Dealing with Drought
Value of Water

- Yield
- Fruit Size
- Fruit Quality
- Cover Crop Mgmt.
- Erosion Control
- Frost Control
- Pest Mgmt.
- Nutrition Enhancement
Dry California Hillside

Irrigated Orchard
Dry farmed vs irrigated apples

10 to 20 tons/acre

30 to 60 tons/acre
May – new growth from a feathered tree planted 2 months earlier

2nd year’s growth (15 months later)
Yield will be 5 tons per acre
Mission Impossible Without Water
Making it Less Bad

• Save as much soil moisture as possible
• Increase OM content of soil – over time
• Irrigate responsibly – don’t waste water
• Manage deficit irrigation – timing
• Prune appropriately
• Select & time crops that use less water
• Get plants to ‘at least’ survive
Low Reservoirs
<table>
<thead>
<tr>
<th>Month</th>
<th>2003-2013 Ave.</th>
<th>2013-2014 % of 'normal'</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>5.24</td>
<td>18%</td>
</tr>
<tr>
<td>Feb</td>
<td>4.91</td>
<td>10%</td>
</tr>
<tr>
<td>Mar</td>
<td>4.41</td>
<td>45%</td>
</tr>
<tr>
<td>April</td>
<td>2.23</td>
<td>51%</td>
</tr>
<tr>
<td>May</td>
<td>1.49</td>
<td>0%</td>
</tr>
<tr>
<td>June</td>
<td>0.22</td>
<td>0%</td>
</tr>
<tr>
<td>July</td>
<td>0.01</td>
<td>0%</td>
</tr>
<tr>
<td>Aug</td>
<td>0.04</td>
<td>0%</td>
</tr>
<tr>
<td>Sept</td>
<td>0.00</td>
<td>0%</td>
</tr>
<tr>
<td>Oct</td>
<td>1.68</td>
<td>0%</td>
</tr>
<tr>
<td>Nov</td>
<td>2.95</td>
<td>1%</td>
</tr>
<tr>
<td>Dec</td>
<td>7.30</td>
<td>7%</td>
</tr>
<tr>
<td>Dec to Jan</td>
<td>30.47</td>
<td>17%</td>
</tr>
</tbody>
</table>
February *** 10-20 inches
Soil Water Holding Capacity

- Clay = 2.0 to 2.5 inches per foot
- Loam = 1.5 to 2.0 inches per foot
- Sand = 1.0 to 1.5 inches per foot

Rainfall from Mother Nature
Rainfall 20 – 90” per year
Most of it runs off
Soil Profiles

Most tree roots are in the top 2 feet = 4”
Deeper in Very Deep Soils

Holding 6-10” of water
Less in Shallow Soils

Holding only 2-3” of water
Sebastopol soil ~ 2 ft. deep underlain by impervious clay
Soil – Root - Profiles

Vegies and Berries are in the top 1 foot = 2”
Soil Survey

Storie index: 0-100
Capability Unit

Soil Type
Soil Horizons
Rooting Depth
Water Holding Capacity
Site Selection
Investigative Tool
Preserving as much rainfall soil-stored moisture as possible

- No weeds
- No cover crop
- Mulch
- Herbicide
- Cultivate
- Add OM
- At least - keep weeds short
Cover crops use water
Organic wood chip mulch

Organic wood chip mulch is expensive, biodegradable, & requires annual application.
Wood chips – vs – weed cloth

Double growth with weed cloth at 20% the cost

$ 4,000/acre

$ 700/acre
Wall to wall if cost is no issue
100% Herbicide
Europe – 100% herbicide = less erosion than cultivation
Clean Cultivation

Stops weeds from using up soil moisture
Cultivation Increases Erosion Risk
Cultivation Reduces Organic Matter
Increasing soil OM by 1% increases water holding capacity by about 0.03 ft$^3$. (0.23 gallons) per ft$^3$. 

