Studies on Subsurface Drip Irrigation (SDI) in Alfalfa - What we’ve learned to date.

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Drip irrigated alfalfa field, California
What does the future hold?
CVP Water Allocations from Bureau of Reclamation

Source: Westlands Water District
Change in Groundwater Storage in the Central Valley, 1920 - 2010

-150 km³ (-130 MAF)

Alfalfa Hay VS Almond Acres in California
2006 to 2015

Source: USDA/NASS *Forecast
January 1 Milk Cows Numbers in California, 1996-2016*

Source: USDA/NASS  *Estimate for 2016

The Hoyt Report
Future trends for Alfalfa?

- Dethroned as #1 acreage crop (~2012)
- ‘Tug of war’ between
  - Restrictions on acreage/production due to competition from other crops, water limitations
  - Strong demand from Western Dairies, Exports, horses, other livestock
- Need for:
  - Higher yields on limited land availability (this is a GLOBAL issue)
  - Lower water use
  - Water transfers
  - ‘Sustainable intensification’
- Alfalfa will remain a major crop for many years to come
Why an interest in SDI in Alfalfa?

- Possibility of Higher Yields
- Experience with other crops
- Higher Hay price
- The Water Squeeze
California Alfalfa

- ~84% Surface irrigation
- ~14% sprinklers (pivots/ wheel lines)
- ~2-3% SDI
UC SDI Studies:

- “Case Studies” of grower’s experiences across a range of environments (18-20)
  - Documenting successes/ failures
  - Costs/ benefits

- Controlled Studies on UC Facilities:
  - SDI compared with Flood
  - Variety interactions (with AZ, NMSU)
  - Deficit Irrigation with drip
  - Spacing Studies, understanding optimum irrigation management
  - Gopher Management
We hope not this:

A learning curve
To consider SDI in alfalfa:

- **Must** improve yields over surface irrigation to justify cost
- Must understand source of water, water quality, delivery
- Must be prepared for higher level of management
# Sample Costs for SDI
*(compared with surface irrigation)*

<table>
<thead>
<tr>
<th>Item</th>
<th>Partial Budget ($/a)</th>
<th>Annualized Costs ($/a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drip Tape (40”) – 6 yr.</td>
<td>$450 (400-500)</td>
<td>75</td>
</tr>
<tr>
<td>Drip Tape Installation– 6 yr.</td>
<td>$200 (100-300)</td>
<td>33.33</td>
</tr>
<tr>
<td>Irrig. Infrastructure (valves/pipes, pump) -15 yr.</td>
<td>$1400 (800-1800)</td>
<td>93.33</td>
</tr>
<tr>
<td>Water Cost (-8% SDI)</td>
<td>-$42 (+10% to -20%)</td>
<td>-$42</td>
</tr>
<tr>
<td>Energy Cost (vs. surface)</td>
<td>$118</td>
<td>$118</td>
</tr>
<tr>
<td>Labor Irrig. Management</td>
<td>-$66</td>
<td>-$66</td>
</tr>
<tr>
<td>Labor for Rodent mgt. &amp; repair</td>
<td>$75</td>
<td>$75</td>
</tr>
<tr>
<td>Remove Driplines—6 yr.</td>
<td>100 (80-120)</td>
<td>16.67</td>
</tr>
<tr>
<td>Total Sample costs</td>
<td>$2,050 initial + $185/yr</td>
<td>302.50/year</td>
</tr>
</tbody>
</table>

*Note: Actual costs may be higher or lower than these amounts*

*March 16 2016  Maricopa, Arizona*
What is needed to Justify SDI?

(Fixed costs)

- Assumptions: 15 yrs. infrastructure (pumps, filters, etc.)
- 6 years drip lines
- Does not consider support by NRCS or state agencies or rotation value

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Are these yield improvements possible?

- Yield Increases appear real
- Confirmed by controlled studies (Lamm et al. 2012, UC studies)
- Growers report approximately 3.1 t/a improvement over flood.
- 20-35% range
- Why is that?
Key Recommendations

Why would we expect improved yields in SDI vs. surface?

