SMART Irrigation Controllers

How smart are they?

Loren Oki

Dept. of Plant Sciences and
Dept. Human Ecology
UC Davis

Get A Grip On Drip
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University of California
Agriculture and Natural Resources

UC DAVIS
UNIVERSITY OF CALIFORNIA

Topics

- Irrigation objectives
- What are SMART controllers?
- Types of SMART controllers
- How do they work?

What I won't cover:

- Which ones are recommended by the University of California?
- Which are the "good" ones?

Manufacturers

(of controllers with 20 stations or fewer)

- Brilliant Technologies
- Cyber-Rain
- Desert Irrigation
- H20
- Hunter
- HydroPoint
- Hydro-Rain
- Irritrol
- Nxeco
- OnPoint
- Orbit
- Rachio
- Rain Bird
- Raindrip
- RainMachine
- RainMaster
- RainPal
- Signature
- SkyDrop
- Toro
- Weathermatic

https://www.epa.gov/sites/production/files/2017-02/watersenses-labeled-products.xlsx

Learning Objectives

Focus on how SMART controllers work

- Show you the different types of controllers
- Provide you with knowledge to understand how they are designed
- Features that are good and some not so good

Irrigation Objectives

Maximize water use efficiency

- Apply the amount the plants need
  - How much
- Use an optimized schedule
  - When

What are SMART controllers?

"Smart sensors and controllers monitor weather and other site conditions and adjust the irrigation system to apply just the right amount of water at just the right time."

Irrigation Association

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Irrigation Association

Types of SMART controllers

What do they monitor?

- Weather
- Soil moisture

Weather-Based Irrigation Controllers

- How to determine
  - How much to apply
  - When to apply

Irrigation Objectives

What SMART controllers calculate

Information needed to determine:

- Valve run time (how much):
  - Depth to wet
  - PAW- plant available water
  - DU- Distribution Uniformity
  - PR- Precipitation (application) Rate
- When to irrigate (when):
  - K_L- Landscape Coefficient
  - ET_0- Reference ET

Weather-Based Irrigation Controllers

- How to determine how much to apply
  - Need to know:
    - Depth to wet
    - Soil type
      - PAW- Plant Available Water
      - Info sources:
        - Reference tables
        - SoilWeb
          - PC, iPhone, Google Play

Soil Information

Depth to wet (in.): 12

Soil Texture		Infiltration- mid rate* (in./hr)	Plant Avail Water- mid**	Irrig to wet to depth (in)†
Coarse	sand / fine sand	2.25	0.05	0.3
	loamy sand	1.5	0.07	0.42
Moderately Coarse	sandy loam	1	0.11	0.66
Medium	loam	0.5	0.16	0.96
	silty loam	0.33	0.20	1.2
	silt	0.4	0.20	1.2
Moderately Fine	sandy clay loam	0.2	0.15	0.9
	clay loam	0.16	0.16	0.96
	silty clay loam	0.09	0.18	1.08
Fine	sandy clay	0.14	0.12	0.72
	silty clay	0.1	0.15	0.9
	clay	0.08	0.14	0.84

*Also known as intake rate. Mid values in the range.

**IA Landscape Irrigation Auditor Manual page 177. Mid value in the range.

†assume 50% dry down (management allowable depletion)

Weather-Based Irrigation Controllers

- Determine how much to apply

Amount to apply= PAW × Depth to wet × MAD

PAW=Plant Available Water

MAD=Management Allowable Depletion

(how much water to be used)

Amount to apply= 0.2 × 12” × 0.5 = **1.2”**

Weather-Based Irrigation Controllers

- Determine how much to apply (1.2”)
- Determine runtime
  - From catch can assessment
    - DU (ex: 0.75)
    - Precipitation Rate (ex: 0.4 in/hr, rotors)

$$\text{Run time} = \frac{\text{Amt to apply}}{\left((0.6\times \text{DU})+0.4\right)\times \text{PR}}$$

$$= \frac{1.2}{\left((0.6\times 0.75)+0.4\right)\times 0.4} = 3.5 \text{ hrs}$$

Weather-Based Irrigation Controllers

- How they work
- Determine how much to apply (1.2”)
- Determine runtime (3.5 hrs)
- **How to determine when to apply**
  - Need information on water use
  - Largely determined by weather

Types of SMART controllers

- Weather-based
  - Information on weather conditions obtained by:
    - Signal
      - Weather data from central source
    - Historical
      - Preprogrammed with local climate data
    - On-site measurement
      - Weather station on location

Weather-Based Irrigation Controllers

Weather-based irrigation controllers "adjust the irrigation system's station run times based on plants' watering needs rather than on a preset, fixed schedule."

from: **EPA's WeatherSense** Labeled Weather-Based Irrigation Controllers

What's wrong with this statement?

