This presentation premiered at WaterSmart Innovations

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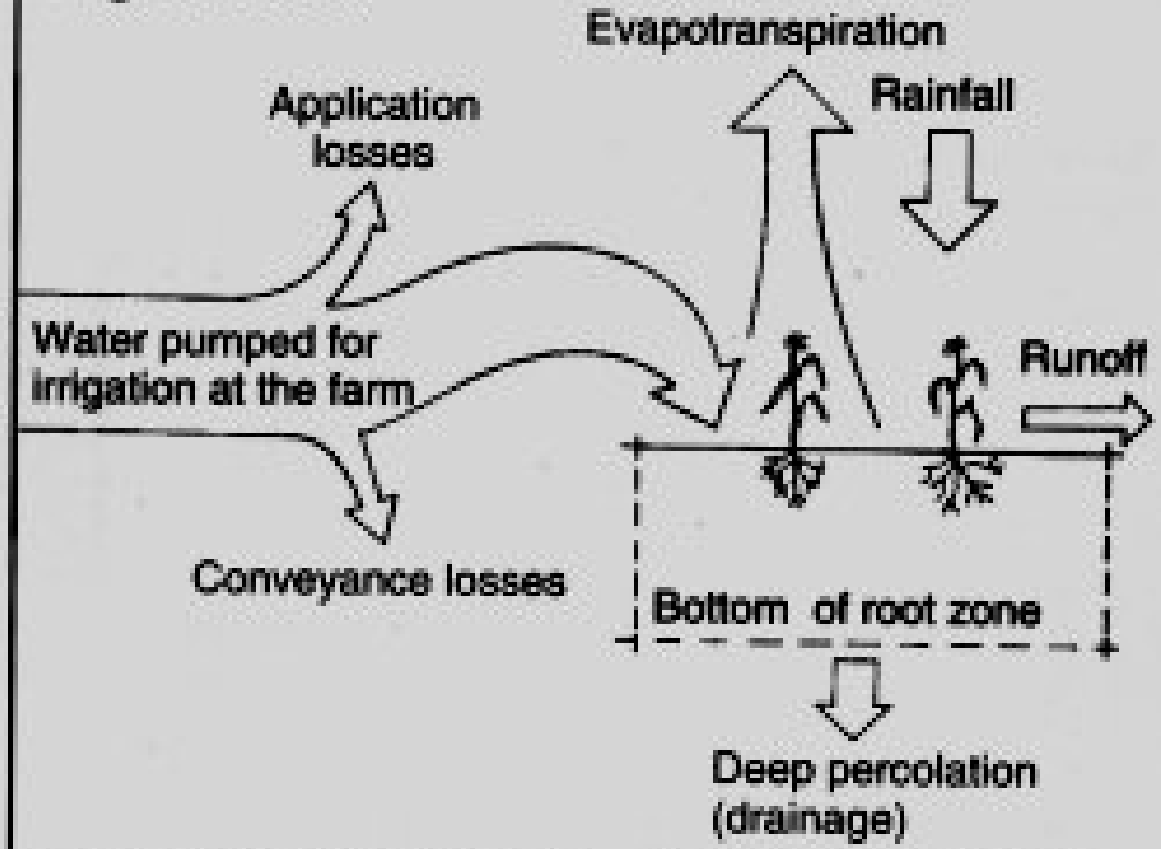
ET versus ETo
Why Water Budgets are Wasting Water

Chris Brown

Figure 1. Water Balance Components of an Irrigated Field



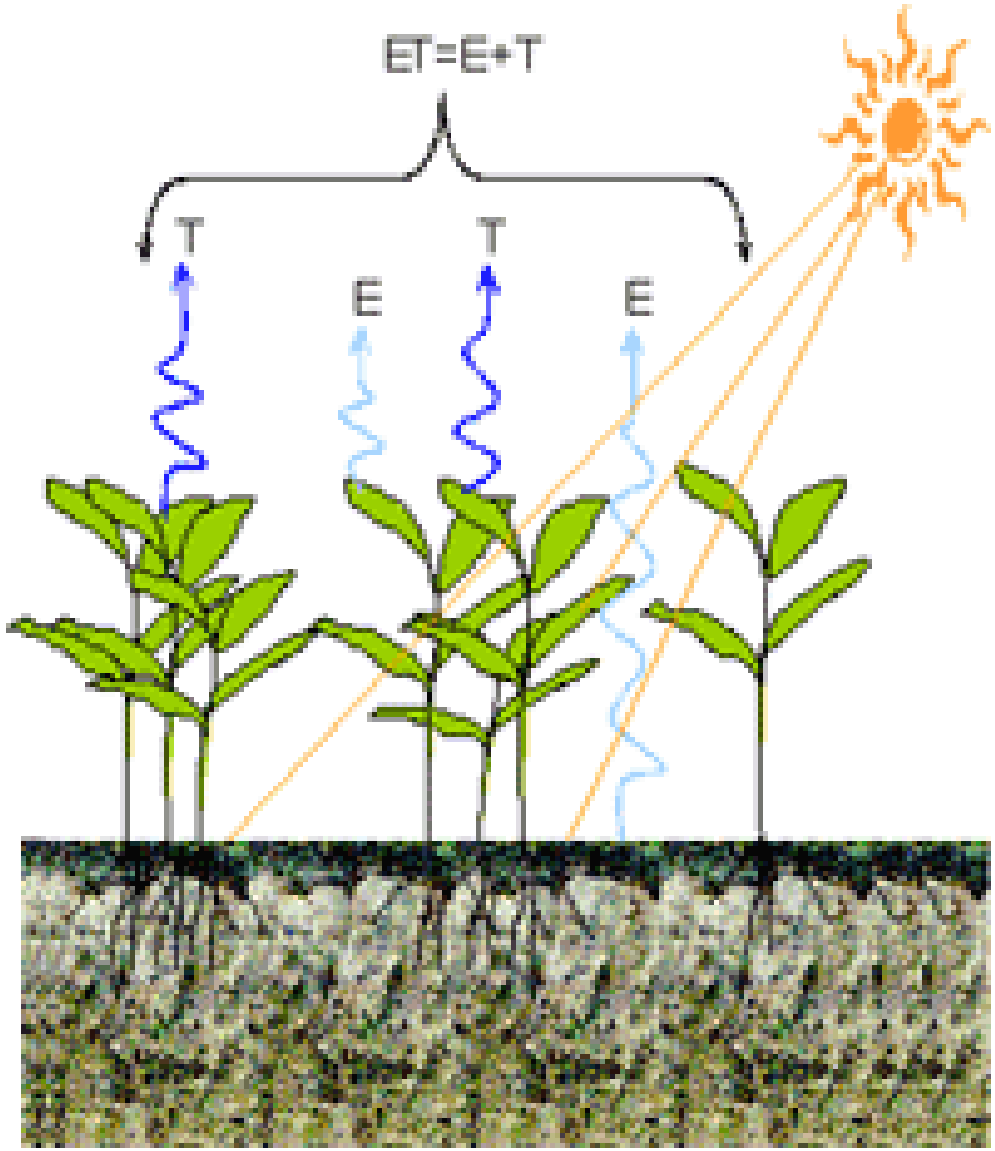
Adapted from A.G. Smajstrla, et al, 1988, *Basic Irrigation Scheduling in Florida*, Bulletin 249, Florida Cooperative Extension Service, University of Florida.

