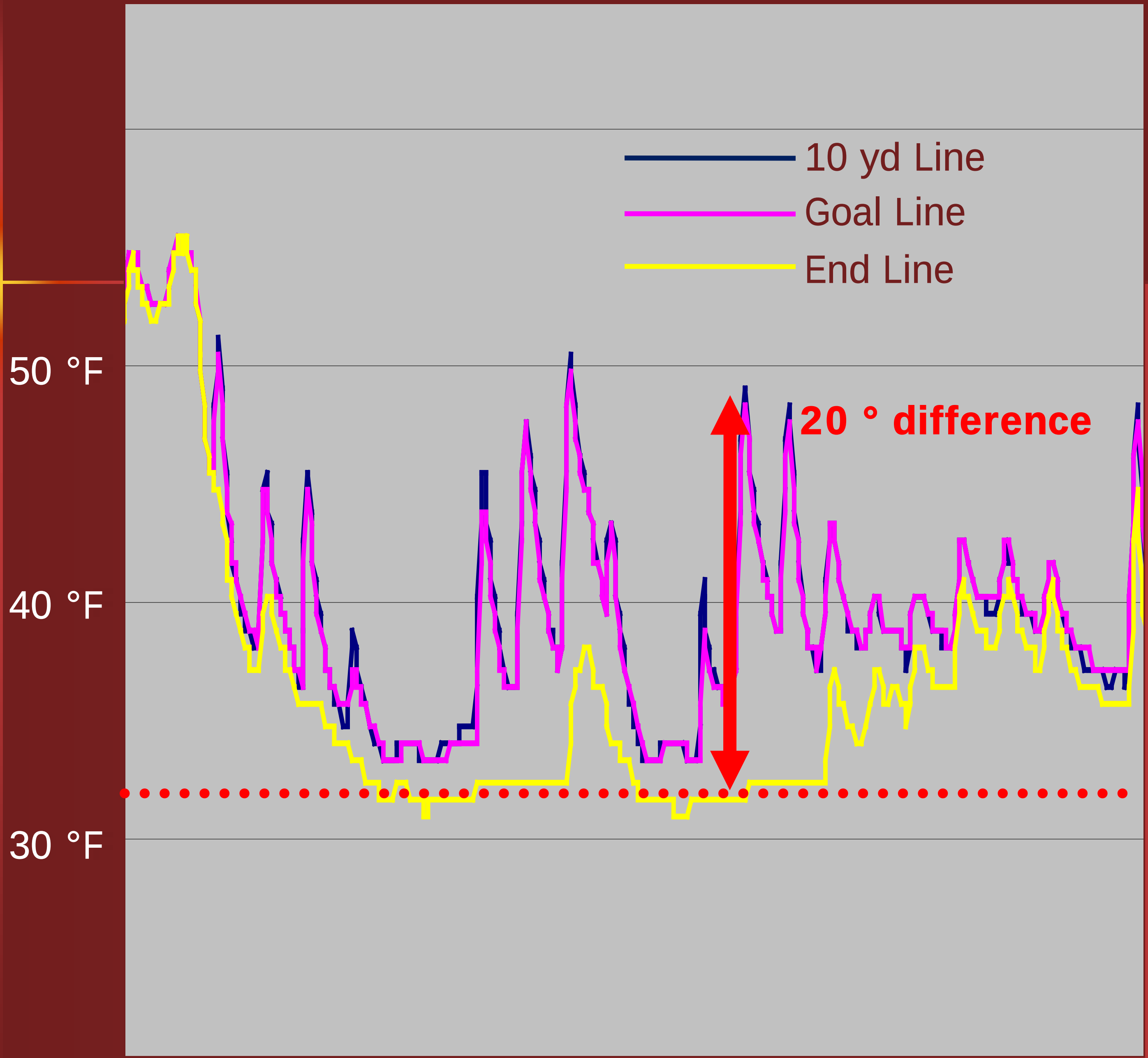

HOME OF THE RAZORBACKS
RAZORBACKS
The height of the southern end of the stadium caused shadowing problems on the last 20 m of turf

Reduced light led to longer durations of cold temperatures during the winter

Winterkill in south end zone -Spring, 2002 (associated with stadium expansion)