Weather-Based Irrigation Controllers

Weather-based irrigation controllers "adjust the irrigation system's station schedule based on an estimation of plants' watering needs rather than using a preset, fixed schedule."

This is more correct.

- Run times should not be modified.
- The ET method is an estimation of plant water needs.

Weather-Based Irrigation Controllers

- How to determine when to apply
- Require weather or ET_0 data
- What is ET_0?
  - Reference Evapotranspiration
    - The amount of water used by the reference crop (**transpiration**) and losses directly from the soil surface (**evapo**ration)
    - Needs to be modified to landscape conditions
    - http://www.cimis.water.ca.gov/

CIMIS

C alifornia
I rrigation
M anagement
I nformation
S ystem

- Collects weather info
- Estimates plant water use
- More than 120 stations

Water use reports are used with a crop or landscape coefficient to estimate site water use

http://www.cimis.water.ca.gov

Weather-Based Irrigation Controllers

- How it works for crops
  - Reference ET (ET_0) is reported by CIMIS
  - Crop coefficient (K_C) is necessary
  - Determine crop ET (ET_C) to estimate water use
    - so, $ET_C = ET_0 \times K_C$
  - Example: citrus orchard
    - $K_C = 0.65$
    - If ET_0 for the past 5 days = 1.75”, then
    - Citrus crop water use was 1.75” x 0.65 = 1.14”

Weather-Based Irrigation Controllers

- How it works for landscapes
  - Reference ET (ET_0) is reported by CIMIS
  - Landscape coefficient (K_L) is necessary
  - Determine landscape ET (ET_L) to estimate water use
    - so, $ET_L = ET_0 \times K_L$
  - Example: moderate water use landscape zone
    - $K_L = 0.4$
    - If ET_0 for the past 5 days= 1.75”, then
    - Landscape water use was 1.75” x 0.4 = **0.7”**

Weather-Based Irrigation Controllers

- How they work
- The amount of water to apply is **1.2”**
  - Landscape water use for the past 5 days was **0.7”** (from: 1.75” x 0.4 = 0.7”)
  - The controller retrieves or calculates ET_0 and determines ET_L each day
  - ET_L is accumulated
  - When the accumulated ET_L reaches 1.2”, Irrigation is initiated

Weather-Based Irrigation Controllers

So, how do they REALLY work?

Weather-Based Irrigation Controllers

Information the controller needs

- Controller obtains:
  - Weather to determine ET_0 or ET_0
    - Historical (see CIMIS)
    - From on-site weather station
    - From central source (web, tel, etc.)

Weather-Based Irrigation Controllers

Information the controller needs

- You need to provide:
  - Plant mix to determine $K_{L,}$ depth to wet
    - Turf, shrubs, trees, etc.
    - Plant water use (Ks, species coefficient)
  - Soil info for PAW
  - Slope for runoff potential
  - Other

From this, the program estimates the specific information it needs to do the calculations presented earlier.

Water Budget Adjustment
(percent adjustment)