1. Superior Distribution Uniformity (in Space)
   - Less difference between top and bottom of field
   - Well known problems with surface systems
Innate Problems with Flood Irrigation

(Distribution uniformity can be poor due to soil infiltration rate, flow, and set duration)

In a 12 hour irrigation set:

- Too Much
- Just Right
- Too Little
- Flooding

Water

Deep Percolation

12 Hours  8 Hours  6 Hours  Accumulation

(1320 feet)
Standing Water
(the enemy of alfalfa)
Tail - End Damage

Weeds intrude in damaged areas
Why would we expect improved yields in SDI vs. surface?

2. Distribution Uniformity (in Time)
   - Ability to ‘charge’ a field within hours, not days
   - Most Flood-irrigated (and some sprinkle irrigated) fields require 4-12 days to irrigate, depending upon flow available.
6- to 20-day period during which fields cannot be irrigated

Steve Orloff, photo
Innate Problems with Flood Irrigation

Check number:

Day 1

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Innate Problems with Flood Irrigation

Check number:

Water

(3300 feet)

Day 2

(1320 feet)

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Innate Problems with Flood Irrigation

In a 28 day growth cycle, some parts of the field get water 7-8 days later.

Since 7 days before, and 7 days after harvest have to be dry, there is only a 14 day window for irrigation – so with flood irrigation, mostly can irrigate either 1x or 2x. Different parts of the field are irrigated differently.

(*Same issue with wheel lines!*)
Why Increased Yields with SDI?

- **3. Ability to Maintain Turgor**
  - Avoid temporary droughts
    - The moment turgor is lost, growth ceases
    - Avoid wetting-drying patterns (flood/drying)
Key Recommendations

Why Increased Yields?

4. Manipulating Irrigation Schedules to match ET

- Essentially any schedule desired
- Can irrigate every day
- Many hours, few hours
- Maintaining turgor
- Irrigating close to harvests (during??)
Innate Problems with Flood Irrigation

- Flood irrigation events can only irrigate between 4” to 8” of water at once, necessary just to push water down the field.
- Typically only 1 or 2 irrigations are feasible in a 14 day irrigation window.
- So: 1 irrigation may apply too little, and 2x may apply too much water for a 28 day ET demand - resulting either in excess or deficit irrigations.
Can a system follow ET?

- Is it restricted in terms of applying small amounts?
- Can it recharge the profile?
Distribution Uniformity was not perfect in SDI fields:

- In many fields, a ‘corrugation’ effect was seen, in spite of improved yields
- Perhaps 10-20% yield hit?
- Likely a spacing issue - soil type dependent
- More to learn on lateral spacing/flow rates
‘Corrugation Effect’
Above Drip Line

Between Drip Lines
Different Rooting Patterns

Khaled Bali, photo

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What we’ve learned:

- Problems during stand establishment can last a long time
- Use sprinklers to bring up the crop
- Keep profile full while crop roots are developing
- Roots need to be deep enough to access water
- Roots don’t ‘seek’ water - they grow in the presence of water!
Over Irrigating to compensate for lack of lateral movement

Standing Water, Loss of Stand, Grassy Weed Intrusion

Above Drip Lines

Between Drip Lines
What we’ve learned:

- Growers were sometimes unable to fully charge fields with moisture at the beginning of the season with SDI
- Try to overcome it with longer sets
- Over irrigation kills plants
- 40” spacing (the most common) may not be ideal for many soil types
- Inability to recharge in mid-summer
Key Recommendations

- Do not take an ‘absolute’ view of application technology
- Sprinklers best for germination.
- Surface flood irrigations may be helpful in addition to SDI
Recommend to Maintain the ability to Flood irrigate:

- Fully re-charge fields periodically (particularly at beginning of season)
- Assists with gopher management
- Assists with salinity management
- Maintain Wildlife Habitat
- Note: Consider less than 40” spacing strategies (e.g. 30”)

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What we’ve learned:

- Rodents are perhaps THE major challenge for SDI in alfalfa.