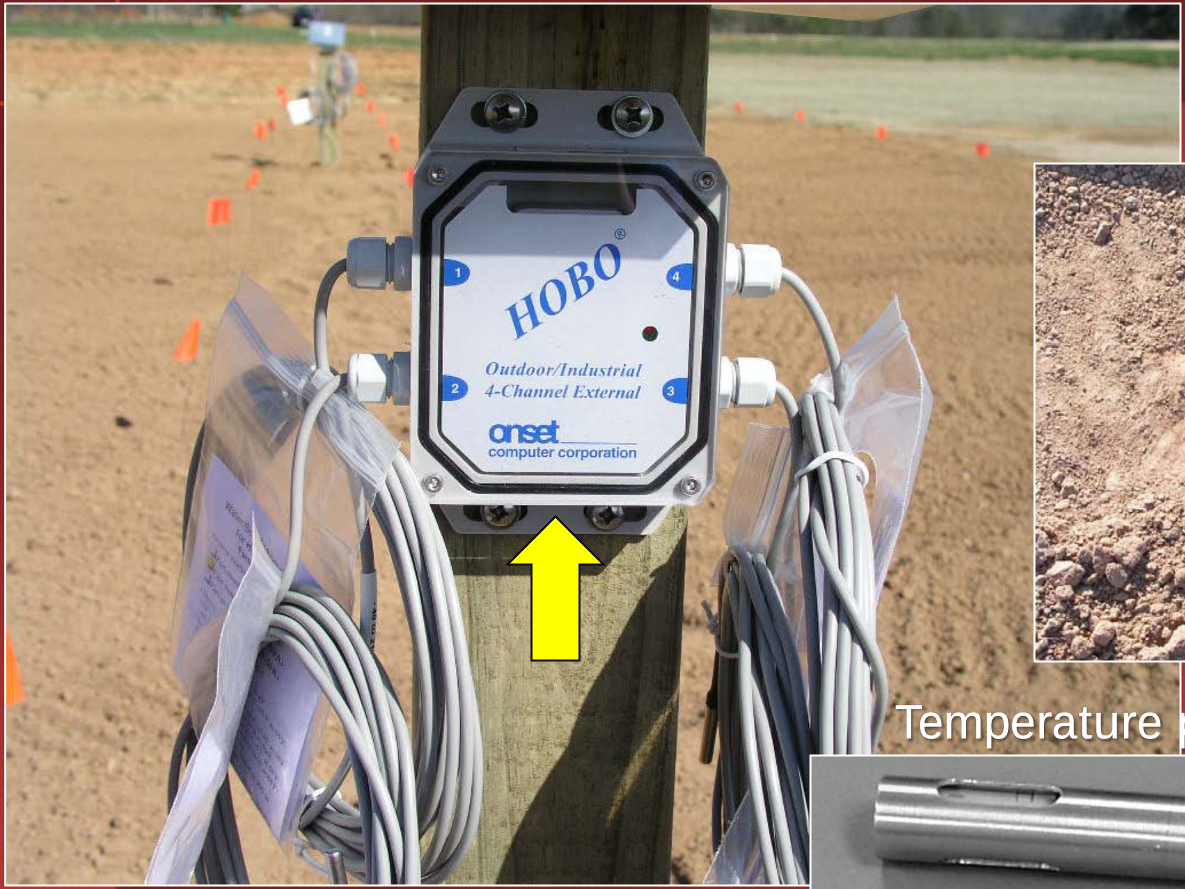

HOME OF THE RAZORBACKS
ARKANSAS
RAZORBACKS
10 yd Line
Goal Line
End Line


80
70
60
50
40
30
20
10
0
12/15/04 08:35:35.0
12/17/04 04:59:35.0
12/19/04 01:23:35.0
12/20/04 21:47:35.0
12/22/04 18:11:35.0
12/24/04 14:35:35.0
12/26/04 10:59:35.0
12/28/04 07:23:35.0
12/30/04 03:47:35.0
01/01/05 00:11:35.0
01/02/05 20:35:35.0
01/04/05 16:59:35.0
01/06/05 13:23:35.0
01/08/05 09:47:35.0
01/10/05 06:11:35.0
01/12/05 02:35:35.0
01/13/05 22:59:35.0
01/15/05 19:23:35.0
01/17/05 15:47:35.0
01/19/05 12:11:35.0
01/21/05 08:35:35.0
01/23/05 04:59:35.0
01/25/05 01:23:35.0
01/26/05 21:47:35.0
01/28/05 18:11:35.0
01/30/05 14:35:35.0
02/01/05 10:59:35.0
02/03/05 07:23:35.0
02/05/05 03:47:35.0
02/07/05 00:11:35.0
02/08/05 20:35:35.0
02/10/05 16:59:35.0
02/12/05 13:23:35.0
02/14/05 09:47:35.0
02/16/05 06:11:35.0
02/18/05 02:35:35.0
02/19/05 22:59:35.0
02/21/05 19:23:35.0
02/23/05 15:47:35.0
02/25/05 12:11:35.0
02/27/05 08:35:35.0
03/01/05 04:59:35.0
10 yd Line
Goal Line
End Line