- Irrigation based on historical ET_0

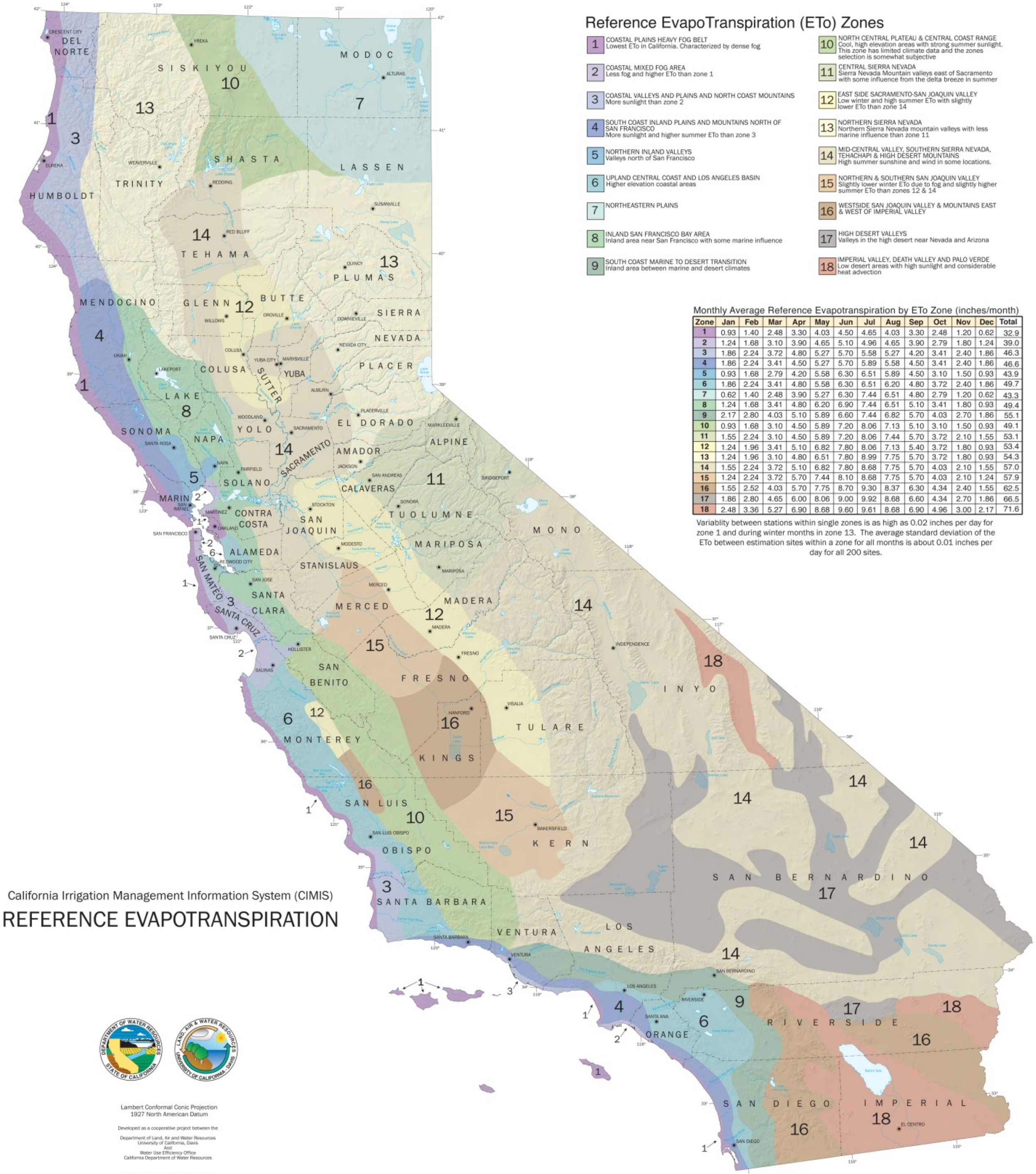
Water Budget Adjustment
(percent adjustment)

- Reduces irrigation as a fraction of that applied in the month of greatest water use
- July has the greatest ET rates
- See CIMIS Reference ET Zones map

http://www.cimis.water.ca.gov/Content/pdf/CimisRefEvapZones.pdf

California Irrigation Management Information System (CIMIS)

REFERENCE EVAPOTRANSPIRATION



Reference EvapoTranspiration (ETo) Zones

- **1** COASTAL PLAINS HEAVY FOG BELT
  Lowest ETo in California. Characterized by dense fog
- **2** COASTAL MIXED FOG AREA
  Less fog and higher ETo than zone 1
- **3** COASTAL VALLEYS AND PLAINS AND NORTH COAST MOUNTAINS
  More sunlight than zone 2
- **4** SOUTH COAST INLAND PLAINS AND MOUNTAINS NORTH OF SAN FRANCISCO
  More sunlight and higher summer ETo than zone 3
- **5** NORTHERN INLAND VALLEYS
  Valleys north of San Francisco
- **6** UPLAND CENTRAL COAST AND LOS ANGELES BASIN
  Higher elevation coastal areas
- **7** NORTHEASTERN PLAINS
- **8** INLAND SAN FRANCISCO BAY AREA
  Inland area near San Francisco with some marine influence
- **9** SOUTH COAST MARINE TO DESERT TRANSITION
  Inland area between marine and desert climates
- **10** NORTH CENTRAL PLATEAU & CENTRAL COAST RANGE
  Cool, high elevation areas with strong summer sunlight. This zone has limited climate data and the zones selection is somewhat subjective
- **11** CENTRAL SIERRA NEVADA
  Sierra Nevada Mountain valleys east of Sacramento with some influence from the delta breeze in summer
- **12** EAST SIDE SACRAMENTO-SAN JOAQUIN VALLEY
  Low winter and high summer ETo with slightly lower ETo than zone 14
- **13** NORTHERN SIERRA NEVADA
  Northern Sierra Nevada mountain valleys with less marine influence than zone 11
- **14** MID-CENTRAL VALLEY, SOUTHERN SIERRA NEVADA, TEHACHAPI & HIGH DESERT MOUNTAINS
  High summer sunshine and wind in some locations.
- **15** NORTHERN & SOUTHERN SAN JOAQUIN VALLEY
  Slightly lower winter ETo due to fog and slightly higher summer ETo than zones 12 & 14
- **16** WESTSIDE SAN JOAQUIN VALLEY & MOUNTAINS EAST & WEST OF IMPERIAL VALLEY
- **17** HIGH DESERT VALLEYS
  Valleys in the high desert near Nevada and Arizona
- **18** IMPERIAL VALLEY, DEATH VALLEY AND PALO VERDE
  Low desert areas with high sunlight and considerable heat advection