Figure 2. Effect of increasing organic matter on available water capacity of silt loam soils. Adapted from Hudson, SWCS, 1994.
Loam soil holds about 1 gallon of water per cubic foot

- Increasing OM by 1% would increase water holding capacity by about 25%
- ~ 10,000 gallons per acre = enough water to last about a week in springtime
- Adding 10 tons of compost per acre (1% of top 8” of soil) every year for many years may slightly increase soil OM
Applying 2 tons/acre compost
2 tons/acre compost
At least - no weeds near trees
Weed Control Comparisons

Burlap – cheap, biodegradable
Wonder weeder
Minimum – keep weeds short

BUT if its green - its using water!!!
Irrigate Responsibly

- Stop leaks
- Reduce waste (drip)
- Don’t over-irrigate
- Keep it uniform
- Time appropriately
- Right frequency
Measure Stem Water Potential

Ken Shackel
Pressure chamber method for measuring water stress

Like measuring the “blood pressure” of the plant

Ken Shackel
Dry petiole

Wet petiole

Ken Shackel
Pressure chamber

Gauge: in psi or bars
Mid-day Stem Water Potential for Almond

- SWP (Bars)

0

-5

-10

-15

-20

-25

-30

-35

(Minimal stress)

(Mild stress)

(Moderate stress)

(Severe stress)

Expected range even under fully irrigated conditions

Will reduce overall growth of young trees, and shoot growth of older trees, but may also have some beneficial effects on older trees

Interior leaf yellowing and drop usually apparent. Not unusual to find under almond production conditions, but probably reduces tree productivity, particularly if these levels occur regularly

Leaf drop, flagging, wilting. Can occur under almond production conditions, particularly around harvest.
Mid-day Stem Water Potential for Olive

Source: Bill Krueger
Olives produce more oil & better quality oil with some water stress

Source: Bill Krueger
Olive shoot growth at different irrigation rates

15% ET

40% ET

89% ET

107% ET
Mid-day Stem Water Potential for Apple

Source: Naor et al. 2008
Calculating Stem Water Potential

In the box below select the CIMIS weather station closest to your orchard, or with the most similar climatic conditions. The map on the right can be used to zoom in on individual locations to help select the best station to calculate reference water potential. After selecting the appropriate station enter the date (within one week) and the time of pressure chamber readings. Temperature, relative humidity, and reference water potential values for almond, prune, walnut, and grape (both SWP and LWP) are displayed.

After selecting the appropriate station enter the date (must be within one week of the current date) and the time of pressure chamber readings. Pacific standard time is used, subtract one hour from daylight savings time.

Active station: 83 - Santa Rosa

Date/Time: Wed, 02-19-2014 1:00 PM

<table>
<thead>
<tr>
<th>Time</th>
<th>Temperature (F)</th>
<th>Relative Humidity</th>
<th>Almond/Prune</th>
<th>Walnut</th>
<th>Grape(SWP)</th>
<th>Grape(LWP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11:00 AM</td>
<td>57.0</td>
<td>57.0</td>
<td>-4.9</td>
<td>-3.2</td>
<td>-2.8</td>
<td>-5.4</td>
</tr>
<tr>
<td>12:00 PM</td>
<td>59.2</td>
<td>49.0</td>
<td>-5.2</td>
<td>-3.3</td>
<td>-2.9</td>
<td>-5.6</td>
</tr>
<tr>
<td>1:00 PM</td>
<td>61.1</td>
<td>47.0</td>
<td>-5.3</td>
<td>-3.4</td>
<td>-3.0</td>
<td>-5.7</td>
</tr>
<tr>
<td>2:00 PM</td>
<td>63.2</td>
<td>44.0</td>
<td>-5.4</td>
<td>-3.5</td>
<td>-3.0</td>
<td>-5.8</td>
</tr>
<tr>
<td>3:00 PM</td>
<td>64.1</td>
<td>41.0</td>
<td>-5.5</td>
<td>-3.6</td>
<td>-3.1</td>
<td>-5.9</td>
</tr>
</tbody>
</table>
IRRIGATION

How much - how often - how long?

**SPRINKLERS**

- Plant Use Rate (ET)
- Application Rate
- Rooting Depth
- Soil Water Holding Capacity

**DRIP IRRIGATION**

- Plant Use Rate (ET)
- Plant Size (Area in Ft²)
- Application Rate (Emitter Spacing and Size)
Plant - USE RATE
How Much Water Plants Use
Evapo - Transpiration (ET)

- Evaporation from soil surface = 10%
- Transpiration = 90% cooling of the leaves
EVAPOTRANSPIRATION (ETo)

REFERENCE

Temperature
Relative Humidity
Wind

How hot & dry & windy is it?
ETo Rates in the Press Democrat
Cold Ocean Current

Fog Influence on climate

California Cold Ocean Current

S.F.

L.A.