10 yd Line
Goal Line
End Line
20 ° difference
50 °F
40 °F
30 °F

Multi-channel data-loggers can be helpful if different readings are needed in close proximity

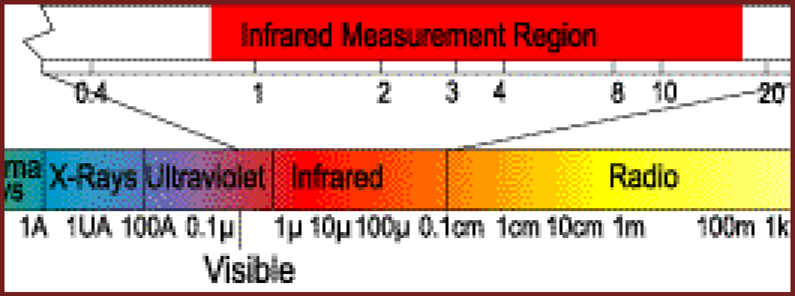


Temperature probe with leads up to 50 ft

4- channel logger - <$200
Probes - ~$50 each

Temperature data can be down-loaded without removing sensors

Infrared Thermometer



- Measure the radiation emitted from an object (non-contact thermometer)
- Advantages:
  - Quick and easy
  - Relatively inexpensive
- Disadvantages:
  - Measurements are not “stable”
  - Not easy to transmit or record the data

Applications of an infrared thermometer

Surface (canopy) temperature measurements

- Synthetic turf temperature measurements
- Effects of syringing on surface temperature
- Effects of chemical application on transpiration

Weather stations

Weather stations

- Numerous sensors available for stations
- Wireless transmission of data to computer
- Degree-day models for disease and insect forecasting available
- Can calculate daily ET values

Basic systems cost between $800-$2000

Wireless transmission of data from station to computer

Short Range Wireless (up to 1,000 feet) - ~$600

Mid Range Wireless (up to 2 miles) - ~$1200

Long Range Wireless - Cellular Modem - ~$1500

Sensors available for the WatchDog Station

~$40

External (Soil) Temperature Sensor

Measure soil, air or water temperature with this durable and accurate temperature sensor.

~$60

Temperature (Micro) Sensor

Measure surface temperature of leaves and other applications with this micro-sensor.

~$500

IR Temperature Sensors

Monitor your plant health by measuring IR temperature with the new Infrared Temperature Sensors. Available in two models with 4:1 field of view (5cm at 20cm).

~$60

Watermark Soil Moisture Sensor

The Watermark Soil Moisture Sensor to pinpoint soil moisture levels and trends affordably. Easy to install. No maintenance required.

~$200

Soil Moisture Transducer

Turn your tensiometer into a soil moisture data logger with this transducer unit.

~$100

Leaf Wetness Sensor

Designed to emulate the surface of a leaf, this leaf wetness sensor tracks wetness periods which lead to plant disease.

~$220

Quantum Light Sensor

Capture radiation between 400 and 700 nanometers (nm) to calculate daily light integral with this Quantum Light sensor.

~$350

6 Sensor Quantum Bar

Six cosine corrected Quantum sensors average their readings to minimize the effects of small shadows such as below a canopy or in a greenhouse.

~$250

UV Light Sensor

Spectrum's UV Light Sensor captures critical ultraviolet radiation between 250-400 nanometers (nm) to calculate daily light integral with this UV sensor.

~$250

Silicon Pyranometer Sensor

Capture solar radiation between 300 and 1000 nanometers (nm) to calculate daily light integral with this pyranometer sensor.

~$625

CO2 Monitor

Use as portable unit or with WatchDog data logger.

~$200

Barometric Pressure Sensor

Records barometric pressure in metric (mm) or U.S. (inches) of Hg.