Monthly Average Reference Evapotranspiration by ETo Zone (inches/month)

Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	0.93	1.40	2.48	3.30	4.03	4.50	4.65	4.03	3.30	2.48	1.20	0.62	32.9
2	1.24	1.68	3.10	3.90	4.65	5.10	4.96	4.65	3.90	2.79	1.80	1.24	39.0
3	1.86	2.24	3.72	4.80	5.27	5.70	5.58	5.27	4.20	3.41	2.40	1.86	46.3
4	1.86	2.24	3.41	4.50	5.27	5.70	5.89	5.58	4.50	3.41	2.40	1.86	46.6
5	0.93	1.68	2.79	4.20	5.58	6.30	6.51	5.89	4.50	3.10	1.50	0.93	43.9
6	1.86	2.24	3.41	4.80	5.58	6.30	6.51	6.20	4.80	3.72	2.40	1.86	49.7
7	0.62	1.40	2.48	3.90	5.27	6.30	7.44	6.51	4.80	2.79	1.20	0.62	43.3
8	1.24	1.68	3.41	4.80	6.20	6.90	7.44	6.51	5.10	3.41	1.80	0.93	49.4
9	2.17	2.80	4.03	5.10	5.89	6.60	7.44	6.82	5.70	4.03	2.70	1.86	55.1
10	0.93	1.68	3.10	4.50	5.89	7.20	8.06	7.13	5.10	3.10	1.50	0.93	49.1
11	1.55	2.24	3.10	4.50	5.89	7.20	8.06	7.44	5.70	3.72	2.10	1.55	53.1
12	1.24	1.96	3.41	5.10	6.82	7.80	8.06	7.13	5.40	3.72	1.80	0.93	53.4
13	1.24	1.96	3.10	4.80	6.51	7.80	8.99	7.75	5.70	3.72	1.80	0.93	54.3
14	1.55	2.24	3.72	5.10	6.82	7.80	8.68	7.75	5.70	4.03	2.10	1.55	57.0
15	1.24	2.24	3.72	5.70	7.44	8.10	8.68	7.75	5.70	4.03	2.10	1.24	57.9
16	1.55	2.52	4.03	5.70	7.75	8.70	9.30	8.37	6.30	4.34	2.40	1.55	62.5
17	1.86	2.80	4.65	6.00	8.06	9.00	9.92	8.68	6.60	4.34	2.70	1.86	66.5
18	2.48	3.36	5.27	6.90	8.68	9.60	9.61	8.68	6.90	4.96	3.00	2.17	71.6