Key Recommendations
Gopher Management

- No one solution
- An Integrated Approach
  - Primarily increased awareness/scouting
  - Allocate the time and labor to this function
  - Trapping
  - Baits
  - Occasional flood irrigations
  - Exclosures (barriers)?
  - Repellents (Pro-Tech T)?
  - Predators (owl boxes)?

‘Professionalize’ rodent management

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Rodent Control is Key

- A number of growers have walked away from SDI as a consequence
- Cannot be tolerated

Future Research
- Professional monitoring & control
- Protected drip tape
- Barriers (exclusions)
- Further work on baits, repellents

Current work - taking a professional view of management
Can you save water?:

- Yes, under some conditions
- Yield is directly related to ET (higher yield, higher ET!), so may not save water
- But can save on evaporation
  - ET question is still pending
- Growers have reported water savings.
  - Soil type (savings on light soils)
  - Efficiency of flood system
  - Are they adequately irrigating for full yields?
- WUE - yield per unit water
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GHG emissions

Seasonal N₂O Emissions

Data: Ryan Byrnes, Martin Berger, Will Horwath

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GHG Emissions

2015 Seasonal Alfalfa N₂O Emissions

Data: Ryan Byrnes, Martin Berger, Will Horwath
March 16 2016 Maricopa, Arizona
Crop Rotation Considerations

- Rotation with tomato, row crops with alfalfa with drip lines remaining
- Assist in covering costs
- Explore spacing issues (60? 40? 30?)
- Double 30s?
- Different rooting patterns for row crops vs. alfalfa
Labor is perhaps one of the primary limitations of surface irrigation.
82% of growers (so far) are highly satisfied.
18% are medium to less satisfied with SDI.
What should one do when there’s not enough water?

- Curl up in a ball?
- Partial Season irrigations?
Alfalfa Cumulative ET (Lysimeter Trail - Davis 2015)

Over 7 cuts

\[ K_a = \frac{CET_c}{CET_o} = 0.85 \]
Variety X Water Deficits under drip Irrigation

-El Centro & Davis
Alfalfa SDI Deficit Trial
Davis (2015)

Cumulative ET, or ETc or Irrigation applied (inch)

Day of Year

- ETc
- 100% of ETc
- 75% of ETc (late-season dry down)
- 75% of ET (late-season deficit)
- 50% of ETc (mid-season dry down)
- ETo

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**Water Use Efficiency (t ac⁻¹ in⁻¹)**
- I1: 0.25
- I2: 0.33
- I3: 0.31
- I4: 0.43

**Diagram:**
- **Dry matter**
- **Irrigation applied**

**Alfalfa dry matter (t ac⁻¹)**
- I1: 100% of ET
- I2: 75% of ET
- I3: 75% of ET
- I4: 50% of ET

**Irrigated applied (inch)**
- I1: 0
- I2: 0
- I3: 0
- I4: 0
Deficit Irrigations:

- May be higher yielding with SDI
- Emphasize Early Irrigation to maximize yield and WUE
- Economics must work (economic water transfers)
- Alfalfa is the best crop to have in a drought
Why alfalfa is the best crop to have in drought (alfalfa blog)

- Deep Roots, use of residual moisture
- Perennial, don’t have to re-establish
- High Water Use Efficiency
- High flexibility with summer deficits
- Lower risk if things go wrong
## SDI - A Balance Sheet