Disease / insect models

Cost - ~$100 / pest

Brown Patch

SpecWare will indicate specific infection events for the onset of **Rhyzoctonia Brown Patch** in turf. (Schumann, Clarke, Rowley, and Burpee 1994)

Rhyzoctonia Brown Patch

Select Report | Where and When | Options | Forecast | View Report

Date	Soil Temp Low	Soil Temp Mean	Air Temp Low	Air Temp Mean	RH>95 Hours	Rain Fall	Infection Warning
08/23	65.6	74.7	64.9	71.5	3.5	0.39	5 RH>95% for < 10 hours
08/24	63.5	68.1	63.5	68.3	14.0	1.51	4
08/25	64.9	68.2	65.6	69.0	11.0	0.56	5 Mean Soil Temp below 70
08/26	60.8	71.2	61.5	72.3	0.0	0.01	3
08/27	60.8	72.8	60.1	75.5	6.5	0.00	3
08/28	66.3	76.0	65.6	78.9	6.3	0.00	4

Infection Warning Thresholds:
- Soil Temperature Mean above 70
- Soil Temperature Low above 64
- Air Temperature Mean above 68
- Air Temperature Low above 59
  - If below 59 in the next 48 hours, Warning is canceled
- Relative Humidity > 95% for at least 10 hours
- Rainfall of at least 0.1 inches

Write Text File | Print | Copy to Clipboard | Exit

The **Brown Patch** model requires **air temperature**, **soil temperature**, **relative humidity**, and **rainfall** data.

Dollar Spot

SpecWare will indicate specific infection events for the onset of **Sclerotinia Dollar Spot** in turf. The software includes two **Dollar Spot** models:

Hall Model (Hall 1984)
Mills/Rothwell Model (Mills and Rothwell 1982)

Sclerotinia Dollar Spot

Select Report | Where and When | Options | Forecast | View Report

Date	Temperature High	Temperature Mean	RH High	Rain Fall	Hall Model	Mills/Rothwell Model
07/19	92.5	78.8	99.5	0.25	Infection	Infection
07/20	88.1	77.8	100.0	0.61	Infection	Infection
07/21	97.1	82.2	100.0	0.02	Infection	Infection
07/22	99.5	83.5	98.7	0.09	Infection	Infection
07/23	96.4	82.6	99.5	0.28	Infection	Infection
07/24	97.1	82.4	99.5	0.00		Infection
07/25	97.9	85.4	98.7	0.00		Infection
07/26	88.8	78.7	96.2	0.00		Infection

Hall Model Infection Warning Thresholds:
- Mean Temperature above 72 with Rain for two days, or
- Mean Temperature above 64 with Rain for three days

Mills/Rothwell Model Infection Warning Thresholds:
- High Temperature above 77 with RH above 90% any three days in seven

Write Text File | Print | Copy to Clipboard | Exit

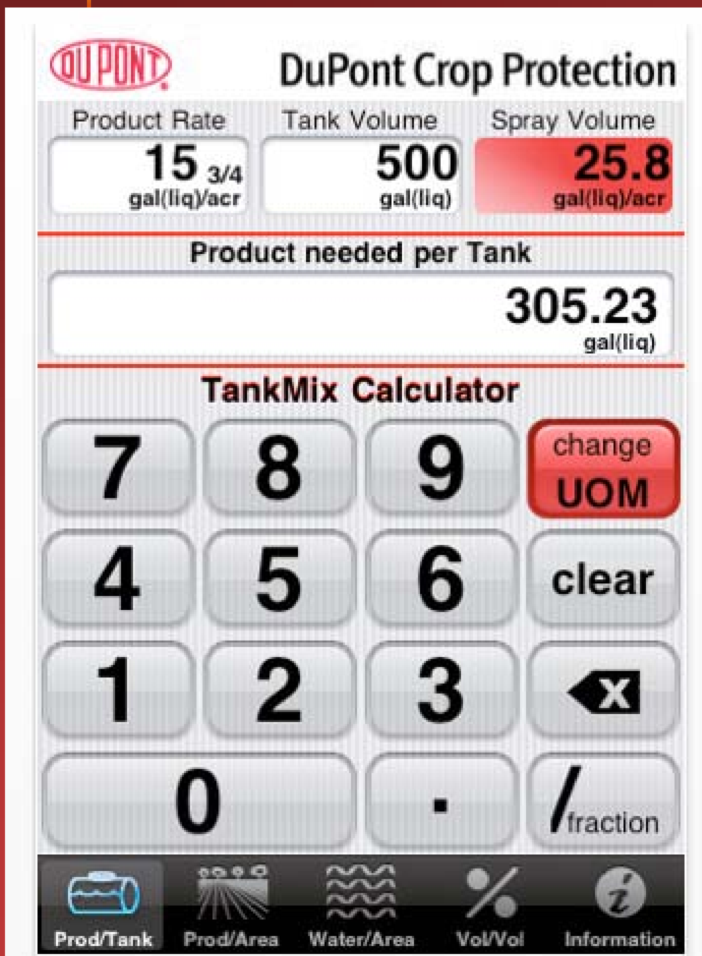
The **Dollar Spot** model requires **air temperature**, **relative humidity**, and **rainfall** data.