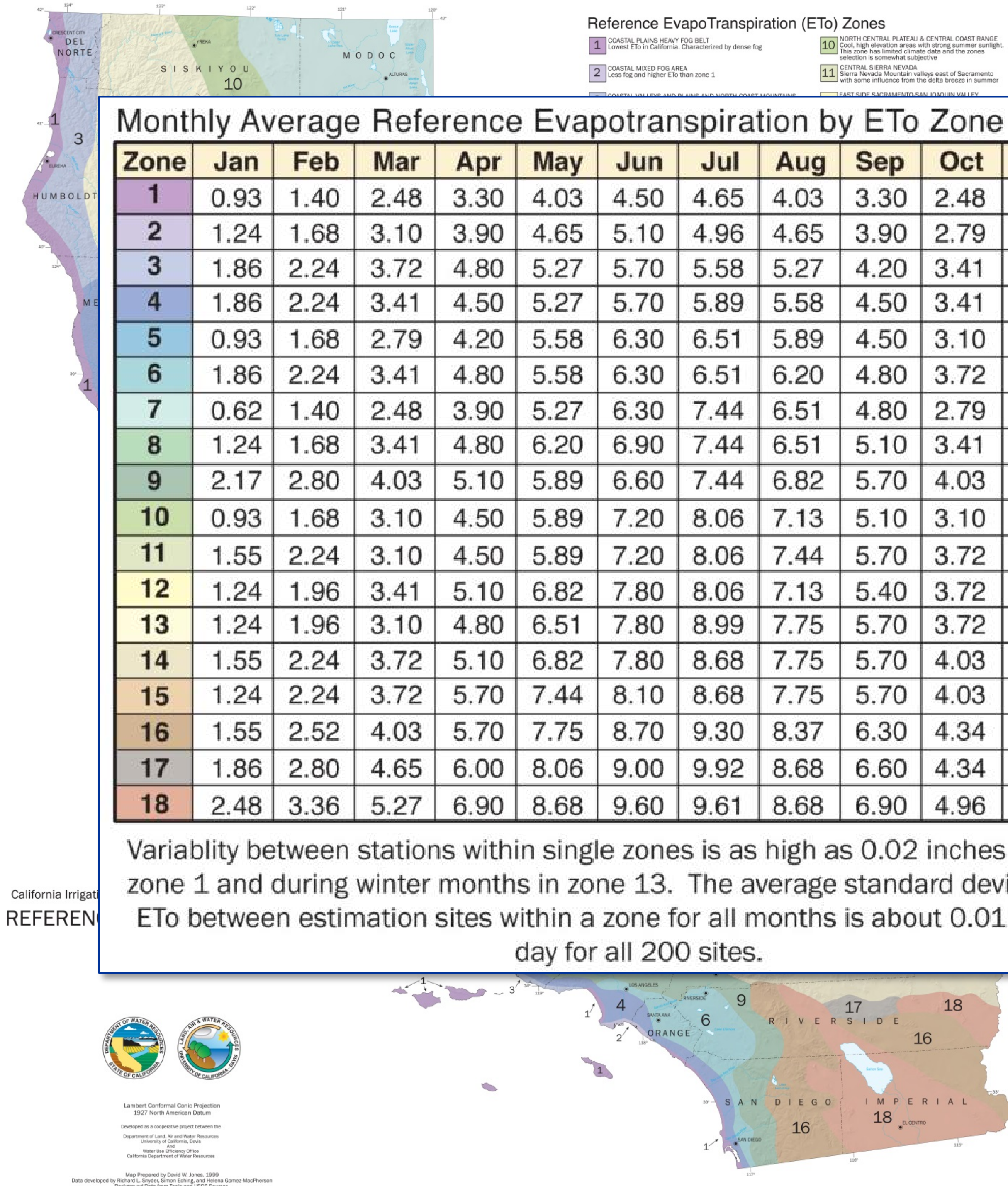
Variablity between stations within single zones is as high as 0.02 inches per day for zone 1 and during winter months in zone 13. The average standard deviation of the ETo between estimation sites within a zone for all months is about 0.01 inches per day for all 200 sites.

Lambert Conformal Conic Projection
1927 North American Datum

Developed as a cooperative project between the

Department of Land, Air and Water Resources
University of California, Davis
And
Water Use Efficiency Office
California Department of Water Resources

Map Prepared by David W. Jones, 1999
Data developed by Richard L. Snyder, Simon Eching, and Helena Gomez-MacPherson
Background Data from Teale and USGS Sources



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Water Budget Adjustment
(percent adjustment* example)

Monthly Average ET (inches/mo)

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14	1.55	2.24	3.72	5.10	6.82	7.80	8.68	7.75	5.70	4.03	2.10	1.55	57.0
	18%	26%	43%	59%	79%	90%	100%	89%	66%	46%	24%	18%	
Min.	4	5	9	12	16	18	20	18	13	9	5	4	

So how does a controller make the adjustment?

- Use the percentage to reduce
  - Valve run time (*aka: “seasonal adjustment)
  - Irrigation schedule

YES! RIGHT WAY!

Water Budget Adjustment
(percent adjustment* example)

Monthly Average ET (inches/mo)

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14	1.55	2.24	3.72	5.10	6.82	7.80	8.68	7.75	5.70	4.03	2.10	1.55	57.0

amount to irrigate=1.2 "

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
ETo	in/mo	1.55	2.24	3.72	5.1	6.82	7.8	8.68	7.75	5.7	4.03	2.1	1.55	57
ETo	in.day	0.052	0.075	0.124	0.170	0.227	0.260	0.289	0.258	0.190	0.134	0.070	0.052	
	K_L	0.4												
ET_L	in.day	0.021	0.030	0.050	0.068	0.091	0.104	0.116	0.103	0.076	0.054	0.028	0.021	
#days btwn irrig		58	40	24	18	13	12	10	12	16	22	43	58	

Types of SMART controllers

- Weather-based
- Soil moisture-based
  - Manages irrigation based on soil moisture condition
    - Requires sensors in the soil