Various Drivers for Plant ET

- Actual ET depends upon plant species and variety, life cycle, nutrients, available water, soil type, and weather/climate
- Transpiration
  - photosynthesis, stem & leaf turgor and plant cooling
- Controlling mechanisms are various including stomata, hormones, leaf physiology, photosynthetic pathway

Actual Evapotranspiration: ETa

- Actual Evapotransipiration = precipitation + irrigation – change in storage – runoff – interflow – percolation below root zone
- If storage term reduces, ETa is greater than Precipitation + Irrigation (plant is using water stored in soil)

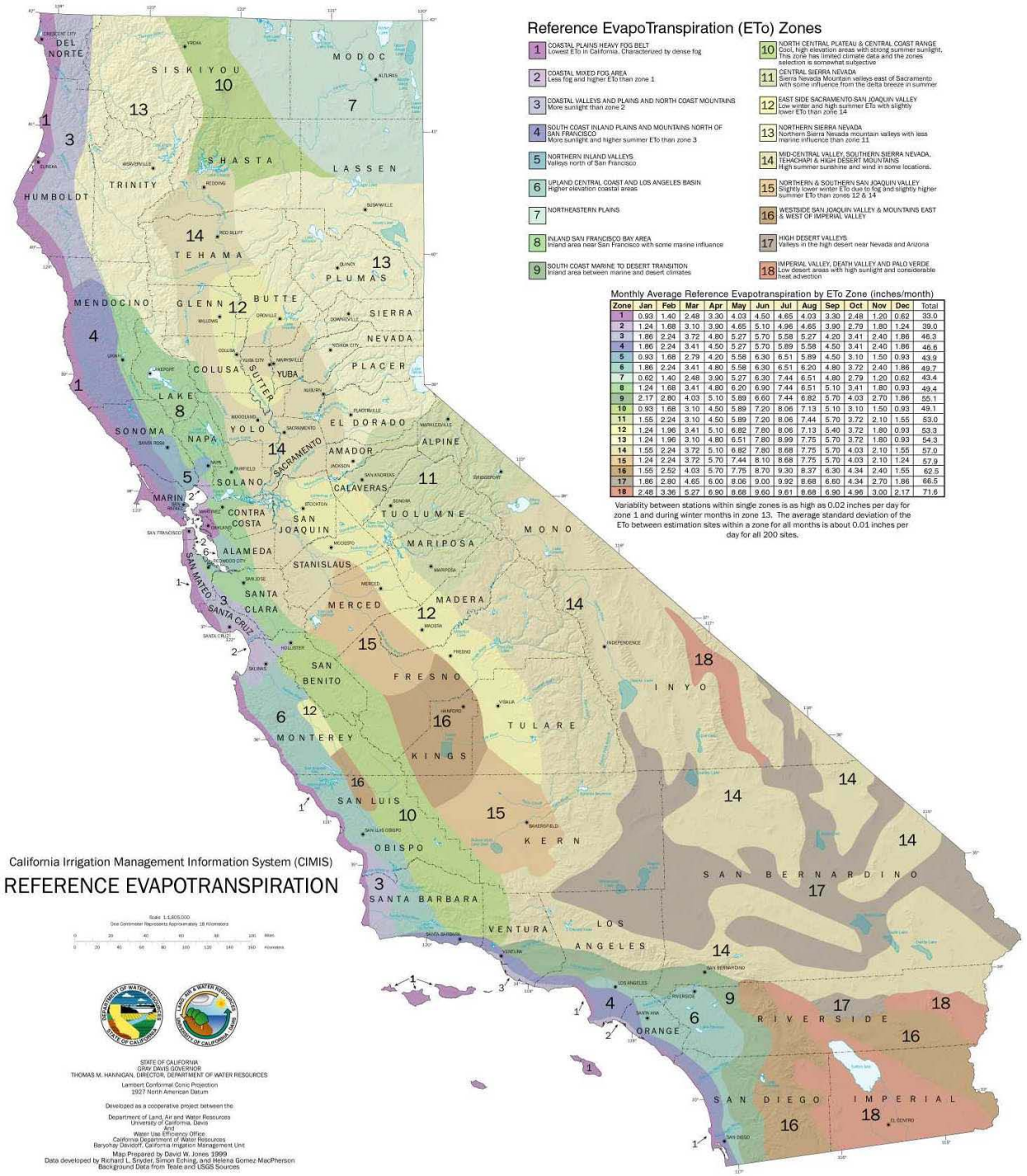

ET=E+T
T
T
E
E

The Climate Factor

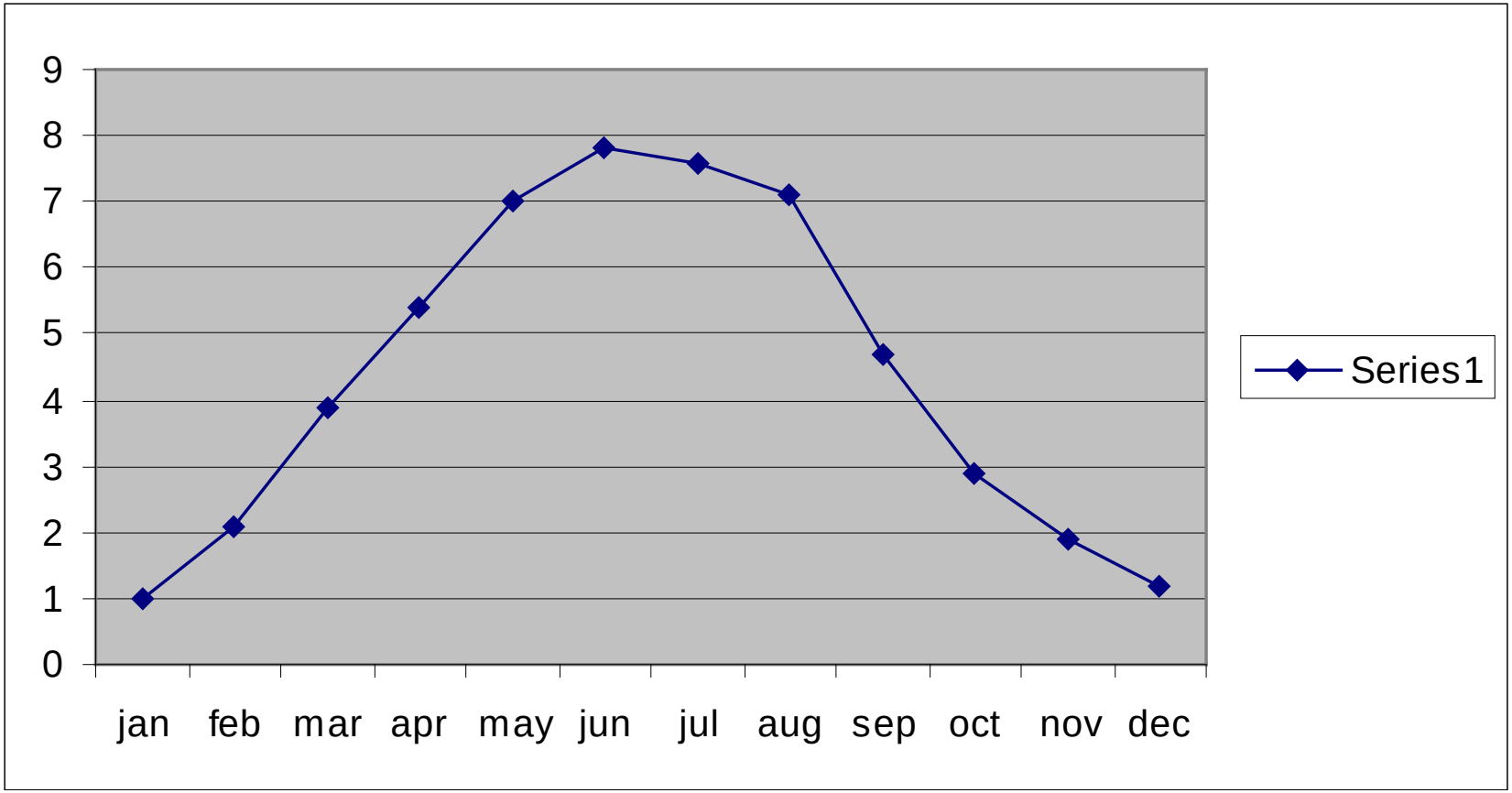
Reference evapotranspiration = ETo

ETo is a standard measurement which estimates the evapotranspiration of:

- **Large field of 4” - 7” tall, cool-season grass that is well watered in full sun**
- **Expressed as a rate, amount of water loss over a given time, usually inches/day**
- **Estimated by the CIMIS system as well as other methods**


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 33.0
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 43.4
