Opportunities for Automation
Optimization of Surface Irrigation

Khaled Bali*, Dan Putnam**, Daniele Zaccaria**, Eduardo Bautista***

*UC Kearney Agricultural Research and Extension Center, Parlier, CA
**UC Davis, Davis, CA
***USDA-ARS, Maricopa, AZ
Irrigation: Controlled amount of water is applied to plants at specific intervals

Irrigation Methods:
1- Surface irrigation (flood or gravity):
   - Border strip (flat) irrigation (slope 0.1-0.2%)
   - Furrow irrigation (slope)
   - Basin irrigation (zero slope)
2- Sprinkler Irrigation (various types)
3- Drip Irrigation (various types)
   - Surface drip
   - Subsurface drip
TRENDS IN CALIFORNIA IRRIGATED AGRICULTURE

- Water Agencies and regulators provide financial incentives to growers to shift to micro-irrigation systems (SWEEP, EQIP, CEC)

Approximately 30% decline in field crops between 2006 and 2015 and increase in permanent crops

Source: Irrigation Survey 2010, (Tindula, Orang & Snyder, 2013)
**Alfalfa Crop Water Use and Irrigation Efficiency**

**Crop ET = Reference ET x Crop Coefficient**

\[ ET_C = ET_0 \times k_C \]

**ETc is also used in system design: Max irrigation depth to be applied (D_{MAX})**

\[ D_{max} = \left[ \frac{E T_{c(peak)}}{E f_{APP}} \right] = \text{in} / \text{day} \]

**Traditional drip (SDI) or sprinkler example:**

Peak ET₀= 0.40/day \quad Max Kc=1.2 \quad AE=80%

Max application depth=(0.4*1.2/.8)=0.60 in/day

80 acre field with just one zone, need to apply this in

~ 8-20 hr/day (4 ac-ft/day) for drip
~ 4-10 hr/day (4 ac-ft/day) for sprinkler

**For flood application rate as high 10 times the above figures (3-4” per irrigation)**

<table>
<thead>
<tr>
<th>System</th>
<th>Potential Eff.(_{APP})</th>
<th>Actual Eff.(_{APP})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravity</td>
<td>70-85%</td>
<td>50-90%</td>
</tr>
<tr>
<td>Drip</td>
<td>85-90%</td>
<td>50-95%</td>
</tr>
<tr>
<td>Micro-sprinkler</td>
<td>80-90%</td>
<td>50-90%</td>
</tr>
<tr>
<td>Sprinkler</td>
<td>70-90%</td>
<td>60-90%</td>
</tr>
</tbody>
</table>
How Much Water do I need to Apply?

- Need to know crop water use (ETc) since last irrigation
- ETc from (Reference evapotranspiration and crop coefficient)

- Typical application rates (vary widely depending on soil type, etc):
  
  - Surface: ~ 3-5 in/irrigation (much higher rate for light soils)
  - Sprinkler: ~ 0.5-1.2 in/irrigation
  - Drip: ~ 0.5 in/irrigation

- Delivery system designed for surface irrigation
Surface Irrigation

Applied water = Root zone storage + runoff + deep percolation
On-Farm Water Conservation
= Higher Application Efficiency (AE)

IRRIGATION = Evapotranspiration (ET) + Deep Percolation + Runoff

Application Efficiency (AE) = $\frac{A}{A+B+C}$

To achieve higher efficiency, reduce B and/or C

BUT

Need to have a balance,
Deep Percolation sometimes is needed for salinity control
(650 ppm ~ 0.9 tons of salt/ac-ft)
Runoff is needed for Uniformity (100% AE means under irrigation)
Surface Irrigation (uniform soil?)