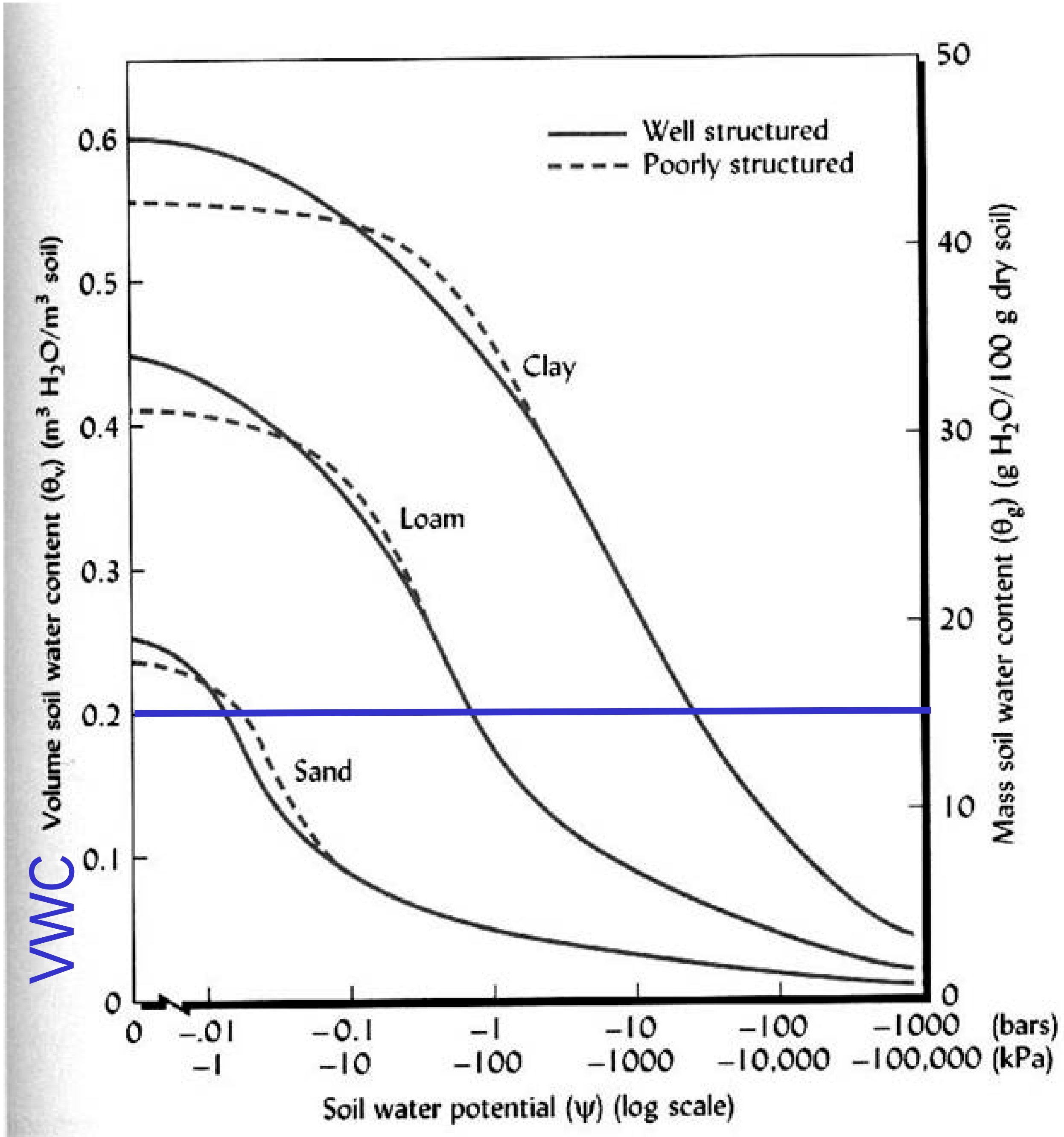
Soil Moisture-Based Irrigation Controllers

Controller types

- Bypass/interruption
  - Does not allow irrigation if soil is wet
- Initiate/terminate
  - Starts irrigation when dry
  - Ends irrigation when soil is rewetted

Soil Moisture-Based Irrigation Controllers

- Sensor types
  - Volumetric Water Content
    - The amount of water
  - Matric potential
    - How tightly the water is held in the soil
    - More important in plant-water relations
- It's important to know the difference