<table>
<thead>
<tr>
<th>Consideration</th>
<th>SDI</th>
<th>Flood</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Use per Acre</td>
<td>(+)</td>
<td>(-)</td>
<td>Generally favors SDI, although will depend upon soil type and efficiency of flood system.</td>
</tr>
<tr>
<td>Water Use per unit prod.(ton)</td>
<td>(+)</td>
<td>(-)</td>
<td>Clearly favors SDI given innate advantages in water application.</td>
</tr>
<tr>
<td>Energy Use per acre</td>
<td>(-)</td>
<td>(+)</td>
<td>Gravity-fed systems are almost always superior in energy flux per unit area</td>
</tr>
<tr>
<td>Energy Use per unit prod. (ton)</td>
<td>(+)</td>
<td>(-)</td>
<td>Improving yield is likely to lower energy use per unit production, depends upon extent</td>
</tr>
<tr>
<td>GHG per unit production</td>
<td>(+)</td>
<td>(-)</td>
<td>Not fully known but likely to be lower in SDI, due to higher yields and lower direct emissions</td>
</tr>
<tr>
<td>Irrigation Mgt.</td>
<td>(+)</td>
<td>(-)</td>
<td>Clear advantages to SDI, if managed correctly</td>
</tr>
<tr>
<td>Refill profile</td>
<td>(-)</td>
<td>(+)</td>
<td>Flood irrigation is likely superior</td>
</tr>
<tr>
<td>Germination</td>
<td>(-)</td>
<td>(+)</td>
<td>Sprinklers are preferred, flood works, SDI no</td>
</tr>
<tr>
<td>Salinity</td>
<td>(-)</td>
<td>(+)</td>
<td>Salinity may be an issue with SDI-mitigated</td>
</tr>
<tr>
<td>Wildlife</td>
<td>(-)</td>
<td>(+)</td>
<td>Favors flood but can be mitigated</td>
</tr>
</tbody>
</table>
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<tr>
<td>Yield</td>
<td>(+)</td>
<td>(-)</td>
<td>Mechanisms for yield increases appear genuine</td>
</tr>
<tr>
<td>Stand Longevity</td>
<td>(+)</td>
<td>(-)</td>
<td>Evidence for superior stand longevity</td>
</tr>
<tr>
<td>Controlling Fertilizers</td>
<td>(+)</td>
<td>(-)</td>
<td>Delivery directly to root system, prevention of losses (N, P).</td>
</tr>
<tr>
<td>Weed Intrusion</td>
<td>(+)</td>
<td>(-)</td>
<td>Evidence for less weed pressure due to dry surfaces and less stand decline</td>
</tr>
<tr>
<td>Surface runoff</td>
<td>(+)</td>
<td>(-)</td>
<td>SDI eliminates surface runoff which protects surface water quality</td>
</tr>
<tr>
<td>(pesticides etc.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxygen to Root system</td>
<td>(+)</td>
<td>(-)</td>
<td>On many heavy soils likely better O2 to roots</td>
</tr>
<tr>
<td>Labor</td>
<td>(+)</td>
<td>(-)</td>
<td>Labor savings in SDI irrigations, but greater management for repairs, gophers are needed</td>
</tr>
<tr>
<td>Rodent Management</td>
<td>(-)</td>
<td>(+)</td>
<td>Rodents are a problem in all systems, but flood irrigation keeps populations in check.</td>
</tr>
<tr>
<td>Flexibility with</td>
<td>(+)</td>
<td>(+)</td>
<td>Both systems can be deficit irrigated. May improve yields under SDI, but higher costs.</td>
</tr>
<tr>
<td>Deficit Irrigation</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Summary

- SDI Not appropriate for all farms—must have yield potential and higher level of management
- Variation in price is an economic limitation
- Improved yields (9-15 t/a range) 2-3 tons/a improvement in CV and desert regions
- Possibility of improved stand longevity, less weeds, Labor savings
- Water benefits, ability to do deficit irrigation
- Sustained effort required to solve problems:
  - Rodent management
  - Scheduling/spacing
  - Water quality
Web Resources for SDI & Alfalfa

- **Training: 2014 Symposium Long Beach:**

- **Irrig. Training: 2015 Symposium Reno**

- **SDI in Alfalfa (UC):**

- **Netafim:** [http://ucanr.edu/sites/adi/files/204432.pdf](http://ucanr.edu/sites/adi/files/204432.pdf)

Questions?

Wagner farm, WA state, photo