DEFICIT IRRIGATION FOR WATER CONSERVATION

Mark A. Crookston P.E., CID, CAIS, CLIA, CIT

Northern Water
Deficit Irrigation

Irrigation management where the full plant water use requirements are not provided by a combination of:

- stored soil moisture,
- rainfall, and
- supplemental watering.

Some level of plant water stress is realized.
Depletion vs. Deficit

**Depletion** is a decrease, reduction, or withdrawal.
- Not detrimental until limits are exceeded.

**Deficit** is the amount by which a resource falls below a required level.
- Deficiency
- Shortage
- Over drafted or ‘in the red’
Kinds of Deficit Irrigation
– More Common than Supposed –

- Selected time periods during growing season to improve crop quality/value.
- Reserve available water supplies for critical periods of growth and yield determination.
- System inability to replace peak season water use – pump/well cannot keep up with demand, so try to rely on soil moisture reserves.
- Irrigation supply ditch doesn’t turn on until later, or shuts off early – pray for timely rains.
Why Manage for Deficits?

- Many plants require deficits to achieve their function and purpose in the landscape.
- Certain plants do not thrive and compete under ‘normal’ moisture conditions.
- Reduced maintenance potential.
- Water supply is limited – **scarcity**.
- Water delivery is restricted – **allocation**.
- Water use is expensive – **costly**.
Managing Deficits

- Appropriate consideration for the **purpose and function** of landscape plantings.
- Knowledge of **plant response** to drought stress is critical – varies significantly by cultivar, ranging widely even in same category.
- Balance objectives/priorities against available resources and limitations.
- Despite the best laid plans and strategies, the **weather** will likely change . . . unexpectedly.
Timing of Deficits is Key

- Target for periods of higher drought resistance followed by ready recovery.
- Avoid deficits during periods critical to plant health and function – *(Spring green-up)*.
- Avoid/prevent added deficits during times of unavoidable stress – *(Winter)*.
- Avoid exacerbating drought stress into prolonged back-to-back periods.
Water Opportunists

- Many drought resistant plants thrive in climates with long periods without rainfall.
- However when the rains arrive, of ‘necessity’ they make ready use of the available supply.
- Consequently, if rain or supplemental irrigation provides abundant water, they will use water at ‘unexpectedly’ higher rates – and the potential for reduced water use will not be realized.
Drought Resistance

Avoidance

- Postpone tissue damaging deficits of dehydration.
- Limit transpiration – reduced leaf temperature and/or stomatal opening.
- Postpone reduced soil water uptake:
  - Deep rooting,
  - Root viability (maintain or recover its potential),
  - Resistance to soil related stresses (texture, drainage, pH).

Tolerance

- Escape – life cycle allows it to survive in a dormant state or as a seed.
- Hardiness – tolerates desiccation through osmotic adjustment, thick cuticles*, and/or low tissue water content.

* Plant cuticle is a protective film covering epidermis of leaves, etc. Impregnated with soluble waxes and hydrophobic.
Shallow Rooting

**Too Often – Too Much**

- Plant roots require oxygen – they need to breathe.
- Roots stay closer to the surface – closer to the interface with the atmosphere.
- Can result in plant water stress – poor health, delayed growth, susceptibility to insects and disease.

**Too Often – Too Little**

- Lower root zone steadily dries down, moisture is scavenged.
- Root hairs can die back in chronically dry soils and then the effective rooting depth decreases.
- Water losses to surface evaporation increase significantly.
- Effective rainfall is reduced.
- Potential for water conservation is diminished.
Deeper Rooting

- Select cultivars with potential for deep rooting.
- Appropriate soil preparation and incorporation of amendments can encourage deeper rooting.
- Drainage to remove excess water can increase rooting depth on soils with a high water table.
- Proper irrigation management can help promote deeper roots.
- Deeply rooted plants are inherently more drought resistant.
When Do Deficits Occur?

- Plant water use is highest following rainfall/irrigation events – surface evaporation is high while transpiration may decline slightly.
- Transpiration continues at relatively steady rates until soil moisture depletion exceeds the level needed to satisfy full plant water needs.
- Plant water stress begins (deficit) and increases steadily as soil moisture depletions increase further. Highest just before irrigation.
Managed Stress Factor - $K_{SM}$


$$K_L = K_{MC} \times [(K_V - K_{C\text{ Soil}}) \times K_D \times K_{SM} + K_{C\text{ Soil}}]$$

- $K_L$ = target landscape coefficient
- $K_{MC}$ = microclimate factor (1.0 for average or reference condition)
- $K_V$ = vegetation species factor (0.9 for cool-season turfgrass)
- $K_{C\text{ Soil}}$ = minimum value for $K_V$ for bare soil (0.15 for evaporation)
- $K_D$ = vegetation density factor (1.0 for full shading of ground)
- $K_{SM}$ = managed stress factor
## Managed Stress Factors - $K_{sm}$