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 53.0
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 53.3
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
Variability 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.
California Irrigation Management Information System (CIMIS)
REFERENCE EVAPOTRANSPIRATION
Scale 1:1,600,000
One Centimeter Represents Approximately 16 Kilometers
STATE OF CALIFORNIA
GRAY DAVIS GOVERNOR
THOMAS M. HANNIGAN, DIRECTOR, DEPARTMENT OF WATER RESOURCES
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
Baryohay Davidoff, California Irrigation Management Unit
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
DEL NORTE
SISKIYOU
MODOC
SHASTA
LASSEN
TRINITY
HUMBOLDT
TEHAMA
PLUMAS
MENDOCINO
GLENN
BUTTE
SIERRA
NEVADA
COLUSA
SUTTER
YUBA
PLACER
LAKE
SONOMA
NAPA
YOLO
EL DORADO
SACRAMENTO
AMADOR
ALPINE
SOLANO
CALAVERAS
MARIN
CONTRA COSTA
SAN JOAQUIN
TUOLUMNE
MONO
ALAMEDA
MARIPOSA
STANISLAUS
SAN MATEO
SANTA CLARA
MERCED
MADERA
SANTA CRUZ
SAN BENITO
FRESNO
INYO
MONTEREY
TULARE
KINGS
SAN LUIS OBISPO
KERN
SAN BERNARDINO
SANTA BARBARA
VENTURA
LOS ANGELES
ORANGE
RIVERSIDE
SAN DIEGO
IMPERIAL

Sacramento Eto 2007-08, in./mo.