42°N 33°N
SONOMA COUNTY climatic zones

Marine
Coastal Cool
Coastal Warm
## Seasonal Water Requirement

April - October (30 yr. average in inches) (Sonoma County)

<table>
<thead>
<tr>
<th></th>
<th>Marine</th>
<th>Coastal Cool</th>
<th>Coastal Warm</th>
</tr>
</thead>
<tbody>
<tr>
<td>April</td>
<td>2.8</td>
<td>4.0</td>
<td>4.5</td>
</tr>
<tr>
<td>May</td>
<td>2.9</td>
<td>5.8</td>
<td>6.9</td>
</tr>
<tr>
<td>June</td>
<td>2.8</td>
<td>5.6</td>
<td>7.0</td>
</tr>
<tr>
<td>July</td>
<td>3.4</td>
<td>6.1</td>
<td>7.9</td>
</tr>
<tr>
<td>August</td>
<td>3.1</td>
<td>5.2</td>
<td>6.8</td>
</tr>
<tr>
<td>Sept.</td>
<td>3.1</td>
<td>4.4</td>
<td>5.7</td>
</tr>
<tr>
<td>Oct.</td>
<td>3.1</td>
<td>3.3</td>
<td>3.7</td>
</tr>
<tr>
<td>TOTAL</td>
<td>21.2</td>
<td>34.4</td>
<td>42.5</td>
</tr>
</tbody>
</table>
Climatic Zones

**Marine:** Foggy, windy, cool
- 2,185 degree days (1,800-2,800)
- Water use ~ 20-22”

**Coastal Cool:** Intermediate – some fog
- 2,582 degree days (1,900-3.600)
- Water use ~ 30-34”

**Coastal Warm:** Warm – little fog
- 2,920 degree days (2,100-4,200)
- Water use ~ 36-42”
## Max Potential Water Use (May-October)

<table>
<thead>
<tr>
<th></th>
<th>ET (inches)</th>
<th>Gal/Acre</th>
<th>Gal/Min</th>
<th>Gal/1,000ft²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marine</td>
<td>20</td>
<td>543,080</td>
<td>2.04</td>
<td>12,464</td>
</tr>
<tr>
<td>Coastal Cool</td>
<td>34</td>
<td>923,236</td>
<td>3.50</td>
<td>21,195</td>
</tr>
<tr>
<td>Coastal Warm</td>
<td>42</td>
<td>1,140,468</td>
<td>4.22</td>
<td>26,181</td>
</tr>
</tbody>
</table>
Typical water use patterns
ETO - Inches per day

- Spring or fall with short cool days = 0.1
- Warm summer days with fog = 0.15
- Hot summer days with some fog = 0.20
- Hot summer days - no fog = 0.25
- Very hot days and windy = 0.30
**Water Use in Gallons / Day**

<table>
<thead>
<tr>
<th>Plant Size</th>
<th>ETo ↓</th>
<th>0.1&quot;/day</th>
<th>0.2&quot;/day</th>
<th>0.25&quot;/day</th>
<th>0.3&quot;/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 ft²</td>
<td></td>
<td>0.062</td>
<td>0.125</td>
<td>0.156</td>
<td>0.187</td>
</tr>
<tr>
<td>10 ft²</td>
<td></td>
<td>0.62</td>
<td>1.25</td>
<td>1.56</td>
<td>1.87</td>
</tr>
<tr>
<td>36 ft²</td>
<td></td>
<td>2.25</td>
<td>4.50</td>
<td>5.61</td>
<td>6.73</td>
</tr>
<tr>
<td>100 ft²</td>
<td></td>
<td>6.20</td>
<td>12.5</td>
<td>15.6</td>
<td>18.7</td>
</tr>
<tr>
<td>200 ft²</td>
<td></td>
<td>12.4</td>
<td>25.0</td>
<td>31.2</td>
<td>37.4</td>
</tr>
<tr>
<td>300 ft²</td>
<td></td>
<td>18.6</td>
<td>37.5</td>
<td>46.8</td>
<td>56.1</td>
</tr>
<tr>
<td>1 acre</td>
<td></td>
<td>2,715</td>
<td>5,431</td>
<td>6,788</td>
<td>8,146</td>
</tr>
</tbody>
</table>

4 gpm X 60 min/hr X 24 hrs/day = 5,760 gallons per day
Deficit Irrigation
Less than maximum