Applied water = Root zone storage (A) + runoff (B) + deep percolation (C)

AE = 3.5 / 5 = 70%
ROR = 1 / 5 = 20%
DPR = 0.5 / 5 = 10%
DU = 3.5 / 4 = 87.5% (Distribution Uniformity)

A = 3.5”
B = 1”
C = 0.5”
Advance and Recession Curves
(also other parameters are needed for system evaluation, flow rates, slope, n, soil type, etc)
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Tools to Improve Surface Irrigation Efficiency

- Evaluation of current irrigation system (AE and DU)-Application Efficiency and Distribution Uniformity
- Inflow rate, outflow rates (runoff and tile water)
- Advance rate (and recession rate) using wireless advance sensors
- WinSRFR (surface irrigation design and simulation model)
Final infiltration profile and irrigation performance measures

Application Efficiency (AE) and Distribution Uniformity (DU)

\[
AE(\%) = \frac{D_{zh}}{D_{app}} \times 100
\]

\[
DU_{lq} = \frac{D_{lq}}{D_{inf}}
\]

\[
DU_{min} = \frac{D_{min}}{D_{inf}}
\]

Dapp – applied depth
Dinf – infiltrated depth
Dreq – required depth
Dro – runoff depth
Ddp – deep percolation depth
Drz – infiltrated depth contributing to the required (Dz in WinSRFR manual)
Dmin = minimum depth
Dlq – low-quarter depth
Typical low desert 80-acre alfalfa field

- **flow rate, Q:** 15-20 cfs
- **Border length:** 1200-1,250 ft
- **Border width:** 60-300 ft  
  - example below (~205 ft)
- **Slope:**  
  - ~ 1.5 ft/1000 ft
- **Water use:**  
  - ~ 6.5-7 ac-ft/ac per year
- **Runoff rate:**  
  - ~ 15-20%
- **No. of irrig.:**  
  - ~ 16-18 events (24 hr per irrig.)
- **Irrigation labor:**  
  - ~ $5,100/year (80-ac)
Results: Tools and practical charts to help growers design efficient surface irrigation system to meet their needs and maximize water use efficiency.
Volume applied = Surface storage + Subsurface storage

Flow rate * time = d * L + z * L
Optimization
(Automation of surface irrigation systems)

- The process of considering all flood irrigation variables to improve on-farm irrigation efficiency

- Adjust irrigation time to allow for changing crop roughness (height and density of the crop)

- Adjusting border/set length to allow for variable soil type across the field

- Adjusting flow rate to an irrigation set (one or more border/land) to improve efficiency

- Computer simulation models are needed

- Accurate measurements during irrigation events (flow rate and advance rate)

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Optimization

- Soil type 114 & 115 (heavy soils) - lower flow rate or high flow rate will work depending on the time of the year (considerations: erosion rate & scalding)
- Soil type 106 or 110 (lighter soil) - higher flow rate to increase efficiency
- Soil type 115 & 106 (change flow rate during the irrigation event)
Reducing field length (light soil): to improve DU and reduce DP (and nitrate into GW)
(good option for light soils, not effective on heavy ground)-SWEEP

1275 ft, 2 valves, 21.4 cfs  6.1 inches applied

600 ft, 1 valve, 21.5 cfs  2.5 inches applied (NO3 in GW)

Source: Marsha Campbell, UCCE
Automation of Surface Irrigation Systems

• Irrigators typically work in 24-hr shifts

• Make decisions on when to turn the water off based on a number of variables (flow rate, advance rate, crop height, etc)

• Automation: smart decisions based on accurate and real-time data (flow rate, advance rate, automated gates, ETc, and other variables)

• Water conservation and labor savings (CA min. wage $15/hr in 2022)
Automation of Surface Irrigation Systems
UC Desert Research and Extension Center
Automation Systems in CA
Commercial fields and UC Research Centers
Watch Technologies
https://watchtechnologies.com/
Efficiency & Uniformity Indicators

AE = 87 %
DUmin = 0.94
DUlq = 0.97
DP% = 11 %
RO% = 3 %
Warning(s)
-- None --

Performance Indicators (from Simulation)

Dapp = 4.61 in
Dinf = 4.5 in
Dro = 0.13 in
Ddp = 0.5 in
Dmin = 4.2 in
Dlq = 4.37 in
Tco = 65 min
TL = 161.1 min
XR = 0.61
Xmax = 660 ft
Ymax = 4.84 in
Verr% = -0.01 %
- Need more emphasis on evaluation of surface irrigation systems

- Room for improvement but you cannot improve what you do not measure

- New tools to analyze and improve the design and management of surface irrigation (technology, modeling, automation)

- Higher efficiency is possible at a reasonable cost

- Higher labor costs will be a key factor in increasing efficiency
Thank You