$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

Reference Evapotranspiration: ETo

- Rn net radiation at the crop surface
- G soil heat flux density
- T mean daily air temperature at 2 m height
- u2 wind speed at 2 m height
- es saturation vapor pressure
- ea actual vapor pressure
- es - ea saturation vapor pressure deficit
- D slope vapour pressure curve
- g psychrometric constant

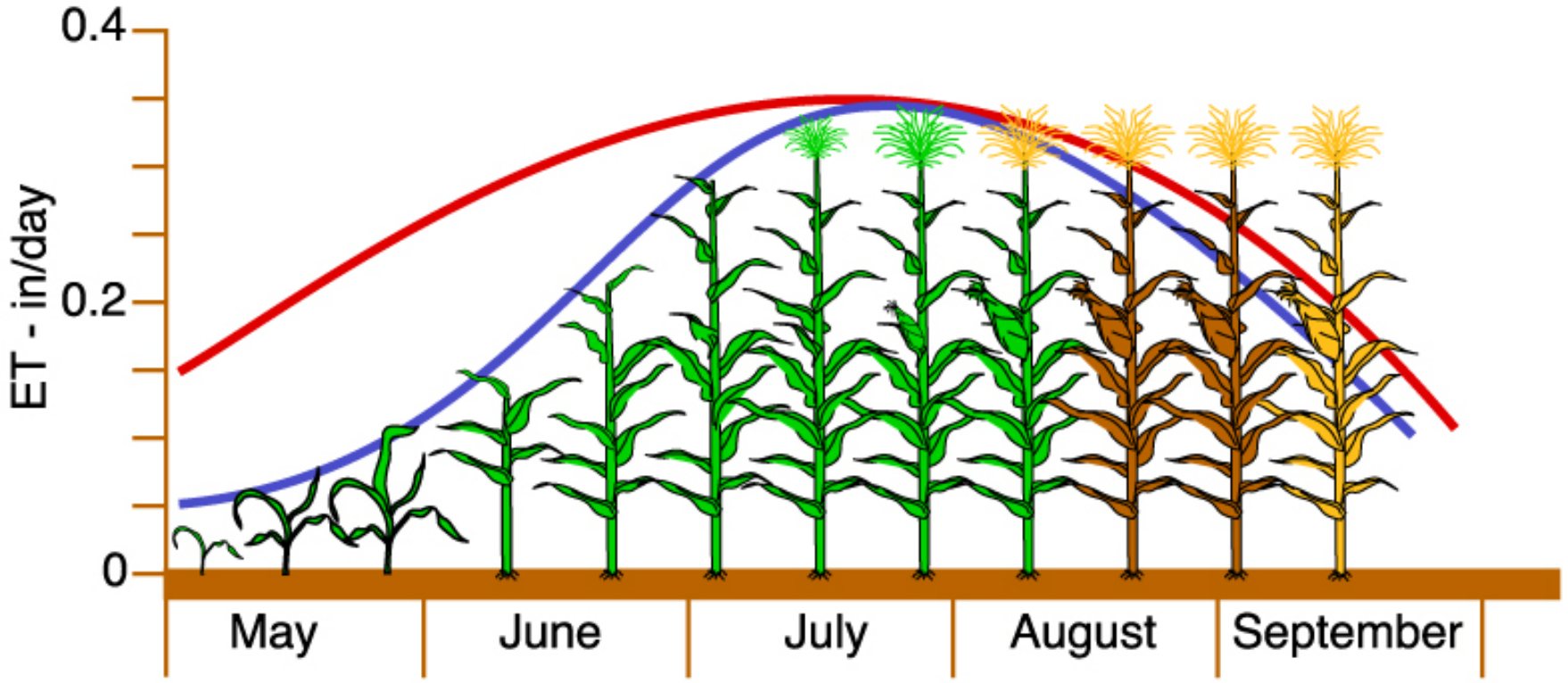
FAO

“In the absence of any supply of water to the soil surface, evaporation decreases rapidly and may cease almost completely within a few days.”

Relating ETa to ETo

- ETo = Reference Evapotranspiration
- ETa ~ Kc * ETo
- Water Budget = Kc * ETo/IE
  - Where IE equals Irrigation Efficiency

Crop ET versus Reference ET



Deficit Irrigation in Turf

- Providing less irrigation water than the plant used the week before (ETa)
- Plants use water from soil storage
  …stomatal conductance declines

  …ETa declines

until soil water storage declines to point that plant stress is evident

- Las Vegas, Nevada

Calculating Irrigation Amounts

- $ETa = I - \Delta S - D$
  - ETa: actual evapotranspiration
  - I: irrigation (l)
  - ΔS: change in storage
  - D: drainage
- Following week: $I = ETa/(1-LF)$
  - LF: leaching fraction
- $I/ETo = 1.04 + 1.03\ LF$, $r^2 = 96.4$