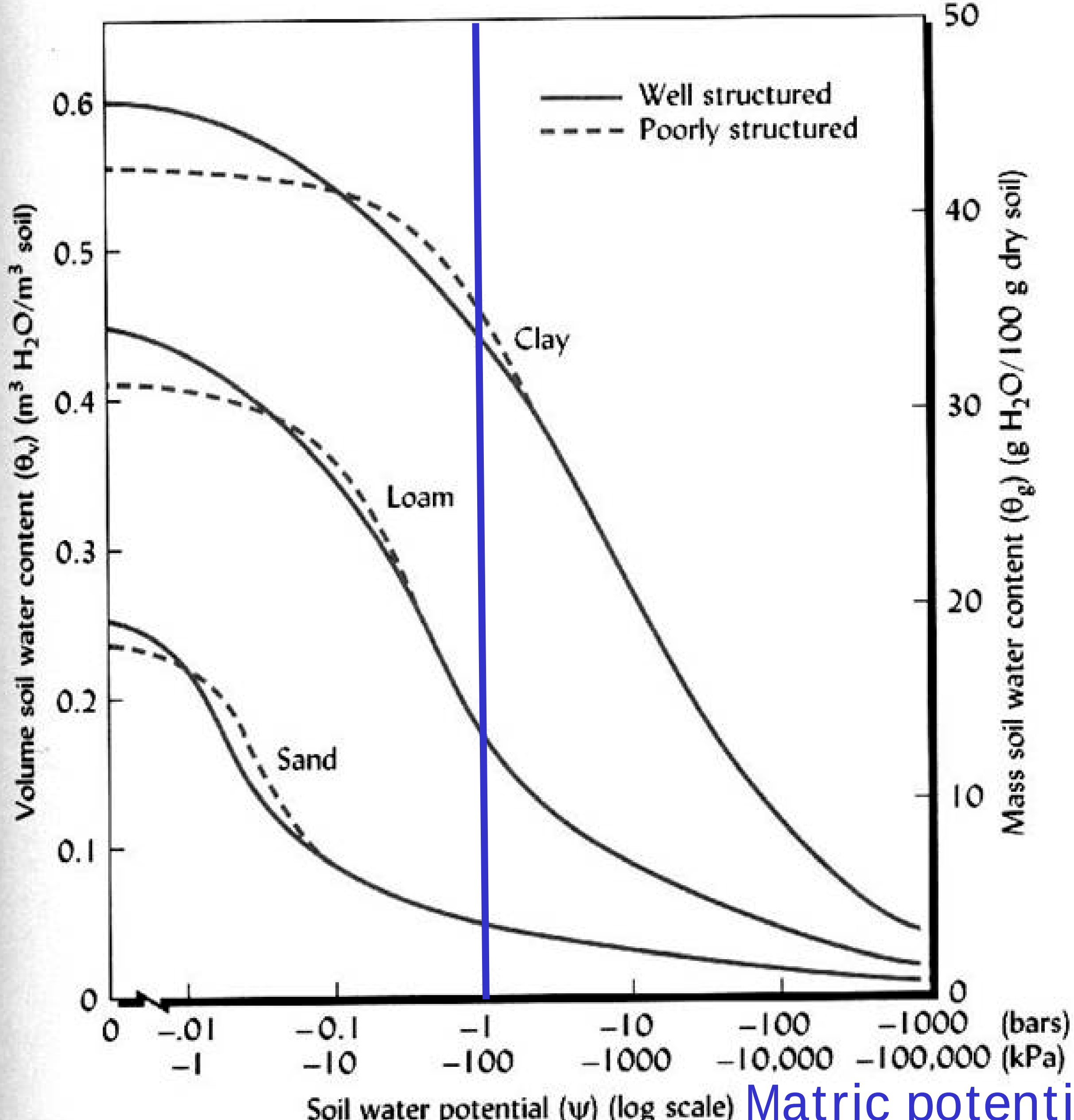


Graphic: Brady & Weil, The Nature and Properties of Soils, 2002

Moisture Retention Curve

All soils have a characteristic curve

20% VWC



Matric potential

Moisture Retention Curve

All soils have a characteristic curve

Permanent Wilting Point at 100 kPa

Graphic: Brady & Weil, The Nature and Properties of Soils, 2002

Soil Moisture-Based Irrigation Controllers

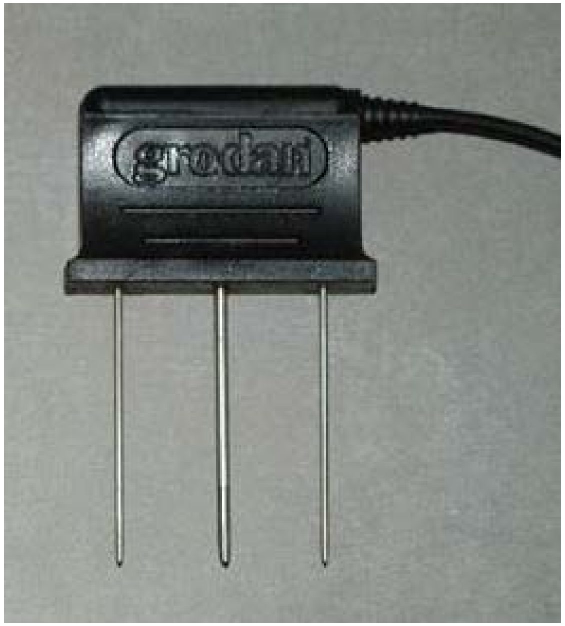
- Sensors, MP
  - Granular matrix sensor
    - Watermark
    - Gypsum block

Soil Moisture-Based Irrigation Controllers

- Sensors, MP
  - Tensiometer

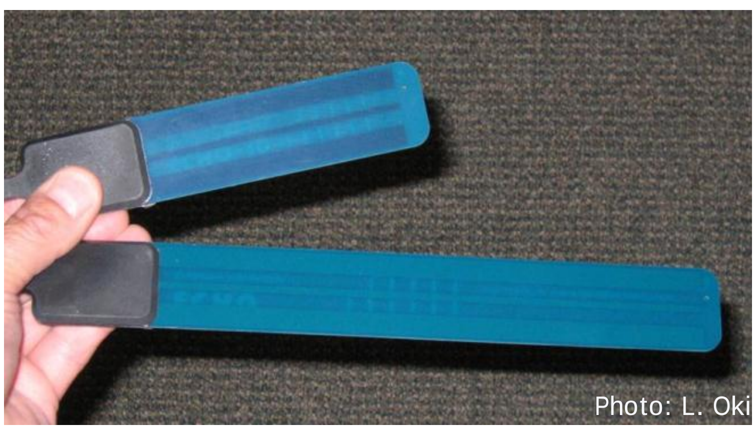
Soil Moisture-Based Irrigation Controllers

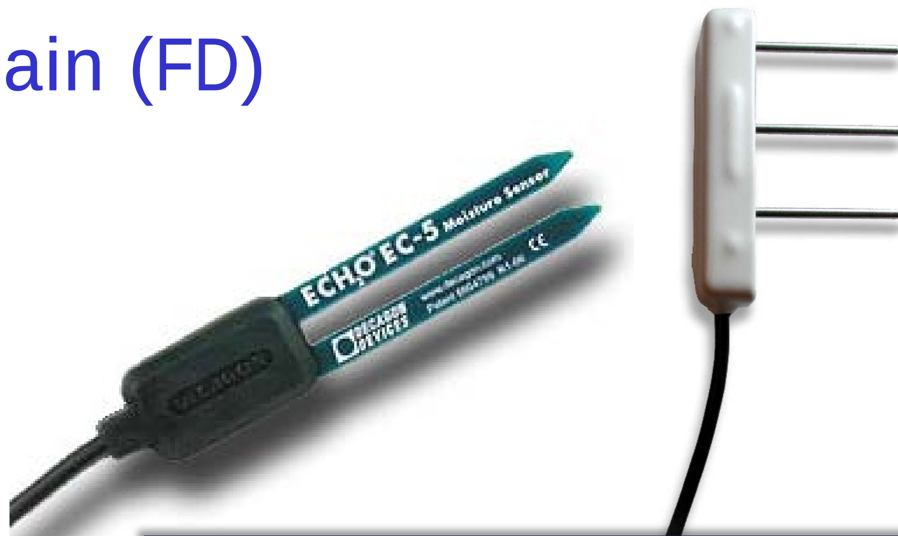
- Sensors, VWC
  - Time Domain Reflectometry (TDR)
  - Time Domain Transmissometry (TDT)



Soil Moisture-Based Irrigation Controllers

- Sensors , VWC
  - Frequency Domain (FD)





Conductance-based sensors are NOT appropriate

Soil Moisture-Based Irrigation Controllers

Sensors- Be aware of what is measured

- Matric Potential
  - Granular matrix sensor
  - Tensiometer
- Volumetric Water Content
  - TDR, TDT
  - FD

Topics

- Irrigation objectives
- What are SMART controllers?
- Types of SMART controllers
  - Weather
  - Soil moisture
- How do they work?

Photo: L.Oki

Soil Information

The best way to get PAW information:

SoilWeb

https://casoilresource.lawr.ucdavis.edu/gmap/

For PC, iPhone, and Android

also look for in Apple Store and Google Play

For PAW information, Look for:

"Available Water Storage (0-100 cm)"

Given as ZZ cm, so it can be converted directly to percent