Phone apps

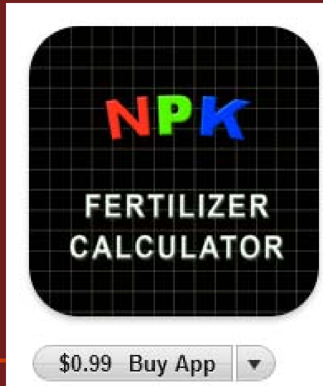
Turfgrass Management
Univ. of Georgia

- App – Free, but requires a $20/year subscription for all content
- Contains image sets for major grasses and pests
- Makes recommendations for control

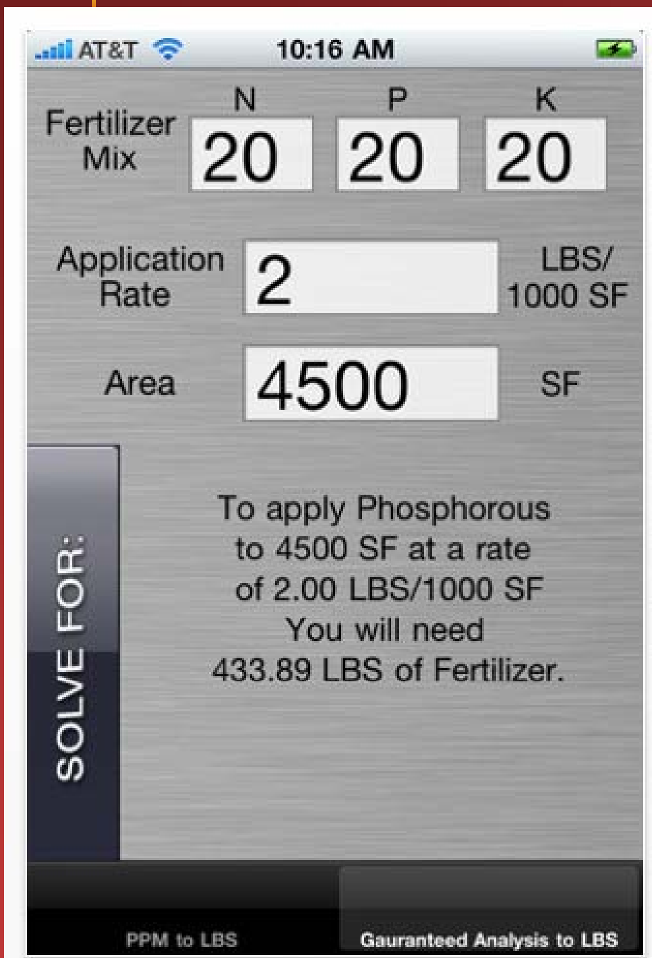
Tankmix - Dupont



- Calculates various components of spray mixes such as:
  - Product to add to tank
  - Product needed for a given area
  - Water needed to cover a given area



Fertilizer calculator



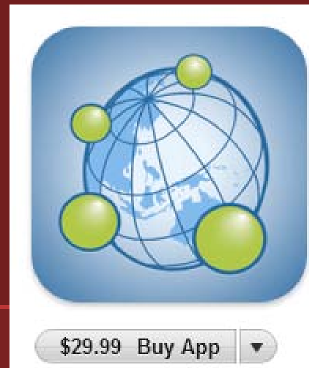
- Calculate total fertilizer needs for a given project
- Can calculate based on N, P, or K

Sun Seeker

- Uses the GPS locator of the Iphone
- Provides a site-specific display of sun patterns for each hour of the day
- Can also generate patterns for future dates

I-Pad

I-Phone



I-GIS

- Download GIS data to your Iphone or Ipad and create layered GIS maps for use in the field
- Can layer data onto aerial photos, topo maps, etc.

Clinometer

- Determine slope of a flat plain (such as a skinned area)
- Use to measure slope on any surface (such as a pitching mound)