FIGURE 12. Daily Irrigation Color by N by LF by Time

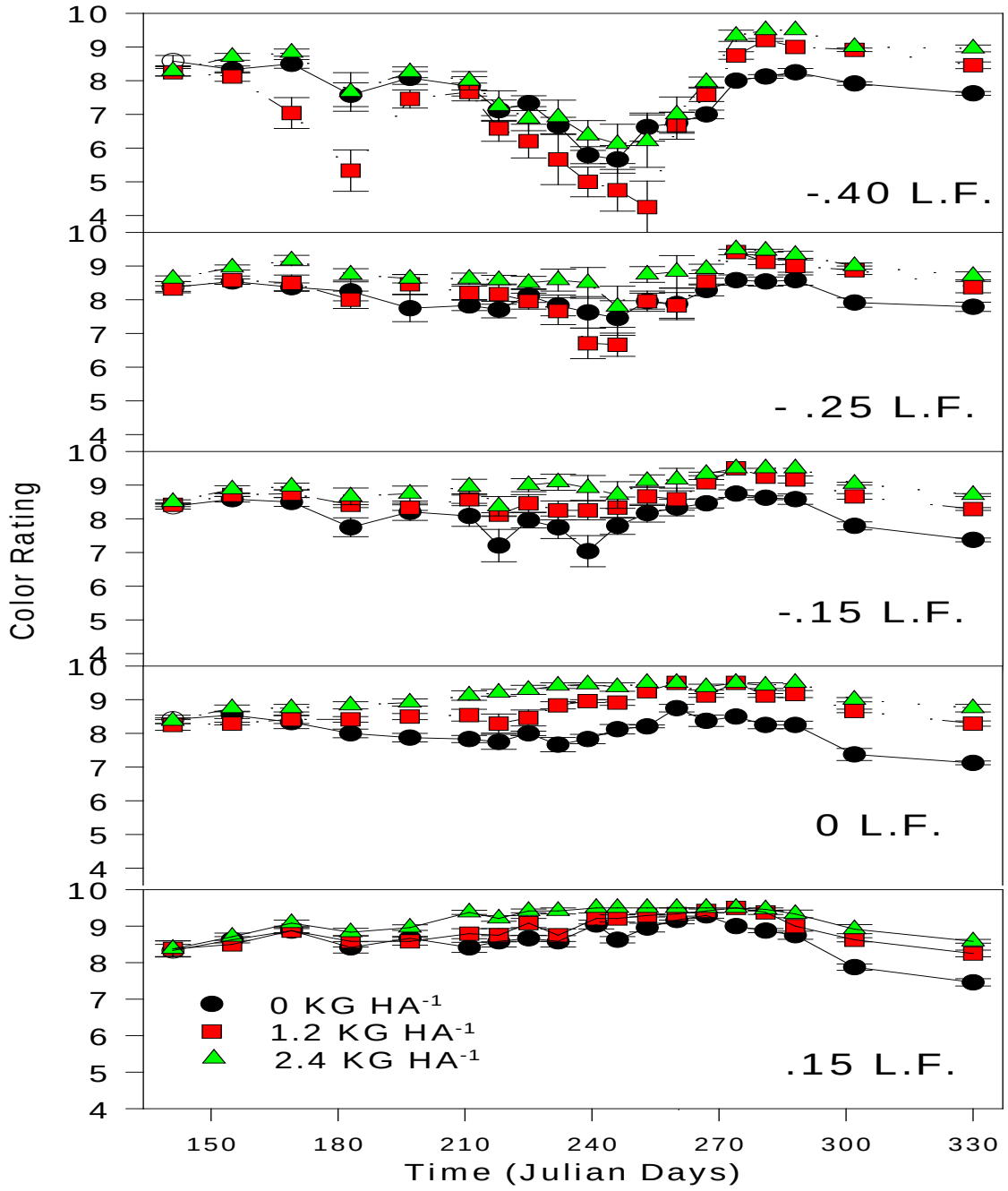