- Reference ET$_{0}$ is maximum
- Young plants use more due to surrounding heat, but they are smaller
- Immature plants use ~ % of surface coverage
- Mature crops use about 75-80%

“Crop Coefficient”
Sprinklers
Sprinkler Irrigation

- Typical Rain-bird Sprinkler
- Applies 0.20” per hour
- 5 hours = 1” water applied
- 1” water soaks down about 6 in
SPRINKLER IRRIGATION
for Vegies

- Rooting depth 12” = 2” total water in soil
- Allowable depletion = 1”
- Water use (Eto = 0.2”/day x 75% = 1.05”/ week
- Sprinklers apply 1” in 5 hours
- Water for 5 hours every 7 days
Berry Irrigation

Applies
½” per hour
Run 2 hrs.
Every 4 days
Convert to Drip & save ~ 20%
Berries: solid moisture
Drip Irrigation

- Water plant daily – lightly – shallow
- Give the plant what it needs/wants
- Need is determined by ETo + coefficient
- Exact an acceptable amount of stress
- Soil water holding capacity is not important
## Water Use in Gallons / Day

<table>
<thead>
<tr>
<th></th>
<th>0.1''/day</th>
<th>0.2''/day</th>
<th>0.25''/day</th>
<th>0.3''/day</th>
</tr>
</thead>
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</tr>
</tbody>
</table>

4 gpm X 60 min/hr X 24 hrs/day = 5,760 gallons per day
FRUIT TREE DRIP IRRIGATION

- Warm summer day: Use is 0.25 Inches
- Tree occupies 100 ft$^2$ = 16 Gallons / Day
- 4 One-gallon per Hour Emitters per Tree
- Water for 4 Hours Every Day

Keep emitters away from trunk
Fruit tree – water stress

- Shoot Growth Slows - Stops
- Fruit Size Reduced
- Leaf Burn
- Trunk Sunburn
- Xylem Damage
- Bud Development Influenced
- Severe Stunting and Death

*Little or no influence on flowering or fruit set*
Reducing fruit tree stress

- Prune moderately when dormant
- Only thinning cuts when dormant
- Summer prune (May-June)
- Reduce crop load (apple & peach)
- Paint SW trunks white
- Time most stress toward summer and autumn – not spring growth stage
Heavy Dormant Topping
Heavy Dormant Topping
Thinning
Cuts to open up the tree
Thinned and Un-pruned
Summer prune to reduce foliage – stunt growth
Summer pruning reduces foliage
What **NOT** to Grow

- Plants that sunburn and die from water stress
- Plants where fruit size is important (fresh)
- Plants that have shallow root systems
- Late maturing varieties
- Plants that need heat and water

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Strawberry, raspberry, blueberry, blackberry, table olive, table grape, peach, nectarine, pear, asparagus, pepper, eggplant, squash, cutting greens, spinach, watermelon, corn, beans, summer onion
What to Grow

- Plants that have been successfully dry farmed
- Plants that are deep rooted
- Plants where fruit size does not matter (processed)
- Plants that naturally tolerate water stress
- Plants that mature in winter & spring
- Short season varieties (early maturing)

- Oil olives, wine grapes, processing apples, some pears, plums, prunes, apricots, potatoes, tomatoes, cole crops, radishes, peas, winter greens, winter alliums, bunch lettuce, melon - -
California Drought Resources

As we enter 2014 in the midst of historic drought, California’s academic institutions serve as a tremendous resource both in offering everything from near-term management advice to farmers and ranchers to the innovative work being carried out by researchers on a vast array of issues from drought resistant crops to snow sensors to climate change.

These pages are being continuously updated as we work to bring the resources of the state’s universities and colleges to a broad range of communities.

- Drought-related events
- Drought information and resources
- Drought experts list
- Media coverage featuring our experts
- Story highlights
Crop Irrigation Strategies

Individual Crop Deficit Irrigation Information

For some crops, primarily perennial crops, there may be growth periods when the crop can be deficit irrigated with minimal impact on yield and quality. Taking advantage of these periods, irrigation systems such as micro precise systems can apply precise irrigations to deficit irrigate without overly stressing the crop.

Click below on your crop of choice for information on irrigation strategies. Each section provides detailed information on irrigation management for crops under drought conditions, as well as a list of resources.

- Almonds
- Pistachios
- Stone Fruit
- Walnuts
- Alfalfa
- Olives
- Winegrapes
- Corn
Thanks! – Questions?

pmvossen@ucanr.edu