Improving the Efficiency of Surface Irrigation Systems in California

Khaled M. Bali
kmbali@ucanr.edu
Irrigation Water Management Specialist
UC Kearney Agricultural Research and Extension Center
Parlier, CA
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
Surface (flood) irrigation:

- Water application methods where water is applied over the soil surface by gravity (no energy is needed).
- Most common irrigation system throughout the world
- High efficiency possible on medium and heavy soils
- Mostly for field crops in California

Reduction in field crops in CA from 3,805,800 acres in 2006 to 2,639,200 acres in 2015 (-30%)

<table>
<thead>
<tr>
<th>System</th>
<th>Eff. APP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface</td>
<td>70-85%</td>
</tr>
<tr>
<td>Drip</td>
<td>85-90%</td>
</tr>
<tr>
<td>Micro-sprinkler</td>
<td>80-90%</td>
</tr>
<tr>
<td>Sprinkler</td>
<td>70-90%</td>
</tr>
</tbody>
</table>

2013 Fraction of irrigated land totally or partially irrigated with gravity methods in western states.
Source: USDA Farm and Ranch Irrigation Survey -FRIS, 2013
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
Improving Irrigation System Efficiency

• Reduce losses (nutrients, pesticides, water)
• Limited water supplies and increased demands
• Labor cost (minimum wage in CA from $10.5 to $15/hr by 2022)
• What is efficiency?
  • Distribution system efficiency (district level, canals, reservoirs, etc.)
  • On farm or field application efficiency (AE), distribution uniformity (DU), and other parameters
Surface Irrigation

Applied water = Root zone storage + runoff + deep percolation

Subsurface

Surface runoff (B)

Root zone storage (A)

Deep percolation (C)
On-Farm Water Conservation
= Higher Application Efficiency (AE)

IRRIGATION = Root zone storage (ETc) + DEEP PERCOLATION + Runoff

\[ \text{Application Efficiency (AE)} = \frac{A}{A+B+C} \]

To achieve higher efficiency, reduce B and/or C

**BUT**

Need to have a balance,

Deep Percolation sometimes is needed for salinity control

(700 ppm ~ 0.96 tons of salt/ac-ft but NOT with every irrigation)

Runoff is needed for Uniformity (100% AE means under irrigation)
On-Farm Water Conservation
= Higher Application Efficiency (AE)

Application Efficiency (AE) = \( \frac{A}{A+B+C} \)
Deep Percolation Ratio = \( \frac{B}{A+B+C} \)
Runoff Ratio = \( \frac{C}{A+B+C} \)

IRRIGATION = Root zone storage (ETc) + DEEP PERCOLATION + Runoff

\[ A + B + C \]

Irrigation Water Requirements (IR)
IR = Crop ET/AE
Distribution Uniformity (DU)

DU = \frac{\text{Average depth in low quarter}}{\text{Average depth infiltrated}}

Many other efficiency parameters

BUT

KEEP IT SIMPLE, AE and DU are all you need
Field Crops

Mostly surface irrigation methods:

- Border (flat) irrigation
  Runoff rate: 5-20% (vary)

- Furrow (bed) irrigation
  Runoff rate: 15-30% (vary)

Surface runoff:
Nutrient losses: surface runoff & deep percolation
Pesticides losses: mostly surface runoff &
  some with deep percolation

* Usually no runoff with basin irrigation
Field A (Alfalfa, Border, UCDREC)
Field B (Alfalfa, Furrow, UCDREC)

- Runoff time (hr)
- Runoff rate (%)
- C (mg/L)

![Graph showing runoff rate and concentration over time for Field B.](image)
Surface Irrigation (uniform soil?)

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

\[ AE = \frac{3.5}{5} = 70\% \]
\[ ROR = \frac{1}{5} = 20\% \]
\[ DPR = \frac{0.5}{5} = 10\% \]
\[ DU = \frac{3.5}{4} = 87.5\% \]
Final infiltration profile and irrigation performance measures

Application Efficiency (AE) and Distribution Uniformity (DU)

$$AE(\%) = \frac{D_{rz}}{D_{app}} \times 100$$

$$DU_{lq} = \frac{D_{lq}}{D_{inf}}$$

$$DU_{min} = \frac{D_{min}}{D_{inf}}$$

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
Flow rate (cfs) and total applied water
Advance and Recession Curves
(also other parameters are needed for system evaluation, flow rates, slope, n, soil type, etc.)
Tools to Improve Efficiency

- Increasing check flow rate (to increase advance rate, avoid erosion, time of the year)
- Reducing field length: to improve DU and reduce DP (good option for light soils, not effective on heavy ground)
- Tailwater recovery systems: to reduce RO (good option for heavy soils, not effective for light soils)
- Selecting an appropriate irrigation water cutoff time (good option for heavy soils to reduce or eliminate runoff)
- Automation of surface irrigation
Tools to Improve Efficiency

- Evaluation of current irrigation system (AE and DU)
- Inflow rate, outflow rates (runoff and tile water)
- Advance rate (and recession rate)
- WinSRFR (surface irrigation design and simulation model)
Tools to Improve Efficiency

Minimum Distribution Uniformity ()

Basin / Border Width (ft)

Basin / Border Length (ft)
Reducing field length: to improve DU and reduce DP (good option for light soils, not effective on heavy ground)

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
Irrigation management – applying the right amount of water

Surface

Subsurface

Surface

Subsurface
Tailwater Recovery Systems

- For water conservation
- Improving the quality of drainage water (TMDL)
Automation of Surface Irrigation Systems
Summary

- 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