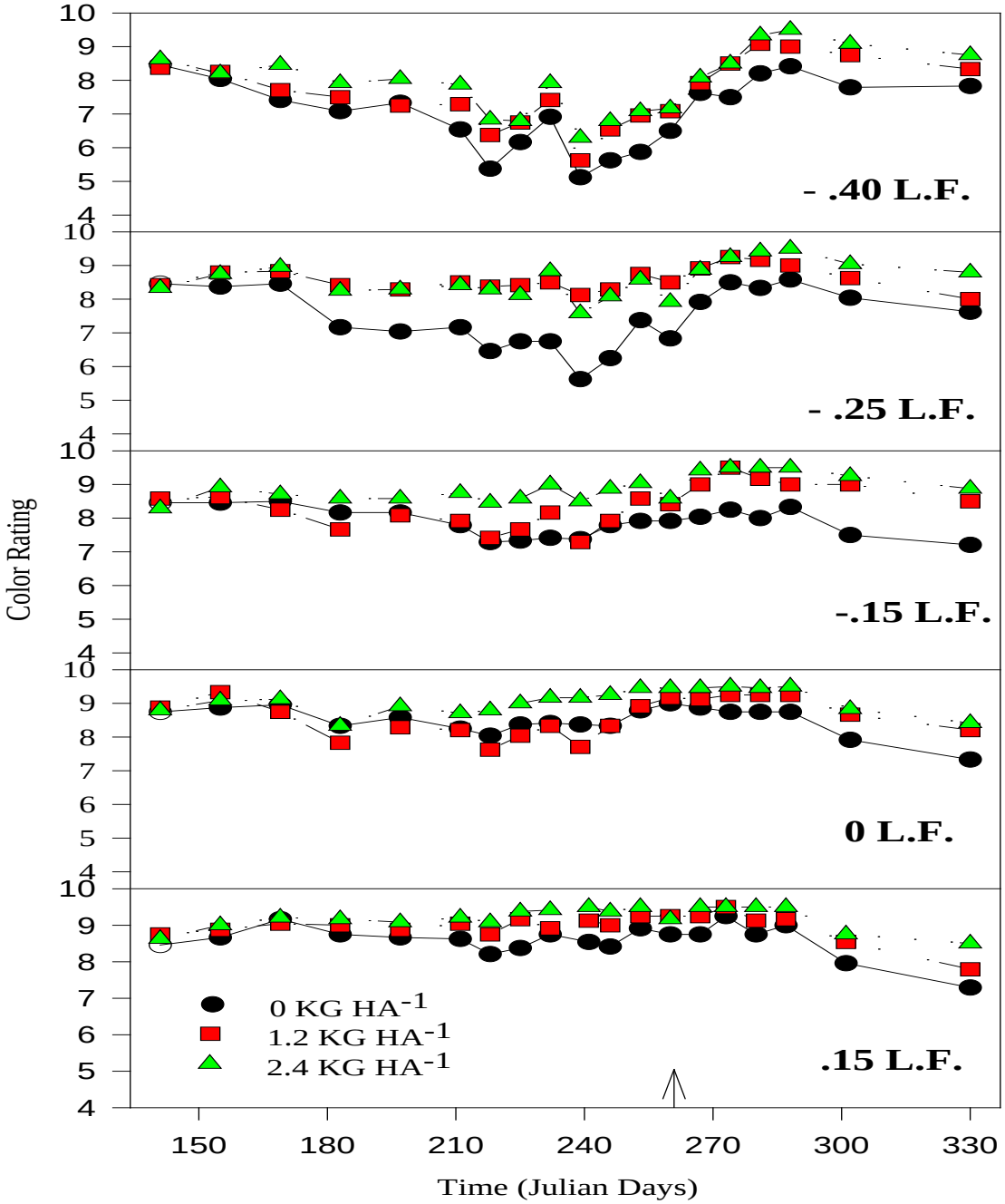
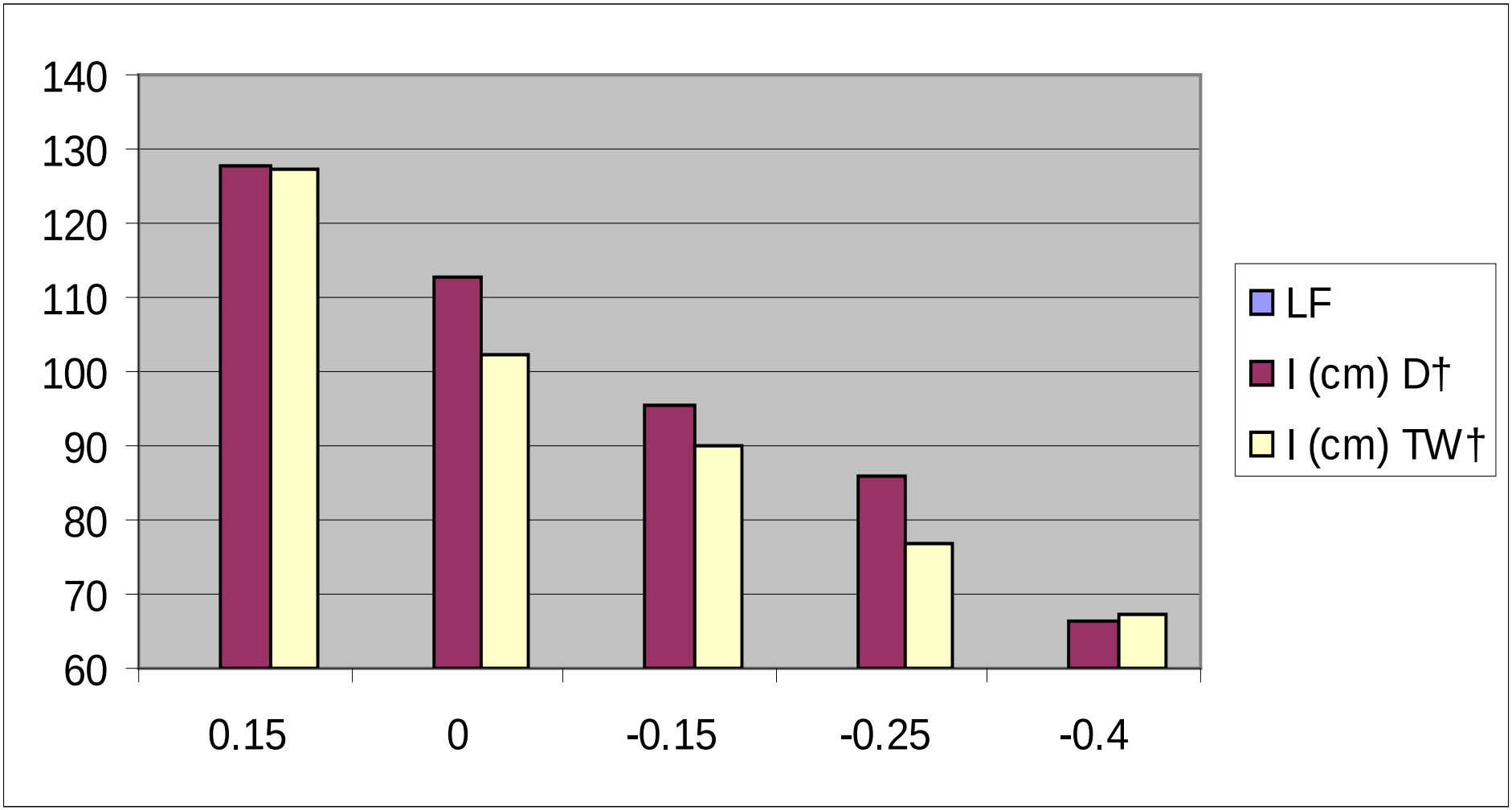