*Irrigation 6th Edition, Table 5.12, p. 151*

<table>
<thead>
<tr>
<th>Vegetation category</th>
<th>High stress</th>
<th>Average managed stress</th>
<th>Low stress</th>
<th>Depletion fraction, $p$, for no stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trees</td>
<td>0.4</td>
<td>0.6</td>
<td>0.8</td>
<td>0.6</td>
</tr>
<tr>
<td>Shrubs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- desert species</td>
<td>0.3</td>
<td>0.4</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>- non-desert</td>
<td>0.4</td>
<td>0.6</td>
<td>0.8</td>
<td>0.6</td>
</tr>
<tr>
<td>Ground cover</td>
<td>0.3</td>
<td>0.5</td>
<td>0.8</td>
<td>0.5</td>
</tr>
<tr>
<td>Annuals (flowers)</td>
<td>0.5</td>
<td>0.7</td>
<td>0.8</td>
<td>0.4</td>
</tr>
<tr>
<td>Mixture of trees, shrubs, and ground cover</td>
<td>0.4</td>
<td>0.6</td>
<td>0.8</td>
<td>0.6</td>
</tr>
<tr>
<td>Cool-season turfgrass</td>
<td>0.7</td>
<td><strong>0.8</strong></td>
<td>0.9</td>
<td><strong>0.4</strong></td>
</tr>
<tr>
<td>Warm-season turfgrass</td>
<td>0.6</td>
<td>0.7</td>
<td>0.8</td>
<td>0.5</td>
</tr>
</tbody>
</table>
### Management Allowed Depletion Fraction

**MAD** from *Irrigation* 6th Edition, Table 5.13, p. 152

<table>
<thead>
<tr>
<th>Managed stress factor, $K_{sm}$</th>
<th>Depletion fraction, $p$, for no stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3</td>
<td>0.4</td>
</tr>
<tr>
<td>1.0</td>
<td>0.30</td>
</tr>
<tr>
<td>0.95</td>
<td>0.47</td>
</tr>
<tr>
<td>0.90</td>
<td>0.55</td>
</tr>
<tr>
<td>0.85</td>
<td>0.62</td>
</tr>
<tr>
<td><strong>0.80</strong></td>
<td><strong>0.68</strong></td>
</tr>
<tr>
<td>0.75</td>
<td>0.74</td>
</tr>
<tr>
<td>0.70</td>
<td>0.78</td>
</tr>
<tr>
<td>0.65</td>
<td>0.82</td>
</tr>
<tr>
<td>0.60</td>
<td>0.86</td>
</tr>
<tr>
<td>0.55</td>
<td>0.90</td>
</tr>
<tr>
<td>0.50</td>
<td>-</td>
</tr>
</tbody>
</table>
Below RAW but above MAD

\[ \text{Ave } K_s = K_{sm} \]
Net Irrigation Depth to Apply $d_{\text{net}}$
Derived from Irrigation 6th Edition, Table 13.4, p. 498

<table>
<thead>
<tr>
<th>Soil type:</th>
<th>Sandy loam</th>
<th>Loam</th>
<th>Silt loam</th>
<th>Silt</th>
<th>Silty clay loam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adjustment variable to account for soil matric potential / soil water content levels:</td>
<td>(1.00)</td>
<td>(1.00)</td>
<td>(1.00)</td>
<td>(1.00)</td>
<td>(1.00)</td>
</tr>
<tr>
<td>Average water-holding capacity, %:</td>
<td>12.0%</td>
<td>13.0%</td>
<td>14.0%</td>
<td>15.0%</td>
<td>13.0%</td>
</tr>
<tr>
<td><strong>Crop</strong></td>
<td><strong>$Z_r$, inch</strong></td>
<td><strong>$p$</strong></td>
<td><strong>Net irrigation to apply ($d_{\text{net}}$), inch</strong></td>
<td><strong>Net irrigation to apply ($d_{\text{net}}$), inch</strong></td>
<td><strong>Net irrigation to apply ($d_{\text{net}}$), inch</strong></td>
</tr>
<tr>
<td>Turfgrass – cool season</td>
<td>24</td>
<td>0.40</td>
<td>1.1</td>
<td>1.3</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>0.40</td>
<td>0.8</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>0.40</td>
<td>0.6</td>
<td>0.6</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>0.40</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Turfgrass – warm season</td>
<td>24</td>
<td>0.50</td>
<td>1.4</td>
<td>1.6</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>0.50</td>
<td>1.1</td>
<td>1.2</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>0.50</td>
<td>0.7</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>0.50</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
</tr>
</tbody>
</table>
Cycle/Soak becomes more important

![Graph showing the relationship between Sprinkler Application Rate (iph) and Time (minutes). The graph indicates that Min Soak Time and Max Run Time become more important as the Sprinkler Application Rate increases.](image-url)
‘SMART’ Controllers

- Great potential for significantly reducing the ‘burden’ of scheduling deficit irrigation.