Figure 13.Twice Weekly Irrigation Color by N by LF by Time



Irrigation by Leaching Fraction

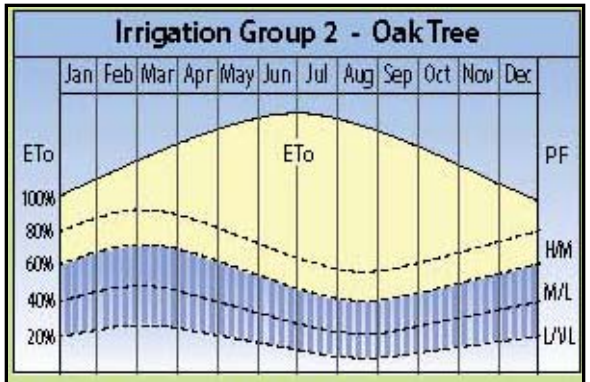


Water Savings – Las Vegas

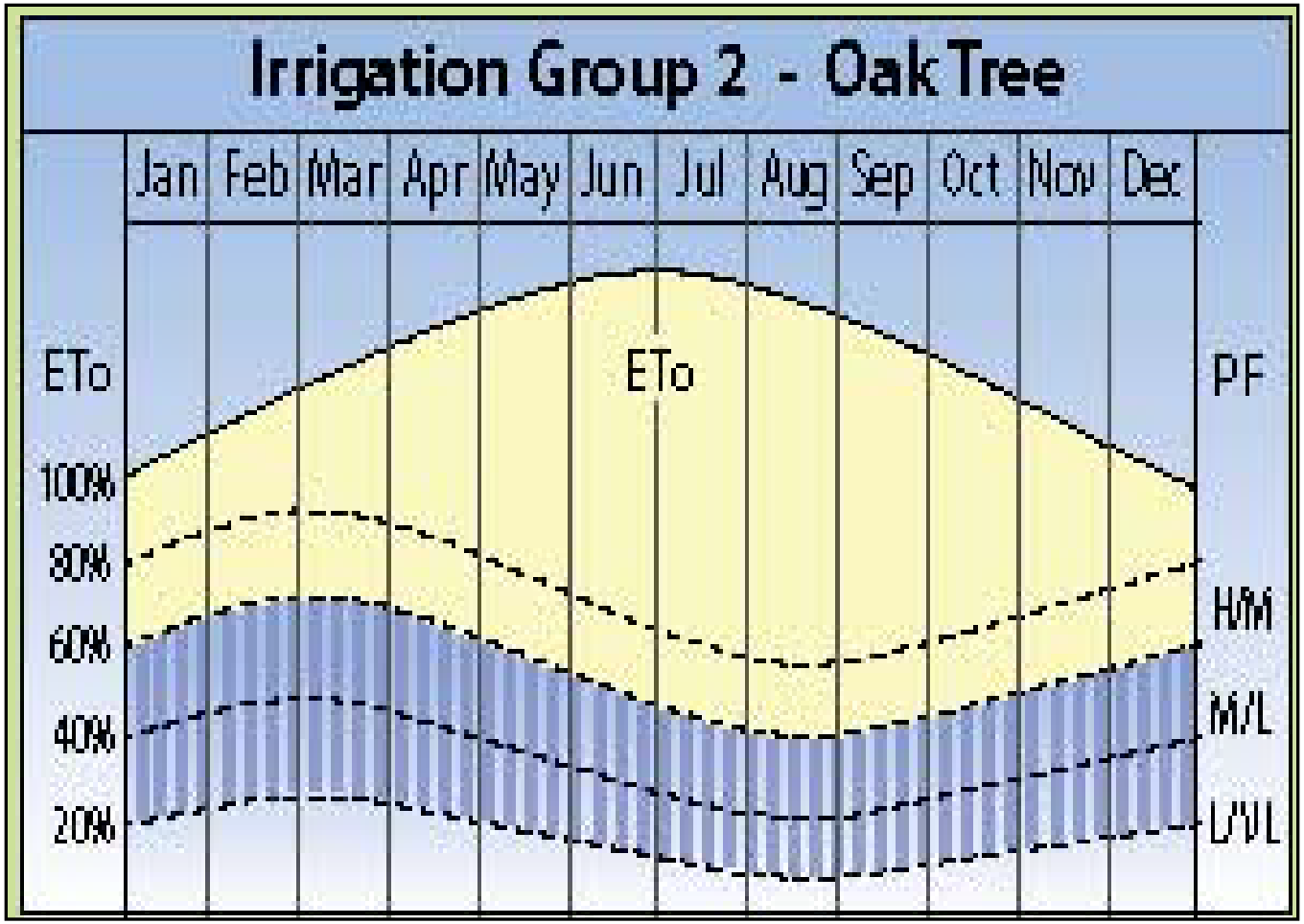
- Twice weekly watering provides water savings:
  - 10, 5.8 and 11.9% at 0, -0.15 and –0.25LF
- And acceptable turf quality:
  - 8+ Color & 100% Cover
- Soil Water Storage at .52 was a threshold for appearance in deficit treatments
- Tradeoffs may lead to greater water savings without loss of turf – up to 47% at –0.40LF

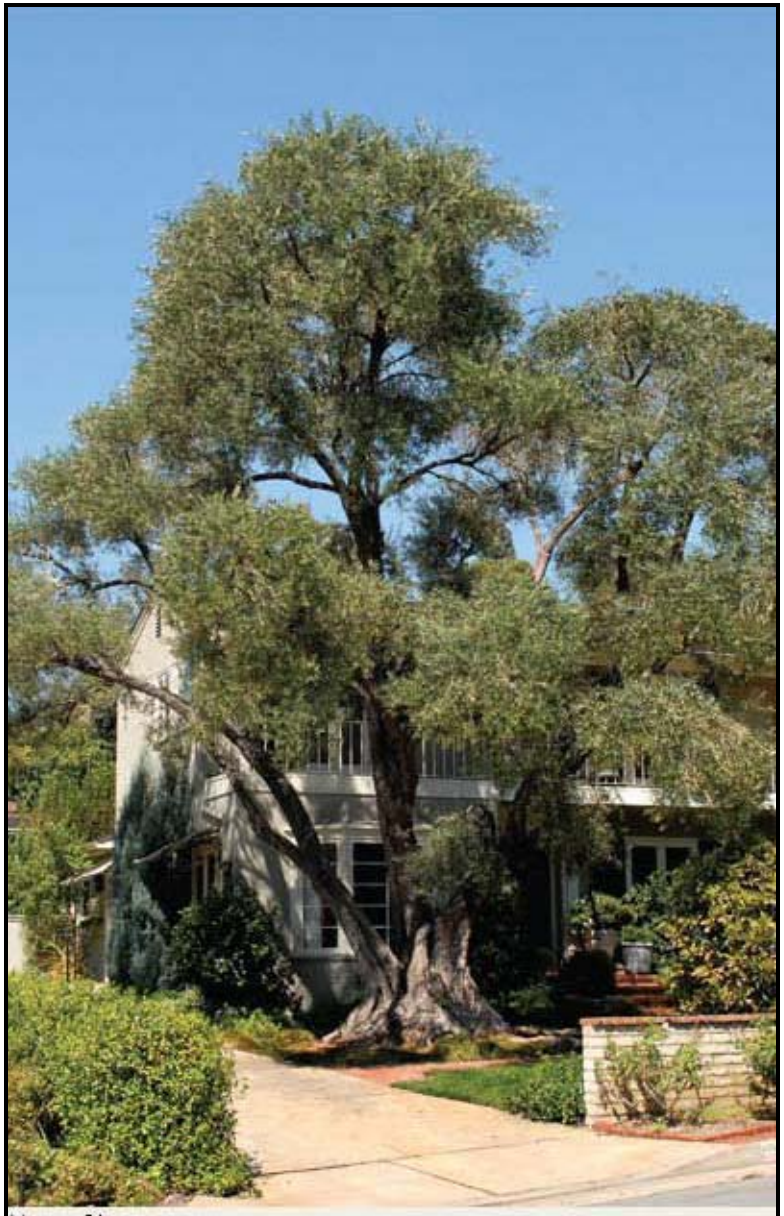
Problems with Water Budgets

- Actual water demand versus ETo
  - Failure to use Kc in calculation
  - Turf quality versus yield
  - Irrigation system uniformity assumptions
  - Impact of urban landscapes, especially shade
- Value of water based upon end use
  - Landscape versus human consumption
  - Family size – justice issues

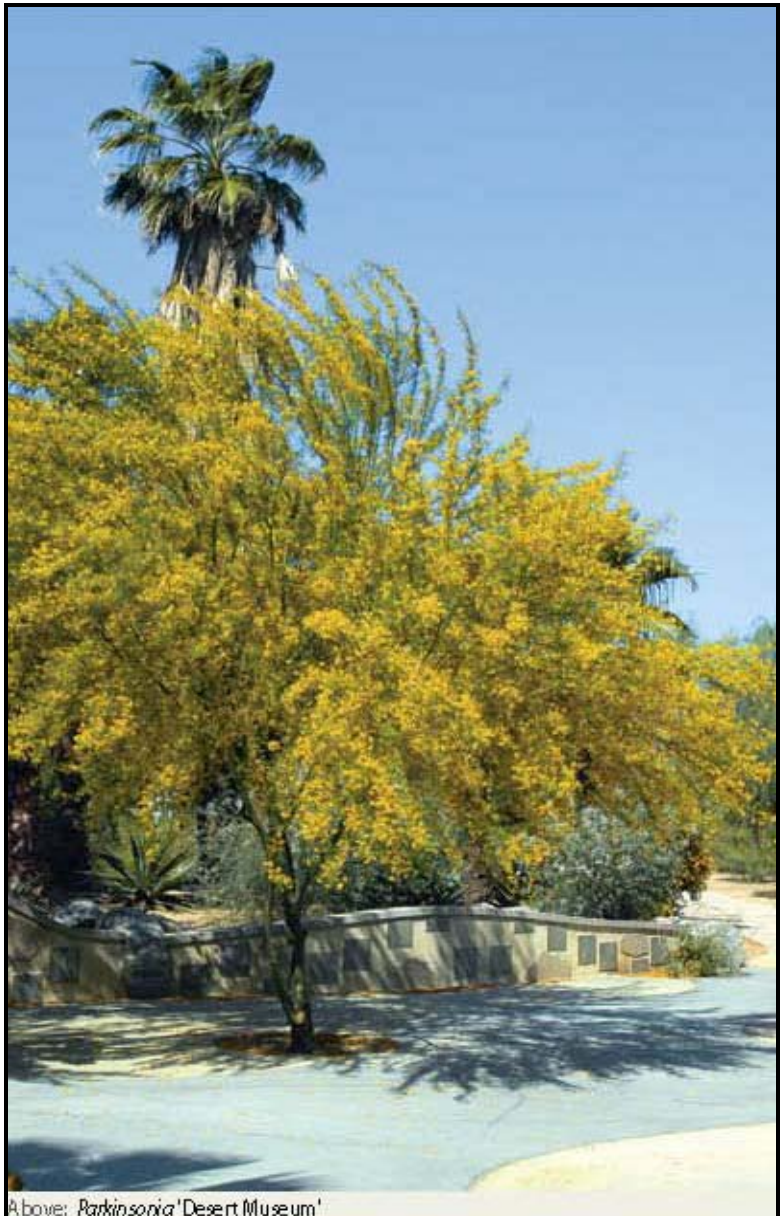


Below: *Quercus agrifolia* with *Cistus skanbergii*


Irrigation Group 2 - Oak Tree
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
ETo
ETo
PF
100%
80%
60%
40%
20%
H/M
M/L
L/VL



Above: *Olea europaea*



Above: *Parkinsonia* 'Desert Museum'

Appropriate Terms

- ETa
  - Deficit
  - Plant water needs
  - Irrigation adequacy
- ETo
  - Reference
  - Theoretical

Climate Change

- Lower overall precipitation in many areas
- Longer and more frequent droughts
- Un–managed or environmental flora and fauna will adapt, flee or perish
- What will happen to the irrigated landscape as water shortages become more prevalent?

Key Questions

- How do we develop more accurate estimates of water demand – necessary and essential, versus current theory?
- Can technology offer solutions, or do the hose draggers already have the answer?
- Where is equity if customers with larger landscapes receive water at lower prices than customers with larger families?