- Features to watch for in ‘SMART’ controllers:
  - Potential to change time (days) between irrigation events rather than just weekly runtime (minutes).
  - Accomplish a ‘check-book balance’ of soil moisture for each zone.
  - Account for local, effective rainfall – accurately.
  - Provides flexibility to manager to override pre-programmed defaults as desired.
Make Management Changes – Gradually –

- Generally, not a good idea to radically change irrigation management practices overnight.
- Plant roots need time to grow deeper and to become more dense – to become more hardy.
- Owners will often be more supportive if landscape appearance remains attractive during transition period.
Pre-Managing for Drought

1. Maintain irrigation system for high application efficiency and uniformity.
2. Irrigate deeply but infrequently – promote deeper rooting with greater density.
3. Reconsider plant choices – include those with mechanisms for drought avoidance or drought tolerance.
4. Reduce planted areas.
5. Lower planting densities.
6. Include plants with shorter ‘active’ growing season.
Managing During Drought

1. Reduce levels of irrigation for turf grasses.
2. Curtail watering of planned sacrificial areas.
3. End the watering of low value, low use, low priority areas that are readily recovered.
4. Cease irrigation of plants adapted to the climate – they are expected to survive.
5. Stop watering of all areas except trees and other high value landscape plantings.
QUESTIONS?

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Northern Water
Rain Shut-off devices – 2014
Conservation Gardens at Northern Water

Rain, inches

Weekly Minutes Off

HunterMiniClik vo
HunterMiniClik vc
Hunter Wireless
HydreonOptical
Irritrol RS1000 wireless
Irritrol RS500 vo
Irritrol RS500 vc
RainBird RSDBEX
RainBird WR2RC wireless
Toro TRS
Toro TWRS wireless
TBucketRain

1-May 29-May 26-Jun 24-Jul 21-Aug
## Smart Controllers – 2014
### Variable Minutes per Scheduled Irrigation

<table>
<thead>
<tr>
<th>Controller</th>
<th>Weather Sensor</th>
<th>Connection</th>
<th>Programs</th>
<th>Starts</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irritrol Climate Logic</td>
<td>Weather sensor</td>
<td>Wireless</td>
<td>ABC</td>
<td>3/program</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RainDial-R</td>
<td>Weather sensor</td>
<td>Wireless</td>
<td>ABCD</td>
<td>8/program</td>
<td></td>
<td>Interrupts irrigation as soon as soil moisture threshold is reached.</td>
</tr>
<tr>
<td>AguaMiser w/ Rainbird ESP Modular</td>
<td>Soil moisture sensor addon</td>
<td>Wireless 900 MHz</td>
<td>ABC</td>
<td>4/program</td>
<td></td>
<td>Higher cost. Sensor is site specific.</td>
</tr>
</tbody>
</table>
### Smart Controllers – 2014

Variable Days to Next Irrigation – deep/infrequent

<table>
<thead>
<tr>
<th>Controller</th>
<th>Weather Sensor</th>
<th>Programs</th>
<th>Starts</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainbird ESP-SMTe</td>
<td>Weather sensor w/ tipping bucket rain gauge</td>
<td>Wired</td>
<td>Every zone</td>
<td>cycle / soak</td>
<td>Keeps soil moisture balance for each zone. Abundance of operating information provided.</td>
</tr>
<tr>
<td>Weather Reach Controller Link w/ Rainbird ESP-Me</td>
<td>Weather data from local stations. No subscription fees.</td>
<td>Wi-Fi</td>
<td>ABCD</td>
<td>6/ Program</td>
<td>Keeps soil moisture balance for four ‘programs’. Can use rain from weather station or connect to tipping bucket gauge. Can check &amp; change settings remotely. Soil moisture balance is easily reset.</td>
</tr>
<tr>
<td>Baseline w/ KRain RPS-469</td>
<td>Soil moisture sensor add-on</td>
<td>Wired</td>
<td>ABCDEF</td>
<td>6/ Program</td>
<td>cycle / soak</td>
</tr>
</tbody>
</table>
### Smart Controllers – 2014

#### Variable Days to Next Irrigation – deep/infrequent

<table>
<thead>
<tr>
<th></th>
<th>Programs</th>
<th>Starts</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toro Evolution</td>
<td>Wireless</td>
<td>ABC</td>
<td>Can utilize three moisture soil sensors.</td>
<td>Surface sensors. Must remove sensor to change batteries.</td>
</tr>
<tr>
<td>Acclima SC6</td>
<td>Wired</td>
<td>ABC</td>
<td>Can utilize six soil moisture sensors.</td>
<td>Sensors are site specific.</td>
</tr>
<tr>
<td>Rainbird SMRT-Y ESP</td>
<td>Wired</td>
<td>ABC</td>
<td>New sensor package.</td>
<td>Low initial cost. Sensor is site specific.</td>
</tr>
<tr>
<td>Modular</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>